Pak. j. life soc. Sci. (2025), 23(2): 128-139 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences

www.pjlss.edu.pk

https://doi.org/10.57239/PJLSS-2025-23.2.0011

RESEARCH ARTICLE

AI Supported Early Warning Systems in Smart Disaster Management: The Case of Kahramanmaraş Earthquakes

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ARTICLE INFO

Received: May 14, 2025

Accepted: Jul 8, 2025

Keywords

Artificial Intelligence
Smart Disaster Management
Early Warning System
Kahramanmaraş

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ABSTRACT

The aim of this study is to evaluate the effectiveness of Artificial Iintelligence (AI) supported early warning systems within the scope of smart disaster management and to examine how effective these systems were specifically in the case of the earthquakes that occurred in Kahramanmaraş. The study aims to analyze the role of early warning systems in reducing disaster risks, the contribution of data-driven approaches to decision-making processes, and the integration of these systems into disaster management strategies in Turkey. By discussing whether it is possible to develop faster, more accurate, and more reliable early warning mechanisms through the use of AI technologies, the study seeks to provide recommendations for policymakers and practitioners.

INTRODUCTION

Turkey has experienced many devastating earthquakes throughout its history due to its geological and tectonic characteristics. Moreover, it is located in an earthquake-prone zone where the likelihood of similar disasters remains high. Accordingly, the most rational approach to earthquakes is to learn how to coexist with this natural phenomenon to implement preventive measures to minimize risks, and to make disaster awareness a sustainable life practice at the individual and social levels.

Natural disasters are an increasing risk worldwide, from earthquakes to tsunamis, volcanic eruptions, heavy rains, floods, landslides, hurricanes, heavy snowfalls, among others. According to the Climate and Catastrophe Insight report published by the world-renowned insurance company Aon in 2025, natural disasters caused economic losses worth USD 368 billion worldwide in 2024. Disasters are therefore a global issue that requires serious consideration and coordinated action.

The rapid development of technology in recent years has created a paradigm shift in disaster management as in many other fields. Search and rescue and disaster control activities, which were carried out mainly by human efforts in the past, have transformed significantly and gained momentum thanks to technological advancements, and the efficiency and success rates of disaster management have increased. Therefore, the range and scope of technological methods used in combating disasters have also expanded in recent years.

Within this framework, technologies such as sensors, mobile internet and the Internet of Things enable the early detection of threats and the necessary measures to be taken in a timely manner through modeling and analysis carried out in the light of data collected in areas under disaster risk (STM Technological Thinking Center, 2024).

The advancement of technical and methodological approaches in hazard and disaster research constitutes a critical challenge within the broader field of disaster management. In this context, Artificial Intelligence (AI) applications ranging from monitoring and mapping, geographic analysis, and remote sensing to robotics, drone technologies, machine learning, telecommunications and network services, accident and hotspot detection, smart city planning, transportation modeling, and environmental impact assessments represent not only technological tools but also catalysts of social transformation. These innovations significantly shape the ways in which societies respond to hazards and disasters, offering new opportunities for analysis, prediction, and strategic planning (Abid et al., 2021).

In this context, the study will first present a literature review on disaster management, then the conceptual framework of Disaster Management will be evaluated, and finally, smart technologies used in disasters are discussed through the Kahramanmaraş example.

1. LITERATURE REVIEW: Use of Ai in Disaster Management

Today, the increasing frequency and intensity of natural disasters, exacerbated by the accelerated impacts of climate change, necessitate proactive and technologically sophisticated approaches to disaster risk reduction. Traditional disaster management methods demonstrate inherent limitations in their ability to respond swiftly and accurately to complex, dynamic, and large-scale disaster scenarios (Andrae, 2025; UNDRR & AP-STAG, 2024). Such inadequacies underscore the urgent need for a fundamental paradigm shift in disaster management.

