ARAŞTIRMA

Geliş Tarihi: 06 Kasım 2024
Kabul Tarihi: 02Ocak 2025

ARTIFICIAL INTELLIGENCE SUPPORT IN DISASTER MANAGEMENT

Afet Yönetiminde Yapay Zekâ Desteği

DOI: 10.58307/kaytek.1580460

Prof. Dr. Veysel EREN / Arş. Gör. Hasret DUMAN

Özet
Dijital teknolojilerin artan oranlı gelişimi yapay zekâ uygulamalarının ilerlemesine ve birçok farklı alanda kullanılmasına yol açmıştır. Bu alanlardan biri de afet yönetimidir. Toplumu afete karşı dayanıklı kılmak ve korumak için yapay zekâ uygulamaları kullanılmaktadır. Ancak bazı yapay zekâ projeleri uygulamada beklentileri karşılayamamakta hatta var olan karmaşıklığı ile daha fazla maliyete, zamana, iş gücüne yol açabilmektedir. Bu nedenle çalışma ikincil veri kaynakları ile afet sürecinde yapay zekâ kullanımını inceleyen bir model geliştirmiştir. Çalışmanın amacı afetlerin önlenmesine, can ve mal kayıplarının en aza indirilmesine, daha acil ve etkin müdahaleye olanak sağlayan afet yönetim modeline ve literatüre katkı sunmaktır. Bu noktada çalışma, ilgili alanda araştırma yapacak araştırmacılara ek bir kaynak olmanın yanı sıra karar vericiler ve uygulayıcılar için de özet kaynak niteliği taşımaktadır.

Anahtar Kelimeler: *Afet, Afet yönetimi, Dijital Teknolojileri, Yapay Zekâ.*

Abstract
The rapid development of digital technologies has driven significant advancements in artificial intelligence (AI) applications, expanding their use across various fields. One notable area is disaster management, where AI is leveraged to strengthen societal resilience and protect communities from disasters. However, some AI projects may fall short of expectations during implementation, often resulting in increased costs, time, and labor due to their inherent complexity. In response, this study presents a model that explores the application of AI throughout the disaster management process, utilizing secondary data sources. The objective is to contribute to both academic literature and disaster management practices by supporting disaster prevention, reducing loss of life and property, and enabling more efficient and timely interventions. Furthermore, this study aims to serve as a valuable resource not only for researchers in the field but also for decision-makers and practitioners, offering a concise reference for more informed, data-driven actions.

Keywords: *Disaster, Disaster management, Digital Technologies, Artificial Intelligence.*

Prof. Dr. Veysel EREN
Hatay Mustafa Kemal Üniversitesi İktisadi ve İdari Bilimler Fakültesi, Siyaset Bilimi ve Kamu Yönetimi,
E-posta: veysel@mku.edu.tr, ORCID: 0000-0003-3607-1583
Arş. Gör. Hasret DUMAN
Hatay Mustafa Kemal Üniversitesi İktisadi ve İdari Bilimler Fakültesi, Siyaset Bilimi ve Kamu Yönetimi,
E-posta: hasret.duman@mku.edu.tr,
ORCID: 0000-0002-7187-7729

Introduction

A disaster is the potential consequence of a hazard that overwhelms a community's ability to manage the destructive effects of that hazard using available resources. Unfortunately, various disasters occur around the world, which can be classified as either natural or human-made. Natural disasters are the overwhelming results of hazards occurring in nature. Events such as earthquakes, tsunamis, storms, hurricanes, floods, and hailstorms are examples of natural disasters. These types of disasters generally occur without human intervention and can lead to significant loss of life and property. Statistics from the International Disaster Database (EM-DAT) indicate that over the past decade (2013-2023), 4,289 disasters have been recorded, resulting in a total of 325,879 fatalities.

Human-made disasters, on the other hand, arise directly or indirectly from human activities or negligence. For instance, industrial accidents, nuclear leaks, and fires typically result from human intervention or neglect and can lead to widespread environmental and social repercussions. A crisis refers to situations that threaten the functioning of government and society and require urgent solutions, particularly when existing mechanisms prove inadequate. A crisis that arises suddenly is associated with risk and can serve as a breaking point or turning point for institutions. Therefore, institutions implement effective risk management to control a crisis, minimize potential damage, and protect existing gains (Eren, 2022, p.6). Consequently, the primary goal of disaster management is to enhance societal resilience against disasters and to proactively safeguard communities through efficient management strategies.

To prepare communities for disasters, efforts are made to instill a culture of preparedness, raise awareness, ensure the implementation of appropriate behaviors, develop emergency action plans, standardize disaster training, utilize international organizations and studies, allocate resources efficiently, restructure, and implement operations and strategies to minimize adverse impacts. Furthermore, significant amounts of data are now provided during disaster situations from sources such as social media, sensors, satellites, security cameras, Unmanned Aerial Vehicles (UAVs), and drones. This data serves as a valuable resource, assisting emergency response teams in assessing the situation and making informed decisions (Nunavath & Goodwin, 2019, p.1).

Data collected from our daily lives is processed by computers and reused in our real world. While this phenomenon is not new, the development of digital technologies has led to increased data production and processing. Emerging technologies profoundly affect and transform the world, ranging from individuals to communities and organizations. Countries and governments are adapting to this transformation by undergoing structural revolutions and developing new policies. As a result, the development of both information and communication technologies and digital technologies has led to the use of AI techniques in processing disaster-related data.

With its diverse applications and inherent degree of uncertainty, AI poses significant risks for society and the future while contributing to public service delivery and decision-making. For example, a review of the relevant literature indicates that governments utilize AI-based applications in their policies and services to enhance efficiency in education, achieve groundbreaking developments in healthcare, ensure traffic regulation and reduce fatalities, manage migration effectively, and lower crime rates, as well as to develop rapid and effective intervention methods for disasters such as floods, earthquakes, and wildfires. However, especially in addressing complex, large-scale challenges, not all AI applications and projects meet expectations; in fact, their existing complexities can lead to increased costs, time, and labor demands.

This study proposes a model that utilizes secondary data sources, which aims to reduce the challenges often encountered in AI projects by creating a more efficient and practical framework for disaster management. The study's focus is not only on enhancing disaster prevention efforts but also on mitigating the loss of life and property while enabling faster and more effective interventions.

The purpose of the study is to develop a model that applies AI across the disaster management process, with the goal of improving societal resilience and protecting communities from disasters. AI has great potential in disaster management, many AI-driven projects struggle during implementation, often resulting in increased costs, time delays, and labor-intensive efforts due to their complexity. The study, expands existing academic literature by offering a fresh perspective on AI applications in disaster management, emphasizing the practical application of AI throughout the disaster management process using secondary data sources. By presenting a model that blends AI with real-world disaster management scenarios, the study positions itself as a resource not only for researchers but also for practitioners and decision-makers, bridging the gap between academic research and practical applications. In this context, the first chapter provides a conceptual framework, followed by an examination of the relevant literature concerning AI applications in disaster management. Subsequently, a conceptual model is developed to facilitate effective disaster management supported by AI. The model focuses on the use of AI both before and after disasters, emphasizing areas such as data collection and analysis, communication and information sharing, disaster prediction and early warning systems, simulation and training, search and rescue operations, and damage assessment. The conclusion offers several recommendations for future research.

