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Integrating AI and lot for Earthquake-Resilient Urban Planning: Optimizing Safer Zones and Evacuation Strategies in Cities

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ABSTRACT

Earthquake events that occur more frequently together with increasing magnitude as well as urban growth demands new innovative solutions for ensuring urban disaster resilience. Standard earthquake evacuation blueprint methods which depend on stationary models together with historical records show inadequacy when dealing with seismic occurrences that follow unpredictable dynamics. The research studies the implementation of Artificial Intelligence and Internet of Things in earthquake protection strategies for urban areas to maximize evacuation plans. This investigation utilizes real-time data acquisition with sophisticated analytical techniques and routing algorithms to establish adaptable solutions that pinpoint safe areas and enhance route optimization for evacuation plans. The analysis of earthquake-prone areas includes the evaluation of essential response parameters concerning road conditions together with population density and structural vulnerabilities. The research proves that AI and IoT systems create opportunities to upgrade early detection systems and strengthen urban construction alongside delivering real-time operational capabilities. Through testing new methods, the research establishes that advanced technological systems are practical solutions for controlling earthquake risk. The research promotes the development of safer urban spaces with minimized seismic disaster impacts by providing a system to integrate contemporary technology platforms into city planning initiatives.

Keywords: Earthquakes, Earthquake-Resilient Planning, Evacuation planning, AI, IoT

INTRODUCTION

City survival against earthquakes demands sophisticated disaster management systems because earthquakes become increasingly dangerous. Standard assessment techniques based on historical data together with static modeling systems do not adapt to seismic patterns in a dynamic manner. Excessive seismic activity in 2023 demonstrated structural system vulnerabilities through the Kahraman Maras earthquake in Türkiye. The 2011 Tohoku and 2010 Haiti earthquake disasters show that modern mitigation approaches are needed because AI and IoT have created new ways to monitor in real-time and find threats early and create evacuation plans. Electronic devices within IoT systems monitor environmental data alongside structural information whereas AI systems analyze large datasets to develop precise risk evaluations combined with optimized evacuation methods. The research merges these technologies into an operational system that determines changing safe zones while developing an effective framework for earthquake evacuation strategies in cities at risk. Non-stop data analysis through AI enhances rapid emergency responses thus minimizing death tolls together with collapsing infrastructure. The study investigates urban seismic vulnerability together with the applications of technology that reduce seismic threats. The rapid advancement of AI technology has brought essential earthquake preparedness to a new level through beneficial data-based solutions which boost urban defenses against the escalating number of natural disasters.

BACKGROUND OF THE STUDY

Urbanization and Vulnerability

An increased health risk exists since urban populations keep increasing which generates denser populations vulnerable to natural disasters such as earthquakes. Earthquakes present higher risks for cities that hold large numbers of residents particularly those located near tectonic plate zones. Better urban planning strategies need development to focus primarily on safety and security concerns.

Importance of Disaster Preparedness

A professional urban designer should create sustainable environments that automatically return to stability after disasters occur. Implementing smart technologies that combine IoT and Artificial intelligence will enhance disaster preparedness systems. Every approach detailed in this paper requires real-time technology solutions for data acquisition as well as assessment and distribution so they can identify both safety evacuation routes and protective locations amidst disasters.

The role of IoT and AI

Multiple aspects including seismographic activity and building structural health and population density can be tracked effectively by IoT devices that operate in urban areas. AI algorithms allow for processing data such that earthquake impact predictions and house-hazard assessment become possible in real-time. Smart sensors detect ground vibrations then send warnings to residents as well as authorities allowing prompt evacuation processes.

Enhancing Urban Resilience

IoT coupled with AI technology both strengthens emergency response capabilities as well as strengthens city sustainability during future sudden incidents. Cities should use the gathered data to reorganize their infrastructure frameworks while creating additional measures for disaster prevention and response systems and integrating citizen participation in disaster planning processes.

NEED OF THE STUDY

An increasing number of people living in cities across India creates additional dangers in earthquake scenarios. Static evacuation strategies used in disaster management fail to generate adaptable responses during seismic events because their plans do not adapt to real-time changes occurring during actual seismic occurrences. Safe zones listed on maps along with signs do not have the capability to respond to environmental changes in real time. The seismic region where Kerala resides has been becoming more fragile as population numbers grow and tall buildings increase. Developing adaptive technology solutions becomes crucial since current frameworks show limitations in the Indian context. AI technology with IoT connectivity enables real-time data assessment and environmental monitoring along with predictive results that improve evacuation programs. Through these technological systems officials can track buildings' conditions while observing population patterns and infrastructures to update their identification of safe zones as well as their evacuation paths in real time. The Smart City initiative of India receives support through AI-driven solutions which deliver sustainable urban resilience benefits. Public awareness should increase together with simple accessible evacuation map distribution to develop stronger community earthquake response abilities. The research targets a convergence between conventional disaster planning and modern technological innovations for international development in urban disaster management systems. Cities that implement AI and IoT systems will enhance their readiness as well as their emergency response capabilities leading to better protection of lives in areas with high seismic risk.

