Natural Disaster Research Report, No. 61; February, 2025

Business Continuity of Water Works and Sewage Administrations during the Kahramanmaras Earthquake

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Abstract

The catastrophic earthquake event that struck Turkiye on February 6, 2023, resulted in extensive devastation across 11 cities. The earthquake severely disrupted essential lifeline systems. Functional disruption of water works and sewage systems due to seismic damage significantly impacts the daily lives of citizens, public health, environment and the overall functioning of society. The devastating earthquake revealed the crucial need for business continuity planning. In this context, the study aims to investigate the business continuity of water works and sewage administrations in the earthquake-affected region. Through face-to-face interviews with officials from KASKI, HATSU, GASKI, and ASKIM, as well as field observations, the study examines the continuity of operations before, during, and after the earthquake. Qualitative analysis of the gathered data compares the practices and challenges faced by these administrations. This paper provides an overview of the experiences and lessons learned from the Kahramanmaras earthquake, focusing on the business continuity of operations and the supply of water and sewage services to consumers.

Key words: Business continuity, Disaster, Earthquake, Infrastructure, Water works and sewage

1. Introduction

On February 6, 2023, Turkiye experienced catastrophic earthquake events. Two major tremors, registering magnitudes of 7.7 Mw and 7.6 Mw, struck the Pazarcik and Elbistan districts in Kahramanmaras. Since the Miocene epoch, the Anatolian Plate has been shifting west-southwest due to compressive forces from the Arabian and African Plates. The North Anatolian Fault Zone (NAFZ) and the East Anatolian Fault Zone (EAFZ) are the primary structures shaping the topography of the Anatolian Plate. The February 6 Kahramanmaras earthquakes occurred along the EAFZ, which extends approximately 500 km[1]. **Fig. 1** illustrates the surface fault ruptures mapped in the aftermath of the event. The devastation extended across 11 cities in Turkiye (Kahramanmaras, Hatay, Gaziantep, Adiyaman, Malatya, Kilis, Sanliurfa, Adana, Osmaniye, Diyarbakir, Elazig) as shown in **Fig. 1**. Besides, the epicenters and the fault ruptures[2] are shown in **Fig. 1**.

Official reports indicated that more than 53,537 people lost their lives and over 100,000 were injured. On the first day alone, more than 39,000 structures collapsed, and 518,000 homes were affected[3]. The country suffered

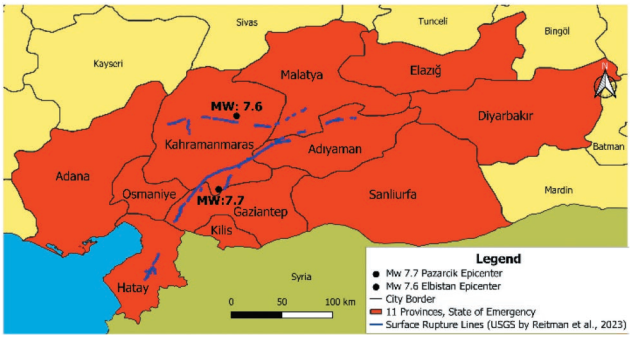

Fig. 1 11 Cities Affected by the Kahramanmaras Earthquakes.

extensive and severe damage as a result of these earthquakes. The earthquakes severely disrupted essential lifeline systems, including electricity, water supply, gas supply, communication networks, and transportation[1, 4]. Disruption of lifeline systems caused crucial problems, significantly impacting public safety, health, and the overall functioning of society. The devastating earthquakes underscored the critical importance of developing resilient cities and revealed the crucial need for robust business continuity planning. Together, these elements ensure not only the safety and well-being of residents but also the sustained functionality of economic activities during and after disasters.

In this context, this research aims to investigate the business continuity of water works and sewage administrations in the event of the Kahramanmaras earthquakes in Turkiye. Face-to-face interviews were conducted with officials from water works and sewage administrations in Kahramanmaras (KASKI), Hatay (HATSU), Gaziantep (GASKI) and Adıyaman (ASKIM). Additionally, field observations were conducted at drinking water treatment plants, wastewater treatment plants, transmission lines, distribution lines and distribution tanks to provide a more comprehensive understanding of the situation.