Conceptual Framework: Disaster Management and Artificial Intelligence

A disaster is the destruction caused by various natural events (TDK, 2024). In other words, disasters refer to natural, technological, and anthropogenic events that disrupt or halt normal life activities, resulting in physical, economic, and social losses (Erkal & Değerliyurt, 2009, p. 149). Disasters can be classified as natural, technological, and human-made, and they are grouped according to their mode of occurrence (for example, geological, climatic, biological, etc.).

Disasters that cause negative destruction to society can develop either suddenly or gradually. The extent of their impact on the affected area, magnitude, distance from populated areas, population density of those affected, and similar factors determine the scale of a disaster. Various types of disasters are observed in Türkiye. For instance, in our country, which is located in a seismo tectonically active region, approximately 98% of the population is affected by earthquakes to varying degrees (Şahin, 2019, p. 183). The most recent example of this is the two major earthquakes that occurred on February 6, 2023, centered in Kahramanmaraş. The two significant earthquakes in the districts of Pazarcık (7.8 Mw) and Elbistan (7.5 Mw) have been recorded as the largest disaster of 2023 in terms of mortality rate and economic damage. These earthquakes caused significant destruction not only in Kahramanmaraş but also in the cities of Hatay, Gaziantep, Malatya, Diyarbakır, Kilis, Şanlıurfa, Adıyaman, Osmaniye, Adana, and Elâzığ, affecting an area of 108,812 km^2. Consequently, they resulted in the deaths of approximately 56,683 individuals and affected 18 million people (EM-DAT, 2023). In addition to earthquakes, Türkiye also experiences other types of disasters such as avalanches, flooding, wildfires, and landslides (AFAD, 2024b).

The primary goal of disaster management is to enhance societal resilience against disasters. Therefore, operations and strategies are implemented to prepare effectively, respond swiftly, provide rescue operations, allocate resources efficiently, rectify damages promptly, and ultimately protect society while minimizing adverse impacts (Sun et al., 2020, p. 2632). Furthermore, reducing disaster risks is not only a cost-effective investment to prevent future losses but also contributes to sustainable development (Sendai, 2024).

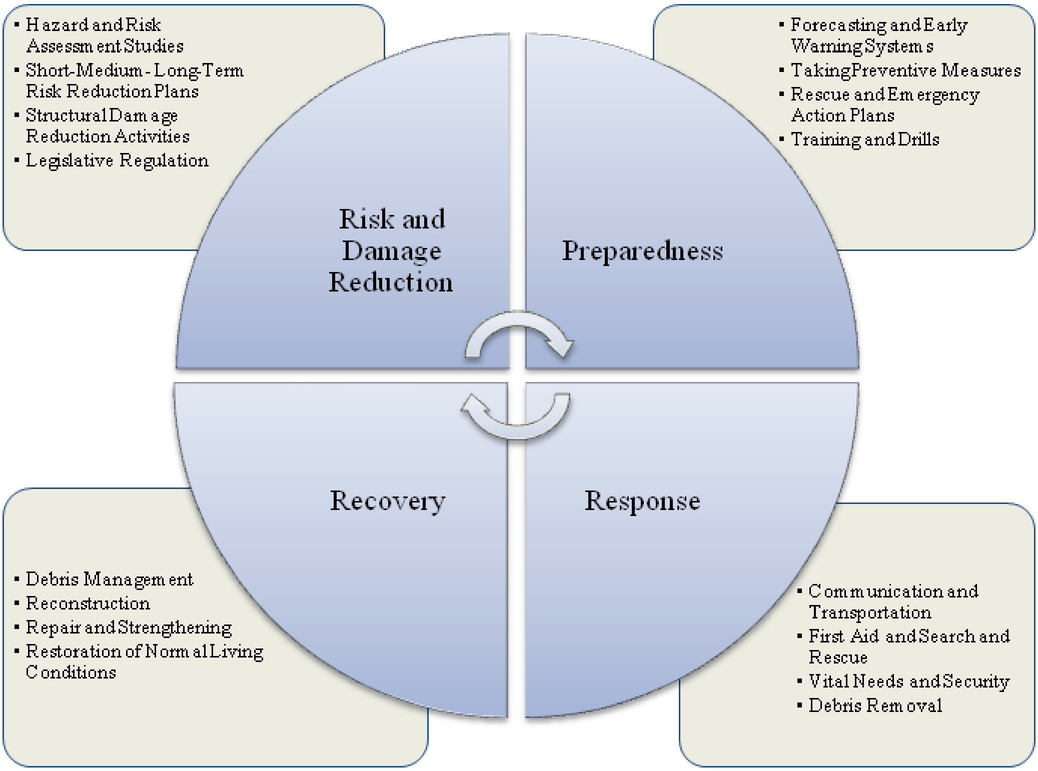


Figure 1. Disaster Management Cycle

The traditional disaster management cycle includes the stages of 'risk and damage reduction, preparedness, response, and recovery' (Figure 1). In the risk and damage reduction phase, hazard and risk maps are created at the national and regional levels, legal regulations are prepared or updated, public awareness is ensured, and sustainable short-, medium-, and long-term plans are developed. The preparedness phase shapes the emergency action plan based on the risk reduction stage. This includes the establishment of forecasting and early warning systems, planning for rescue, evacuation, and gathering centers, organizing training and drills, and training volunteer helpers. The response phase encompasses activities that begin with the occurrence of a disaster, with the duration varying according to parameters such as the type, scale, and magnitude of the disaster. The primary objective at this stage is to intervene in the disaster as quickly as possible. Therefore, this phase covers all activities ranging from meeting basic needs such as transportation, communication, first aid, shelter, food, and water to identifying and demolishing damaged buildings and removing debris. The recovery phase involves reconstruction activities aimed at restoring socio-economic life to normalcy, such as the construction of electricity and sewage systems and permanent housing.

AI, characterized by various definitions and analyses, can be described as systems or machines equipped with cognitive abilities unique to humans. With the advancement of digital technologies, vast amounts of data are being generated, and the volume and speed of this data are increasing daily. Analyzing this data manually, verifying its accuracy, or utilizing it is impractical. For this reason, AI leverages multiple and complex data sources to analyze large quantities of various types of data and transform them into actionable insights. Figure 2 presents the technologies that come together to form AI.