Figure 1 : Earthquake prone India seismic zone map

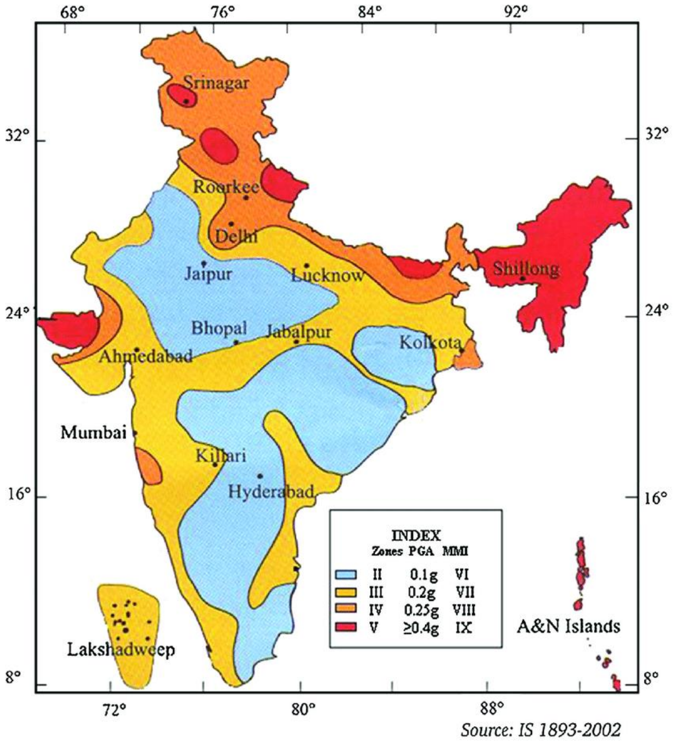
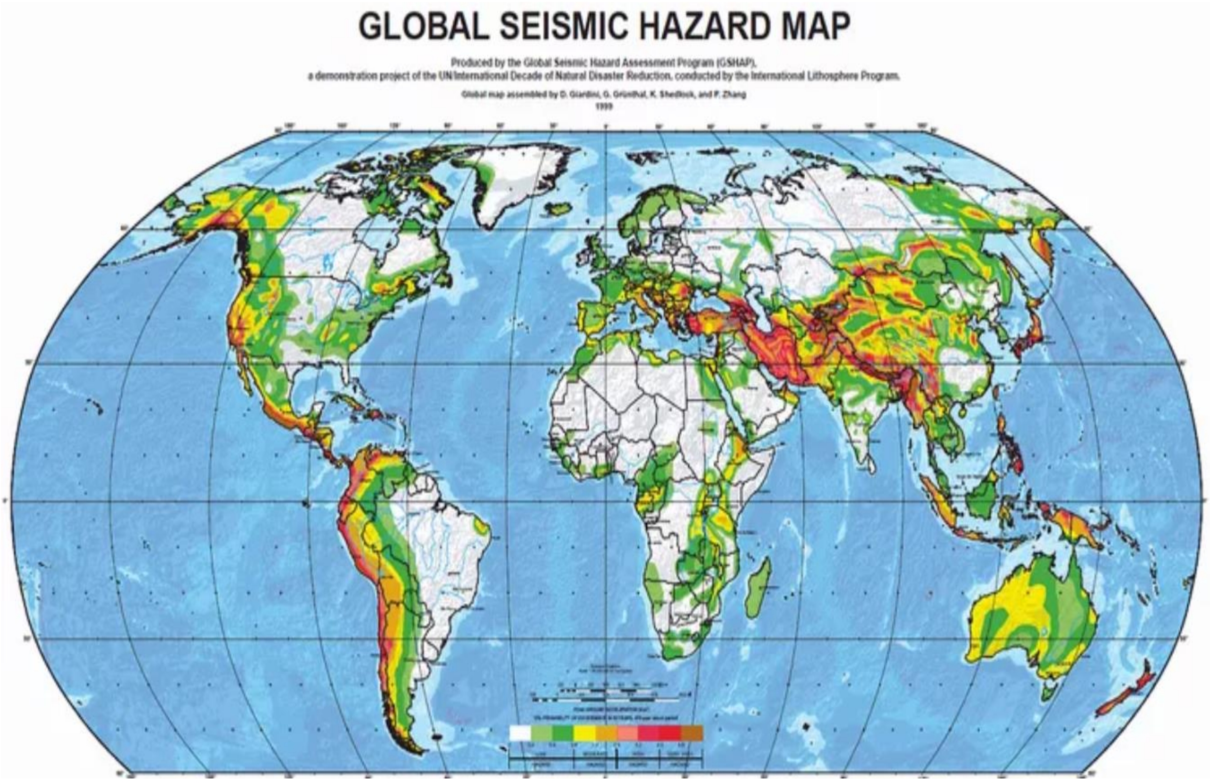
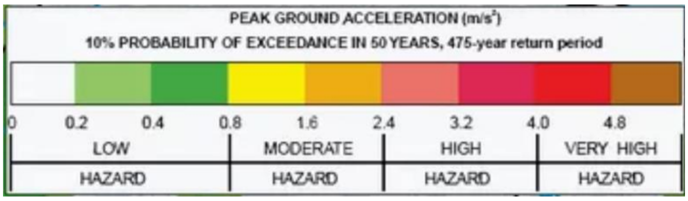


Figure 2 : Earthquake prone World seismic zone map





The entire nation of India represents a seismic risk zone because 59% of its territory falls into Zone II through Zone V categories. The most dangerous region of Zone V encompasses the Himalayan region and Kutch in Gujarat and the Northeastern parts of India. The regions of Indo-Gangetic Plain together with Western Ghats and Andaman & Nicobar Islands represent significant high-risk earthquake areas. These tectonic regions require high levels of disaster resilience because they exist in areas of active tectonic activity. Urban population increases make current evacuation methods insufficient for protecting people. The combination of AI and IoT enables the real-time gathering of evacuation route information as well as data-based identification of safe areas. Numerous countries including Japan and China and Indonesia and Turkey together with the United States are steadily integrating these technologies to increase their urban resilience. Secondary hazards arise from earthquakes which include landslides combined with tsunamis and fires that lead to extensive destruction across territories. These unpredictable seismic events need Humans to study nucleation and slow slip events and tectonic ruptures because of their complex fault dynamics. Historical major earthquakes take place at three geologic locations which include subduction zones and mid-Atlantic ridges and transform faults. The M7.8 magnitude earthquake that struck the East Anatolian Fault during 2023 Türkiye-Syria generated $100 billion worth of destruction while claiming more than 56,000 lives. Seismic prediction advances depend on three main areas including seismic observation using GPS DAS and InSAR and AI and ML progress and IoT-based live monitoring systems.

RESEARCH QUESTION

How can AI and IoT be integrated into earthquake-resilient urban planning to optimize evacuation strategies?

