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Research Article

Artificial Intelligence and Social Trust in Earthquake Early Warning Systems: A Comparative Perspective

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Abstract

This study argues that earthquake early warning systems should be evaluated not only in terms of their technical efficiency but also in terms of their capacity to generate social trust. The effectiveness of these systems is shaped not only by their technical performance but also by their ability to influence disaster outcomes, including social vulnerability and post-earthquake housing crises. Although AI-supported early warning systems have significantly improved the early detection of seismic risks, their societal effectiveness remains uneven. This study aims to examine the performance of early warning systems within a broader framework that includes technological infrastructure, social trust, risk perception, and public policy. Adopting a comparative perspective, the cases of Japan and Turkey are analysed to highlight the role of social factors in determining system effectiveness. The findings suggest that technological advancements alone are insufficient for reducing disaster impacts. Instead, the integration of technology with social trust and institutional capacity is essential.

Keywords

Earthquake, Artificial Intelligence, Early Warning Systems, Social Vulnerability, Welfare State, Social Trust

1. Introduction

Earthquakes are not only natural disasters that cause physical destruction but also complex social crises that affect risk perception, individual behaviour, and institutional trust. In recent years, earthquake early warning systems have benefited significantly from advances in artificial intelligence, machine learning, and real-time data processing. These technologies enable seismic data to be analysed rapidly and can provide warnings before the arrival of destructive ground motion. Even a few seconds of warning may allow individuals and institutions to take protective measures and reduce potential losses. However, the effectiveness of early warning systems cannot be determined solely by their technical capacity. Their societal impact also depends on how warnings are communicated, perceived, and acted upon by the public [1, 2].

Existing research demonstrates that artificial intelligence can improve the speed and accuracy of earthquake detection and early warning processes. AI-supported systems are increasingly capable of processing large volumes of seismic data in real time, while machine learning techniques can improve detection performance and reduce false alarms [1-3]. At the same time, research on disaster communication and risk perception emphasizes that the effectiveness of warnings depends strongly on public understanding and trust. Technically accurate warning systems may fail to achieve their intended outcomes when individuals do not perceive them as reliable

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or do not respond appropriately to the information provided [4-6]. Research on earthquake early warning acceptance, particularly in Japan, further indicates that institutional trust, public awareness, and previous experience with disaster preparedness influence how individuals respond to warnings [7].

Taken together, the existing literature indicates that technological performance and social response should not be considered independently. Although substantial attention has been given to the technical development of AI-supported earthquake early warning systems, the relationship between technological capacity, social trust, risk perception, and institutional capacity requires further examination within a broader comparative framework. This study addresses this issue by examining earthquake early warning systems from both technological and social perspectives. It aims to analyse how the effectiveness of such systems is shaped not only by their ability to detect seismic events rapidly, but also by the extent to which they generate public trust and support appropriate behavioural responses. A comparative analysis of Japan and Turkey is employed to illustrate how differences in institutional structures, disaster preparedness, public awareness, and social trust may influence the societal effectiveness of early warning systems.

The findings demonstrate that technological advancement alone is insufficient to ensure effective disaster protection. AI-supported early warning systems provide important advantages in terms of rapid detection and information processing; however, their societal benefits depend substantially on public trust, risk perception, institutional capacity, and preparedness. The comparison between Japan and Turkey indicates that the alignment between technological infrastructure and social acceptance is a critical determinant of system effectiveness. While Japan demonstrates a stronger integration of technological capacity, institutional structures, disaster education, and public trust, Turkey faces greater challenges in translating technological development into effective societal responses. These findings suggest that successful earthquake early warning systems require not only continued technological investment but also policies aimed at strengthening public awareness, preparedness, and institutional trust.

2. Conceptual Framework

2.1. Artificial Intelligence and AI Ethics

Artificial intelligence refers to systems capable of analysing large datasets and producing rapid and accurate decisions. In disaster management, AI plays a critical role in processing sensor data in real time and detecting seismic waves at an early stage [17] Machine learning algorithms used in early warning systems accelerate decision-making processes and reduce the need for human intervention [2].

However, AI applications are not purely technical; they also involve ethical considerations. False alarms, data security concerns, and algorithmic errors may lead to a loss of public trust [6]. Therefore, AI systems must be evaluated not only in terms of efficiency but also in terms of transparency, accountability, and reliability [8].

2.2. Earthquakes as Natural Disasters

Earthquakes are among the most destructive natural hazards due to their sudden and severe impacts. Their ability to cause significant loss of life and property in a short period distinguishes them from other natural events [4].

Beyond physical destruction, earthquakes also affect social structures, economic systems, and the psychological well-being of individuals [19]. Their social impact is particularly pronounced among vulnerable groups, highlighting the need to address disaster management not only through technical solutions but also through social policies [20].

2.3. Earthquake Early Warning Systems

Earthquake early warning systems operate based on the principle that P-waves travel faster than S-waves, allowing alerts to be issued before destructive shaking occurs [2]. Even a few seconds of warning can enable critical interventions.

