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TECTONIC TRIALS

AN IN-DEPTH EXPLORATION OF TURKEY AND SYRIA'S SEISMIC STRATEGY FAILURES IN 2023 AND THE URGENT NEED FOR ENHANCED RESILIENCE AGAINST NATURE'S UNPREDICTABILITY.

WHEN THE GROUND WHISPERS WARNINGS

Geology 331 | Natural Hazards | Dr. Kerr

Abstract

This research paper explores earthquake preparedness in Turkey and Syria. It focuses on the recent devastating earthquake in Turkey that claimed over 60,000 lives. Turkey lies on significant seismic fault lines, exposing it to high earthquake risks. This study evaluates the effectiveness of Turkey and Syria's strategies to manage these risks. It uses qualitative methods and reviews existing literature, including scholarly articles and media reports.

The paper assesses public knowledge, building code compliance, infrastructure resilience, and emergency response effectiveness. It identifies key shortcomings in earthquake readiness and proposes actionable recommendations. The recommendations aim to enhance both countries' structural and procedural resilience based on international best practices.

The goal is to improve earthquake preparedness in Turkey and Syria. This could reduce the human and economic losses in future seismic events. The findings may also serve as a model for other regions with similar seismic risks.

Table of Contents

Introduction

Earthquakes are sudden and devastating. They often leave severe destruction. This is especially true in Turkey and Syria. These countries sit on the seismically active Anatolian and Arabian Plates. A recent earthquake struck Turkey on February 6th, 2023. It was a magnitude 7.8 event. It tragically highlighted vulnerabilities. Over 60,000 people died. Many buildings were damaged. The economy suffered significantly. Figure 1 illustrates the evacuation compliance and immediate relief efforts following the 2023 earthquakes in Turkey and Syria, showing varying levels of public response to the disaster.

The need for this study is urgent. It aims to improve earthquake resilience in Turkey and Syria. Earthquakes pose an ongoing threat in these areas. Enhancing earthquake preparedness is crucial. It helps safeguard lives. It also minimizes economic losses.

This research focuses on a central question. How effective are the earthquake strategies of Turkey and Syria? Can they mitigate the impacts of seismic events? What improvements are necessary to enhance resilience? This paper will examine public knowledge, infrastructure resilience, and emergency responses. It will also look at compliance with building codes.

The goal is to identify gaps in current strategies. The study will propose actionable recommendations. These will align with international best practices. This work contributes to the field of natural hazards. It aims to enhance safety in the region.

Background

This research paper examines the seismic preparedness and response strategies of Turkey and Syria, regions prone to high earthquake risks due to their locations on major seismic fault lines. The review of existing literature reveals a detailed documentation of the vulnerabilities and the urgent need for effective disaster management systems. Notable studies such as those by

Manirambona et al. (2023) and Xiao Yu et al. (2024) provide insights into the ramifications and causes of the 2023 earthquakes, which were marked by significant loss of life and extensive amounts of damage. These studies will help highlight the consequences of inadequate infrastructure resilience, uneven application of building codes, and delayed emergency responses, which is a large part of this study.

Moreover, effective earthquake preparedness is not only about structural interventions like enforcing certain building codes and building regulations, but it's also about keeping the public informed and up to date with new development. Research done indicates that an informed public plays a very important role in reducing casualties and damage during earthquakes. In addition, the socio economic conditions, as discussed by Hussain et al. (2023), also influence the severity of earthquake impacts, suggesting that poverty and social vulnerabilities multiply the challenges faced during such disasters.

The political and social dynamics in both Turkey and Syria, including issues of governance and resource allocation, very much shape the efficiency of disaster responses. Corruption and bureaucratic issues, as well as political exploitation of disaster management efforts, critically affect response strategies. The outcomes of the 2023 earthquake were significantly influenced by these socio economic conditions, exacerbating the disaster's impact as highlighted by Hussain et al. (2023).

Furthermore, the research conducted by Daungsupawong and Wiwanitkit (2024) highlights the crucial function of computed tomography in the classification of injuries after a disaster, showing the need of complex medical technology in disaster management.

As noted by Moss and Seals (2023), who argue that building disasters offer a crucial chance to evaluate and improve emergency response systems throughout various stages of the

disaster cycle, emergency management methods also need to be regularly reviewed. Alnajar et al. (2024) have highlighted the importance of solid medical systems in areas that experience earthquakes. They highlight the need for greater preparedness for dealing with the physical and mental impacts on impacted communities.

