J. Int. Environmental Application & Science, Vol. **19**(1): 31-45 (2024)
Research Paper

Kahramanmaras Earthquakes: How Critical is the Uninterrupted Fuel Supply

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Received October 10, 2023; Accepted March 5, 2024

Abstract: Historically, many cataclysmic earthquakes shook Türkiye, but the most devastating ones were on Feb. 6, 2023. Unprecedentedly, a pair of earthquakes caused a massive death toll, thousands of casualties, displacement of millions of people and damage to infrastructure. Logistically, fuel was indispensable for conveying urgent need goods to the disaster zones, so meticulous monitoring of fuel supply was critical. Under these chaotic and unexpected conditions, accessing real-time market data is invaluable for governmental authorities to make instant decisions. During the operations of disaster management, a fuel monitoring system, unique in the world in terms of providing real-time fuel data, was utilized in Türkiye. The data obtained from this system guided Turkish decision-makers to analyze and assess the impacts of the quakes on the market. This paper aims to reveal how the fuel supply and demand have been affected by the recent devastating Kahramanmaras earthquakes based on the monitoring system data. For this purpose, gasoil and gasoline sales between Jan. 30 and Feb. 13, 2023 were used as inputs for indexing/escalating, and daily sales data were adjusted by taking sales made on Jan. 30 as 100. The outputs of this study indicate that people ran to the stations in panic on the first day of the earthquakes. Hence, fuel sales increased remarkably in the less-affected zones, and some regions faced the risk of running out of gasoline due to the destruction of infrastructure and stations. Along with these striking outcomes, some recommendations for mitigating the negative impacts of upcoming earthquakes are also provided in this paper.

Keywords: *Fuel Monitoring; Kahramanmaras Earthquakes; Impacts on Fuel Market; Indexation*

Introduction

The sudden release of energy in the Earth's lithosphere that creates seismic waves results in numerous earthquakes every year. These unpredictable natural events can cause significant casualties (deaths and injuries) and damage infrastructures (residential areas, cultural heritages, industrial facilities, highways, etc.). Some countries have a higher propensity for earthquakes than others due to their location close to tectonic plates. Türkiye, among the world's most seismically active countries, has experienced several devastating earthquakes in its history, lost more than hundreds of thousands of people, and faced widespread destruction. In 2022, there were 20,288 earthquakes registered in Türkiye, or an average of 56 earthquakes per day (BDTIM, 2023).

On Feb. 6, 2023, two severe earthquakes with a magnitude of 7.8 and 7.5 (Kahramanmaras earthquakes) struck ten provinces in the southeastern part of Türkiye. These quakes are among the most powerful in the country's history, killing over 50,000 people and wounding thousands. Because of a pair of cataclysmic earthquakes, a three-month state of emergency was declared in 10 provinces of Türkiye: Adana, Adiyaman, Diyarbakir, Gaziantep, Hatay, Kahramanmaras, Kilis, Malatya, Osmaniye and Sanliurfa.

Kahramanmaras earthquakes occurred on Feb.6, 2023, at 4:17 a.m. and 1:24 p.m. local time (GMT+3), respectively. People in earthquake zones experienced the destructive impacts of the first earthquake while sleeping. After these two earthquakes, more than 200,000 buildings in ten provinces collapsed, and many people were stuck under the rubble. Search and Rescue (SAR) teams were deployed to initiate their operations as soon as possible to minimize the death toll and save people from demolished buildings. In the aftermath of the quakes, providing some crucial needs such as containers, tents, food and water, became the priorities of the governmental bodies and charities to save lives,

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evacuate victims and make the lives of survivors easier. Therefore, continuous fuel supply was crucial for the organizations racing against time in earthquake-stricken areas.

Under these unexpected and chaotic circumstances, real-time market data on fuel sales and stocks became invaluable for immediate decision-making. The Turkish fuel monitoring system comprised of the automation systems at the petrol stations and the storage facilities were utilized to provide hourly and daily data on fuel stocks and sales to the governmental agencies. Although this system was implemented to monitor the entire fuel market activities and prevent fuel tax evasion and smuggling, it was particularly useful for Türkiye to obtain real-time market data after devastating earthquakes.

This paper aims to provide information about how the Kahramanmaras earthquakes affected the Turkish fuel market and how governmental agencies used real-time fuel data to make instant decisions. The rest of the study is organized as follows. Earthquakes in Türkiye are introduced in Section 2. Turkish fuel monitoring system and the impacts of the Kahramanmaras Earthquakes on the Turkish fuel market are discussed in Section 3. Section 4 offers further implications on the earthquakes, and Section 5 concludes the paper.

Post-earthquake decision-making is quite challenging for governmental bodies, non-governmental organizations and municipalities. Explaining the priorities and making critical decisions under severe stress conditions are of great importance for search and rescue and delivery of urgent needs (Basbug et al., 2015). After Feb. 6, 2023, Turkish authority as a decision-maker faced a number of dilemmas, such as balancing short- and long-term needs (e.g. fuel supply to the quake-affected region) (Platt, 2016).The 10 provinces were not impacted by the two earthquakes to the same extent and also the pillars of the market in each province (such as daily fuel consumption, differentiated supply sources etc.) are different from each other.

So, indexation is one of the most effective methods for adjusting fuel sales in different geographic areas so as to predict the impact of the quakes on the market. Both gasoil and gasoline indices for each province were calculated by setting sales on Jan.30, 2023 as 100.