2. Research Background

2.1 Business continuity

Business continuity is the "capability of the organization to continue the delivery of products or services at acceptable predefined levels following a disruptive event" according to ISO 22301 definition. Business continuity management (BCM) is a multifaceted process that aims to enhance an organization's resilience against disruptions. It encompasses managing a sustainable process of critical functions and continuing these functions by eliminating or minimizing the effects of disruption. BCM enables to develop detailed strategies, train personnel, and maintain necessary resources to execute these plans effectively[5)].

Business continuity is crucial for critical infrastructures and lifeline systems, ensuring their resilience and uninterrupted operation in case of disruptions. Maintaining the continuous functionality and integrity of critical infrastructure should be perceived as a process influenced by available resources and aimed at delivering value to the customers, who are the citizens. It involves organizational, personnel, material, technical, financial, and other measures aimed at reducing disruption and securing essential resources, also maintains the conditions required for carrying out activities, such as the construction, maintenance, and operation of critical infrastructure[6)]. There exist some studies related to the business continuity of critical infrastructures based on ISO 22301 or the BS 25999 standards (e.g., 7, 8)). A series of measures were outlined for the periods before, during, and after an earthquake.

2.2 Critical infrastructure

Main problems in large-scale disasters are damage in critical infrastructure, transportation and supply chain disruptions. Critical infrastructures are crucial to the functioning of economies and societies. Water works and sewage systems which maintain water supply and sewage processing are one of the most critical lifeline infrastructures for society.

3. Water Works and Sewage Administrations in the Earthquake Region

3.1 General information

Each city was affected by the earthquake at different levels and has distinct characteristics such as local topography and geology, proximity to fault lines, seismic intensity, the age and maintenance status of the water and sewage systems, population density, urbanization rates, available resources and budgets. These factors all contribute to how each city's water and sewage systems responded to the earthquake and their ability to maintain and restore services during and after the disaster.

Three main geohazard-related problems affected water and sewage systems: landslides, liquefaction, and fault movement[9)]. Landslides, particularly in Adiyaman and Hatay, had a significant impact, especially where transmission pipelines crossed unstable slopes. Common landslide types included rockfalls and translational slides. Field observations indicated that pipelines damaged by landslides were often situated at the base of these slopes during seismic activity. Liquefaction posed another major issue for water and sewage systems, notably in Iskenderun (Hatay) and Golbasi (Adiyaman), where liquefaction-induced settlement caused infrastructure damage. Additionally, fault movements exceeding 4–5 meters resulted in severe damage to water and sewage systems[10, 11)].

3.1.1 Kahramanmaras Water Works and Sewage Administration (KASKI)

Kahramanmaras relies on surface water from rivers and streams, groundwater, dams and reservoirs. The city has four main water sources: Karasu (spring water), Ayvali Dam (treatment), wells, and Pinarbasi (spring water). The water is primarily delivered by gravity flow, with some areas, such as the wells, requiring pumping stations. As a result of the earthquake, different components of the water system were damaged.

3.1.2 Hatay Water Works and Sewage Administration (HATSU)

Harbiye, Dortyol Besikgol, Kirikhan Delibekirli, Payas Karacaoren, and Bagriyanik are the primary natural water sources that provide water to Hatay by gravity. HATSU serves fifteen districts, and six of them, including Antakya and Iskenderun, suffered substantial infrastructural damage, including water transmission line damage after the earthquake. For instance, as discussed by Toprak *et al.* (2024) [10)], rockfalls occurred in the Degirmendere region, where the average slope is 32% and the maximum slope reaches 70%. The terrain in this area is composed of Neritic Limestone. Another issue was liquefaction in Hatay, which caused damage to wastewater pump stations and pipes in Iskenderun. The observed damage likely resulted from a combination of permanent ground movement and transient ground shaking[10)]. In addition to technical problems, unbalanced population fluctuations in different regions of Hatay and the insufficient number of personnel after the earthquake caused difficulties in the delivery of water to users.

3.1.3 Gaziantep Water Works and Sewage Administration (GASKI)

Drinking water for Gaziantep city primarily comes from three sources: Duzbag Stream intake, Mizmilli Wells, and Kartalkaya Dam. While the amount of water from each source can vary, the majority is supplied by Duzbag. Large diameter transmission pipelines are used to transport the water to the city. After the earthquake, there was damage and several issues related to both the water sources and the transmission pipelines (**Fig. 2**). Some of the damage was due to fault crossings, but there was also damage caused by strong shaking. For example, the Duzbag water transmission pipeline, with a diameter of 2,600 mm, was damaged by a surface fault rupture. The fault experienced approximately 4.5 meters of left-lateral strike-slip movement, with no vertical displacement observed.