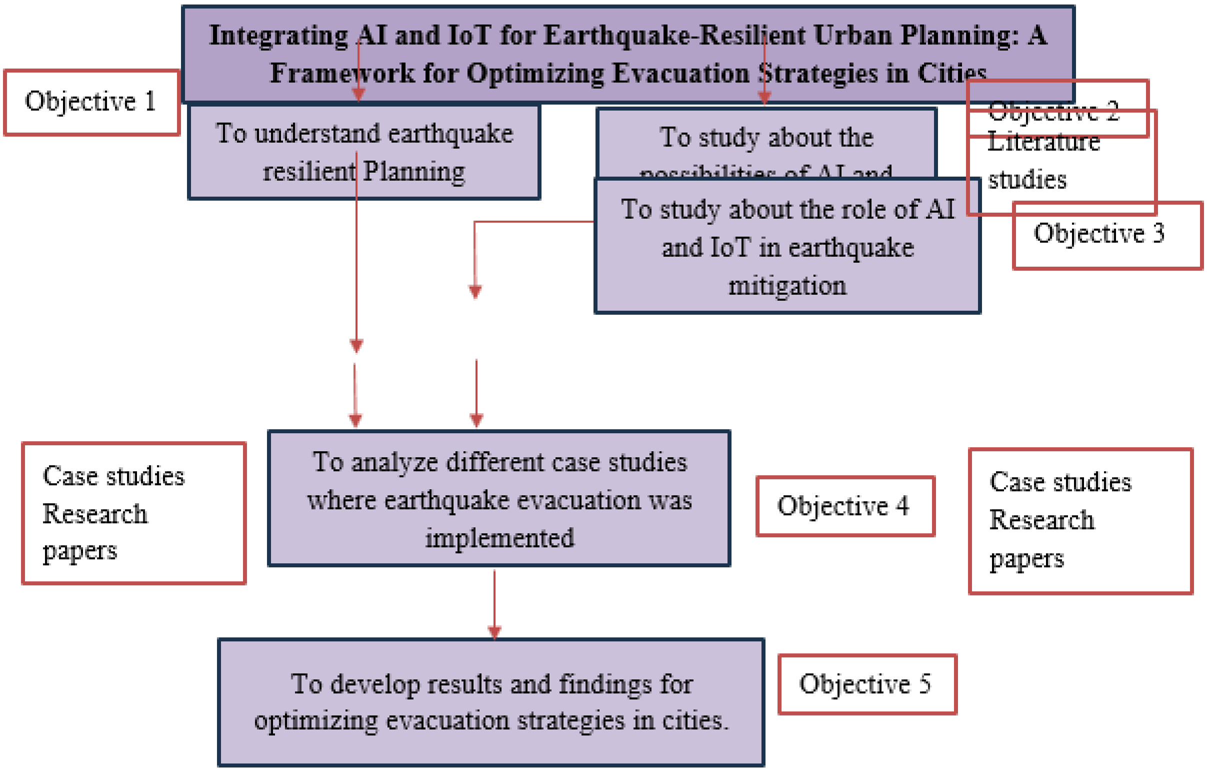
AIM

To integrate AI and IoT in earthquake-resilient Urban planning by analyzing case studies and identifying key parameters for optimizing evacuation strategies in cities.

OBJECTIVES

- To study earthquake-resilient planning.
- To study about the possibilities of AI and IoT in planning.
- To study about the role of AI and IoT in earthquake mitigation.
- To analyze different case studies where earthquake evacuation was implemented.
- To develop results and findings for optimizing evacuation strategies in cities.

METHODOLOGY



SCOPE

- To study about the potential applications of AI and IoT for earthquake early warning and evacuation.
- To integrate AI and IoT into earthquake-resilient spatial planning.

LIMITATION

RESEARCH GAP

Standard planning approaches focused on physical infrastructure construction alongside structural retrofits dominate research on earthquake-resistant urban planning yet the utilization of AI and IoT technology remains understudied. The advancement of early warning systems and evacuation plans remains insufficient because researchers need to explore more ways to combine AI and IoT for urban real-time decision-making processes. The difficult process of designing evacuation plans becomes more apparent because of the irregular city layouts. Current literature lacks complete frameworks which integrate AI and IoT systems for identifying dangerous areas and finding optimal safe areas together with accelerating evacuation routes. Scientists must research standard methods of combining AI systems with IoT technology for spatial design because this advancement would enhance the seismic resilience of buildings and provide better flexible real-time responses.

PROBABLE OUTCOME

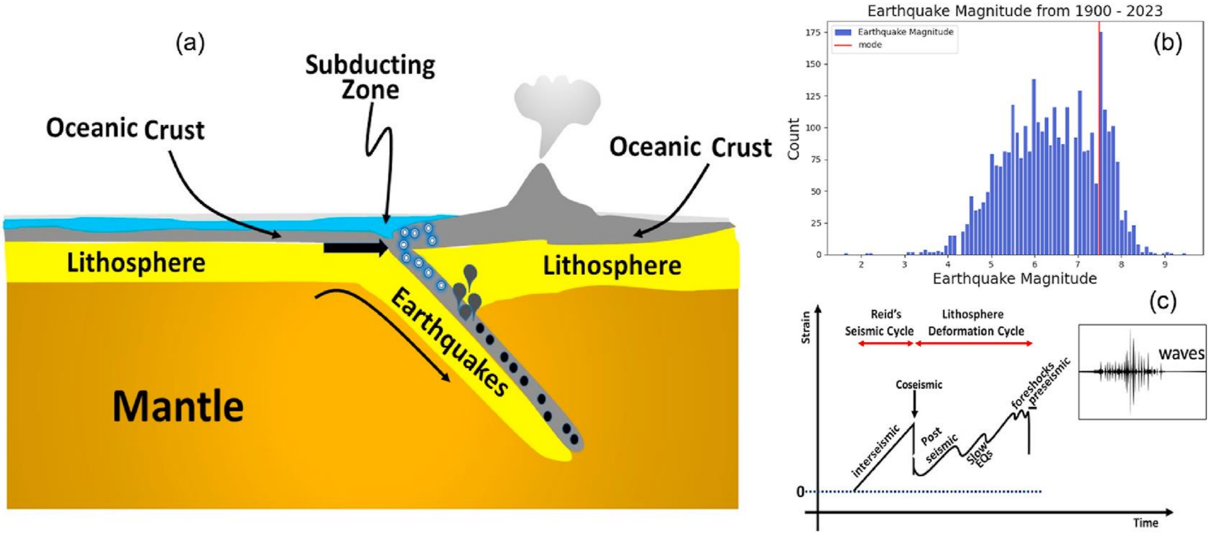
This research aims to offer complete knowledge about earthquake-safe city development methods through studying how modern technologies can boost safety measures. The study evaluates IoT and AI potential to discover novel monitoring optimization and early warning system and dynamic evacuation routing techniques. The essential evacuation data should come solely from previous earthquake case studies to understand layouts of effective versus ineffective evacuation strategies. Such analyses prepare cities for future disasters. Through the combination of AI and IoT with these important characteristics the research could maintain continuous updates for safe areas and efficient evacuation plans. The final work enables developers to construct cybersecurity-resistant urban structures while creating better strategic methods to protect against disasters that leverage smart technological solutions.