Earthquakes in Türkiye

Seismologically, Türkiye is one of the most active countries in the world. The Anatolian plate, on which Türkiye is mainly located, is adjacent to three main tectonic plates: Arabian, African, and Eurasian. While the Anatolian plate is compressed towards the north by the Arabian and African plates, it interacts with the Eurasian plate (Kalafat et al., 2021).

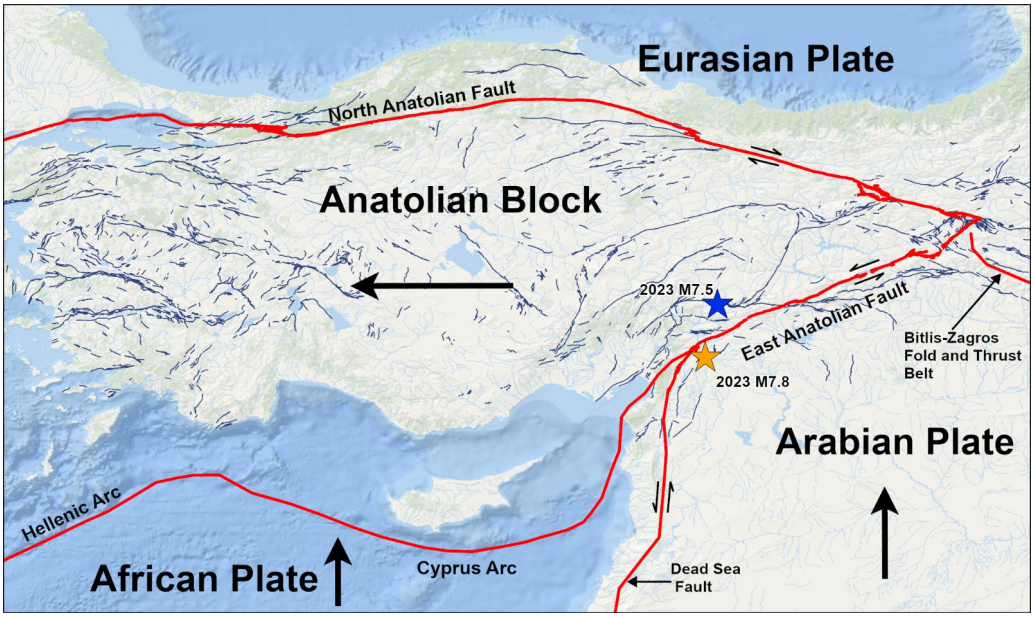

Figure 1: Tectonic map of Türkiye (**Source:** USGS, 2023b)

As seen in Figure 1 illustrating tectonic plates and their movement and interactions in Türkiye, this interaction between the plates makes the country more vulnerable to earthquakes and results in

tectonic activities in the region (Jacobo, 2023). Indeed, the complexity of the Turkish tectonic structure has been responsible for the deadly quakes in the last century.

Table 1. Major earthquakes (Magnitude > 7.0) in Türkiye (1900-2023) (ranked by death toll) (**Source:** Kandilli Observatory and Earthquake Research Institute at Bogazici University (NEMC, 2017) and Anadolu Agency (Oz, 2023)

Date	Location	Magnitude	Death Toll
February 6, 2023	Kahramanmaras	7.8 7.5	50,783
December 27, 1939	Erzincan	7.9	32,968
August 17, 1999	Kocaeli	7.8	17,480
November 27, 1943	Samsun	7.2	4,000
February 1, 1944	Bolu	7.2	3,959
November 24, 1976	Van	7.5	3,840
November 18, 1919	Balikesir	7.0	3,000
December 20, 1942	Tokat	7.0	3,000
May 7, 1930	Türkiye-Iran Border	7.2	2,514
March 28, 1970	Manisa	7.2	1,086
November 12, 1999	Duzce	7.5	763
October 23, 2011	Van	7.2	644
March 18, 1953	Canakkale	7.2	265
August 9, 1912	Tekirdag	7.3	216
April 25, 1957	Mugla	7.1	67
May 26, 1957	Bolu	7.1	52
October 30, 2020	Izmir	7.0	115
July 22, 1967	Adapazari	7.2	89
October 6, 1964	Balikesir	7.0	23

Twenty quakes greater than seven, detailed in Table 1, struck Türkiye between 1900 and 2023, killing more than 124 thousand people (NEMC, 2017 and Oz, 2023). Nonetheless, the Kahramanmaras earthquakes on Feb. 6, 2023, were the deadliest. The earthquakes occurred nine hours apart on different fault lines in the southern part of Türkiye and caused severe destruction in these regions.

Earthquakes on Feb.6, 2023

On February 6, 2023, two devastating earthquakes with magnitudes of 7.8 and 7.5 (USGS, 2023a) badly affected ten provinces of Türkiye, covering 13% of the total area with 16% of the country's population. More than 50,000 died, 200,000 buildings collapsed and 1,000,000 were severely damaged due to the earthquakes and aftershocks in Türkiye (MSF, 2023). After the earthquakes, with Presidential Decree No. 2023/6785 published in the Official Gazette dated Feb. 8, 2023, a three-month state of emergency was declared in ten provinces of Türkiye hit by a pair of cataclysmic earthquakes, which reveals the extent of the destruction. Table 2 gives the population, land area and density of these provinces stated as disaster zones in the Decree.