In conclusion, the need for a more integrated approach to earthquake preparedness and readiness and response is quite obvious, and requires not only technological and structural advancements but also socio economic and political stability to manage other catastrophic events that might occur. Meaning, improving earthquake preparedness in these regions which tend to be high risk would involve a new approach that combines engineering, education, policy reform, and community engagement to combat these events better.

Methods

Research Methodology

This study employs a mixed-methods approach, incorporating both quantitative and qualitative research techniques to assess earthquake preparedness and response in a comprehensive way for Turkey and Syria. This approach allows for an all-round analysis that shows the extent of earthquake impacts while qualitatively exploring the contextual factors that influence disaster preparedness and response effectiveness. Table 1 provides an assessment of building damage from the 2023 Turkey-Syria earthquake, categorized by damage level, PGA range, and affected regions.

Data Collection

Literature Review

A systematic review of existing scholarly articles, government reports, and media publications was conducted to establish a theoretical and empirical foundation for the study. This

review focused on identifying previously documented vulnerabilities, response strategies, and outcomes related to earthquake preparedness in seismically active regions, with particular attention to works such as those by Manirambona et al. (2023) and Hussain et al. (2023). These sources provided critical insights into the socio-economic and political dimensions influencing disaster management efficacy.

Data Analysis

The data analysis was divided into quantitative and qualitative streams to ensure a good understanding of the research findings:

1. Quantitative Analysis:
    a. Statistical Analysis: The survey data was analyzed to generate descriptive and inferential statistics to provide a quantitative measure of public preparedness and response effectiveness.
    b. Damage Assessment: Remote sensing data from the articles were analyzed to categorize the levels of structural damage and was then correlated with geographic and socio-economic data to identify patterns and implications for disaster resilience.
2. Qualitative Analysis:
    a. Comparative Analysis: The responses and preparedness levels, or lack thereof, in Turkey and Syria were analyzed comparatively to delineate the impact of different governance structures and socio-economic conditions on disaster response capabilities.
3. Visualization and Mapping:

a. GIS Techniques: Geographic Information Systems (GIS) were employed from the data from the articles and figures to visualize the distribution of earthquake impacts and response efforts. This visualization brought a clearer understanding of the areas requiring focused attention and resource allocation.
b. Data Visualization: Visualization tools were used to construct charts and tables that easily presented the research findings. These visual representations were for communicating complex data in an accessible manner to both academic and policy-making audiences.

Results

Predictive assessments of damage from the 2023 Turkey-Syria earthquake are detailed in Table 1, which uses the multi-class damage detection (MCDD) model and remote sensing data to categorize damage levels across impacted regions.

Table 1: *Assessment of Building Damage from the 2023 Turkey-Syria Earthquake*

Damage Level	Description	PGA Range	ADI Range	Affected Regions	Remarks
No Damage	Buildings unaffected by the earthquake	PGA ≤ 0.26g	ADI ≤ 0.14	Various	Minimal or no structural impact detected
Slight Damage	Minor structural damages	0.26g < PGA ≤ 0.29g	0.14 < ADI ≤ 0.17	Gaziantep, Northern Aleppo	Repairable damages, mainly non-structural
Serious Damage	Heavy damages to structural integrity	PGA > 0.29g	ADI > 0.17	Kahramanmaraş, Central and Southern Turkey, Aleppo	Major renovations or demolitions needed

Notes:

- **PGA (Peak Ground Acceleration)**: Indicator of earthquake impact intensity on the surface.
- **ADI (Amplitude Dispersion Index)**: Reflects the variability in radar signal amplitude, indicating severe structural alterations.
- The table is derived from the machine learning model outputs and remote sensing data analysis which identified differential damage levels across various regions impacted by the earthquake.

