Jurnal Kebijakan Publik
Vol. 17, No. 1, March, 2026
Homepage: http://jkp.ejournal.unri.ac.id

Building an Earthquake Early Warning System in Indonesia: Lessons Learned from Mexico

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Received : March 11, 2025
Revised : October 15, 2025
Accepted : March 30, 2026

Keywords:
Early Warning System, Earthquake Lessons, Disaster Mitigation, Indonesia-Mexico

ABSTRACT

Indonesia and Mexico have similar earthquake disaster risk characteristics. These two countries will experience only small losses from earthquakes if they have the effective management system. Mexico has established itself as one of exceptional early earthquake warning system through a learning process. The country is able to reduce the number of disaster victims significantly in recent years. In this regard, this research attempts to explore Mexico's experience in disaster management and the valuable lessons for potential earthquake preparedness in Indonesia. To gain a comprehensive pictures of public policy's efforts in mitigating the earthquake risks in both countries, the research has used a qualitative approach especially through focus group discusssions participated by key stakeholders including professors, researchers, and relevant practicioners from both countries. In addition, the research also optimizes the use secondary sources, policy documents and international academic publications, to strengthen our analysis. The study has discovered several critical factors behind Mexico's significant capability to reduce the earthquake risks. These include the strong public awareness of earthquake, where people are more alert towards signals and indications of the catastrophe, the country's effort in advancing the monitoring and warning technology through the development of algorithms and cross-agency collaborations. It is also combined with extensive facilities to dessiminate and communicate effectively the early warning to cover all public areas, and the robust government's support in encouraging routine public simulation of earthquake disaster, also involving the large corporations. In conclusion, the study argues that these Mexico's practical experiences could enrich Indonesia's disaster management strategies particularly through fostering the early warning system technology, enhancing public preparedness, and strong cross-agency collaboration in strengthening monitoring and warning system.

INTRODUCTION

Indonesia is a country that has abundant natural resources and beautiful natural panoramas. However, there is a substantial risk of natural disasters behind the abundant natural resources and beautiful panoramas. This is not only due to Indonesia's geographical location in the world's Ring of Fire but also in the position of three active plates in the world, namely the Indo-Australian Plate to the south, the Pacific Plate to the East, and the Eurasian Plate to the North (Figure 1). The active movement of these three plates has made Indonesia prone to earthquakes.

Earthquakes are shocks on the Earth's surface that result from the sudden release of energy in the Earth's lithosphere, creating seismic waves (Grover & Sharma, 2017). Areas located in earthquake-prone regions are very vulnerable, since many buildings are still not designed to withstand earthquakes, and communities and governments are not prepared for disasters, such as what actions to take before, during, and after an earthquake (Santos-reyes, 2019). This is particularly true in developing countries such as Indonesia.

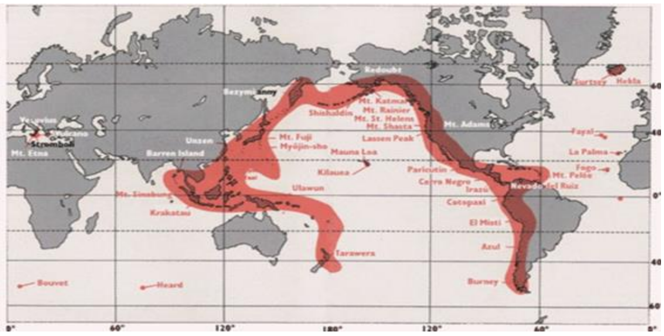

Figure 1. Map of the Pacific Ring of Fire

The number of earthquake-related events and losses in Indonesia continues to rise (Hutahaean & Sihombing, 2025). Since 2013, there has been an increasing trend in earthquake activity in Indonesia, from 4,000-5,000 per year to more than 10,000 per year (BMKG, 2023). The occurrence of earth-quakes with significant impacts has also shown an upward trend from year to year (Figure 2). In the last three decades, earthquakes with significant impacts have caused 160 trillion in economic losses and more than 200,000 deaths (Meilano et al., 2022). Given the high frequency and magni-tude of earthquakes in Indonesia, a system that can notify of earthquakes as early as possible is required.