Although Kahramanmaras earthquakes were felt by most parts of Türkiye, ten provinces illustrated in Figure 2 were heavily impacted and destructed by the earthquakes greater than 7. In disaster zones, 84% of the total death toll (50,783) was recorded in Hatay, Kahramanmaras and Adiyaman (Turkish Ministry of Health, 2023). Besides many deaths in these regions, the unprecedented earthquakes also caused many religious places and cultural heritages to be demolished. Also, natural gas transmission pipelines and public buildings such as hospitals and schools heavily deteriorated (Gunasekera et al., 2023). According to the Türkiye Earthquakes Recovery and Reconstruction Assessment (TERRA) prepared by the Strategy and Budget Office (SBO) of the Turkish Presidency, economic losses of Türkiye are estimated as 9 percent of Türkiye's forecasted GDP for 2023, or equivalent to $103.6 billion (SBO, 2023).

Table 2. Population, land area and density in the provinces affected by the earthquakes (sorted by population) (**Source:** TUIK, 2023a)

Provinces	Region	Land Area (sq. km)	Population (2022)	Density (person /km^2)
Adana	Mediterranean	13,844	2,274,106	164
Sanliurfa	Southeastern Anatolia	19,242	2,170,110	113
Gaziantep	Southeastern Anatolia	6,803	2,154,051	317
Diyarbakir	Southeastern Anatolia	15,101	1,804,880	120
Hatay	Mediterranean	5,524	1,686,043	305
Kahramanmaras	Mediterranean	14,520	1,117,436	77
Malatya	Eastern Anatolia	12,259	812,580	66
Adiyaman	Southeastern Anatolia	7,337	635,169	87
Osmaniye	Mediterranean	3,320	559,405	168
Kilis	Southeastern Anatolia	1,412	147,919	105
Total		**99,362**	**13,361,699**	**134**
Grand Total		**780,043**	**85,279,553**	**109**
%		**12.74%**	**15.67%**	**-**

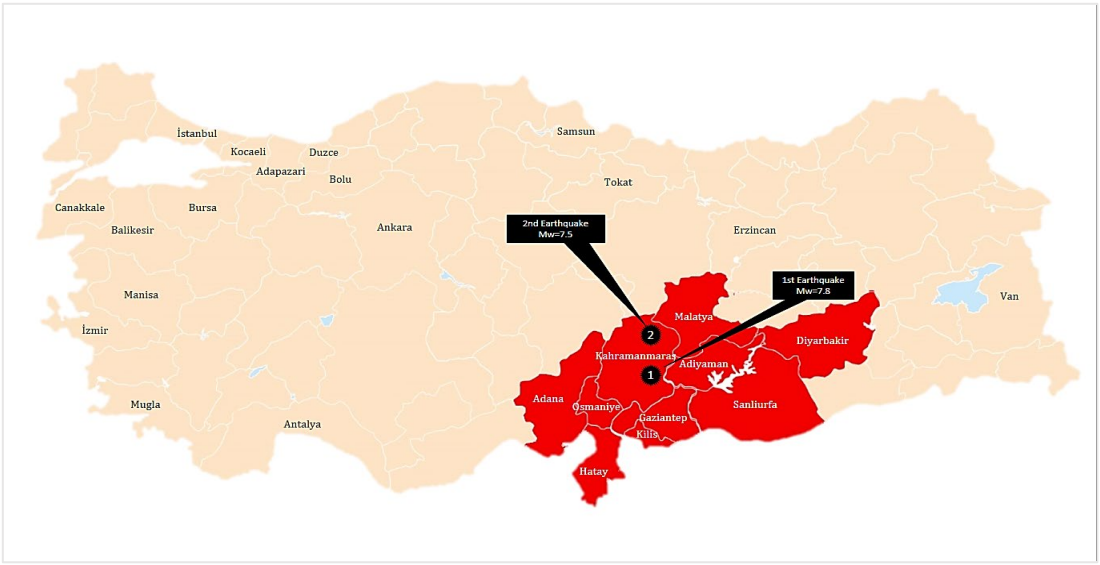

Figure 2. Provinces affected by the Kahramanmaras earthquakes (**Source:** Authors' own illustration)

Impacts of the Kahramanmaras Earthquakes on the Turkish Fuel Market

Alongside the high amount of death toll and causalities, the life stood at a standstill after the earthquakes in these provinces. Similar to other infrastructures in disaster zones, some petrol stations, roads, railways, and a few storage facilities were severely damaged. These provinces, with more than 1,800 petrol stations, accounted for 11% of the country's fuel consumption. Following the devastating earthquakes, many people ran to the stations along with rising fear, panic, and chaos; some of them left without shelter in frigid temperatures wanted to get fuel to heat themselves in their cars on the cold winter day, or rescue crews needed more fuel for the operations of ambulances or cranes, which brought supply problems in the first days of the earthquakes. Uninterrupted fuel supply is also critical for delivering sufficient emergency supplies promptly to affected individuals to alleviate their suffering. Indeed, the scarcity of fuel could potentially cause more harm than the shortage of emergency supplies. (Suzuki, 2012). Thus, forecasting future gasoline shortages can assist agencies in directing supplies to the appropriate regions and alleviating the shortage (Khare et al., 2020).

At this point, the importance of monitoring systems at storage facilities and petrol stations became prominent in the case of a force majeure, and these systems served a different purpose in Türkiye that had never been foreseen before, as in the earthquakes. In order to carry out the damage estimation and assessment and to maintain fuel activities in the areas hit by earthquakes, receiving real-time fuel data

from the whole country and processing them quickly were crucial for rescue teams and many government agencies.