The concept of smart disaster management, developed as a result of this orientation, aims to transform existing disaster management systems through the integration of information and communication technologies. These systems acquire real-time information gathering and decision-making capabilities by speeding up the transmission of information and reducing the error rate in decision-making processes. The main motivation of smart disaster management is to ensure public preparedness for disasters through the correct and efficient use of technologies and to reinforce trust through technological applications. Innovative tools provided by computer science, such as big data analytics, artificial intelligence, the Internet of Things (IoT), blockchain, and cloud computing (Table 1), make the management of disaster processes more predictable and efficient, while also enabling the minimization of human impacts. These technological advances have the potential not only to improve the operational efficiency of disaster management but also to serve broader social goals, such as increasing disaster awareness and fostering a culture of preparedness within society. This demonstrates that the role of AI in disaster management is not only as a technical tool but also as an instrument for social transformation (Özkan, 2025; Ibrahim & Mishra, 2021).

Table 1. Disaster Management Stages and Related Technologies

Disaster Management Phase	Main Objective	Role of Technology	Example Technologies
Risk Reduction	Preventing the occurrence of hazards or limiting their effects. Reducing the impact of disasters on life and property.	Risk measurement, disaster prediction and forecasting, risk assessment, environmental planning, and standard setting.	Geographic Information Systems (GIS) (risk mapping), Big Data Analytics, AI (prediction models), Satellite Technologies
Preparedness	Planning, training, and equipping for disaster response.	Disaster monitoring, detection, early warning systems, drills.	AI (early warning), Internet of Things (IoT) (sensors), Satellite Technologies, Mobile Applications, Cloud Computing
Response	Saving lives, reducing losses, and alleviating suffering during a disaster.	Needs assessment, coordination, real-time data flow.	IoT (real-time data), Drones, Mobile Applications, GIS (situational awareness), AI (resource allocation)
Recovery	Restoring community functions and initiating the normalization process.	Post-disaster assessment, infrastructure restoration, financial aid management.	AI (damage assessment, resource optimization), Blockchain (aid transparency), Cloud Computing

AI-technology offers promising opportunities to enhance the effectiveness and efficiency of disaster management amid the increasing global risks posed by natural disasters. AI-based models can assist emergency managers in taking proactive measures to mitigate impacts by accurately detecting early signs of disasters (Ibrahim & Mishra, 2021). This facilitates the transformation of disaster management from a reactive to a proactive approach, thereby not only reducing losses but also strengthening the resilience of societies to disasters.

In recent years, there has been a remarkable and rapid increase in AIresearch within the field of disaster management. A bibliometric analysis of the Scopus database reveals an impressive annual growth rate of 15.61% in scholarly publications concerning the use of AI in disaster management (Wibowo et al., 2025). This trend clearly reflects the rising academic interest and research output on the subject. The rapid growth underscores the growing recognition of AI's potential as a solution to the escalating frequency and complexity of disasters.

Previous scientific contributions in the field of AIapplications in disaster management hold significant importance for future research. Beyond the articles indexed in the Scopus and Web of Science (WoS) databases, conference proceedings available through the IEEE (Institute of Electrical and Electronics Engineers Inc.) database have also made substantial contributions to the discipline. Given the dynamic nature and continuous updates of these platforms, the data may vary over time. Nevertheless, pioneering studies and highly cited publications in recent years provide valuable insights into the evolving trends and directions within the field.

Mosavi et al. (2018) conducted a comprehensive literature review examining the applications of machine learning models, a subset of artificial intelligence, in flood prediction. Their study emphasized the critical role of AI in the disaster prevention and preparedness phases, particularly focusing on the development of reliable and accurate flood risk maps to support prevention, protection, and preparedness efforts. Similarly, Khosravi et al. (2018) presented a comparative evaluation of various decision tree algorithms for flood susceptibility mapping, highlighting the integration of Geographic Information Systems (GIS) and AI techniques in disaster risk assessment. Furthermore, Tehrany et al. (2015) explored AIapplications in disaster risk analysis and mapping by employing a novel ensemble support vector machine combined with the frequency ratio method for flood susceptibility analysis. Fotovatikhah et al. (2018) conducted a comprehensive review of computational intelligence (CI) techniques, including artificial neural networks and fuzzy logic, applied to flood management, providing a valuable roadmap for future research directions. Additionally, a 2018 study examined the application of machine learning methods in landslide susceptibility modeling through a detailed case study, demonstrating a successful example of utilizing AIfor pre-disaster risk assessment. Tien Bui et al. (2016) integrated data mining and ensemble learning techniques with Geographic Information Systems (GIS) to model rainfall-induced landslides, highlighting the significance of combining multiple AI models in disaster forecasting.