Early warning comprises procedures and tools that disseminate actionable information in advance of threatening circumstances to reduce potential risks (Basher, 2006). Since earthquakes are unpredictable, earthquake early warning systems (EEWS) are becoming increasingly important, as they can potentially reduce risk (Espinosa-Aranda et al., 2011; Nakamura et al., 2011). The lack of early warning systems has led to devastating consequences, such as the earthquake and tsunami in Central Sulawesi in 2018 (M & Royfandi, 2022; Martin, 2018). This shows the importance of EEWS.

Figure 2. Significant Earthquake Events in Indonesia
Source: processed from various sources, 2024

Early warning systems could strengthen disaster management and are an effective means of reducing the impact of earthquakes (Fujinawa & Noda, 2013; Wu et al., 2019). In Japan, for example, early warning systems can provide 15 to 20 seconds' notice before an earthquake occurs (Fujinawa & Noda, 2013; Nakamura et al., 2011). In addition, earthquake early warning systems have been tested and are active in several countries, such as Italy (Colombelli et al., 2020; Festa et al., 2018), Taiwan (Wu et al., 2013; Yang et al., 2023), China (Peng et al., 2022), America (Chung et al., 2020), and Mexico (Espinosa-Aranda et al., 2011; Suárez et al., 2018).

In Indonesia, the country's EEWS still relies on information from the Meteorology, Climatology, and Geophysics Agency (BMKG) via social media, such as Instagram and X, and television broadcasts. The problem will arise because the limited information that is not spread quickly makes the early warning ineffective.

On the contrary, Mexico has been able to disseminate warnings to the public in large numbers. Similar to Indonesia, Mexico has a high earthquake vulnerability as a country in the Ring of Fire, especially in areas adjacent to the Pacific Ocean. Mexico has a long history of earthquakes, such as the September 19, 2017, earthquake that claimed more than 200 lives. Previously, the Mexico City Earthquake on September 19, 1985, also known as the Michoacan Earthquake, measured 8.0 on the Richter Scale and claimed more than 10,000 lives. Since then, the Mexican government has continued to improve EEWS.

The early warning system is integrated with a computer so that real-time data can be displayed, and it is integrated with sirens or alarms in each house so that information can be conveyed more effectively. With a short waiting time, generally from a few seconds to tens of seconds, humans and automated systems can take appropriate actions to prevent potential damage, such as taking shelter from the rubble, moving to a safer location within a certain period, stopping elevators on nearby floors, turning off gas pipes, and slowing down high-speed trains (Cremen & Galasso, 2020).

As a country with an earthquake early warning system, Mexico has been able to put the system into good practice. This should be emulated by Indonesia, which shares similar characteristics in terms of earthquake risk. The efforts made by Indonesia must receive support from all stakeholders. However, this is not enough. Learning efforts are needed from countries that have practiced well. Therefore, this study aims to analyze the earthquake early warning system in Mexico, and the lessons learned that Indonesia could utilize in building an early warning system.

RESEARCH METHOD

The research method used in this research is qualitative. As a disaster is a complex social phenomenon, the qualitative approach provides more flexible and multiple data collection tools to comprehend deeply about an event in natural catastrophes, and their impacts on social, political, and economic dimensions (Köhler, 2024; Lim, 2024). In line with the study's objective of identifying lessons to be learned from Mexican government efforts to mitigate substantial loss of life from natural disasters, we employed an exploratory qualitative approach to reveal essential and best practices in disaster management in Mexico. The exploratory research design offers researchers a significant opportunity to conduct an in-depth study of specific social phenomena (Mbaka & Isiramen, 2021). Researchers emphasize notes with detailed, complete, in-depth sentence descriptions that describe the actual situation to support data presentation. Researchers try to analyze data in its original form, as it was recorded or collected, and understand and interpret it within our analysis.