Turkish Fuel Monitoring System

Türkiye's proximity to oil-rich regions, inconsistent fuel market tax rates, lubricant oil used as a substitute for fuel, and inadequate inspection and monitoring mechanisms were the main factors accounting for raising smuggling activities in the country in the past (Yalta & Yalta, 2016). To deal with these problems, the authorities devised a solution, such as monitoring the petrol stations through electronic systems, namely automation systems. In 2007, necessary amendments were made in Turkish Petroleum Market Law No. 5015 (from now on referred to as PML) and in 2011, the obligation of establishing the automation systems was imposed in the Turkish fuel market apart from Liquefied Petroleum Gas (LPG) that is used as a complementary fuel.

The automation system at the petrol stations allows monitoring of underground tanks and sends some information about the volume, temperature of the fuel, the amount of fuel filled into the tank and exited from the tank to the system users instantly. The fuel distributors have to submit these data over the Internet to the Energy Market Regulatory Authority (EMRA). In this way, EMRA can control the obligations of license holders and analyze fuel market by utilizing automation data (the amount of fuel sold and stored at the stations).

In addition to the automation systems in the petrol stations, some terms and conditions were added to the PML in 2017, and a storage tank monitoring system was envisaged in the country. Since 2018, all fuel activities at refineries and storage facilities can also be monitored in detail by EMRA. In the tank monitoring system, fuel and LPG distributors, refineries and storage facilities eligible to store petroleum products regarding the PML have to send comprehensive fuel data such as fuel type, customs tariff number (HS codes) of fuel, measured fuel density, volume/level of fuel and fuel temperature over the Internet to EMRA for further analysis and compilation. Table 3 provides the details on the data compilation process through both station and tank storage automation systems in Türkiye. In addition to hourly and daily fuel data sent to EMRA, the administrative authority can monitor real-time fuel stocks and sales at the petrol stations and storage facilities remotely.

Table 3: Fuel monitoring system and data compilation process in Türkiye (**Source:** Authors' own compilation)

System	Data Provider	Data Sent to EMRA	Submission Period to EMRA	Correction Time (if needed)
Petrol Stations Monitoring System	Fuel Distributors	- The volume of fuel in the underground tank -Temperature of the fuel -The amount of fuel filled into the tank and exited from the tank -Fuel sales -Fuel price	Daily	24 hours after submission to EMRA
Storage Tank Monitoring System	Refineries Fuel Distributors Storage Facilities	-Fuel type -Customs tariff number (HS Codes) of fuel -Measured fuel density -Volume/level of fuel -Fuel temperature	Hourly and Daily	24 hours after submission to EMRA

As given in Table 3, a considerable amount of fuel data is gathered from the market players mainly to control obligations. In the aftermath of the Kahramanmaras earthquakes, governmental agencies conducted analyses by using real-time fuel data:

- to make damage assessment of the petrol stations and storage facilities,
- to detect fuel shortages,
- to guide and advise market players on how to refuel stations,

- to follow supply-demand balance in disaster areas.

With the implementation of these systems, EMRA can perform real-time monitoring at 100 storage facilities, 38 fuel distributors and more than 13,000 petrol stations. In other words, most fuel activities carried out in the Turkish oil infrastructure, given in Figure 3, can be tracked with this fuel monitoring system. In Figure 3, the complex Turkish oil infrastructure is illustrated and the capacities of refineries, storage facilities and railways and the pipelines used to transmit crude oil and oil products are shown thoroughly.

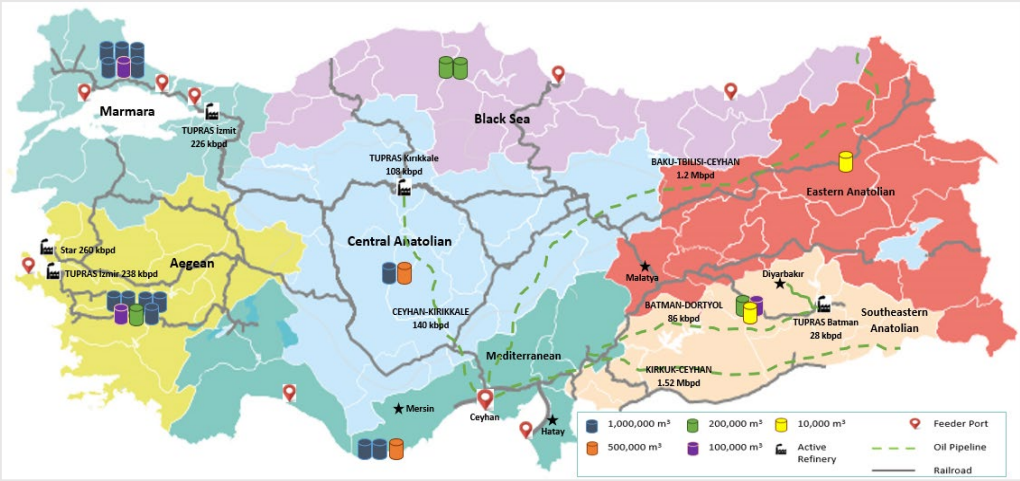

Figure 3. Turkish oil infrastructure (**Source:** Authors' own illustration)

Five refineries with a distillation capacity of 43 million tons/year (860 kb/d) (EPDK, 2023b) are scattered over Turkish territory. Three refineries on the Aegean and Marmara coasts are designed to refine imported crude oil by sea tankers. Although refineries on the coastline are fed by seaborne imports, the inland refineries in Central and Southeastern Anatolian regions are supplied via pipeline and road tankers. While crude oil is mainly transmitted to the Kirikkale refinery via the pipeline extending from Türkiye's Mediterranean oil hub, Ceyhan, to Kirikkale, with a length of 448 km and an annual capacity of 7.2 million tons (IEA, 2021), the Batman refinery, which refines dominantly indigenously produced oil, obtains oil through road tankers and a pipeline with a length of 518 km and an annual capacity of 4.5 million tons extending from Ceyhan (Dortyol) to Batman (Botas, 2023).