Barmpoutis et al. (2020) investigated optical remote sensing systems for the early detection of forest fires, emphasizing the integration of remote sensing technologies with artificial intelligence, digital image processing, and classification techniques. Vitoriano et al. (2011) developed a multi-criteria decision-making model to optimize humanitarian aid distribution, highlighting the potential of AI-based optimization models for logistics and resource management during the post-disaster response phase. Rolnick et al. (2023) explored various applications of machine learning in combating climate change, with their study closely linked to disaster prevention and climate change adaptation efforts. Jaafari et al. (2019) proposed hybrid models that combine fuzzy neural networks and metaheuristic optimization algorithms to predict forest fire probabilities.

Imran et al. (2015) conducted a pioneering study that comprehensively examined the use of AI techniques to analyze social media data during disasters. Their work demonstrated particular effectiveness in post-disaster information gathering and the development of situational awareness. The study emphasized that citizen reporting on social media platforms during disasters is among the most effective methods for rapid situational awareness. Similarly, Arabameri et al. (2019) integrated Geographic Information Systems (GIS) with a boosted regression tree model to predict flash flood and landslide susceptibility, underscoring the significance of combining GIS and AI techniques. More recently, Albahri et al. (2024) systematically reviewed the applications of AI in disaster management, providing an extensive overview of contemporary techniques and advancements, including machine learning, deep learning, data fusion, data mining, fuzzy logic, and multi-criteria decision making. This systematic contribution establishes a solid foundation for future research in AI-based natural disaster management Zhang et al. (2019) investigated the application of deep learning models for earthquake early warning systems. Their study proposed a deep learning–based early warning system designed to provide real-time earthquake source parameters. Yu et al. (2018) examined the role of big data analytics in disaster management by analyzing key data sources and exploring how emerging big data ecosystems can be utilized to monitor and detect natural disasters, mitigate their impacts, and support relief, rescue, and recovery operations. In addition, Zhao and Zhang (2020) employed satellite imagery combined with deep learning models for post-disaster damage assessment, demonstrating a practical application of AI in post-disaster intervention and recovery phases.

Akhyar et al. (2024) conducted a comprehensive review on the application of semantic segmentation and deep learning techniques in major natural disasters such as forest fires, earthquakes, and floods. Damaševičius et al. (2023) focused on the integration of Internet of Things (IoT) devices and systems within the framework of "emergency services internet" for enhanced emergency management and response. Their study emphasizes that the emergency services internet will improve disaster coordination, reduce response times, enhance recovery efforts, increase situational awareness, and improve forecasting capabilities. Abid (2021) carried out an extensive investigation of various machine learning–based methods and systems utilized for forest fire prediction and detection. Finally, the bibliometric analysis by Wibowo et al. (2025) provides valuable insights by summarizing the current state of research in the field and identifying the most cited publications in the literature. According to their findings, research on the use of AI in disaster management gained significant momentum in 2018, with the study by Mosavi et al. (2018) standing out as the most highly cited article of that period.

Disaster management research conducted 20 to 30 years ago primarily focused on the response and recovery phases, emphasizing emergency and reactive measures. However, over time, greater attention has shifted toward risk reduction and disaster preparedness. This shift reflects an initial tendency to prioritize immediate emergency response over longer-term strategies for risk prevention and mitigation. The potential of AI in early warning systems and its accuracy in disaster prediction continues to grow. Increased emphasis and investment in mitigation and preparedness highlight the need for a strategic transition to fully leverage AI's proactive disaster management capabilities. Such a development supports the overarching goal of building more resilient communities. Despite these advancements, significant gaps remain in AI applications targeting specific natural disasters, including droughts, wildfires, storms, and tsunamis, representing promising areas for future research (Sharma et al., 2022; Sun et al., 2020; Wibowo et al., 2025). Efforts to improve data collection and model development in these domains will further enhance the overall effectiveness of AI in disaster management. This situation underscores the critical importance of international cooperation and data sharing, as data scarcity remains a key constraint limiting the full potential of AI technologies.

1. Conceptual Framework of Disaster Management

Monitoring disasters, managing them effectively, and taking both global and local measures represent one of the most significant challenges facing humanity. All communities are vulnerable to a wide range of natural and man-made disasters. These events often occur suddenly and unpredictably, causing extensive damage, destruction, and loss of life. In many cases, their impacts exceed local response capacities and necessitate external assistance at the national or international level (Arslan et al., 2017).