LITRETURE REVIEW

Earthquakes

Seismic waves emerge from earth under pressure when it breaks apart which produces violent vibrations in the ground called earthquakes. Such seismic ruptures measured between millimeters to meters penetrate the earth from the top surface to depths of up to 700 kilometer depths yet most events remain below the 60 kilometer depth. Severe structural destruction in human settlements dates back to earthquakes while modern developments have not improved city defenses against these natural disasters. Proper measures implement to minimize the effects of earthquakes despite their inability to prevent them. Earthquakes continue to pose the most dangerous natural disaster globally since they cause mortality rates higher than any other disaster and strike more than 35 countries. The study of earthquakes identifies three main categories of investigation which include the initiation of earthquakes and the mechanics of fault ruptures with different slip mechanisms together with the effects of fluid motion on seismicity. The occurrence of earthquakes heavily depends on subduction zones because these zones create 90% of all seismic events. The total magnitude of earthquakes stems from the seismic moment release occurring within the seismogenic zone. Research conducted by Kanamori together with Wells & Coppersmith and Pacheco et al. indicates that earthquakes reaching M > 8 magnitude become stronger because of large fault rupture areas and high seismic efficiency. According to Scholz (1998) seismic process enlargement occurs with big asperities while small asperities restrict the propagation of ruptures. Studying these natural processes helps improve both forecasting seismic events and building resilience against earthquakes thus minimizing disaster impacts.

Figure 3: (a) A simple schematic diagram of a subduction zone with earthquake occurring along the interface of the two plates.



Earthquake-Resilient Urban Planning

The study adopted participatory method of focus group discussion and selected, key spatial planning components to understand the interrelation of spatial planning and community resilience. The spatial planning components selected are crucial for safety of populations and have a potential impact on the community resilience in the earthquake.

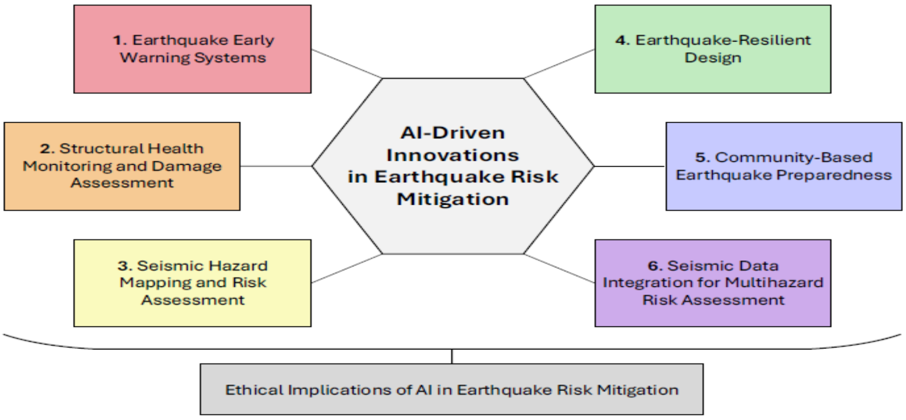
These components are:

1. Population
2. Land use
3. Roads
4. Open spaces
5. Physical infrastructure
6. Critical infrastructure

Urban planning that makes cities earthquake-resistant involves designing structures that can withstand earthquakes and minimizing both destruction and fast restoration processes. Administrative planning starts through seismic hazard evaluation which maps fault zones and studies geotechnical properties to recognize danger zones. Vulnerability analysis provides decision-making tools for assessing population vulnerabilities together with susceptibility of infrastructure in dense areas that contain critical facilities. The implementation of seismic zoning together with the establishment of buffer zones by land use policies restricts dangerous construction areas but reserves essential open areas for emergency evacuations. Redefinition of building codes mandates units to use reinforced materials for seismic safety and installation of strengthening upgrades to existing buildings. Healthcare facilities together with power generation facilities utilize engineering technologies that allow them to function when earthquakes occur. Flexible service rerouting becomes possible through reduplicative transport and water as well as power network infrastructure channels. The combination of IoT sensors together with AI-driven analytics instruments both early warning systems and earthquake modeling processes. Emergency planning for disasters includes pre-planned evacuation routes together with disaster training for the public while also having recovery plans to restore essential aid delivery. Resilient urban design creates tight urban environments that combine many resources and morphable materials and protected green areas for protection. The strength of preparedness arises from policy integration between civil engineering and emergency management and health sectors and from active community engagement. A complete comprehensive strategy lowers death rates concurrently with minimizing property destruction and enabling successful recovery.