Over the past decades, the production of refineries has increased substantially with the activation of the Star Refinery at Izmir and the implementation of the Residuum Upgrading Project (RUP) at TUPRAS Izmit Refinery. However, refinery throughput has been far from meeting ever-growing Turkish oil demand. For this reason, Türkiye imports massive amounts of petroleum products (gasoil/diesel, LPG, aviation fuel, etc.) through the seaports on the Marmara, Aegean, Black Sea and Mediterranean coasts (Figure 3). All domestically produced and imported oil fuels are delivered to the end users in the coastal regions dominantly by sea transportation. Consumers in the inland of Türkiye are fed by pipeline, road and rail transport.

Table 4: Modes of fuel transportation to the earthquake-affected regions (**Source:** Authors' own compilation)

Type of Transport	**Provinces**			
	Diyarbakir	**Hatay**	**Mersin** *	**Malatya**
Railway	X	x	x	
Sea		x	x	
Road		x	x	x

*This province on the Mediterranean coast is very active in oil trade.

Fuel in earthquake-stricken zones is normally supplied by pipeline, road, sea and rail transport. In Table 4, the primary transport sources of fuel are exhibited. Although storage facilities are scattered in Diyarbakir, Hatay, Mersin and Malatya, high volumes of fuels are stored in Hatay and Mersin. The fuels

stored in these two provinces are transported to the southern part of the Central Anatolian Region, the Southeastern Anatolian Region and some parts of the Eastern Anatolian Region.

Impacts of the Earthquakes on the Turkish Fuel Market

In the scope of this paper, the impacts of the Kahramanmaras earthquakes on the Turkish fuel market were investigated by using data gathered from the fuel monitoring system and the market players, mainly refineries and fuel distributors. In this study, only gasoil and gasoline data are taken into account, and the data of Liquefied Petroleum Gas (LPG), used as a complementary fuel in the market, was not utilized because the fuel monitoring system was implemented to track fuel transactions other than LPG. Although the Turkish fuel monitoring system was not mainly designed to compile the latest fuel data to make decisions about the fuel market, after the quakes on Feb. 6, 2023, the use of real-time data collected remotely from data providers became vital for the authorities.

After two devastating earthquakes and aftershocks, Türkiye utilized station and storage facility systems data to monitor the balance of fuel supply and demand in ten provinces. Consequently, Türkiye was able to know how much fuel stock was in the storage facilities and petrol stations and whether there was an urgent need in disaster zones considering the remaining stock and daily consumption patterns.

The Turkish fuel market was affected in various ways after the quakes. In disaster zones, damage to infrastructure (railways, roads and transmission pipelines) and destruction of petrol stations and storage facilities negatively impacted fuel distribution and sales. Using data from the fuel monitoring system, in the following section, the effects of the quakes on the market were assessed under three sections: impacts on infrastructure, fuel supply and fuel sales.

Impacts on Infrastructure

The first damage control of all petrol stations and storage facilities in the earthquake-affected provinces was carried out by EMRA through the monitoring system. After the quakes, most of the data providers could send daily data despite power outages and internet connection losses, which made the Turkish authorities permanently control the fuel stocks and take action in the earthquake zones. It was confirmed that the data of more than 93% of the tanks in the stations could be submitted to EMRA, even in the provinces such as Hatay, Adiyaman, Kahramanmaras and Malatya, where the earthquake had hit the hardest.

According to TERRA, the earthquake-related damage is estimated at roughly 355 million Turkish Liras (18.8 million USD) (SBO, 2023). The total loss of oil infrastructure (mostly petrol stations) by provinces was also revealed by SBO and is given in Figure 4. According to the first damage assessment by EMRA, some petrol stations in the earthquake-affected region were completely or partially demolished. In addition, some underground storage tanks and the connection parts collapsed and had to be repaired. As illustrated in Figure 4, approximately 89% of the total damage occurred in Hatay, Kahramanmaras, Malatya and Adiyaman.

All fuel movements in the disaster zone faced logistical difficulties due to unexpected infrastructure damage. After two devastating earthquakes, cracks on highways and roads, and meters of displacement at the road and railways occurred. According to the statement made by the Turkish Ministry of Transport and Infrastructure, 1,275 km of railway lines, 446 bridges and 175 tunnels in the disaster zone were significantly impacted (Artymiuk, 2023). As stated in TERRA, 17.4 billion Turkish Liras (922 million USD) are required to repair and reconstruct damaged railways (SBO, 2023).