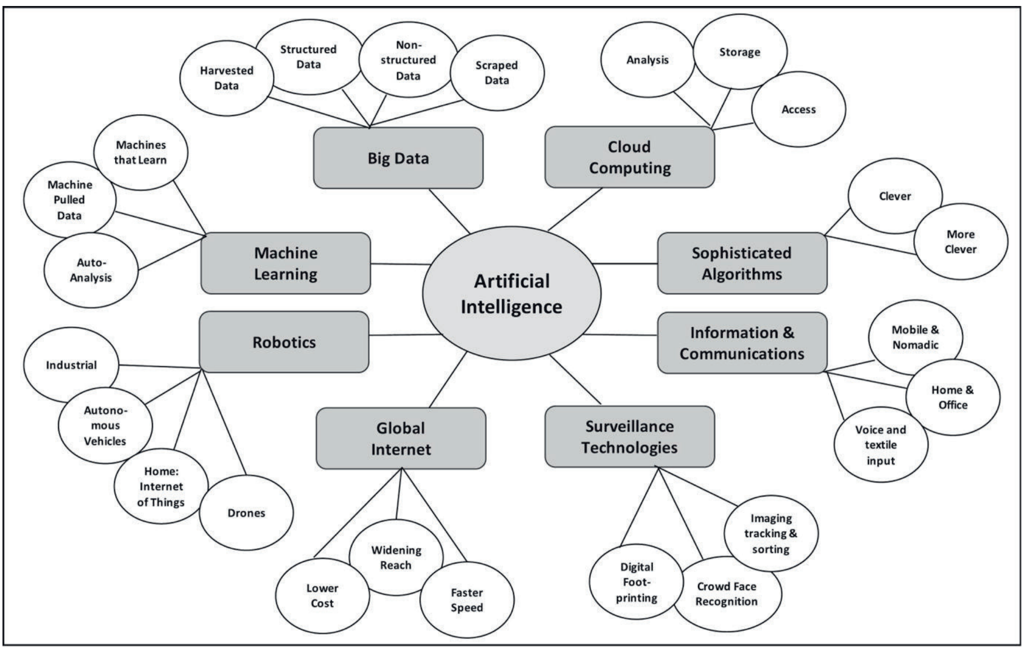


Figure 2. Technologies that Constitute Artificial Intelligence

AI fundamentally involves the creation of systems that possess characteristics such as learning and problem-solving. These systems aim to simulate human intelligence by utilizing historical data to facilitate rational decision-making processes. In this context, AI programs can identify thousands of objects, assist doctors, compile thousands of example court rulings in legal cases to derive main judgments, perform natural language translations, and enable easier access to information through chatbots.

A review of the relevant literature reveals that the body of work related to AI has grown exponentially, establishing it as a popular research area, particularly regarding its increasing impact on daily life. The public sector, like the private sector, also leverages AI to enhance its services. While AI is utilized in various capacities within public administration; it is applied across numerous sectors and industries, including manufacturing, logistics, finance, agriculture, transportation, education, healthcare, law, gaming, migration management, and security.

According to literature that views the use of AI positively in the public sector, AI aids government bodies in forecasting and improving decision-making processes, enhances communication between citizens and the government, enables the personalization of public services, and reduces administrative burdens (Margetts & Dorobantu, 2019; Pencheva et al., 2020; Kulal et al., 2024). Similarly, in the public sphere, AI contributes to the delivery of public services, public safety, administrative decision-making, and citizen satisfaction (Mehr, 2017; Gesk & Leyer, 2022). For instance, it enhances both public efficiency and satisfaction through processes such as answering questions, completing forms, searching, guiding, and translating.

With the realization of AI's utility in surveillance policies, it has also begun to be utilized in migration management to register and manage vulnerable populations. In this regard, governments are employing AI algorithms to predict any potential 'migration crises' with greater sensitivity, as well as to reduce and expedite costs. They are utilizing AI for automatic facial recognition, transliteration for refugees or asylum seekers, identity verification, and the examination and detection of counterfeit documents (Duman, 2024, p. 180-181).

As a result, the use of AI in public service delivery leads to the automation of services, thus saving time, money, space, personnel and task management. Automation of routine and repetitive tasks frees up staff time for other responsibilities. On the other hand, AI plays an important role in responding to complex environmental problems. In particular, the development of digital technologies and information and communication technologies and their integration with AI have increased technological efficiency in disaster management.

Artificial Intelligence in Disaster Management

Disaster prediction can be achieved through the use of computer models, which can prevent the spread of disasters and facilitate the rapid and effective utilization of critical time following such events. These types of predictions enable better preparedness for emergencies, save lives, and contribute to making communities safer, stronger, and more resilient. For instance, Figure 3 illustrates the increasing trend in the number of publications on AI in disaster management in WorldCat from 1991 to 2018.

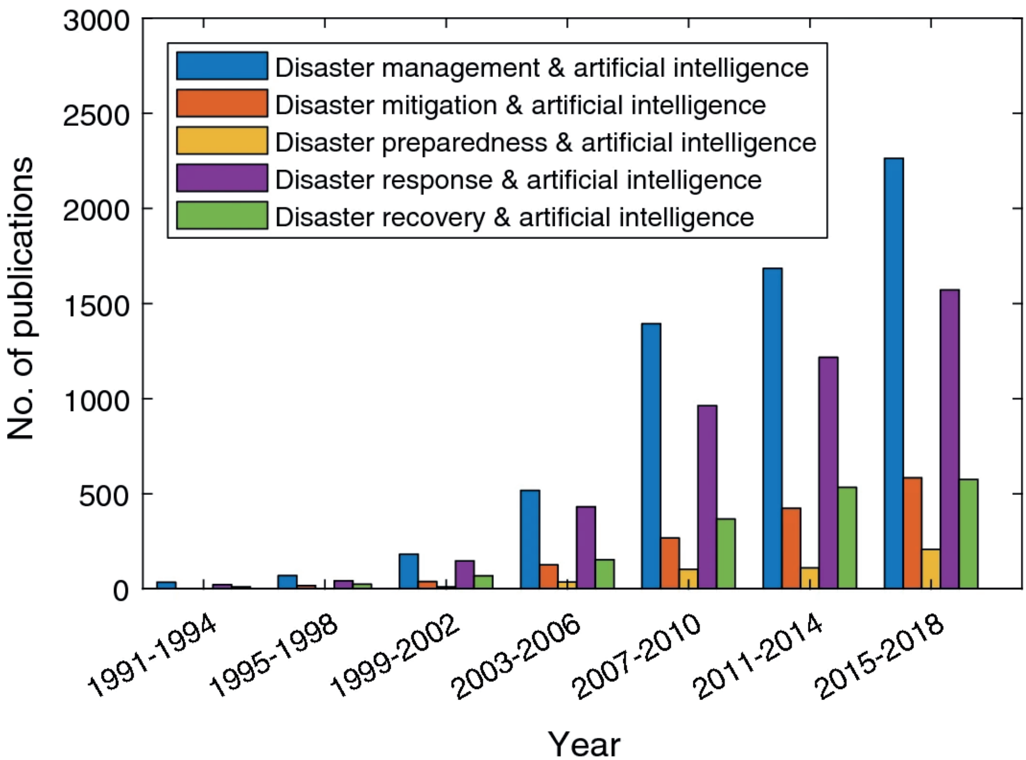


Figure 3. Disaster Management and Artificial Intelligence Studies

Source: Sun et al., 2020: 2637.

According to the disaster management literature, AI is widely used in disaster management. In general, AI contributes to more accurate disaster prediction and then to rapid and effective interventions. At this point, AI-based tools such as satellite images, mapping, geographic analysis, remote sensing, robotic technologies, programs, information and communication technologies and machine learning have made significant contributions to the study of hazards and disasters (Abid et al., 2021).

As the use of digital technologies in disaster management has increased, these technologies have enabled greater resilience against disasters worldwide (Figure 4). For instance, while a storm in Bangladesh in 1985 resulted in 15,000 fatalities, in 2020, thanks to early warnings, evacuations, and increased resilience, only 26 deaths were recorded, potentially saving tens of thousands, if not hundreds of thousands, of lives (Ritchie, 2024).