Possibilities of AI

Figure 4:The six areas of AI-driven innovations in earthquake risk mitigation which are covered in the manuscript



The application of AI in EEWS leads to fast P-wave identification which results in proper protective responses being carried out before damage occurs. AI-based Structural Health Monitoring continuously evaluates building structures to detect damage while providing predictions for future events following disasters. The capabilities of AI-driven Seismic Hazard Mapping enhance risk evaluation processes to maximize land-use and zoning benefits. AI provides engineering support for creating expense-efficient safer structures together with systems that train the public in personalized ways to prepare for emergencies. AI eliminates the boundaries between seismic database processing and multiple trigger assessment methods to deliver full-scale disaster control systems. The application of AI which utilizes Machine Learning (ML) enhances earthquake forecasting because it both enhances wave discrimination abilities and minimizes incorrect alerts and speeds up decision-making processes. AI models Deep Shake and BNGCNNATT model improve seismic event forecasting through combination of neural networks alongside IoT systems. Properties of transparency along with accountability measures and balanced operation need to be resolved with regard to this technology. The hidden processes of artificial intelligence make understanding difficult and failure outcomes are not clearly defined. Technology automation through artificial intelligence enhances existing social divides by supporting well-observed urban centers rather than underprivileged neighborhoods. Fair resource allocation together with inclusive data collection and bias auditing form the solutions that need implementation. The establishment of global rules for AI along with international partnerships will guarantee that earthquake resilience gains through AI benefit every community with fairness.

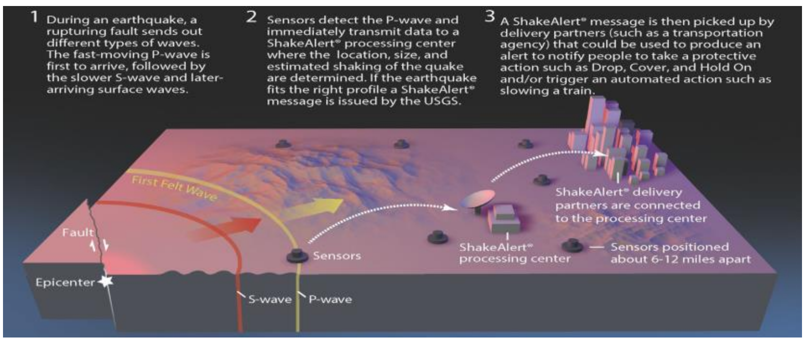


Figure 5: How the Shake Alert EEWS work

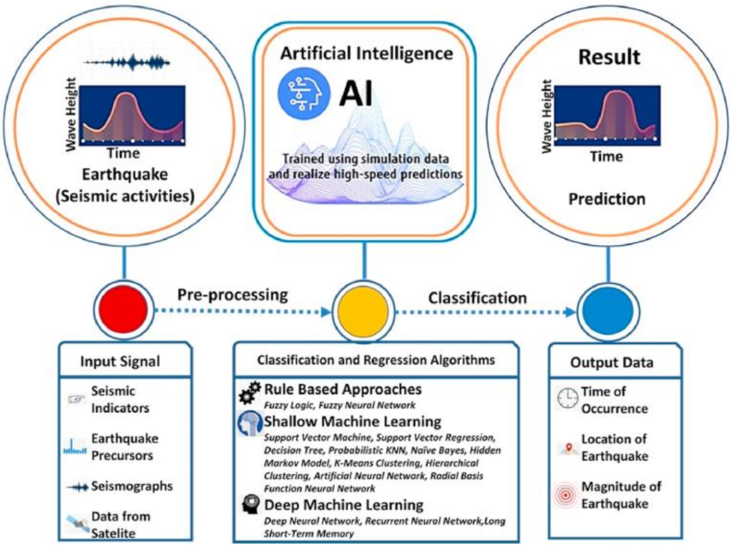


Figure 6: The Role of AI in the processing of data obtained from seismic activities used in Earthquake Prediction

Real-Time Data Collection and Early Warning Systems:

Urban infrastructure contains IoT sensors that track permanent building health status along with seismic activity information on a real-time basis. The sensors act as detectors that recognize earthquake precursors which activates alarms for early warning notification. The implementation of IoT within urban areas establishes quick emergency communication channels to speed up both public protective actions and service-based evacuation procedures.

Post-Earthquake Response and Damage Assessment:

Fast delivery of disaster assessment data can occur through IoT networks because they transmit information from earthquake-affected regions to central control systems. The collected information allows emergency responders together with urban planners to identify critical regions so they can save resources by focusing on the most crucial areas during recovery operations.

Smart Cities and Infrastructure Monitoring:

Smart cities implement IoT sensors to monitor bridges and buildings through which they ensure infrastructure safety during earthquakes. IoT emerged from RFID development during 1999 through the combination of AI and ICT as well as data analysis to enable device connectivity and data exchanging. The concept that led to IoT emerged decades ago but established itself as a prominent technology during the previous ten years before entering various scientific and residential and medical sectors. Three essential parts exist in IoT systems which include (a) devices carrying sensors that collect information and transmit data and further (b) system software used for device configurations and management and finally (c) network infrastructure facilitating device connections through the internet to perform real-time observation and global identification and physical location services and system operation monitoring.

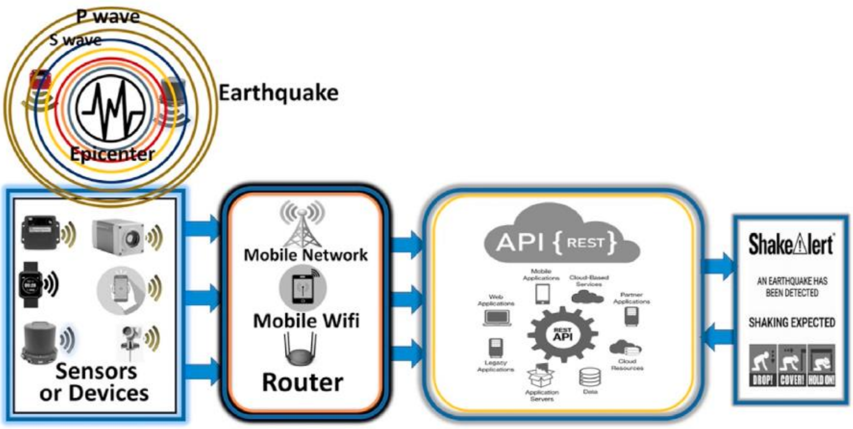


Figure 7: The general structure of IoT platform and its role in Earthquake Prediction