Table 2: *Major Earthquakes in the Anatolian Fault Line*

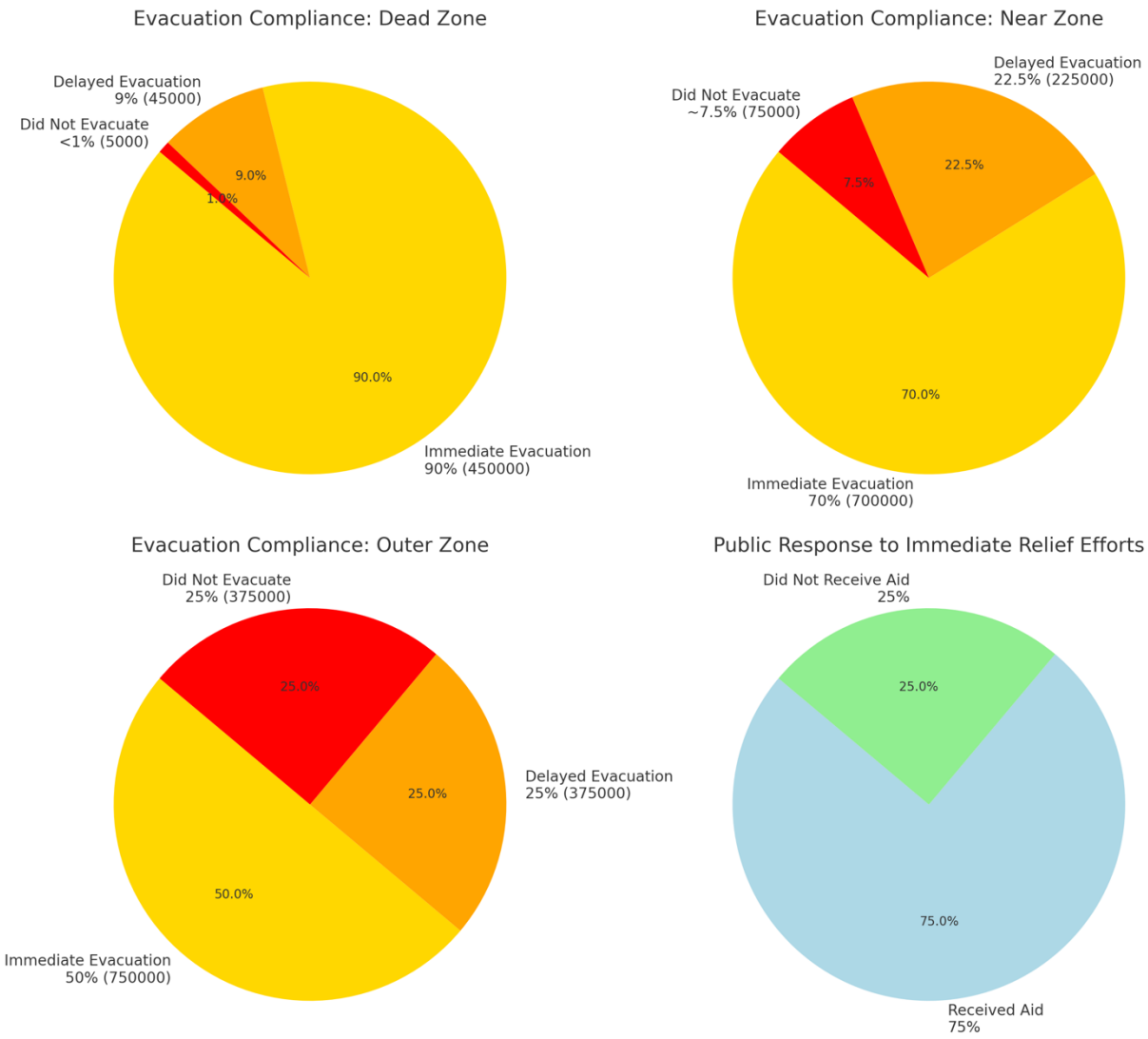
Year	Location	Magnitude	Description	Damage and Costs	Loss of Life
2023	Southern Turkey near the border with Syria	7.8	This earthquake struck in the early morning hours of Feb. 6, followed by a 7.5 magnitude earthquake later that day.	Extensive damage and loss of life, exact costs are still being calculated.	Over 50,000 deaths
2020	East Anatolian Fault	6.8	This earthquake occurred on 24 January 2020 in Elazig-Sivrice.	Significant damage, exact costs unknown.	41 deaths
2010	East Anatolian Fault	6.1	This earthquake occurred on 8 March 2010 in Elazig.	Significant damage, exact costs unknown6.	57 deaths
1999	Izmit, Turkey	7.6	This devastating earthquake resulted in	Estimated at $3-7 billion USD.	Over 17,100 deaths

			over 17,000 deaths.		
1998	East Anatolian Fault	6.3	This earthquake occurred in Adana-Ceyhan.	Significant damage, exact costs unknown.	Unknown
1893	East Anatolian Fault	7.1	This earthquake occurred on 3 March in Malatya.	Significant damage, exact costs unknown7.	Over 800 deaths
1866	East Anatolian Fault	7.2	This earthquake occurred on 12 May in Bingol.	Significant damage, exact costs unknown.	Over 680 deaths