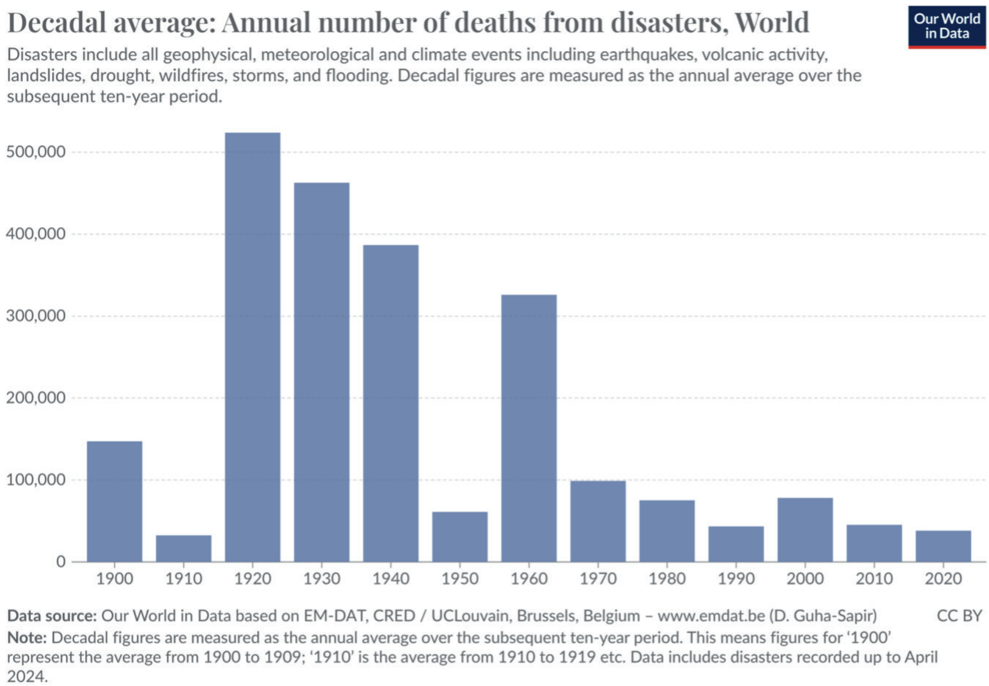


Figure 4. Death Toll from Disasters

Source: Our World in Data, 2024

The data presented in Figure 4 should not be interpreted as suggesting that climate change is absent or that weather events are not worsening. The world is continually facing chaos and disaster. While there are many reasons behind the decrease in fatalities during disasters, the enhanced resilience and protection of communities have played a significant role.

Ritchie (2024) correlates the risk of damage from a hazard to three factors (Figure 5): the physical characteristics of the hazard, such as the intensity of a hurricane, the magnitude of an earthquake, the severity of a heatwave, and the degree of drought, are all important. Secondly, the number of people exposed to the hazard, or the condition of the infrastructure is significant. Finally, the vulnerability of those affected by the disaster is crucial. According to Ritchie (2024), the risk of disaster lies at the center of these three factors, and an increase in any of these dimensions raises the overall risk, whereas a decrease lowers it.

Figure 5. Damage Risk of a Hazard

Source: Ritchie, 2024.

Hazards transform into disasters when they affect communities and individuals. Therefore, this study has developed a model that examines the use of AI throughout the disaster process to reduce the risk of a hazard turning into a disaster (Figure 6). The objective of this model is to contribute to the prevention of disasters, minimize loss of life and property, and facilitate more urgent and effective interventions. The model addresses the use of AI both before and after disasters, focusing on data collection and analysis, communication and information sharing, disaster forecasting and early warning systems, simulation and training, search and rescue operations, and damage assessment.

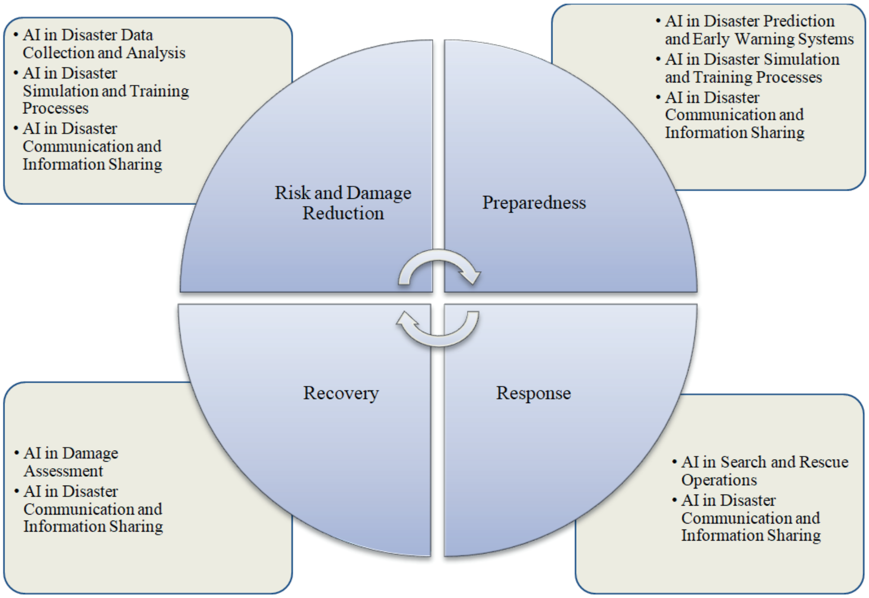


Figure 6. Artificial Intelligence Application Model in Disaster Management

Artificial Intelligence in Disaster Prediction and Early Warning Systems

Developing early prediction and mitigation strategies is vital to building safer and more resilient communities. Numerous studies in the relevant literature have proposed the use of AI techniques to improve disaster prediction and monitoring (see Ogie et al., 2018; Saravi et al., 2019; Sun et al., 2020). The development of AI methods (such as image recognition, natural language processing, object recognition, machine learning, deep learning, support vector machines, and neural networks) is increasingly making AI applicable for disaster management.

Every year, numerous flooding disasters occur worldwide, leading to fatalities and adversely impacting lives. However, AI-supported disaster prediction and early warning systems analyze meteorological data to estimate the likelihood of disasters. For instance, Google Research has developed AI models to predict floods, resulting in the creation of the 'Flood Hub' system. This system processes various data from rain gauges, river levels, and soil moisture sensors to predict when and where floods may occur, thereby alerting communities in the affected areas before a disaster strikes (Google Research, 2024). Similar studies are also present in the relevant literature. For example, Lin et al. (2009) developed an early warning system for typhoon rainfall using support vector machines.

AI can also provide effective solutions for predicting the spread of wildfires or for the early detection of their ignition points. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia has developed a system called Spark, which predicts the spread of wildfires using AI. This system facilitates better allocation of firefighting resources and the development of strategies to prevent the spread of fires. In this context, the system can read weather data from meteorological forecasts and develop fire spread models using geographical information such as terrain slope, vegetation, and roads (CSIRO, 2024).

Large-scale earthquakes and the tsunamis they trigger can result in significant material and emotional loss. In recent years, advancements in deep learning technologies, including image recognition, natural language processing, and object recognition, have aimed to facilitate the early prediction of large-scale earthquakes. For instance, AI-supported machine learning can predict seismic activities. Machine learning algorithms analyze historical seismic data to create predictive models that assist in forecasting earthquake occurrences, their potential magnitudes, and the areas they may affect (Doma & Şener, 2024). Huang et al. (2018) proposed a deep learning method for earthquake prediction based on Taiwan's historical seismic events. Similarly, Rafiei and Adeli (2017) introduced a new early warning system model that predicts the magnitude and location of earthquakes weeks before their occurrence, based on machine learning and mathematical optimization algorithms. In Türkiye, applications such as the 'Earthquake Network PRO' and the Google Android Earthquake Warning System are used for earthquake alerts (Balbay, 2024, p. 26-27). However, both in Türkiye and globally, there is a pressing need for applications that provide earlier warning systems to reduce the risk of hazards turning into disasters.