Fig. 2 Kartalkaya Pipeline Damage Repairs (Courtesy of GASKI).

3.1.4 Adiyaman Water Works and Sewage Administration (ASKIM)

The city receives water from four sources (natural water sources): Havseri, Gurlevik, Tut, and Koru. Additionally, wells are utilized as a source when the flow rates from these primary sources decrease. Damages in water transmission and distribution lines occurred because of rock falls, landslides and ground deformations after the earthquake.

As discussed in Toprak *et al.* (2024) [10, 11)], the Gurlevik transmission line encounters six distinct lithological formations along its 29 km route, which include variations in rock types and soil structure, contributing to terrain instability. Toprak *et al.* (2024) [10, 11)] also examines variations in peak ground velocity (PGV) and slope values in heavily damaged and undamaged areas. Damage was primarily observed in sloped regions, while smoother terrains experienced minimal damage.

3.2 Business Continuity Phases

3.2.1 Pre-event preparation

There were no business continuity plan studies conducted at the water and sewage authorities in the provinces affected by the Kahramanmaras earthquakes. However, disaster preparedness was considered. One key effort was the disaster risk reduction studies (IRAP) by the Disaster and Emergency Management Presidency (AFAD)[12)]. In 2020, AFAD developed a provincial disaster risk reduction plan, designating Kahramanmaras as a pilot region. The AFAD report assessed the risk and impact of a 7.5 Mw earthquake, predicting significant effects due to the city's proximity to an active fault zone and ground susceptibility to liquefaction. KASKI participated in related studies and meetings, but these measures did not have the intended impact. In Hatay, the Metropolitan Municipality's Disaster and Emergency Coordination Center (AKOM) conducted a drill one month before the earthquake, which went smoothly. However, communication breakdowns hindered the execution of the plan during the actual event. In Gaziantep and Adiyaman, emergency response plans were still in development.

Despite the region's earthquake awareness, the magnitude and scale of the disaster were unexpected. Officials from KASKI, HATSU, GASKI, and ASKIM highlighted the need for realistic earthquake preparedness plans and emphasized infrastructure renewal. Upgraded transmission and distribution lines, planned and completed before the earthquake, were not significantly impacted.

3.2.2 Event management

The earthquake directly affected all citizens, including water and sewage administration personnel. To ensure their safety and expedite water system recovery, employees and their families were accommodated in administration campuses and buildings, such as KASKI and GASKI. This arrangement allowed employees to focus on their work, knowing their families were safe.

KASKI, GASKI, and ASKIM continued operations in minimally damaged buildings, initially shutting off the city's water supply due to anticipated infrastructure damage. HATSU, however, relocated to an expo area after their municipal building collapsed, causing data loss and communication breakdowns.

The earthquake severely damaged the water and sewage infrastructure, with ruptured pipelines, collapsed water tanks, and significant water loss at sources and wells. In such situations, having backup pipes readily available is crucial to replace damaged sections, as maintaining drinking water supply after an earthquake is essential for public health, local satisfaction, and swift recovery[10, 11)].

Power outages rendered pumps inoperable, leading to early water shortages. Packaged drinking water was used initially, and temporary solutions were implemented, including installing taps in neighborhoods and using water tankers for hard-to-reach areas. Mobile toilets and showers were also set up.

Technical teams conducted damage assessments and routine monitoring. Reports from citizens helped identify issues, and acoustic listening techniques were used to detect hidden leaks. Technical teams from other cities assisted with repairs, although demolition activities caused further pipeline damage. Ongoing demolition and foundation work continue to pose risks to the infrastructure.

3.2.3 Post-event continuity

Post-disaster activities include restoring operations to normal functioning levels in the affected cities, reviewing and updating plans to address new situations related to migration following the earthquake, developing new temporary and permanent housing, and improving the water system to achieve target performance levels.

In determining the projects to be carried out after the earthquake, factors such as population change, capacity, the condition of existing infrastructure, new urban development areas, and financing are crucial. The increase in migration, particularly to rural areas after the earthquake, has resulted in population shifts. The establishment of new city centers and the construction of new housing are expected to further alter the population distribution. Therefore, it is imperative to plan and construct relevant infrastructure accordingly.