By employing a purposive sampling, the study targeted information sources from the relevant authorities, including the National Disaster Management Authority (BNPB), Meteorology, Climatology, and Geophysics Agency (BMKG), *Servicio Sismologico Nacional* (SSN), *Centro de Instrumentacion y Registro Sismico, A.C.* (CIRES, A.C), and *Centro Nacional de Prevencion de Desastres* (CENAPRED). Primary data was obtained through focus group discussions (FGDs) and direct observation at the research location. Meanwhile, secondary data was obtained from relevant prior research, annual reports, maps, photos, regulations, and the internet.

RESULT & DISCUSSION

History of the Earthquake Early Warning System in Mexico

As a country with a high level of vulnerability to earthquake disaster risk, Mexico has a long history of earthquakes. Large earthquakes with significant impacts that Mexico has experienced include the earthquake on September 19, 2017, which claimed more than 200. Previously, the Mexico City Earthquake on September 19, 1985, or commonly called the Michoacan Earthquake with a magnitude of 8.0 on the Richter Scale (SR) claimed the lives of more than 10,000 people and more than 30,000 people were injured. In addition, more than 3,000 buildings were destroyed and another 100,000 were seriously damaged. The situation was exacerbated by power outages and exploding gas pipelines that completely paralyzed public transportation and traffic lights in Mexico City, (Chfivez-garcia & Bard, 1994).

The 1985 earthquake was a wake-up call for the Mexican Authority to improve its early warning system. After the earthquake, the Mexican Authorities formed a team of engineers and seismologists to build a seismological early warning system. Since 1989, the Mexico City Authority has promoted the design and evolution of the *Sistema de Alerta Sísmica* (SAS), to reduce the likelihood of future disasters and damages due to earthquakes caused by latent seismic hazards (Espinosa-Aranda et al., 1995).

The Mexican authorities continued to develop early warning systems until, thanks to budgetary support by the Mexican authorities, the initial idea for SAS was developed by the *Centro de Instrumentación y Registro Sísmico Civil Association* (CIRES). This technological resource began operating experimentally in August 1991 and has been available and evaluated as a public service since 1993. To date, it has been implemented and evaluated in more than 80 elementary schools, both private and public, located in urban areas prone to earthquake risk and where early-warning seismic signals from SAS are useful, as well as in the Mexico City subway transportation system.

In May 1993, SAS identified and anticipated the impact of a 6.0-magnitude earthquake in Mexico City. The local government decided to announce an early warning notice to the public through commercial radio and television channels. This early warning dissemination was successful as a fruitful cooperation between local authorities and the civil society organization *Asociación de Radiodifusores del Valle de Mexico* (ARVM). The use of radio and social media can reduce the risk of earthquake disasters. The use of social media allows for communication between communities, which can increase the capacity for mutual aid and self-help, both of which are needed to further enhance disaster risk reduction capabilities (Kitazawa & Hale, 2021).

Almost 10 years after the tragic 1985 earthquake in Mexico City, SAS detected the 7.3-magnitude earthquake near the town of Copala, Guerrero, 72 seconds before it struck. This earthquake proved that SAS can operate effectively, as evidenced by the community's and schoolchildren's response and evacuation capabilities (Espinosa-Aranda et al., 2011). Early warning systems are considered to be effective if end users can understand the warnings (Tan et al., 2022). After all, the purpose of a public early warning system is for people to use the information to take protective actions.

On June 15, 1999, a destructive 6.7 earthquake caused the Oaxaca Department of Civil Protection to ask CIRES to design, build and install the *Sistema de Alerta Sísmica de Oaxaca* (SASO). The system was required to generate an evolution of the algorithm. It was initiated by the Oaxaca Authority, the Mayor of Mexico, with the participation of the Mexican Secretariat of the Interior. They agreed to integrate the functions of SASO and SAS into a single entity, called *Sistema de Alerta Sísmica Mexicano* (SASMEX). Regional and Federal Governments in Mexico have recently increased the number of seismic sensors to provide and disseminate the earliest possible warning to vulnerable areas.