Artificial Intelligence in Disaster Communication and Information Sharing

Effective communication plays a significant role in the disaster management process (risk and damage reduction, preparedness, response, recovery). Increasingly, information and communication technologies are being utilized throughout the disaster process. The development of information communication technologies such as social media, telecommunications data, and remote sensing is making digital technologies used in disaster management more effective.

In the event of a disaster, people exchange messages to inform their loved ones of their situations or to request assistance. However, in some disasters, communication channels can sustain severe damage, leading to communication disruptions. In this context, flying base stations serve as an important application. In Türkiye, flying base stations (Dronecell) have been actively used in natural disasters and search and rescue operations to provide connectivity. Additionally, individuals can share their locations directly and receive information through the AFAD Emergency or 112 Emergency Button applications.

Following a disaster, it is essential to establish rapid and organized logistics to meet people's needs, as well as to facilitate evacuation procedures, health services, and security measures. However, the enormous amount of data generated during emergencies, coupled with a lack of a robust communication infrastructure, poses a significant challenge for countries (Agurbash, 2023). In affected areas during disasters, government agencies, non-governmental organizations, first responders, or rescue personnel may face various challenges in effectively conducting relief and rescue operations. More explicitly, individuals communicate with each other through communication platforms, report locations or missing persons, and contribute to providing assistance and forming volunteer teams. Obtaining real-time information about the disaster after the disaster is of vital importance. Therefore, data produced through especially social media platforms is important. However, the complexity of the language and vocabulary used and the high volume of data flow make real-time analysis difficult. Therefore, utilizing AI methods such as machine learning, deep learning, support vector machines, decision trees, neural networks, and algorithms to extract content and categorize it into various subject classes enhances the effectiveness of the process (Lamsal & Kumar, 2020).

AI can facilitate information sharing and guidance after disasters through virtual assistants, enhancing communication among emergency response teams, government agencies, and affected populations. For example, in Japan, Weathernews Inc. has designed a chatbot to inform citizens about where to find evacuation and relief supplies during a disaster (Doma & Şener, 2024). Furthermore, various lifesaving applications have been developed that utilize phone GPS features for real-time location sharing or provide information on what actions to take before, during, and after a disaster. Notably, the BİP application has become one of the most preferred applications during the February 6 earthquake due to its ability to provide location information through offline messaging and Bluetooth technology (Balbay, 2024, p. 41). Additionally, there are various AI-supported communication and information applications developed not only for the preparedness and response phases but also for the recovery stages. For instance, there are various web or mobile applications/virtual assistants supported by different associations or organizations that offer psychological support to disaster victims.

Artificial Intelligence in Disaster Data Collection and Analysis

Data becomes a significant resource in reducing, preventing, or improving the risks associated with a disaster. As the volume of data provided regarding real-time events, crises, or disasters increases, disaster effectiveness improves, particularly in visualizing, analyzing, and predicting disasters, with data management providing various contributions. Reliable, accurate, and timely information emerges as a critical element in all processes of disaster management, and in this regard, AI plays a significant role. For instance, the Disaster and Emergency Management Authority in Türkiye has developed the "AYDES – UZAL" and "AYDES – Crowdsourcing" software to utilize images obtained through remote sensing technologies for various analyses before or after disasters, according to identified needs (AFAD, 2024a).

Data collection and analysis during disaster situations face challenges. AI-supported technologies contribute to the collection and analysis of almost real-time data in disaster and crisis situations. AI is used especially in the integration of heterogeneous data: disaster management efficiency is increased by utilizing heterogeneous data sources such as machine learning, social media, crowd-sourced data, satellite images, maps, reports and news; and AI offers the opportunity to obtain and process large volumes of data (Fan et al., 2021). For example, after the February 6 earthquake in Kahramanmaraş, Türkiye developed the "DerinGÖRÜ" application, which utilized facial recognition and matching software to identify hundreds of displaced children (Anadolu Ajansı, 2023).

AI plays a vital role in analyzing data and transforming of data into understandable and reliable information during disasters (Abid et al., 2021; Doma & Şener, 2024). The analysis of collected data allows for the rapid determination of the disaster's location, impact scale, severity, damage, etc. Text processing algorithms can enhance the readability of shared information regarding the disaster, thereby contributing to the decision support process. Satellite imagery can be used to create disaster maps. As part of efforts to provide real-time information, AI analyzes social media data, and this information can subsequently be presented to individuals through dashboards, smartphone notifications, and email alerts. Critical points can be identified for aid and resource distribution following a disaster. In summary, many AI components can be actively utilized in processing the vast data obtained after a disaster, contributing to a more efficient operation of the process.

Artificial Intelligence in Disaster Simulation and Training Processes

The use of AI technologies in the simulation and training phases of disaster management processes offers significant opportunities for strengthening preparedness and enhancing response capacities. AI facilitates the more realistic and dynamic modeling of disaster scenarios, enabling decision-makers, response teams, and disaster victims to be better equipped for potential disaster situations.

Virtual reality-supported training simulations can be employed to improve the decision-making skills of disaster response teams under high stress (Mishra et al., 2019). More explicitly, AI algorithms can analyze participants' decisions during simulations, simulate the outcomes of these decisions in real time, and provide feedback. For example, in a fire extinguishing operation simulation, an AI-based system can monitor the movements of firefighters and assess whether they are applying the correct firefighting techniques. In particular, it can provide feedback focused on personal development areas by analyzing each individual's performance for a more effective training process.

In addition to personnel training, AI can also be utilized in public disaster awareness training. Ultimately, AI-based simulation and training systems play an effective role in the fundamental stages of disaster management, contributing to the development of a more prepared and resilient society against disasters.

Artificial Intelligence in Search and Rescue Operations

Search and rescue operations are a critical component in reducing human and environmental risks during disasters and in challenging environments. The first 72 hours following a disaster are vital for locating and rescuing individuals who are lost or trapped. Therefore, it is essential to take rapid actions during search and rescue operations.

Various technologies, including wireless sensor networks, UAVs, satellite observations, data processing, and social networks, are used to increase the effectiveness of search and rescue operations (Erdelj et al., 2017; Alsamhi et al., 2022; Farsath et al., 2024). For example, according to Alsamhi et al. (2022), UAVs can fly over the targeted area during disasters, provide rapid and real-time data about the situation, and transmit information such as photos and videos to rescue personnel (Figure 7). When combined with AI, UAVs can collect results in real time and analyze the collected images. In this case, AI-enabled UAVs can quickly reach remote locations, provide real-time aerial images of the scene, and collect valuable data for informed decision-making (Farsath et al., 2024, p. 1). Similarly, thermal cameras using heat monitoring systems can significantly contribute to disaster search and rescue operations.