Examples include stopping trains, shutting down industrial systems, and guiding individuals to safe locations [7]. However, the effectiveness of these systems depends not only on technical accuracy but also on how individuals respond to the warnings [10].

2.4. The Technological Trust Gap

The concept of the “technological trust gap” refers to the discrepancy between the existence of advanced early warning systems and the lack of sufficient public trust in them. This gap reflects a mismatch between technological capacity and societal acceptance.

Research on risk communication and trust indicates that individuals’ responses to warning systems are strongly influenced by their level of trust [18]. Even technically accurate systems may fail to produce the desired outcomes if they are not perceived as reliable [14]. Therefore, building social trust is as important as technological investment in disaster management.

2.5. The Welfare State and Its Protective Role

The welfare state refers to a system in which public institutions develop regulatory and protective policies aimed at ensuring individual well-being and reducing social risks [5]. In the context of disaster management, the role of the welfare state extends beyond emergency response to include risk reduction and preventive mechanisms.

The establishment and effective operation of early warning systems can be considered part of the protective function of the welfare state. However, the success of these systems depends not only on technical infrastructure but also on the level of trust in public institutions. When institutional trust is high, individuals are more likely to respond appropriately to warnings, thereby increasing the effectiveness of these systems [16].

2.6. Social Vulnerability and Disasters

Social vulnerability refers to the reduced capacity of individuals or communities to anticipate, cope with, resist, and recover from the impacts of disasters [3]. Factors such as income level, education, infrastructure, and institutional capacity play a critical role in determining vulnerability.

The impact of disasters varies across societies depending on these vulnerability levels. Communities with higher levels of social vulnerability tend to experience more severe consequences, even when exposed to similar hazards. Therefore, the effectiveness of early warning systems cannot be assessed solely in terms of technical performance but must also be evaluated within the broader social context in which they operate.

2.7. Social Trust

Social trust refers to the confidence that individuals place in public institutions and the technological systems they use. It is one of the most important factors influencing behaviour during crisis situations [9].

In disaster contexts, the ability of individuals to respond quickly and appropriately to warnings largely depends on their level of trust. In societies where trust is low, even technically effective early warning systems may fail to produce the desired behavioural outcomes. This highlights the direct relationship between technological efficiency and social response.

3. Artificial Intelligence and Early Warning Systems

The effectiveness of earthquake early warning systems largely depends on their data processing capacity and decision-making speed. While traditional systems have achieved a certain level of success, increasing data volume and the need for rapid analysis have necessitated more advanced methods.

In this context, artificial intelligence has transformed early warning systems by enabling real-time processing of large datasets. AI-supported systems not only detect earthquakes more quickly but also produce more accurate and reliable warnings. However, the extent to which these technological advancements translate into societal effectiveness remains a key determinant of overall system performance [1].

3.1. AI-Based Earthquake Early Warning Systems

Earthquake early warning systems have traditionally relied on the rapid analysis of data obtained from seismic sensors. However, the integration of artificial intelligence and machine learning techniques has significantly improved both the speed and accuracy of warning processes [1].

AI algorithms analyse seismic wave characteristics in real time, enabling warnings to be issued before destructive impacts occur. Machine learning models can learn from past earthquake data and make predictions based on new inputs, reducing false alarm rates and increasing system reliability [11].

Another important feature of AI-based systems is their capacity for continuous learning. As they are exposed to new data, their performance improves, allowing them to adapt to different geographical conditions. However, the accuracy of these systems depends heavily on the quality and diversity of the datasets used for training [11].

3.2. Sensors and Data Analysis

The foundation of early warning systems lies in networks of seismic sensors distributed across large geographical areas. These sensors detect ground motion in real time and transmit data to central processing units, where AI algorithms convert it into actionable information [2].

Deep learning techniques have proven particularly effective in analysing complex and noisy data. They enable systems to distinguish seismic signals from other types of vibrations, thereby improving accuracy [15]. However, system performance is strongly influenced by factors such as data quality, sensor density, and infrastructure capacity.

Additionally, integrating data from different types of sensors presents challenges due to variations in sensitivity and measurement accuracy. AI algorithms help address this issue by processing heterogeneous datasets into coherent outputs. Nevertheless, data latency and communication infrastructure remain critical constraints, especially in regions with limited technological capacity [2].

3.3. Early Detection and Warning Optimization

The most critical feature of early warning systems is their ability to make accurate decisions within extremely short time frames. AI enhances this process by increasing both data processing speed and decision-making efficiency. Real-time analysis and automated systems enable rapid warnings without requiring human intervention [1].

However, optimization in early warning systems is not purely technical. It also involves risk communication strategies. The way warnings are delivered—including language, tone, and communication channels—directly influences how individuals respond [10].