In 2007, to support Civil Protection activities in the coastal state of Guerrero, Mexico City Authorities authorized the installation of Alternative Transmitters for alerts issued by SAS (EASAS) in the Cities of Acapulco and Chilpancingo. The EA SAS of Guerrero provides a public automatic warning service offered to 102 institutional users. To improve the early warning information dissemination service that was initially provided only to schools, *La Autoridad del Centro Histórico* in Mexico City recently sponsored the installation of three dedicated VHF radio transmitters, allowing the public to benefit commercially at a low cost.

Table 1. History of the Earthquake Early Warning System in Mexico

Period	Description	Policy Action
1985	A magnitude of 8.0 on the Richter Scale (SR) claimed the lives of more than 10,000 people and more than 30,000 people were injured. More than 3,000 buildings were destroyed and another 100,000 were seriously damaged.	A wake-up call to improve EWS
1989	After this major earthquake, the Mexican government established a professional team comprising engineers and seismologists to build a seismological early warning system.	Aimed at reducing potential risk from future calamities, the Mexico City Authority has promoted the design and evolution of the *Sistema de Alerta Sísmica* (SAS) since 1989
1991	Enhancement of early warning system technology	With continous budgetary support, Mexican authorities began operating experimentally SAS in August 1991. It has been available and evaluated as a public service since 1993. To date, it has been implemented and evaluated in more than 80 elementary schools, as well as in Mexico City subway transportation.
1993	Technological Progress: SAS was able to identify and anticipate the impact of a 6.0 magnitude earthquake in Mexico City.	This early warning dissemination was successful thanks to the cooperation between local authorities and *Asociación de Radiodifusores del Valle de Mexico* (ARVM). Besides, they also optimized the use of social media allowing for broader communication access among the communities.
1999	A destructive 6.7 earthquake caused the Oaxaca Department of Civil Protection to ask CIRES to design, build and install the *Sistema de Alerta Sísmica de Oaxaca* (SASO).	Integrated System: The system was required to generate an evolution of the algorithm. In this phase, Oaxaca Authority, the Mayor of Mexico,

		along the Mexican Secretariat of the Interior, agreed to integrate the functions of SASO and SAS to make them a single entity, called *Sistema de Alerta Sísmica Mexicano* (SASMEX).
2007	Mexico City Authorities authorized the installation of Alternative Transmitters for alerts issued by SAS (EASAS) in the Cities of Acapulco and Chilpancingo.	It is considered as important development since it provides a public automatic warning service offered to 102 institutional users. Moreover, *La Autoridad del Centro Histórico* in Mexico City also sponsored the installation of three dedicated VHF radio transmitters, allowing the public to gain from this early warning system.

Source: processed from various sources, 2024

Earthquake Early Warning System in Mexico

As a high-hazard country, Mexico has good experience in earthquake early warning. Early warning and monitoring systems are defined as the set of capacities required to generate and disseminate meaningful and timely information to enable individuals, communities and organizations threatened by a hazard to prepare and act appropriately to reduce the likelihood of harm or loss (UNDRR, 2015).

The previous paradigm explained EWS's focus on risk knowledge and monitoring and warning services. Today, a complete and effective early warning system requires four interconnected and interdependent components: a. risk knowledge, which includes hazards, exposure, and vulnerability; b. monitoring and warning services, which include the ability to monitor and disseminate warnings; c. dissemination and communication, which includes accessibility, understanding and action; and d. response capability, which includes plans, resources, and practices.

First, the Mexican community's knowledge of earthquake risk is good. Risk arises when the combination of hazard and vulnerability is operative in a particular location. People accept the limitations of the system as a token of appreciation for the Mexican authorities, who have worked hard to raise awareness of earthquake hazards and encourage protective behaviors such as evacuating people from buildings prone to collapse.