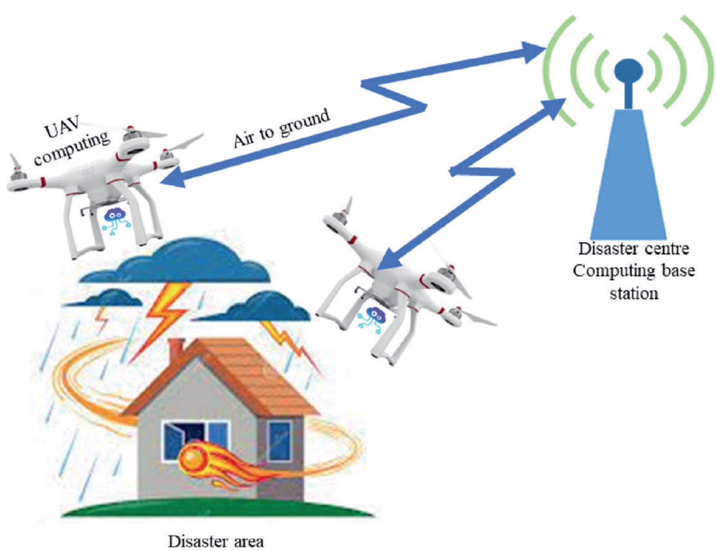


Figure 7. UAV-Supported Disaster Area

Source: Alsamhi et al., 2022

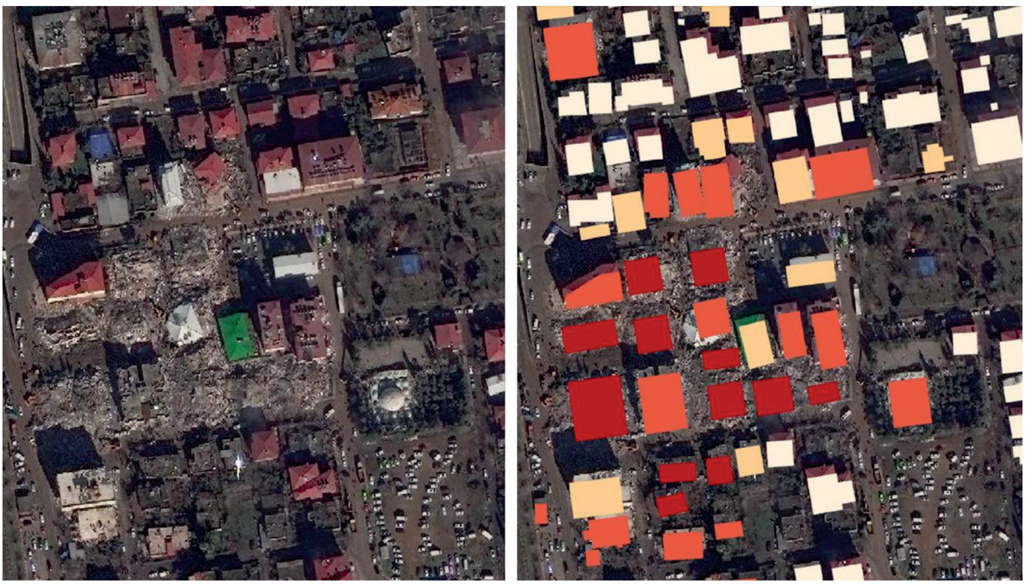
AI robots can undertake important roles in disaster prevention and rescue, assisting humans in dangerous environments—during crises, robots can help extinguish fires, locate survivors after earthquakes, detect and repair leaks on oil platforms, carry equipment for rescue teams, and more (Wilk-Jakubowski et al., 2022). For example, Zhang et al. (2022) designed a smart firefighting robot based on multi-sensor fusion, emphasizing that robots are increasingly playing a significant role in detecting fire sources and combating fires.

After a major earthquake, it is essential to be able to respond quickly and reach earthquake victims in a timely manner. However, sometimes there may be a few critical challenges such as a shortage of emergency rescue and intervention teams or equipment, and access restrictions to the area. Intervention to rescue people trapped under large debris can be quite difficult or take too much time. In this context, disaster robots and unmanned aerial vehicles can significantly improve search and rescue operations. Search and rescue robots equipped with real-time imaging technology and sensors can reach people trapped in difficult debris; help draw a debris map; instantly monitor environmental conditions; and track vital signs with heat monitoring; and thus, contributing to the accuracy and effectiveness of disaster search and rescue efforts, thus saving more lives. According to a study conducted by Li et al. (2023), urban search and rescue robots have participated in rescue missions in many disasters. In Türkiye, following the February 6 earthquake, tools such as wall radar systems, UAVs, carbon dioxide detectors, thermal cameras, endoscopic cameras, radar life detection technology, and life detection sensors were used, providing significant contributions to search and rescue teams (Balbay, 2024, p. 31-35). Similarly, the FINDER technology (Finding Individuals for Disaster and Emergency Response) has been utilized to locate earthquake victims based on minute movements such as heartbeats or breathing.

Robots play a key role not only in the response phase of devastating disasters such as earthquakes, but also where hazards are created. For example, robots used in hazardous environments can contribute to the prevention and reduction of loss of life in a possible disaster (leak, poisoning, explosion, etc.). Similarly, they can obtain real-time images and data from hazardous areas; dynamically monitor environmental changes; operate with minimum risk in high-risk environments; rescue people in danger; and collect environmental data for analysis (Xu and Xue, 2023). In Japan, the Quince robot has specifically developed to investigate areas affected by chemical, radioactive, or explosive hazards and served as a safer alternative to traditional fire brigades (Web Japan, 2024).

Artificial Intelligence in Damage Assessment

Damage assessment is a critical step in the aftermath of a disaster. Field research conducted by teams requires a significant amount of time and resources (Cheng et al., 2022). Advances in remote sensing, imaging from satellites and drones, and developments in AI have improved the automatic and rapid assessment of disaster damage. AI-supported programs that analyze images can more easily detect the extent and spread of damage after a disaster. For instance, the open-source xView2, supported and developed in 2019, utilizes machine learning algorithms to identify building and infrastructure damage in disaster-affected areas. To accelerate search and rescue operations and support the accurate identification of debris, satellite imagery detection technology has been developed to scan satellite images and determine the locations of debris.



Source: Ryan-Mosley, 2023.

Image 1 (left) depicts a satellite image of an area in Gaziantep-Islahiye following the February 6, 2023, Kahramanmaraş earthquake, while Image 2 (right) presents an output obtained with xView2. As the colors darken (the darker the red), the condition of the debris worsens. According to disaster risk management experts, such assessments typically take weeks to complete, whereas with AI, this timeframe can be reduced to hours or even minutes. Additionally, xView2 has been used in the past five years during wildfire rescue efforts in the United States and Australia, as well as during flood recovery efforts in Nepal (Ryan-Mosley, 2023). However, there are still some issues that xView2 cannot solve at its current stage: the inability to obtain clear satellite images and adverse weather conditions that hinder image acquisition led to the first usable images of the earthquake arriving three days later, on February 9, in Türkiye. Therefore, there is a need for newly developed imaging techniques.

Similarly, geographic information systems and remote sensing technologies can be integrated with AI to develop risk analyses, identify weak points in infrastructure, and define high-risk areas. This can facilitate the creation of more resilient urban planning and land-use policies (Doma & Şener, 2024). The February 6, 2023 earthquake affected 11 cities in Türkiye, resulting in the destruction and damage of thousands of buildings. At this juncture, using AI-supported structural modeling in the construction or assessment of new buildings can help prevent potential damage in the future.

Conclusion

The prevention and mitigation of loss of life and property prior to the occurrence of disasters is a critical objective in contemporary disaster management. While the effective implementation of established disaster management strategies remains essential, fostering resilience in the environment, society, and individuals is equally paramount. Advancements in technology, particularly AI, offer promising avenues for enhancing disaster management practices. Therefore, this study has developed a model that examines the use of AI throughout the disaster process to reduce the risk of a hazard turning into a disaster. The model addresses the use of AI both before and after disasters, focusing on data collection and analysis, communication and information sharing, disaster forecasting and early warning systems, simulation and training, search and rescue operations, and damage assessment. The objective of this model is to contribute to the prevention of disasters, minimize loss of life and property, and facilitate more urgent and effective interventions.