Disasters experienced worldwide are generally classified under two main categories: natural disasters and man-made (or anthropogenic) disasters. Natural disasters may be geological—such as karstic collapses, volcanic eruptions, earthquakes, and tectonic movements—or meteorological, including heavy rains and extreme weather events, avalanches, floods, storms, hurricanes, rockfalls, droughts, and meteorite impacts (Yaman & Düger, 2017). A considerable proportion of natural disasters are meteorological in nature and have become more severe and frequent in recent years. Human-induced factors such as unplanned urbanization, industrialization, global climate change, environmental degradation, and resource exploitation can either trigger these disasters or intensify their impacts. Notably, meteorological disasters differ from other types of natural disasters in that their damages can be mitigated through monitoring and early warning systems (Kadıoğlu, 2020).

Man-made disasters, by contrast, are not the result of natural processes but are directly caused by human actions and technological developments (Ege, 1986). For this reason, they are often referred to in the literature as "technology-induced disasters." These disasters can be categorized into those that develop gradually and persist over time, and those that occur suddenly with devastating effects. Sudden disasters include events such as fires, explosions, collisions, aircraft or ship accidents, oil tanker incidents and fuel spills, nuclear accidents, and radiation emissions. Slow-onset disasters include global warming, the greenhouse effect, climate change, drought, chemical exposure, and environmental pollution. Particularly in developed and developing countries, technological advancement, complex industrial infrastructure, and high population density in urban areas increase both the likelihood and the destructive potential of such disasters (Şengün, 2007).

In today's world, the risks posed by natural and man-made disasters can result in significant loss of life, economic damage, and disruption of social and environmental systems. Disaster management refers to a set of analytical, planning, decision-making, coordination, and evaluation processes aimed at organizing existing resources to prepare for these hazards, reduce risks, respond effectively, and support recovery efforts (Kadıoğlu, 2020).

Disaster management typically encompasses actions taken before, during, and after a disaster. In the literature, these stages are categorized using various terminologies. However, according to widely accepted frameworks (Kahn & Kahn, 2008; Kadıoğlu, 2020; McLoughlin, 1985; National Research Council, 2007; Sun et al., 2020), a comprehensive disaster management program consists of four primary components: risk reduction, preparedness, response, and recovery (McLoughlin, 1985).

- Risk Mitigation: These are activities aimed at reducing the long-term risk of loss of life and property caused by natural and man-made hazards and disasters. Examples include disaster insurance, risk mapping, land use planning, building codes, safety regulations, and tax-based incentive or disincentive policies.
- Preparedness: Preparedness refers to activities designed to enhance operational capacity in responding to disasters. These activities include the establishment of early warning systems, disaster response plans, emergency operation centers, resource management plans, disaster communication systems, public awareness campaigns, disaster management training programs, emergency drills, and mutual aid agreements.
- Response: Response activities aim to save lives, reduce economic losses, and support the initial stages of recovery immediately before, during, or just after a disaster. These include the activation of emergency plans and systems, informing and instructing the public, managing emergency operation centers, and providing services such as search and rescue, humanitarian assistance and care, evacuation and sheltering, and emergency medical aid.
- Recovery: Recovery involves short-term activities that restore essential life-support systems to minimum operational levels and long-term efforts to return life to normal conditions. Examples include debris removal, pollution control in both natural and built environments, economic and unemployment assistance related to the disaster, and the construction of temporary housing and public facilities.

The majority of the world's population resides in urban centers. As cities become increasingly crowded, land and natural resource use continue to rise due to expanding construction activities. Rapid population growth and urbanization lead to consequences such as inadequate infrastructure, unplanned development, environmental degradation, and a decline in urban resilience. Production and consumption practices that disrupt natural systems—combined with negative externalities from sectors such as construction, agriculture, tourism, and industry, as well as technological advancements—contribute to the rising risk of both natural and human-induced disasters. When such disasters occur in densely populated urban areas with significant built environments and economic investments, their impacts are magnified. This reality necessitates a broader, more inclusive, and holistic approach to disaster management. Disasters are inherently complex and dynamic phenomena that often bring multiple multi-disciplinary and multi-stakeholder challenges to the forefront of governance structures.