Integration of AI and IoT in earthquake-resilient planning

The combination of AI with IoT technologies produces superior systems to predict earthquakes while managing disasters since they help urban planners make better decisions. Time-sensitive data from IoT sensors processes with AI algorithms helps enhance earthquake predictions and produces early warning systems as well as risk protection methods. Rephrase the following sentence. Multiple AI-based models exist which includes deep learning (DL) approaches such as the 3 S-AE-CNN model able to generate earthquake magnitude and location results within three seconds. The IoT applications for EEWS developed by Clements (2021) and Wu et al. (2021) deploy MEMS accelerometers to achieve better detection performance and improved speed. The relevant literature demonstrates the use of machine learning (ML) and deep learning (DL) algorithms in detecting earthquake P-waves according to Pughazhendhi et al. (2019) and Khan and Kwon (2022). Investigative teams have established integrated systems between AI and mobile computing devices, remote sensing platforms and IoT networks to create more productive earthquake monitoring systems. Through its Crowd Quake analysis system researchers process vast acceleration datasets from dense IoT networks and the Fed Quake federated learning models strengthen data prediction accuracy by integrating multiple data dimensions. Edge computing solutions described by Bassetti & Panizzi (2022) provide decentralized earthquake detection capabilities. Smart cities deploy AI with ML and IoT to gather seismic data in real time which produces alerts and predictive analytics that make cities more resilient to earthquakes.

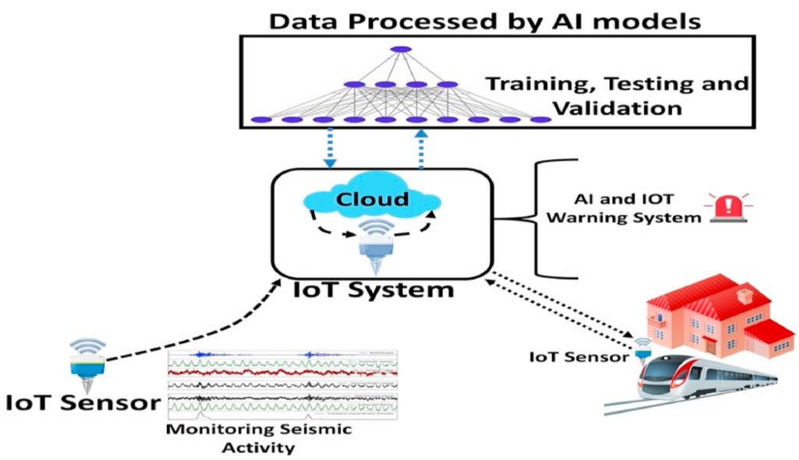
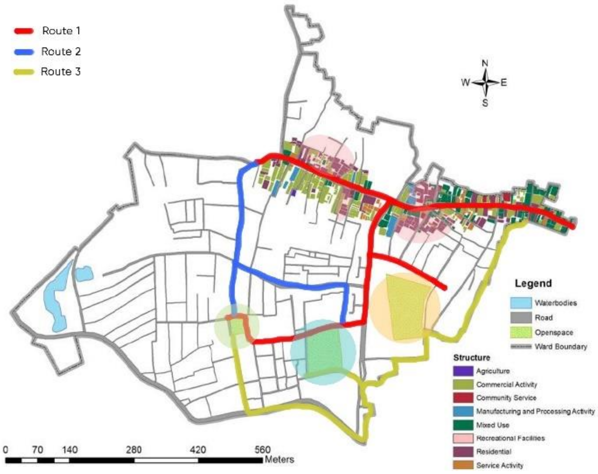


Figure 8: The structure of AI and IoT integrated together and used in earthquake

CASA STUDY ANALYSIS

1. **Effective evacuation management and mitigation plan for earthquake: A case study on Lalbagh area of Dhaka city**

Figure 9: Open spaces



Road Network

Route 1 =1610m - 1.61km

- Time= Distance/ Speed = 1.61 km /5 km=0.322hours
- Converting 0.322 hours to minutes: 0.322×60≈ 19.32 minutes
- So, it would take approximately 19.32 minutes to walk 1.61 kilometers at an average speed.

Route 2 =770m

- Time= Distance/ Speed = 0.77 km /5 km= 0.154 hours
- Converting 0.154 hours to minutes: 0.154 ×60≈ 9.24 minutes
- So, it would take approximately 9.24 minutes to walk 770 meters at an average speed.

Route 3 =1330m - 1.33km

- Time= Distance/ Speed = 1.33 km /5 km= 0.266 hours
- Converting 0.266 hours to minutes: 0.266 ×60≈ 16 minutes
- So, it would take approximately 16 minutes to walk 1.33 kilometers at an average speed.

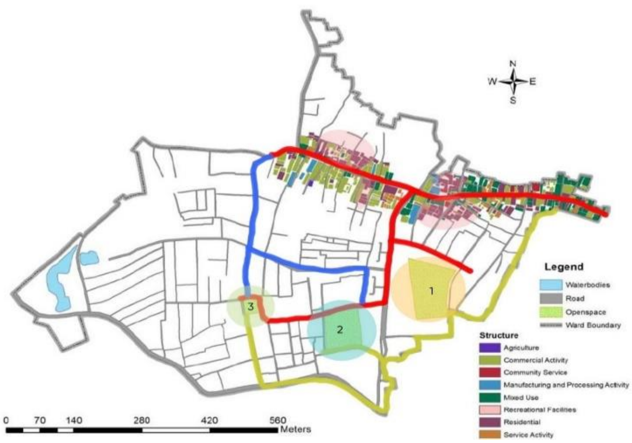


Figure 10: Open spaces

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Open spaces

For a cyclic quadrilateral with side lengths a, b, c, and d:

Using Brahmagupta's formula, Area=(s−a)(s−b)(s−c)(s−d)

where s is the semi-perimeter:

s=(a+b+c+d)/2

Open space – 1

Area = 12153.92 square meters

Approx. 4,051 people can occupy in Open space – 1

Open space – 2

Area = 9058.99 square meters

Approx. 3,020 people can occupy in Open space – 2

Open space – 3

Area = 1225 square meters

Approx. 408 people can occupy in Open space – 3

Analysis

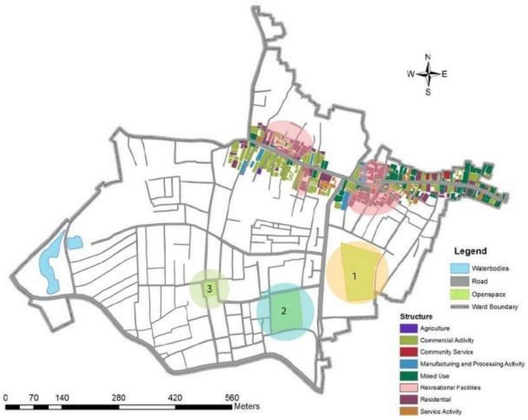

Figure 11: Population

Comfortable Evacuation: 2 to 3 people per square meter

Urgent Evacuation: 4 to 5 people per square meter

Population

For planning purposes, it's generally best to assume 2 to 3 people per square meter for safe and effective evacuation strategies.