AI technologies enable significant improvements across various stages of disaster management. The utilization of AI for processing large-scale data, which enhances the accuracy and timeliness of disaster predictions. Furthermore, AI supports the optimization of Early Warning Systems by integrating real-time data, thereby providing extended lead times before the onset of a disaster. Autonomous robots and UAVs, powered by AI, minimize human intervention in high-risk, complex environments. The application of AI-driven algorithms assists decision-makers in making more informed and efficient choices during critical moments. The use of advanced systems such as neural networks, decision trees, and geographical mapping tools further improves the overall disaster management process. AI-powered simulations and training programs contribute to the increased preparedness of both the public and response personnel, reinforcing resilience at the societal level.

Despite these advancements, the integration of AI in disaster management is not without its challenges. One significant issue is the requirement for vast amounts of high-quality data to ensure accurate and rapid predictions. This data-intensive nature of AI necessitates robust data collection and processing mechanisms, which can raise concerns regarding data privacy and security. Safeguarding this data is essential to mitigate the risks associated with potential breaches. Additionally, regional disparities in technological infrastructure pose a challenge; areas with less-developed technological frameworks may struggle to collect sufficient data, hindering the development and deployment of effective AI applications or limiting their scope. Furthermore, the increasing unpredictability of both natural and anthropogenic factors complicates disaster response, as AI systems may struggle to adapt to the unforeseen complexities resulting from these evolving circumstances.

In conclusion, the use of AI in disaster management presents both significant opportunities and notable challenges. The transformation of a hazard into a disaster is often determined by the scale of the destruction it causes, underscoring the necessity of AI-supported processes to reduce the likelihood of hazards escalating into full-scale disasters. AI and digital technologies play a crucial role in facilitating efficient and accurate management throughout all phases of disaster response. Moving forward, research efforts should prioritize addressing the inherent difficulties associated with implementing AI in disaster management. Furthermore, the development of digital technologies aimed at enhancing resilience both at the individual and national levels should be a focal point in the effort to create more robust disaster management frameworks. Future studies can contribute to the progression of AI in disaster management by concentrating on the following areas:

- Future studies could explore innovative solutions to ensure data security and privacy in AI applications, particularly in regions with varying levels of technological development. This includes the development of decentralized data storage or encryption techniques to safeguard sensitive disaster-related information.
- Investigating AI applications in low-resource and less-technologically developed regions would help identify strategies to overcome infrastructure limitations. Research should focus on the creation of adaptable AI systems that can operate with limited data while maintaining efficacy in disaster management.
- Research could be directed towards enhancing AI's ability to handle the increasing complexity of disaster scenarios, particularly those involving combined natural and man-made factors. This would involve the development of more sophisticated algorithms capable of predicting and responding to unpredictable, multi-dimensional threats.
- There is a need for further exploration into the role of AI in public and personnel training. Specifically, studies should examine the effectiveness of AI-driven simulation programs in building disaster resilience and their potential to enhance real-time decision-making during crises.
- Future studies may focus on the integration of AI with multi-agent systems, which involve the coordination of various entities (robots, drones, emergency responders, etc.) in disaster management. This approach could improve efficiency and responsiveness in dynamic disaster environments.

Etik Beyanı: Yazar bu çalışmanın tüm hazırlanma süreçlerinde etik kurallara uyulduğunu yazar beyan eder. Aksi bir durumun tespiti halinde Kamu Yönetimi ve Teknoloji Dergisinin hiçbir sorumluluğu olmayıp, tüm sorumluluk çalışmanın yazarına aittir.

Ethics Statement: The author declares that the ethical rules are followed in all preparation processes of thisstudy. In the event of a contrary situation, the Journal of Public Administration and Technology has noresponsibility and all responsibility belongs to the author of the study.

Yazar Katkıları: Prof. Dr. Veysel EREN ve Arş. Gör. Hasret DUMAN çalışmanın tamamında birlikte katkı sunmuştur.

Author Contributions: Prof. Dr. Veysel EREN and Arş. Gör. Hasret DUMAN have contributed to all parts and stages of the study.

Çıkar Beyanı: Yazarlar ve herhangi bir kurum/ kuruluş arasında çıkar çatışması yoktur.

Conflict of Interest: There is no conflict of interest among the author and any institution.

Teşekkür: Yayın sürecinde katkısı olan hakemlere teşekkür ederiz.

Acknowledgement: We would like to thank the referees who contributed to the publication process.

KAYNAKÇA

Abid, S., Kamran, N. S., Chan, S. W., Nazir, U., Abid, M., Han, H., Ariza-Montes, A., & Vega-Muñoz, A. (2021) ''Toward An Integrated Disaster Management Approach: How Artificial Intelligence Can Boost Disaster Management''. *Sustainability, 13*(22), 12560. https://doi.org/10.3390/su132212560

AFAD (2024a). AYDES Uzaktan Algılama (UZAL). https://www.afad.gov.tr/aydes-uzaktan-algilama-uzal55 (20.08.2024)

AFAD. (2024b). Afet Türleri. https://www.afad.gov.tr/afet-turleri (20.08.2024)

Agurbash, E. (2023) ''Autonomous Robots for Disaster Management''. https://aiforgood.itu.int/autonomous-robots-for-disaster-management/

Alsamhi, S. H., Shvetsov, A. V., Kumar, S., Shvetsova, S. V., Alhartomi, M. A., Hawbani, A., Rajput, N. S., Srivastava, S., Saif, A., & Nyangaresi, V. O. (2022) ''UAV Computing-Assisted Search and Rescue Mission Framework for Disaster and Harsh Environment Mitigation''. *Drones, 6*(7), 154. https://doi.org/10.3390/drones6070154

Anadolu Ajansı. (2023). Refakatsiz Depremzede Çocuklar İçin Yüz Tanıma Yapan 'Deringörü' Yazılımı Devrede. https://www.aa.com.tr/tr/asrin-felaketi/refakatsiz-depremzede-cocuklar-icin-yuz-tanima-yapan-deringoru-yazilimi-devrede/2818155 (29.09.2024)

Balbay, E. (2024) ''Türkiye'de Meydana Gelen Kahramanmaraş Depremlerinde Yapay Zekâ ve Dijital Teknolojilerin Kullanımının Incelenmesi''. Yüksek Lisans Tezi. Ufuk Üniversitesi Sosyal Bilimler Enstitüsü.

Cheng, C.-S., Behzadan, A. H., & Noshadravan, A. (2022) ''Uncertainty-Aware Convolutional Neural Network for Explainable Artificial Intelligence-Assisted Disaster Damage Assessment''. *Structural Control and Health Monitoring, 29*(10), e3019. https://doi.org/10.1002/stc.3019

CSIRO (2024). Spark: Predicting Bushfire Spread. https://www.csiro.au/en/research/technology-space/ai/Spark (07.09.2024)

Doma, O. O., & Şener, S. M. (2024) ''Doğal Afet ve Yapay Zekâ: Deprem Yönetimini Dönüştüren Bilişim Teknolojileri''. İTÜ *Vakfı Yayınları*. https://www.ituvakif.org.tr/dogal-afet-ve-yapay-zeka

Duman, H. (2024) ''Use of Digital Technologies in Migration and Asylum Management''. In *Media representation of migrants and refugees* (pp. 169-188). IGI Global.