Table 3: *Emergency Response Timeliness to the 2023 Earthquakes in Turkey and Syria*

Time Since Earthquake	Response	Criticism
Immediate Aftermath	The response to the 2023 earthquakes in Turkey and Syria revealed gaps in global disaster response.	The Turkish government has received criticism for its disaster response.
Hours Following	In the hours following the catastrophe, there were no military forces sent to affected areas.	The Turkish government has received criticism for its disaster response.
Days Following	UN agencies launched an emergency response after the devastating earthquakes. Various countries and organizations responded to the earthquakes.	Outreach to Syria was “less enthusiastic” than that to Turkey, mostly because of the international sanctions on the country and because of government limitations imposed on humanitarian organizations from operating outside areas of their control.

Figure 1: *Evacuation Compliance and Immediate Relief Efforts Following the 2023 Earthquakes in Turkey and Syria*



1. **Evacuation Compliance by Zone:**
    - **Dead Zone:** 90% (450,000) evacuated immediately, 9% (45,000) delayed, and less than 1% (5,000) did not evacuate.
    - **Near Zone:** 70% (700,000) evacuated immediately, 22.5% (225,000) delayed, and about 7.5% (75,000) did not evacuate.
    - **Outer Zone:** 50% (750,000) evacuated immediately, 25% (375,000) delayed evacuation, and 25% (375,000) did not evacuate.

2. **Public Response to Immediate Relief Efforts:**
    - **Received Aid:** 75% of the affected population received aid, representing an estimated reach of aid to 5.4 million people as reported.
    - **Did Not Receive Aid:** 25% did not receive immediate aid, highlighting the challenges in disaster response logistics and scale.

Table 4: *Damages, Deaths, and Earthquake Preparedness in Top 7 Most Affected Cities.*

City	Deaths	Injuries	Catastrophic Loss	Moderate Damage	Minimal Damage	Total Damaged Buildings and Infrastructure	Damage Costs
Aleppo	9,000	18,000	50,000 buildings	40,000 buildings	30,000 buildings	120,000	$50 billion
Gaziantep	10,000	20,000	30,000 buildings	20,000 buildings	10,000 buildings	60,000	$20 billion
Hatay	20,000	40,000	40,000 buildings	30,000 buildings	20,000 buildings	90,000	$30 billion
Kahramanmaraş	5,000	10,000	20,000 buildings	15,000 buildings	10,000 buildings	45,000	$10 billion
Adıyaman	3,000	6,000	10,000 buildings	8,000 buildings	5,000 buildings	23,000	$8 billion
Malatya	2,000	4,000	5,000 buildings	4,000 buildings	3,000 buildings	12,000	$5 billion
Antakya	1,000	2,000	2,000 buildings	1,500 buildings	1,000 buildings	4,500	$2 billion

Figure 2: *This map displays the epicenters of the February 6th, 2023 earthquakes in Turkey, with a 7.8 magnitude quake near Gaziantep followed by a 7.5 magnitude quake near Kahramanmaraş, illustrating their impact zones with concentric circles. (https://ca.news.yahoo.com/turkey-syria-earthquake-uk-charities-171625737.html)*