The FGD results show that after the 1985 earthquake, Mexicans held a favorable view of the earthquake early warning system. People realized the benefits of the early warning system for evacuation, even when they received warnings without feeling or noticing shaking. We note that people are more concerned about not receiving timely warnings than getting early warnings of small-scale earthquakes or even no shaking.

The community has good knowledge of the risk of earthquake threats. This can be seen in the responses of people who realize their lives are at risk of earthquake disasters. People seem to realize that risk knowledge is very important for, adapting to the environment. The results of previous research by Gouzeva et al. (2019) also showed that high enthusiasm of school children aged 14-19 years to learn about earthquake risk, including their awareness of the potential threat of geological disasters in the future.

Knowledge of earthquake risk is a key factor in disaster risk reduction. Without good knowledge of earthquake disaster risk, potential losses will certainly be greater. A dark example is the 2004 Indian Ocean earthquake and tsunami in Aceh. When the seawater receded due to the earthquake, many people ran to the beach to pick up stranded fish. People did not know that the receding seawater was a sign of a tsunami. This resulted in many casualties who were unable to evacuate when the waves hit the beach. In contrast to the people of Simeulue who know smong (tsunami in the local language of Simeulue), local people have local knowledge about efforts that must be made when an earthquake occurs, and sea water recedes (Abdi et al., 2022).

Second, the provision of optimal monitoring and warning services. Monitoring and warning have received global attention in recent years to improve communication about disaster-related hazards and risks. Monitoring and early warning systems aim to provide relevant information to policymakers and decision-makers to reduce the negative impacts of earthquake disasters. Monitoring and early warning systems should be able to identify and mitigate future disasters, meaning that the purpose of earthquake monitoring is to provide the most complete and accurate earthquake information.

Earthquake monitoring and warning services in Mexico are carried out by the *Centro de Instrumention y Registro Sismico* (CIRES). As explained earlier, CIRES was established after the 1985 earthquake to create an institution capable of earthquake observation and early warning to the public. CIRES operates under the policy of the *Sistema de Alerta Sísmica Mexicano* (SASMEX), which is responsible for the earthquake early warning system in Mexico in collaboration with other government agencies. SASMEX focuses on the subduction zone in western Mexico where the most damaging earthquakes originating from Mexico's South Pacific Coast and the most earthquake-prone zone occur.

As a government agency focused on providing earthquake monitoring and early warning services, SASMEX has published several publications on its system and algorithms. Its algorithm focuses on warning locations using the amplitude of the first wave to estimate parameters, in contrast to the Japanese approach of using the maximum amplitude. SASMEX provides warnings without specific magnitude information. To determine which algorithm to use, SASMEX analyzes the first 3 seconds of the P wave and, if the wave meets one of the algorithms, acquires and disseminates data. The algorithms are embedded directly into the sensors developed by SASMEX.

SASMEX uses three algorithms to determine the magnitude of the earthquake to be disseminated. Earthquake early warning sensors continue to be developed and have been certified. The coverage of SASMEX sensors is divided into two categories: shallow earthquake sources and deep earthquake sources. Automatic reports containing magnitude parameters and estimated time of arrival are sent to the authorities. After an earthquake occurs, the report will be updated to include the estimated impact. Alerts will be received by radio receivers within the CENAPRED network coverage to help evacuate the public.

The second monitoring and early warning service is provided by *Servicio Sismológico Nacional* (SSN). SSN is a research institute under the Geophysics Department of the *National Autonomous University of Mexico* (UNAM), which was previously an independent institution. Most of the SSN's activities are focused on research and development for earthquake monitoring and warning. Besides, the SSN's tasks include waveform retrieval, recording earthquake databases and disseminating earthquake parameter information to relevant agencies or ministries. If an earthquake has the potential to cause a tsunami, earthquake information will be forwarded to the Mexican Navy.

Currently, SSN uses Seiscomp for processing system waveforms. SSN uses accelerometers, seismometers, and GNSS sensors in earthquake monitoring. Earthquake monitoring operations are conducted for 24 hours every day by 30 active staff. In addition, monitoring is also carried out by 12 experts who are specifically responsible for managing computing and data systems, conducting outreach activities, and preparing communication materials with the public.