EM-DAT. (2023). Earthquakes in Türkiye: A Review from 1900 to Today. https://files.emdat.be/2023/09/CredCrunch72.pdf (08.07.2024)

Erdelj, M., Król, M., & Natalizio, E. (2017) ''Wireless Sensor Networks and Multi-UAV Systems For Natural Disaster Management''. *Computer Networks, 124,* 72-86. https://doi.org/10.1016/j.comnet.2017.06.019

Eren, V. (2022) ''Kriz Yönetimi Kavramı ve Kriz Yaratan Durumlar''. In *Kamu Sektöründe Kriz Yönetimi: Kavram, Kuram ve Uygulamalar* (pp. 1-29). Nobel Yayınları.

Erkal, T., & Değerliyurt, M. (2009) ''Türkiye'de Afet Yönetimi''. *Doğu Coğrafya Dergisi, 14*(22), 147-164.

Fan, C., Zhang, C., Yahja, A., & Mostafavi, A. (2021) ''Disaster City Digital Twin: A Vision for Integrating Artificial and Human Intelligence for Disaster Management''. *International Journal of Information Management, 56,* 102049. https://doi.org/10.1016/j.ijinfomgt.2020.102049

Farsath, R., Jitha, K., Marwan, V. K. M., Ali Jouhar, A. M., & Musrifa, K. A. (2024). ''AI-Enhanced Unmanned Aerial Vehicles for Search and Rescue Operations''. In *2024 5th International Conference on Innovative Trends in Information Technology (ICITIIT)* (pp. 1-10). IEEE. https://doi.org/10.1109/ICITIIT50450.2024.00010

Gesk, T. S., & Leyer, M. (2022). ''Artificial Intelligence in Public Services: When and Why Citizens Accept Its Usage''. *Government Information Quarterly, 39*(3), 101704. https://doi.org/10.1016/j.giq.2022.101704

Google Research. (2024). Flood Forecasting. https://sites.research.google/floodforecasting/#:~:text=Flood%20Hub%20for%20Governments%20and%20Organizations&text=It%20is%20a%20visual%2C%20easy,models%20and%20global%20data%20sources

Huang, J. P., Wang, X. A., Zhao, Y., Xin, C., & Xiang, H. (2018) ''Large Earthquake Magnitude Prediction in Taiwan Based on Deep Learning Neural Network''. *Neural Network World, (2).*

Kulal, A., Ur Rahiman, H., Suvarna, H., Abhishek, N., & Dinesh, S. (2024) ''Enhancing Public Service Delivery Efficiency: Exploring the Impact of AI''. *Journal of Open Innovation: Technology, Market, and Complexity, 10*, 329. https://doi.org/10.3390/joitmc10030029

Lamsal, R., & Kumar, T. V. (2020) ''Artificial Intelligence and Early Warning Systems''. In *AI and Robotics in Disaster Studies* (pp. 13-32).

Li, F., Hou, S., Bu, C., & Qu, B. (2023) ''Rescue Robots for the Urban Earthquake Environment''. *Disaster Medicine and Public Health Preparedness, 17*, e181. https://doi.org/10.1017/dmp.2022.159

Margetts, H., & Dorobantu, C. (2019) ''Rethink Government With AI'', *Nature, 568*(7751), 163-165. https://doi.org/10.1038/d41586-019-01372-8

Mehr, H. (2017) ''Artificial Intelligence for Citizen Services and Government'', *Harvard Ash Center Technology & Democracy Fellow*, August 1, 12.

Mishra, D., Kumar, S., & Hassini, E. (2019) ''Current Trends in Disaster Management Simulation Modeling Research'', *Annals of Operations Research, 283*(1), 1387-1411. https://doi.org/10.1007/s10479-018-2987-2

Nunavath, V., & Goodwin, M. (2019) ''The Use of Artificial Intelligence in Disaster Management: A Systematic Literature Review'', In *2019 International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)* (pp. 1-8). https://doi.org/10.1109/ICT-DM.2019.00012

Ogie, R. I., Castilla Rho, J., & Clarke, R. J. (2018) ''Artificial Intelligence in Disaster Risk Communication: A Systematic Literature Review'', In *2018 5th International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)* (pp. 1-8). https://doi.org/10.1109/ICT-DM.2018.00007

Our World in Data. (2024). The World Has Become More Resilient to Disasters, But Investment is Needed to Save More Lives. https://ourworldindata.org/the-world-has-become-more-resilient-to-disasters-but-investment-is-needed-to-save-more-lives (23.09.2024).

Pencheva, I., Esteve, M., & Jankin Mikhaylov, S. (2020) ''Big Data And AI—A Transformational Shift for Government: So, What Next for Research?'', *Public Policy and Administration, 35*(1), 24-44. https://doi.org/10.1177/0971685820901223

Rafiei, M. H., & Adeli, H. (2017) ''NEEWS: A Novel Earthquake Early Warning Model Using Neural Dynamic Classification and Neural Dynamic Optimization'', *Soil Dynamics and Earthquake Engineering, 100,* 417-427. https://doi.org/10.1016/j.soildyn.2017.06.022

Ritchie, H. (2024) ''The World Has Become More Resilient to Disasters, But Investment Is Needed To Save More Lives'' Published online at OurWorldinData.org. https://ourworldindata.org/the-world-has-become-more-resilient-to-disasters-but-investment-is-needed-to-save-more-lives (22.08.2024).

Ryan-Mosley, T. (2023) ''How AI Can Actually be Helpful in Disaster Response'', https://www.technologyreview.com/2023/02/20/1068824/ai-actually-helpful-disaster-response-turkey-syria-earthquake/ (02.08.2024).

Saravi, S., Kalawsky, R., Joannou, D., Rivas Casado, M., Fu, G., & Meng, F. (2019) ''Use of Artificial Intelligence to Improve Resilience and Preparedness Against Adverse Flood Events'' *Water, 11*(5), 973. https://doi.org/10.3390/w11050973

Sendai. (2024). Sendai Afet Risk Azaltma Çerçevesi 2015-2030. https://uclg-mewa.org/uploads/file/748e86d91ae4409e9188794ddb6c004d/Sendai_TR.pdf (25.09.2024).

Sun, W., Bocchini, P., & Davison, B. D. (2020) ''Applications of Artificial Intelligence for Disaster Management'', *Natural Hazards, 103*(3), 2631-2689. https://doi.org/10.1007/s11069-020-04263-1

Şahin, Ş. (2019) ''Türkiye'de Afet Yönetimi ve 2023 Hedefleri'', *Türk Deprem Araştırma Dergisi, 1*(2), 180-196.

TDK. (2024). Türk Dil Kurumu Sözlükleri. https://sozluk.gov.tr/ (09.07.2024).

Web Japan. (2024). Disaster-Prevention Technology in Japan. https://web-japan.org/trends/11_tech-life/tec202112_disaster-prevention.html (25.09.2024).

Wilk-Jakubowski, G., Harabin, R., & Ivanov, S. (2022) ''Robotics in Crisis Management: A Review'', *Technology in Society, 68,* 101935. https://doi.org/10.1016/j.techsoc.2022.101935

Zhang, S., Yao, J., Wang, R., Liu, Z., Ma, C., Wang, Y., & Zhao, Y. (2022) ''Design of Intelligent Fire-Fighting Robot Based On Multi-Sensor Fusion And Experimental Study On Fire Scene Patrol'', *Robotics and Autonomous Systems, 154,* 104122. https://doi.org/10.1016/j.robot.2022.104122

Xu, C., & Xue, Z. (2023) ''Applications and Challenges of Artificial Intelligence in The Field of Disaster Prevention, Reduction, and Relief'', *Natural Hazards Research*.