Of course, a disaster management plan is also necessary for slow-onset disasters with long-term impacts, such as global warming and resource depletion. However, effective disaster management becomes even more critical when dealing with sudden, emergency, and catastrophic events. Both short- and long-term planning, early warning systems, rapid response, accurate decision-making, and effective implementation are essential. Disaster management is a multidisciplinary, complex, and variable process requiring attention to a wide range of factors. Systematic approaches, communication tools, and digital technologies are vital for continuous analysis of both internal and external environments, as well as for collecting, evaluating, and processing data before a disaster strikes. Technology plays a key role in detecting warning signals, mitigating risks, and enhancing resilience. During and after a disaster, technological tools help improve the efficiency of response and rescue operations, and ensure effective communication and coordination.

Modern disaster management differs from traditional approaches by moving beyond reactive responses that begin only after a disaster occurs. It emphasizes the development of proactive strategies during the pre-disaster phase—such as deploying early warning systems and designing disaster-resilient infrastructure. Moreover, because it involves multiple disciplines and stakeholders, modern disaster management is inherently interactive and holistic. The acquisition, storage, evaluation, processing, and dissemination of information are all essential components of effective disaster response and communication.

For these reasons, the integration of technology into modern disaster management has become increasingly important. Technological tools are crucial for enabling communication among stakeholders at the time of the disaster. Equally important is the role of technology in obtaining accurate and reliable data throughout all phases of disaster management. New tools and applications make it easier to collect, analyze, and present data effectively (Memiş & Babaoğlu, 2020). In this context, smart disaster management refers to a technology-driven, data-informed, and proactive approach aimed at reducing disaster risks, accelerating emergency responses, and improving recovery efforts.

1. Emerging Paradigms in Disaster Response: Smart Technologies and the Kahramanmaraş Case

Disasters, which cause significant social, economic, and physical losses, are increasingly managed more effectively with the advancement of technology. The positive impacts of technological integration can be observed concretely in the field. This process, referred to as smart disaster management, entails the use of advanced technologies such as AI , the Internet of Things (IoT), big data analytics, and geographic information systems (GIS) throughout the disaster prevention, response, and recovery phases. While traditional disaster management relies largely on reactive measures, smart disaster management adopts a proactive approach that includes foresight, early warning systems, real-time monitoring, and data-driven decision-making.

With the development of AI, the parameters for decision-making as well as principles related to forecasting and predictability have undergone a fundamental transformation. Machine learning and deep learning algorithms can process and analyze thousands of potential scenarios within minutes using big data and can determine optimal decision pathways (Sun et al., 2020). The use of AI in disaster management serves three major functions: predicting potential disasters, conducting impact assessments, and enhancing social resilience (Partigöç, 2022).

Early warning systems are designed to disseminate timely and accurate alerts about disasters either before or during an event, allowing for preventive and proactive measures to minimize potential damage and losses (Lamsal & Kumar, 2020). With the emergence of IoT technologies and sensor-based systems, vast amounts of data are generated rapidly. This data must be captured, stored, and analyzed by early warning systems, as it contains valuable indicators and offers important opportunities for monitoring and managing both natural and human-induced disasters (Lamsal, 2020).

On February 6, 2023, a 7.7 magnitude earthquake struck the Pazarcık district of Kahramanmaraş at 04:17 AM Turkish time. Later the same day, at 13:24, a second earthquake with a magnitude of 7.6 occurred, centered in Elbistan. These earthquakes brought the reality of disaster back into national focus due to their multidimensional, widespread, and deeply destructive effects. Numerous aftershocks followed. The earthquakes severely impacted Kahramanmaraş, as well as Hatay, Adana, Malatya, Adıyaman, Gaziantep, Şanlıurfa, Diyarbakır, Osmaniye, Kilis, and Elazığ, and were felt across many other provinces (AFAD, 2023). According to official figures, 50,783 people lost their lives, 115,353 were injured, and 37,984 buildings collapsed. These numbers exceeded the death tolls and destruction of previous major earthquakes in Turkey, such as those in Erzincan and Düzce (AFAD, 2025). During and after the disaster, various technologies were effectively deployed in search and rescue operations, coordination, and aid distribution.