The network system used by SSN is VSAT with a data *latency* of two to three seconds. SSN uses automatic retrieval of the first five minutes of the recorded waveform, followed by manual retrieval to automatically correct the analyzed parameters. SSN collaborates with the Department of Geophysics on earthquake research and the Department of Engineering on research into earthquake impacts, shaking maps, and structural geology. Cooperation between authorities and academia is important to support disaster risk reduction.

Third, effective dissemination and communication. Warnings must reach everyone at risk. Clear messages containing simple but useful information are essential for an appropriate response, which will help save lives and livelihoods. National, regional and local communication systems should be identified and ensured to function properly. Moreover, the use of multiple communication channels is necessary to ensure that as many people as possible receive warnings and anticipate the failure of any one channel.

Failure to communicate early warning information to the public is considered a major problem in most major disasters this century. To close this gap, we recommend investing in multiple communication channels that provide location-specific warning messages and impact-based forecasts. For example, in Bangladesh, people living far from riverbanks will not automatically translate river level forecasts into personal impacts, and historical experience may not serve them well if floods are very large. Mobile messaging can help disseminate information with localized content and increase community mobilization and engagement (Coughlan de Perez et al., 2022).

Most areas in Mexico City have pre-existing public speaker systems that can be used to sound earthquake alarms, but many residents would like to be notified on their smartphones. At least two private companies independently operate earthquake detection and warning systems in Mexico, sending alerts to Internet-connected devices. However, it remains unclear how quickly alerts can be sent to millions of smartphones running an app. This uncertainty creates a potential mismatch between how the public receives earthquake alerts and the technical challenges of sending push notifications to smartphone apps.

The FGDs found that an earthquake early warning system should provide the simplest possible early warning for technological purposes and protective measures. The warning should only indicate an earthquake and instruct people to take immediate protective measures. More complex warning is not necessarily useful for public warning. Follow-up information is required within seconds and minutes after a warning is issued. Follow-up information can be simple, such as indicating that an earthquake occurred and possibly estimating its magnitude. This information can help the public take further mitigation actions, such as seeking safe shelter, and it can help individuals who do not feel shaken in frustration.

Fourth, the ability to respond to good early warnings. The community's initial response to early warnings is very important. The ability to respond determines what people should do when they hear a warning, where to evacuate, and when to take shelter from collapsing buildings. Not only that, but the ability to respond to early warning is also related to investment in infrastructure such as office buildings, houses, public facilities, evacuation routes, and assembly points.

Findings from the field show that earthquake early warning can contribute to a certain culture of prevention that fosters awareness of hazards and certain response behaviors. People would rather lose 30 minutes every two months for a simulation than have to lose more when there is a strong shock. Even some large companies consciously set aside budgets to install early warning devices in their buildings.

Following the 1985 earthquake in Mexico City, Mexican Federal and Local Government Authorities enacted legislation on civil protection. The regulations require individuals and companies to develop action plans and emergency drills to mitigate vulnerabilities and reduce the severity of disasters. Safety and security procedures when people are in buildings are mandatory for building owners. These offices must be adequately staffed and equipped, and have proper coordination mechanisms for self-evacuation.

Development of appropriate policies and plans for reacting to forecasted events. These plans should assign responsibility for taking action based on earthquake forecasts. Individual Mexican communities or organizations should register and certify each action plan before municipal or local authorities, who also oversee and enforce the routine practice of emergency response procedures. To conduct an effective response, not only is capacity required, but also a good contingency plan, pre-arranged funding and an agreed mechanism to trigger the response (Lentz et al., 2020).

Lessons Learned from Mexico's Earthquake Early Warning System for Indonesia

Mexico’s substantial experiences in managing an effective early warning system should become a good lesson for countries vulnerable to earthquakes, such as Indonesia. Mexico has enhanced its earthquake early warning system by utilizing experience, technology and knowledge. It is an important reference for evaluating Indonesia’s existing condition, and what needs to be improved.