Essential ports for Turkish trade were damaged. Mersin, the third biggest port in Türkiye, and Hatay (Iskenderun), the seventh one, suspended their operations after the quakes (Rubenstone, 2023). Because of the earthquakes, nearly 38 million Turkish Liras (2 million USD) of damage occurred (SBO, 2023). Considerable demolition of logistics infrastructure in the disaster zones after the quakes caused the oil movement to be disrupted. Deliveries in and out of the damaged ports were diverted to nearby ports (Johnson, 2023).

Road freight transport has always been indispensable for earthquake-affected provinces due to the geographical and infrastructure constraints (e.g., limited number of storage facilities). Fuel stored in Mersin and Hatay provinces is transported to the inner parts of the Eastern and Southeastern Anatolia regions by road tankers. In these regions, Nurdagi, one of the most critical connection points in the region, is located on the shortest route between Mersin-Gaziantep and Hatay-Gaziantep. During the

earthquakes, the highway near Nurdagi became unusable and was blocked. For this reason, fuel transmission into disaster zones, except for Hatay and Adana, was stopped entirely.

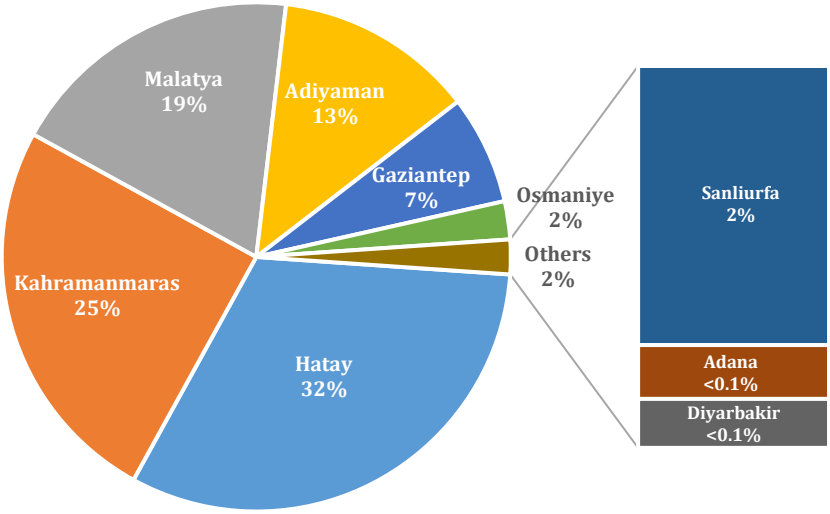

Figure 4: Total loss of Turkish oil infrastructure (mostly petrol stations) (**Source:** SBO, 2023)

Destruction of essential highways, railroads and ports in the earthquake-stricken provinces made it difficult for market players (refineries and fuel distributors) to deliver fuel to the disaster zones. Therefore, alternative itineraries were used to transport fuel to these provinces. To illustrate, fuel was delivered from the Black Sea and Central Anatolia Regions to the inner parts of the Eastern and Southeastern Anatolia regions by road freight transport.

Impacts on Fuel Supply

The massive earthquakes caused a cataclysm in 10 provinces of Türkiye, where 11.46% of total Türkiye's fuel sales in 2022 were realized. Based on Table 5, presenting the number of petrol stations and storage facilities and the amount of sales in the earthquake-affected provinces, 15.14% of total petrol stations and only 9.6% of total storage facilities in Türkiye exist in these ten provinces. Most of these facilities with very limited storage capacities are located in Hatay on the Mediterranean coast, indicating the importance of supplying fuel to these regions with different alternatives.

Table 5: Number of petrol stations and fuel sales in the provinces affected by the Earthquakes (sorted by region) (**Source:** Petroleum Market Reports (EMRA, 2023a), Licenses at Turkish Oil Market (EMRA, 2023b) and Turkey 2021 Energy Policy Review (IEA, 2021))

Province	Region	# of Stations as of Feb.6, 2023	# of Storage Facilities as of Feb. 6, 2023	Storage Capacities as of Feb.6, 2023 (m^3)	Gasoline and Gasoil Sales in 2022 (ton)
Adana	Mediterranean	295	1*	2,568	644,557
Hatay	Mediterranean	238	5	249,177	489,229
Kahramanmaras	Mediterranean	197	-	-	290,895
Osmaniye	Mediterranean	95	-	-	128,038
Adiyaman	Southeastern Anatolia	144	-	-	142,180
Diyarbakir	Southeastern Anatolia	216	1	9,256	282,625
Gaziantep	Southeastern Anatolia	252	1*	677	552,823
Kilis	Southeastern Anatolia	22	-	-	26,511
Sanliurfa	Southeastern Anatolia	288	-	-	329,166
Malatya	Eastern Anatolia	132	1	4,980	183,149
Total		**1,879**	**9**	**266,658**	**3,069,172**
Grand Total		**12,413**	**94**	**14,791,209****	**26,787,937**
%		**15.14%**	**9.6%**	**1.8%**	**11.46%**

*It represents the storage facility where aviation fuels are stored at Adana and Gaziantep airports.

** It is calculated by the authors considering the storage capacities of EMRA licensed tanks.

Figures 5 and 6 reveal the quakes' immediate impacts on the amounts of the fuel stored and purchased. Considering the gasoil and gasoline stocks and sales after the earthquakes, the beginning fuel stocks of February 7 provide some clues about refueling to stations and the status of fuel stocks.