Furthermore, system performance depends not only on speed but also on accuracy. False alarms can undermine public trust and lead to negative social consequences [12]. Therefore, a balance between speed and accuracy must be achieved. Ultimately, the effectiveness of warnings depends on how individuals perceive and respond to them, reinforcing the link between technological efficiency and social trust.

4. Social Impacts

The impact of earthquake early warning systems extends beyond technical accuracy and speed. Their true effectiveness depends on how individuals respond to warnings and the extent to which they take them seriously.

In this context, the social impacts of early warning systems can be examined through fear, behavioural responses, loss of life, and post-disaster social crises. Social trust emerges as a key factor shaping both the direction and intensity of these effects [19].

4.1. Fear and Trauma

Earthquakes generate intense fear and psychological trauma. When early warning systems function effectively, they can help manage and reduce these effects. However, system failures or false alarms may increase panic, uncertainty, and distrust among individuals [10].

Repeated exposure to traumatic experiences or persistent risk perception may lead to a state of hypervigilance, negatively affecting individuals' quality of life and increasing long-term societal stress [19]. Reliable warning systems, on the other hand, can reduce anxiety and enable individuals to assess risks more rationally.

Moreover, false or delayed warnings may lead to "alert fatigue," a condition in which individuals become desensitized to warnings and less likely to respond appropriately [12].

4.2. Loss of Life

The primary objective of early warning systems is to reduce loss of life. Even a few seconds of warning can provide critical time for individuals to move to safer locations or avoid hazardous environments [1].

However, this potential benefit depends on how individuals respond to warnings. In contexts where social trust is low, individuals may ignore warnings or fail to act appropriately. As a result, the advantages provided by early warning systems cannot be fully realized.

Thus, reducing fatalities depends not only on technological infrastructure but also on public awareness, education, and preparedness [14].

4.3. Housing Crisis

One of the most significant social challenges following earthquakes is the housing crisis. Although early warning systems do not directly solve housing problems, they can influence the scale of such crises.

Timely and accurate warnings can reduce casualties and help maintain order during disasters. In contrast, system failures may lead to panic and disorder, complicating post-disaster management processes [3].

The management of housing crises is closely linked to state capacity. Effective early warning systems can facilitate more organized and controlled crisis management, whereas inadequate systems may exacerbate inequalities and disproportionately affect vulnerable populations [20].

5. Comparative Analysis

The effectiveness of earthquake early warning systems depends not only on technological capacity but also on how these systems are perceived and utilized by society. In this regard, the cases of Japan and Turkey provide a meaningful comparison.

5.1. The Case of Japan

Japan is one of the most advanced countries in earthquake early warning systems. With extensive sensor networks and integrated systems, warnings can be delivered to millions of people within seconds.

Systems operated by the Japan Meteorological Agency are supported by automated mechanisms such as stopping trains and shutting down industrial operations [2].

Research shows that public trust in early warning systems is high in Japan, and individuals tend to respond quickly to warnings [12].

Additionally, disaster education, regular drills, and public awareness campaigns contribute to effective behavioural responses [13]. This demonstrates a strong alignment between technological capacity and social trust [12].

5.2. The Case of Turkey

In Turkey, although efforts have been made to develop early warning systems, their implementation and societal integration remain limited. Experiences from major earthquakes indicate that technical infrastructure alone is insufficient.

Limited use of warning systems and low public awareness reduce their effectiveness. Furthermore, low levels of institutional trust may discourage individuals from responding to official warnings.

Differences in disaster awareness and education levels also limit the potential impact of these systems. This highlights the need to support technological solutions with social policies [3].

5.3. Comparative Evaluation

The comparison between Japan and Turkey demonstrates that the success of early warning systems cannot be explained solely by technological advancement.

While Japan benefits from strong institutional structures and high levels of social trust, Turkey faces challenges in aligning technological development with societal acceptance.

This comparison illustrates the concept of the "technological trust gap." Even when technology exists, a lack of social trust can limit its effectiveness. Therefore, successful early warning systems require a balance between technological capacity and societal integration.

6. Conclusion

This study has demonstrated that the effectiveness of earthquake early warning systems cannot be explained solely by technological capacity but must also be understood in relation to social trust, risk perception, and institutional structures.

AI-supported systems provide significant advantages in early detection, yet their societal impact depends on public trust and behavioural responses.

The comparative analysis of Japan and Turkey highlights that technological success is closely linked to social factors. While Japan achieves strong alignment between technology and society, this relationship remains weaker in Turkey.

Therefore, improving early warning systems requires not only technological investment but also efforts to enhance public awareness, education, and institutional trust. Otherwise, a "technological trust gap" will persist between system capacity and societal benefit.

Ultimately, success in disaster management depends not only on technological progress but also on whether society trusts and adopts these technologies.

The issue is not merely the existence of technology, but whether society trusts it.

Abbreviations

AI	Artificial Intelligence
P-wave	Primary Wave
S-wave	Secondary Wave

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