Following the Kahramanmaraş earthquakes, numerous national and domestically developed technologies and systems produced by the Turkish defense industry were used effectively in disaster response. These included Unmanned Aerial Vehicles (UAVs), satellite systems, various types of surveillance cameras, radar systems, generators, and communication technologies (STM Technological Thinking Center, 2023). Among these, electro-optical cameras have emerged as critical components of modern imaging systems due to their ability to convert light energy into electronic signals. These systems use optical lenses and electronic sensors to produce digital images that are both meaningful and analyzable. Electro-optical devices are capable of operating not only within the visible light spectrum but also in infrared (IR) and ultraviolet (UV) ranges that are invisible to the human eye. Due to their versatility, they are indispensable tools across military, scientific, industrial, and civilian applications (Akarsu, 2025). The deployment of such advanced technologies in the search and rescue operations following the Kahramanmaraş earthquakes once again demonstrated the critical role of technology in disaster management.

Table 2 presents the major technologies and systems deployed during and after the 2023 Kahramanmaraş earthquake, with a focus on their respective areas of application in disaster response, coordination, communication, transportation, energy supply, and decision-making.

Table 2. Application of Advanced Technologies in the Kahramanmaraş Earthquake

System / Technology	Application Area
Reconnaissance, Surveillance and Imaging Systems	
Wall-Penetrating Radar (DAR) Device	Direction and distance detection
EKS-2WX Body Cameras	Recording of high-resolution images
GÜKAS (Solar-Powered Domestic Camera System)	Real-time image transmission
Bayraktar Akıncı UAVs	Detection, search and rescue, coordination
Rapid Mapping Pod on Bayraktar TB2 UAVs	Mapping of large areas
BAHA and POYRAZ UAVs	Support in search and rescue, and security
Kırlangıç UAV	Intelligence, reconnaissance, and surveillance support
Telescopic Cameras	Visual support for search and rescue under debris
Göktürk Satellite Imagery	Preliminary damage assessment
Proton Elic RB-I M-4 Ground Imaging Device	Locating individuals under rubble
ANKA-S UAVs	Active in reconnaissance, detection, and coordination
Communication Systems	
Jandarma Integrated Communication and Information System	Uninterrupted communication
Base Station on AKSUNGUR UAV	Communication support
Satellite Communication Terminals (TÜRKSAT Inc.)	Communication infrastructure in the disaster zone
Mobile Base Stations (ULAK Communication Inc.)	Deployment of emergency communication systems
Energy Storage Systems	
Fixed and Portable Energy Storage Systems	Continuous power supply
Solar Energy Stations	Alternative power source
Transportation Systems	
SANCAK and JACKAL-M UAVs	Transport of cargo and materials
BARKAN Unmanned Ground Vehicle (UGV)	Casualty evacuation and logistics support
Decision Support Systems	
Computer-Aided Image Analysis (STM)	Damage/change detection, digital support via open-source platforms

Emerging and Developing Technologies	UAV-based base stations, robotic exoskeletons, virtual/augmented reality, 3D printing, AI-powered tools, wide-area surveillance, seismic isolators, early warning systems, quantum technologies, integrated system architectures, and acoustic detection devices.

1. Other Systems Under Development and Increasingly Adopted

A range of advanced technological solutions, either currently under development or already implemented, are being utilized during major disasters such as earthquakes. These include UAV-integrated base stations, robotic exoskeletons, virtual and augmented reality applications, 3D printing technologies, AI-powered systems, wide-area surveillance tools, seismic isolation devices, early warning infrastructures, quantum-based technologies, integrated system architectures, and debris detection devices.

All these technologies represent comprehensive interventions after a disaster. However, one of the most important stages of the disaster management process is to make necessary preparations and take precautions before a disaster occurs. Although some material losses seem inevitable, in some cases—especially in very large and infrequent events—the loss of human life could have been prevented if appropriate precautions and measures had been taken. On December 26, 2004, the Indian Ocean tsunami, which caused over a quarter of a million deaths, killed more than 34,000 people in Sri Lanka due to the lack of a tsunami early warning system. Although there was sufficient time to warn some of the coastal population, the lack of tsunami awareness, the absence of an early warning system, and inadequate training on how to respond prevented both authorities and local communities from taking effective measures that could have significantly reduced the loss of life (Leon, 2006).