Let's assume 3 people per sqm –

That is , 5219/3 =1740 sqm

Only 1740 sqm is needed for the population of ward 29. There is large amount of population in these nearby areas.

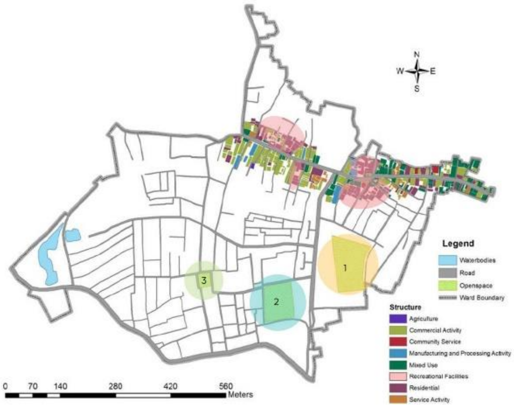

Figure 11: Land use

Land use

- This is the land use of Ward 29 of Dhaka city, Lalbagh.
- In this map, the land use shows that there are fewer residential buildings; most of them are commercial and mixed use.
- The distance to the open spaces from their buildings is about 10-20 minutes.
- That much time is very crucial for evacuation in earthquake situations.

Evacuation Method used in this case study

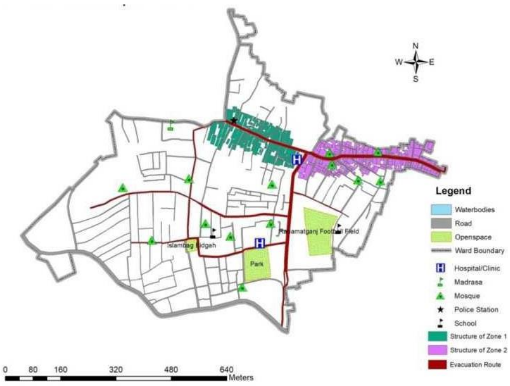

Figure 12: Evacuation method

- The O-D method determines the shortest route to a safe assembly site.
- The method considers the potential damage of an earthquake and the need for critical facilities.
- The Water Works Road houses are divided into two zones.
- Ward 29 of Dhaka South City Corporation has three identified open spaces: Rahamatganj football field, a medium park, and Islambagheidgah.
- The eastern part of the road is zone-2 (purple) and the western part is zone-1 (green).
- The evacuation route map shows road connectivity, with most buildings with critical facilities near the route.

2. Evaluation of seismic evacuation behaviour in complex urban environments based on GIS: A case study of Xi'an, China

Road network

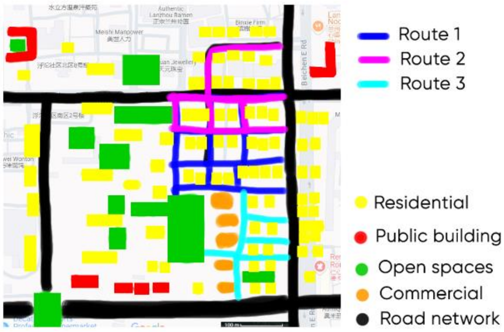

Figure 13: Road Network

Route 1 =250m – 0.25km

- Time= Distance/ Speed = 0.25 km /5 km=0.05hours
- Converting 0.06 hours to minutes: 0.05×60≈ 3 min
- So, it would take approximately 3 minutes to walk 250 meters at an average speed.

Route 2 =350m

- Time= Distance/ Speed = 0.35 km /5 km= 0.07 hours
- Converting 0.07 hours to minutes: 0.07×60≈ 4.2 min So, it would take approximately 4.2 minutes to walk 350 meters at an average speed.

Route 3 =300m – 0.30km

- Time= Distance/ Speed = 0.30 km /5 km=0.06hours
- Converting 0.06 hours to minutes: 0.06×60≈ 3.6 min
- So, it would take approximately 3.6 minutes to walk 300 meters at an average speed.

Open space

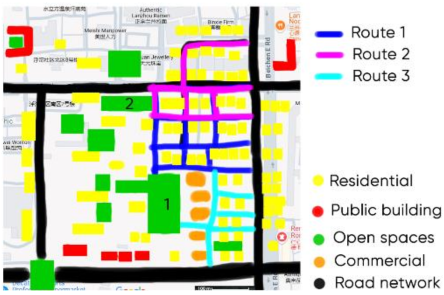

Figure 14: Open space

Open space – 1

Area = 10500 square meters

Appro. 3500 people can occupy in Open space – 1

Open space – 2

Area = 5000 square meters

Appro. 1666 people can occupy in Open space – 2

Population

- Comfortable Evacuation: 2 to 3 people per square meter
- Urgent Evacuation: 4 to 5 people per square meter

For planning purposes, it's generally best to assume 2 to 3 people per square meter for safe and effective evacuation strategies.

Let's assume 3 people per sqm can occupy

That is, 5219/3 =1740 sqm

Only 1740 sqm is needed for the population of ward 29. There is large amount of population in these nearby areas.