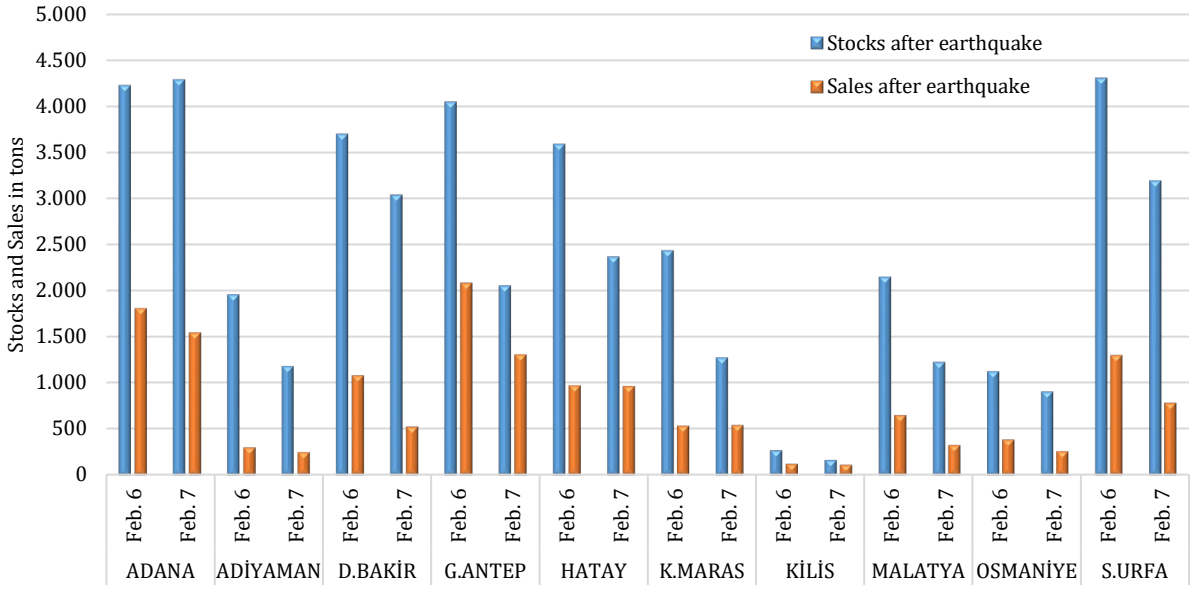

Figure 5: Gasoil stocks at the beginning of the day and sales at petrol stations before and after the quakes (**Source:** Authors' own elaboration based on the Turkish fuel monitoring system data)

Figure 5 shows that almost all provinces had enough supply to meet gasoil demand in the first two days of the earthquakes. Nonetheless, in Figure 6, the gasoline stocks on February 7 in some provinces, such as Gaziantep, Hatay, Kahramanmaras, and Kilis were alarming, which could lead to the authorities taking additional measures to prevent a supply crisis there. Indeed, the Turkish authority, EMRA, directed many distributors to supply fuel to these areas.

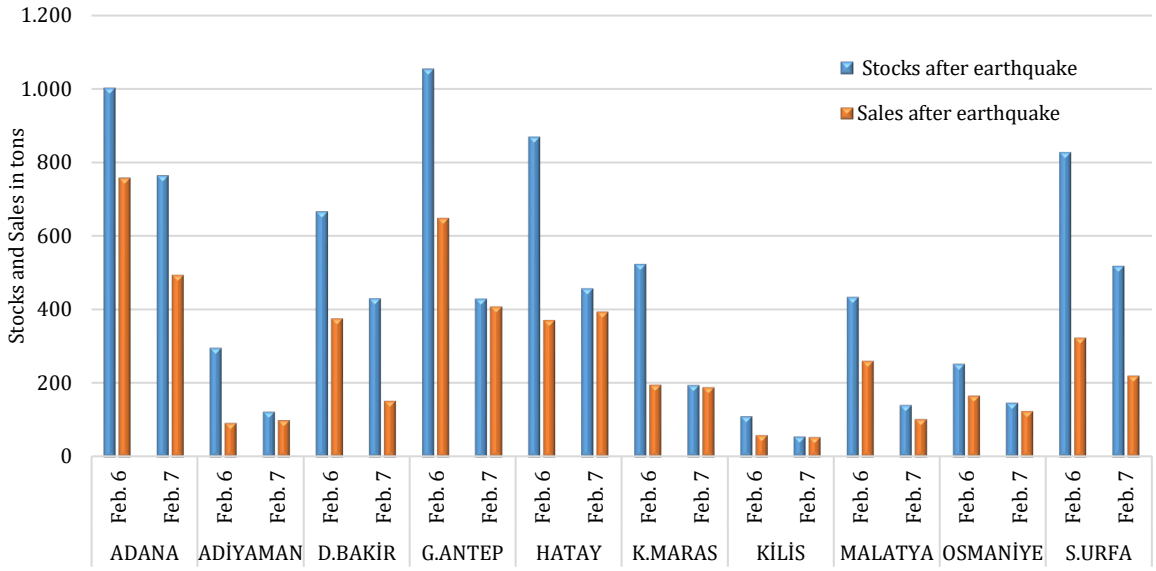

Figure 6: Gasoline stocks at the beginning of the day and sales at petrol stations before and after the quakes **(Source:** Authors' own elaboration based on the Turkish fuel monitoring system data)

Figures 5 and 6 also show the impacts of railroad and highway damage on the fuel market in the provinces apart from Adana and Hatay. In most earthquake-affected provinces, gasoline stocks at the

beginning of Feb. 7 were equal to fuel sales on Feb. 7. This situation indicating supply problems warns the authorities to take necessary measures before the stocks run out at the stations.