The first lesson for Indonesia is that Mexico can document its earthquake history well. Mexico used the 1985 earthquake as a wake-up call for the development and research of earthquake early warning systems. Indonesia was unable to learn from the earthquake and tsunami that occurred in December 1992 in Flores, East Nusa Tenggara. Indonesia only realized the importance of earthquake early warning after the earthquake and tsunami that occurred in Aceh and North Sumatra in December 2004. The earthquake and tsunami became Indonesia's first national disaster.

The Minister of Finance, Frans Seda, stated that "Flores is back in the 1970s" as thousands of dwellings and buildings were destroyed (Lassa et al., 2022). The earthquake and tsunami resulted in more than 2,500 dead and missing, 500 injured, 90% of buildings destroyed in Kalatoa, 50-80% of structures in Flores damaged or destroyed. Landslides and ground cracking were reported in several locations. The disaster resulted in Flores becoming a region with poverty levels similar to those in 1970 (Hasibuan & Hasibuan, 2020).

Documentation of disaster history is very important for future learning. Research Hariyono (2017) on historical disaster data and documents in Indonesia can improve preparedness in the school environment. For instance, the people of Simeulue could learn from the history of earthquakes and tsunamis, and this was well-documented in *Smong* poetry. This could create a precious opportunity through combining local knowledge and technology to minimize high earthquake risk in Indonesia.

The second thing is the Mexican authorities' commitment to research and development of earthquake early warning systems. Following the devastating 1985 earthquake, the Mexican authorities assembled four professors and one expert to conduct seismic research in Mexico (Allen et al., 2018). The development of science and technology, including early warning systems, has an important role in disaster risk reduction (Sriwanti & Ardyansyah, 2023). Thus, investments in technology development and research will save lives, prevent damage, reduce recovery costs and mitigate development setbacks, thereby increasing community resilience.

The third lesson learned for Indonesia is the community's mindset of awareness of disaster risk. As explained earlier, the Mexican community has a good perception of the earthquake early warning system. The community is more accepting when there is an earthquake warning but no shaking. People have a positive attitude toward hearing warnings issued by Mexican authorities. This is an important lesson for Indonesia.

The mindset of the Indonesian people is largely unaware of the importance of early warning systems. The number of unfulfilled government promises has left people disappointed and ultimately indifferent to the threat of disasters. The involvement and empowerment of low-risk communities in setting up and running an EWS leads to their lack of ownership of the system. This affects trust in the system within the community, and a small proportion of the population is dissatisfied with the warnings.

CONCLUSION

Based on our findings, Mexico’s productive efforts in managing the country’s earthquake risks could not be separated from several crucial factors, including technological capacity, institutional continuity, public communication, and social preparedness. The Mexican case illustrates how the successful early warning system requires the combination of deeper community knowledge, stronger monitoring and warning services, obvious mechanism in disseminating and communicating disaster-related situations, and the greater public’s ability to respond effectively and properly.

These critical backgrounds have positioned Mexico as a country more capable of reducing number of victims and damages due to earthquake catastrophe despite its high seismic vulnerability. For Indonesia, it is important to notice that the early warning system is not a matter of technological advancement, but it also demands a stronger inter-agency coordination, sustained research and development, and continuous public literacy and education, including broader society awareness of disaster vulnerabilities in their surrounding areas.

Subsequently, this research also underscored the importance of historical records for future policy references. Mexico’s frequent earthquake events have become a strategic turning point for authorities to learn what to improve and develop, which illustrates institutional learning and long-term commitment. In the Indonesian case, the country has comprehensive disaster records that should benefit the archipelagic nation in anticipating possible earthquake calamities.

Thus, Mexico is a relevant reference for Indonesia and other developing countries in strengthening earthquake preparedness strategies. The strategy is to broaden the early warning network through a comprehensive approach that links technology, governance, and community response. It requires a more integrated approach to lift up the function of early warning from just an information source to become a strategic instrument for reducing disaster risks.

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