Evacuation Method used in this case study

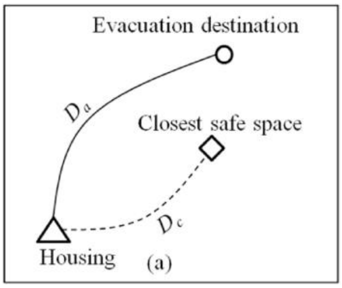

Figure 15: Evacuation Method

INTEGRATING AI & IoT IN TO THE CASE STUDIES

Table 1: Integrating AI & IoT into the case studies

Parameters	Case study 1	Integrating AI & IoT	Analysis
Road network	In this case study, the minimum time required to reach a safe place is 9 minutes maximum, is 19 minutes.	*AI-driven seismic monitoring can sometimes offer a 10 to 30-second warning for cities within 50-100 miles of the epicenter. *IoT can help to find the shortest route to the safe places through maps.	*In 10 to 30 seconds, a person walking at a normal pace can cover approximately 14 to 42 meters. *In this case, the mini time to reach to the open space is 9 minutes. *The evacuation could not be possible when the prediction time is 10-30 seconds, according to the road network.
Open spaces	The three open spaces in this case study are accessible and capable of holding all people.	IoT can help to find the shortest route to the safe places through maps and the carrying capacity of the open spaces.	*The three open spaces identified in the case study offer accessible locations capable of accommodating all

			evacuees, providing essential capacity for safe refuge. *IoT technology can further enhance evacuation efficiency by identifying the shortest routes to these spaces and monitoring their real-time occupancy, ensuring both quick access and effective crowd management.
Land use	From this case study, we can analyze that at daytime, there were more people to evacuate than at night, and most of the buildings must be vacant at night because most of them are mixed-use and commercial.	AI-driven seismic monitoring can sometimes offer a 10 to 30-second warning for cities within 50-100 miles of the epicenter.	*In 10 to 30 seconds, a person walking at a normal pace can cover approximately 14 to 42 meters. *In this case, the minimum time to reach the open space is 9 minutes. *That will lead to death, so for city planning, there must be open space or a safe place after every 40-50 m.
Population	Population is high. There is large amount of population in these nearby areas.	Utilize IoT-enabled communication channels (e.g., smartphone apps, digital signage) to alert residents nearby areas. immediately after a seismic warning is triggered.	*Population is a main factor in evacuation. Here the population is high and in nearby areas. *Only with the availability of 3 open spaces can everyone accommodate these 3 spaces. Only one ward can accommodate. *By interfacing AI and IoT, the evacuation would be easy because

			of the IoT alert mechanisms.
Parameters	Case study 2	Integrating AI & IoT	Analysis
Road network	In this case study, the minimum time required to reach a safe place is 30sec minimum is 4.2 maximum.	*AI-driven seismic monitoring can sometimes offer a 10 to 30-second warning for cities within 50-100 miles of the epicenter. *IoT can help to find the shortest route to the safe places through maps.	*In 10 to 30 seconds, a person walking at a normal pace can cover approximately 14 to 42 meters. *In this case, the mini time to reach to the open space is 9 minutes. *The evacuation could not be possible when the prediction time is 10-30 seconds, according to the road network.
Open spaces	Open spaces are enough for the people	IoT can help to find the shortest route to the safe places through maps and the carrying capacity of the open spaces.	IoT technology can further enhance evacuation efficiency by identifying the shortest routes to these spaces and monitoring their real-time occupancy, ensuring both quick access and effective crowd management.
Land use		AI-driven seismic monitoring can sometimes offer a 10 to 30-second warning for cities within 50-100 miles of the epicenter.	*In 10 to 30 seconds, a person walking at a normal pace can cover approximately 14 to 42 meters. *In this case, the minimum time to reach the open space is 9 minutes. *That will lead to death, so for city planning, there must be open space or a safe place after every 40-50 m.

RESULTS AND FINDINGS

Seismic Early Warning Systems: AI can analyse early seismic waves (P-waves) that precede the more destructive waves (S-waves) in an earthquake. These P-waves are detected by sensors closer to the earthquake's epicentre, giving a few seconds to a minute of warning for areas further away. This system allows immediate action, like halting trains, stopping elevators, and initiating automated emergency systems in buildings.

Seconds to Minutes of Advance Notice:
- **10-30 Seconds**: AI-driven seismic monitoring can sometimes offer a 10 to 30-second warning for cities within 50-100 miles of the epicentre. This warning is sufficient to trigger automated systems and initiate a brief, orderly evacuation from buildings, but may not allow for full evacuation.
- **Up to 1 Minute**: For regions much farther from the epicentre, AI systems might give up to a minute of warning. This additional time can be critical for densely populated areas or critical facilities like hospitals to initiate protective actions.

Limitations:
- AI cannot predict earthquakes in the way weather forecasts predict storms; it can only provide a warning once an earthquake has started based on real-time seismic data.
- The warning time heavily depends on the distance from the earthquake's epicentre. Areas close to the epicentre might not receive any warning, as the destructive waves arrive almost simultaneously with the initial seismic signals.

CONCLUSION

Through collaborative interference of AI with IoT capabilities urban planners receive advanced decision-support systems that aid earthquake prediction and disaster management. The real-time data from IoT sensors becomes useful for AI to produce enhanced predictions of earthquakes as well as provide early warnings and reduce disaster risks. AI researchers have created multiple models including deep learning (DL) approaches represented by the 3 S-AE-CNN frameworks for forecasting earthquake magnitude and location within three seconds. The IoT applications for EEWS developed by Clements (2021) and Wu et al. (2021) deploy MEMS accelerometers to achieve better detection performance and improved speed. The relevant literature demonstrates the use of machine learning (ML) and deep learning (DL) algorithms in detecting earthquake P-waves according to Pughazhendhi et al. (2019) and Khan and Kwon (2022). Researchers combined AI technology with mobile systems and IoT networks and remote sensing elements to create efficient earthquake monitoring capabilities. The Crowd Quake system processes extensive acceleration datasets within dense IoT networks and the Fed Quake model enhances prediction precision through multi-dimensional data combination. Edge computing solutions described by Bassetti & Panizzi (2022) provide decentralized earthquake detection capabilities. Smart city implementations that unite AI, ML, and IoT systems deliver continuous earthquake data acquisition and rapid warning signals along with data predictions which builds seismic resistance throughout urban environments.

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