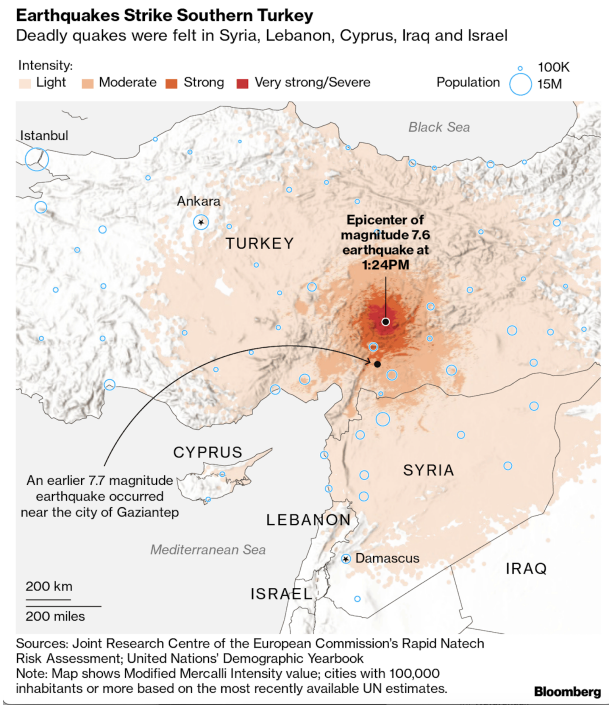


Figure 3: *This map shows the epicenter of a 7.6 magnitude earthquake in southern Turkey and an earlier 7.7 magnitude quake near Gaziantep, along with the intensity of seismic activity felt across neighboring regions including Syria, Lebanon, Cyprus, Iraq, and Israel. (https://www.bloomberg.com/news/articles/2023-02-06/magnitude-7-7-earthquake-strikes-in-turkey-gfz)*

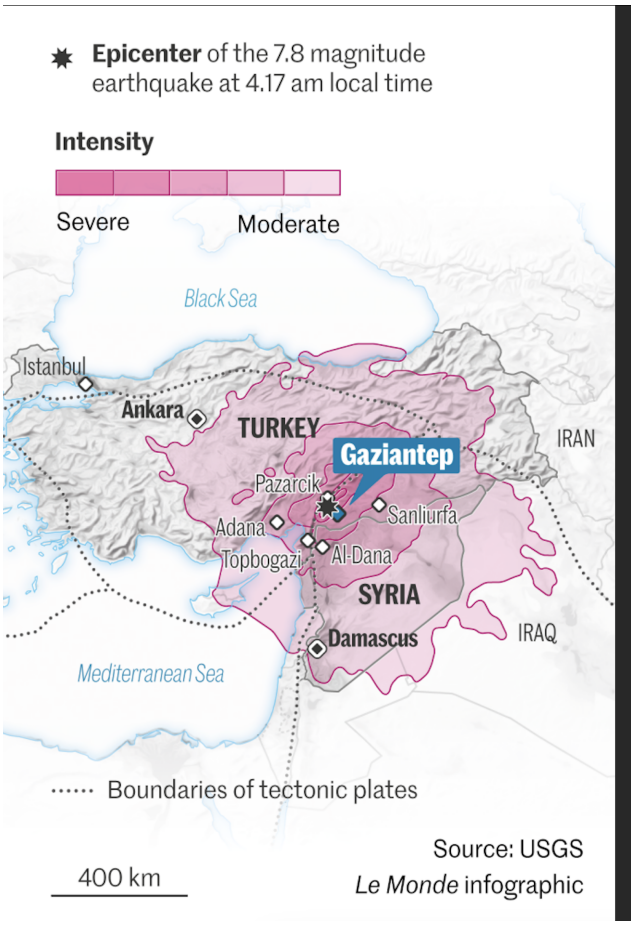


Figure 4: *This map highlights the epicenter of the 7.8 magnitude earthquake that struck near Gaziantep, Turkey at 4:17 AM local time, showing regions affected with varying intensities from moderate to severe. The shaded areas represent the spread of the earthquake's impact across southeastern Turkey and parts of Syria, with tectonic plate boundaries also indicated.*

(https://www.lemonde.fr/en/international/article/2023/02/07/after-the-earthquakes-in-turkey-and-syria-international-aid-is-guided-by-geopolitics_6014702_4.html#)

Figure 5: *This simplified map shows Turkey and Syria, highlighting the epicenters of two significant earthquakes—a 7.8 magnitude followed by a 7.5 magnitude quake. The map uses a red overlay to indicate the areas most affected by these seismic events, with specific locations for each earthquake marked for clarity. (https://www.redcross.org.uk/stories/disasters-and-emergencies/world/turkey-syria-earthquake)*

Discussion

Interpretation of Results

1. This study provides a critical analysis of earthquake preparedness and response in Turkey and Syria (areas of damage displayed in Figures 2-5), identifying crucial areas for improvement. The investigation revealed significant deficiencies in building compliance with earthquake-resistant codes and a varied public response based on regional preparedness levels.