KASKI and ASKIM indicated that water loss has reached more than 70% because of old infrastructure, leakage, and earthquake damage, while GASKI reported a 30% water loss level using its real-time data system. Therefore, technology adoption[9], infrastructure renewal and the establishment of new facilities are necessary for the effective use of limited water sources. Another point is that administrations have been conducting studies to improve water quality for public health and safety. The construction of drinking water treatment plants and wastewater treatment plants has been planned.

The economic impact of earthquake-induced damage, interrupted billing for a certain period after the earthquake, unauthorized water usage, energy expenses for supplying water to high-altitude areas, and fees paid to subcontractors have caused financial challenges for the institutions. To support the development of new projects in the water works and sewage administrations in the earthquake-affected region, government institutions and certain international organizations provided financing in the form of grants and loans.

4. Recommendations and Conclusions

The catastrophic earthquakes exposed significant vulnerabilities in the water and sewage administrations of Kahramanmaras, Hatay, Gaziantep, and Adiyaman. Despite some prior disaster preparedness efforts, including those by AFAD, there were notable gaps in planning and execution. Immediate responses were impeded by the timing of the earthquakes and communication breakdowns. Quick actions, such as shutting off water supplies to prevent further damage and setting up temporary water supply solutions, were crucial in managing the immediate aftermath of the disaster.

The extensive infrastructure damage highlighted the need for more resilient systems. The evaluation of the surface ground structure and careful selection of materials with more flexibility for strong shaking are significant. For example, the utilization of Hazard Resilience Ductile Iron Pipe (HRDIP), characterized by joint flexibility (extension, compression, and rotation) and locking capabilities, is advised to increase the resiliency. The influence of landslide-prone areas on pipeline damage emphasizes the need for strategic planning in vulnerable regions. Understanding the technical problems is essential for designing, maintaining, and repairing transmission lines to improve resilience against landslides. Pipe failure types and recommendations for enhancing resilience are discussed comprehensively by Toprak *et al.* (2024) [10, 11].

Restoring operations involved significant challenges, including addressing high water loss rates and financial constraints due to earthquake damage and operational costs. Besides, migration and population shifts necessitate careful planning for infrastructure development to meet changing demands.

To address these issues, water and sewage administrations should develop comprehensive, detailed and regularly updated business continuity plans covering all disaster management phases. Enhanced disaster preparedness, including systematic risk assessments, realistic training drills, public awareness and coordination with other organizations and government authorities, is essential. Infrastructure resilience must be prioritized through the renewal and upgrading of critical systems with materials and designs that can withstand seismic activity. Technological adoption, especially real-time data systems, is crucial for effective monitoring and management. Strengthening coordination among water and sewage administrations, municipal authorities, and emergency management organizations is critical in disaster response. Further, agreements with vendors and external partners can be established for rapid deployment of resources and services during emergencies. Financial planning and securing support from government and international organizations will help manage operational costs, support recovery efforts, continue ongoing projects and develop new projects.

Acknowledgments

This research is funded by JST's J-RAPID program for the Kahramanmaras Earthquake and partially supported by the EU under code 2022-1-PL01-KA220-HED-000087357 as part of CLOEMC VI. We thank NIED for their support during our visits to the earthquake zone.

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(Received: August 16, 2024
Accepted: January 20, 2025
Published [online first]: February 28, 2025)

カフラマンマラシュ地震における上下水道事業の継続性

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要　旨

2023 年 2 月 6 日にトルコを襲った大地震は，11 の都市に甚大な被害をもたらした．この地震により，ライフラインは大きく寸断された．地震被害による上下水道システムの機能停止は，市民の日常生活，公衆衛生，環境，社会全体の機能に大きな影響を与える．今回の壊滅的な地震は，事業継続計画の重要な必要性を明らかにした．そこで本研究では，地震被災地の上下水道行政の事業継続性を調査することを目的とする．KASKI，HATSU，GASKI，ASKIM の職員との対面インタビューや現地観察を通じて，震災前，震災中，震災後の事業継続性を検証する．収集したデータの質的分析により，これらの行政が行った実践と直面した課題を比較する．本稿では，カフラマンマラシュ地震から学んだ経験と教訓について，事業の継続性と上下水道サービスの消費者への供給に焦点を当てて概観する．

キーワード：事業継続，災害，地震，インフラストラクチャー，上下水道