According to scientific reports published by the US Geological Survey and the European Seismological Center, calculations have shown that an early warning could have been issued 20–25 seconds before the devastation in provinces such as Diyarbakır, Adıyaman, and Hatay. Prof. Dr. Haluk Eyidoğan from the Department of Seismology, Geophysical Engineering, Istanbul Technical University, stated that early warning systems can be used very efficiently in some places in Turkey, but the Disaster and Emergency Management Presidency (AFAD) does not currently have such an initiative (T24, 2023).

Boğaziçi University's Kandilli Observatory and Earthquake Research Institute is working on a new earthquake early warning system that is critical for Istanbul and its surroundings. It is stated that the system utilizes advanced technology capable of issuing warnings 5 to 7 seconds in advance. The system aims to facilitate millions of people in reaching safe areas. It is expected to be activated in all districts of Istanbul by the end of 2025 (IBB Earthquake and Ground Investigation Directorate, 2021).

On the other hand, EDIS, developed at Yıldız Technical University Technopark, aims to reduce the loss of life and property by detecting earthquakes seconds in advance across Turkey as an artificial intelligence-supported early warning system. It was effectively activated for the first time during the 6.2 magnitude earthquake off the coast of Silivri, Istanbul, on April 23. It was determined that it issued a warning 8 seconds before the earthquake at the epicenter and 69 seconds before the earthquake in remote cities such as İzmir and Manisa. It is stated that all installations of the system will be completed within five years and made available to the public (Güner, 2025; EDIS, 2025).

Many countries around the world are actively and effectively using early warning systems. These systems use the speed of seismic waves to calculate the distance to the epicenter and the expected intensity of the earthquake. Countries such as Japan, the USA, and Chile are among the best examples of these technologies. Moreover, the functioning of these systems is based on seismic wave analysis and is constantly updated by experts. Japan can send information to citizens within a few seconds using the J-Alert system. The USA provides information via the ShakeAlert mobile application. Chile disseminates alerts through the Onemi National Emergency Management System, and Mexico implements a nationwide voice warning system called Sisnet (Earthquake Search and Rescue Association, 2025).

In conclusion, although Turkey is located in a region with high earthquake risk, it does not yet have an effective and widely used national earthquake early warning system. Considering technological developments and international examples, early warning systems hold a significant place in disaster risk reduction strategies. In Turkey, early warning studies are being conducted in some pilot areas, particularly in the Marmara Region, and various projects are being developed to implement these technologies. However, in order for these systems to become holistic, integrated, and publicly accessible, more comprehensive steps must be taken in terms of infrastructure, institutional capacity, and legislation.

CONCLUSION

This study evaluates the effectiveness of artificial intelligence-supported early warning systems within the framework of smart disaster management in the context of the earthquakes centered in Kahramanmaraş in 2023. To enhance the quality of this review, the bibliometric analysis method allowing a holistic analysis of literature and identifying general trends was employed. The analysis shows that academic interest in this field is increasing and that artificial intelligence-based disaster management solutions will occupy a more prominent place on the research agenda in the near future.

Findings from the literature and harsh experiences demonstrate that artificial intelligence-based technologies offer critical support to decision-makers before, during, and after disasters. In particular, the timely implementation of measures such as early warning systems plays a vital role in reducing casualties and property damage.

Although Turkey lies on active fault lines and faces significant seismic risk, it does not yet possess an effective, sustainable, and widely used national earthquake early warning system. However, today's advancements in artificial intelligence, big data, and sensor technologies present a significant opportunity to enhance pre-disaster response processes and reduce loss of life and property. International examples show that such systems have been successfully implemented in high-risk countries like Japan, Mexico, and the USA, significantly boosting societal preparedness.

In Turkey, several pilot early warning systems with limited coverage have been launched, especially in densely populated and strategically critical areas like the Marmara Region. Universities and public institutions have initiated numerous research and implementation projects. However, these efforts are generally regional and lack institutional coherence.

For smart disaster management practices to succeed, interdisciplinary collaboration, enhanced data sharing, and a coherent national strategy must be adopted. The Kahramanmaraş earthquakes were not only a natural disaster they served as a test case for disaster management systems. In this context, the institutional adoption of artificial intelligence-based early warning systems and their enhancement through continuously updated dynamic structures are key to improving social resilience in the face of future disasters.

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