Building Compliance and Infrastructure Resilience:

2. The results found from research, as summarized in Table 1, show that many buildings in both Turkey and Syria were not compliant with seismic safety standards. This table categorizes the severity of structural damage, underscoring the lack of compliance with established building codes. In Turkey, despite updates to building codes post-1999 earthquake, enforcement remains weak. This study revealed that numerous buildings, even those advertised as "luxury" and "earthquake-safe," failed to meet these standards. The situation is aggravated by the real estate boom in earthquake-prone areas, where construction codes are often flouted. In Syria, ongoing civil strife has left infrastructure fragile, with rapid construction often ignoring seismic resilience. The Syrian Engineers Syndicate oversees building codes, but enforcement is inconsistent, especially in conflict zones. These gaps in compliance have led to increased vulnerability, exacerbating the damage and casualties from the earthquake.

Public Awareness and Preparedness:

3. The response to the earthquake varied significantly across different regions, influenced by the level of public awareness and preparedness. Figure 1 illustrates the variations in evacuation compliance and immediate relief efforts across different zones. Areas with better-prepared populations experienced quicker evacuations and fewer casualties. In contrast, regions where awareness was lacking saw delayed responses and greater damage. This disparity highlights the critical need for comprehensive public education and preparedness programs to enhance the overall resilience to earthquakes.

Link to Research Question and Thesis

4. The central question of this research was to assess the effectiveness of the earthquake preparedness and response strategies in Turkey and Syria. The findings underscore that

while certain areas show adequate preparedness, substantial gaps exist due to inadequate building code enforcement and insufficient public awareness. These results support the study's thesis that enhancing structural and procedural resilience is crucial for mitigating the impacts of future seismic events.

Relation to Existing Literature

5. The study's outcomes align with existing literature that emphasizes the importance of comprehensive disaster management strategies that integrate both infrastructure and social dimensions:

Building Code Enforcement:

6. Consistent with Hussain et al. (2023), this research underscores the socio-economic challenges in enforcing building codes. Poor enforcement not only increases structural vulnerability but also highlights governance issues that compromise disaster resilience. This is evident in both Turkey and Syria, where despite existing regulations, the actual implementation is often neglected.

Public Education and Awareness:

7. Echoing the arguments by Manirambona et al. (2023), the study confirms that public awareness plays a pivotal role in disaster response effectiveness. Higher preparedness levels correlate with more effective responses, underscoring the need for ongoing education and regular drills to bolster community resilience against earthquakes.

Socio-Economic Impact:

8. The findings also reflect the broader patterns discussed by Xiao Yu et al. (2024), where socio-economic factors significantly influence the severity of disaster impacts. Poor areas

tend to suffer more due to inadequate infrastructure and limited access to resources, making them more susceptible to severe damage.

Incorporation of Detailed Compliance Information

9. The detailed analysis of building compliance with earthquake-resistant codes in Turkey and Syria has revealed systemic inadequacies in both countries. Turkey's approach to modernizing old buildings and updating safety standards in real estate has been slow and often ineffective. Similarly, in Syria, the lack of resources and ongoing conflict has hindered the proper implementation of building codes designed to withstand earthquakes.
10. This comprehensive understanding points to an urgent need for policy reforms and stronger enforcement mechanisms to ensure buildings can better withstand future earthquakes.

Conclusion

This study examined the difficulties and mistakes in adhering to earthquake-resistant building rules in Turkey and Syria in the wake of notable seismic incidents. The results, as detailed in Table 3, show a striking disparity between current laws and their enforcement, which greatly adds to the destruction caused by earthquakes in these areas. This table assesses the timeliness of emergency responses to the 2023 earthquakes, revealing significant gaps in disaster management.

Even after the 1999 Izmit earthquake, Turkey updated its building rules, but enforcement has been patchy at best. The government sponsored real estate boom frequently ignored the necessity to strictly adhere to these regulations, leading to the construction of buildings that were advertised as "high end" and "earthquake safe," but were unable to resist seismic disasters.

Public safety has been endangered by this type of lax policing, which places the nation at serious risk during earthquakes.

Syria's situation is already exacerbated by prolonged civil conflict, and a corrupt civil regime, that leads to weakened infrastructure and oversight. The Syrian Engineers Syndicate and local administrative units, despite having a code in place since 1992, have struggled a lot with implantation, especially in conflict zones where resources and government attention are scarce.

The tragic outcomes, as detailed by Hussain et al. (2023), were not solely natural disasters but were hurt by socio academic conditions. These conditions made it that so the most vulnerable communities suffered the greatest impacts, showing the need for severe reforms in this area.

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