Impacts on Fuel Sales

To measure the impact of the earthquakes on fuel sales, whole fuel sales in Türkiye were scrutinized thoroughly, and it was found that the effects of Kahramanmaras earthquakes on the fuel market varied from region to region. Although the impact of the quakes on the market was insignificant in some regions, such as the Marmara and Aegean Regions, the main effects can be observable in the earthquake-affected provinces and their neighboring ones. Therefore, only fuel transactions in the earthquake-affected provinces and their neighbors were taken into account in this study so as not to make a misleading assessment.

In order to measure the effects of the quakes on the fuel market, seven days before and after the day of the Kahramanmaras earthquakes, periods namely Jan.30 and Feb.13, 2023, were chosen as the time interval. As a starting point, fuel sales between Jan.30 (Monday) and Feb. 13 (Monday) are rescaled by taking the sales on Jan.30, 2023, as 100. Based on the data submitted by the automation system to EMRA, rescaled gasoil and gasoline sales are illustrated in Figures 7 and 8. In this way, it was aimed to exhibit the daily fuel sales in the quake-affected provinces and how the sales fluctuate in response to the earthquakes. In Figure 7, gasoil sales in the earthquake zone on the day of the earthquakes (Feb. 6) jumped suddenly and increased by 250% compared to the sales on Feb.5. After the quakes, gasoil sales skyrocketed on Feb. 6 and then fell sharply on Feb. 7. The impact of quakes on the local fuel market in Kilis, Malatya and Diyarbakır is more remarkable than in other provinces. Unlike these three provinces, gasoil sales remained relatively stable in severely damaged provinces, such as Hatay, Kahramanmaras, and Adiyaman. As seen from Figure 7, the gasoil sales generally decreased on the second day of the earthquake, Feb. 7, which may raise some critical questions, such as whether there were enough stocks in these cities, whether the panic environment on the first day of the earthquakes led people to rush to the stations was annihilated later. Considering gasoil used by construction machinery, ambulances, SAR teams and lightening equipment (e.g., generators) during SAR operations, it is expected that the amount of gasoil is higher than usual in all disaster-stricken provinces. However, according to the data in Figure 7, this was not the case in some provinces such as Adiyaman, Hatay and Kahramanmaras.

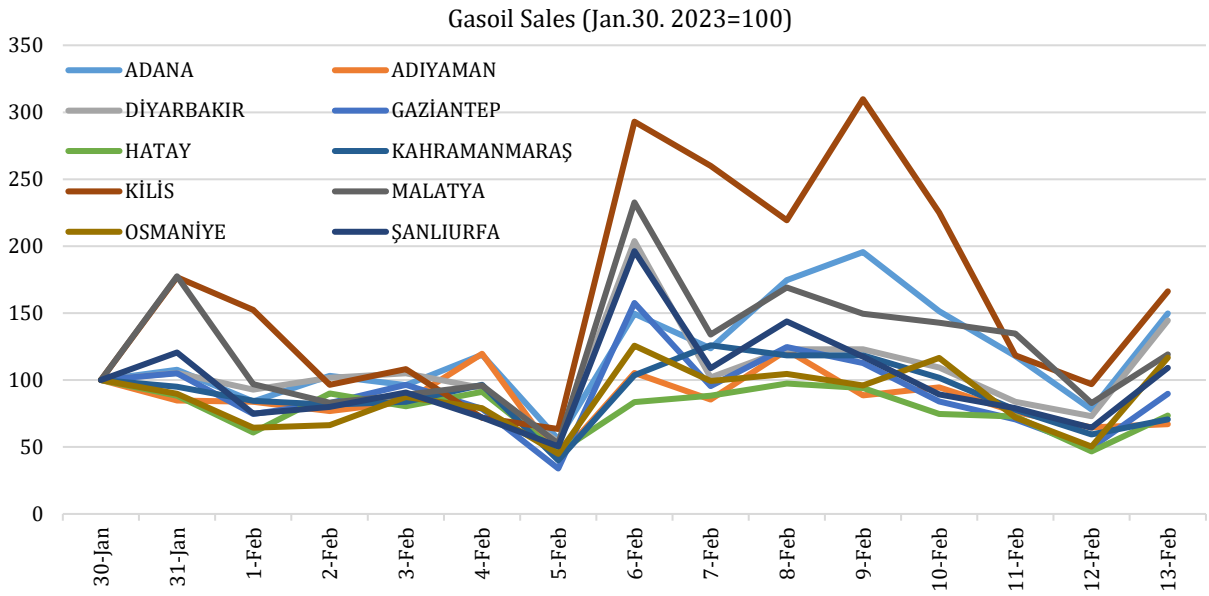

Figure 7: Gasoil sold at the stations in disaster zones before and after the quakes (**Source:** Authors' own elaboration based on the Turkish fuel monitoring system data)

Similar to Figure 7, Figure 8 exhibits gasoline sales in the disaster zones for the period starting from Jan.30 to Feb.13, 2023, to analyze the effects of the quakes. Unlike gasoil sales in the region, an increase in gasoline sales on the day of the quakes is higher than the rise in gasoil sales. Similar changes

in gasoline sales were observed before and after the quakes. As shown in Figure 8, gasoline sales increased significantly in all provinces on Feb. 6, 2023, by 560% compared to Feb. 5, 2023.

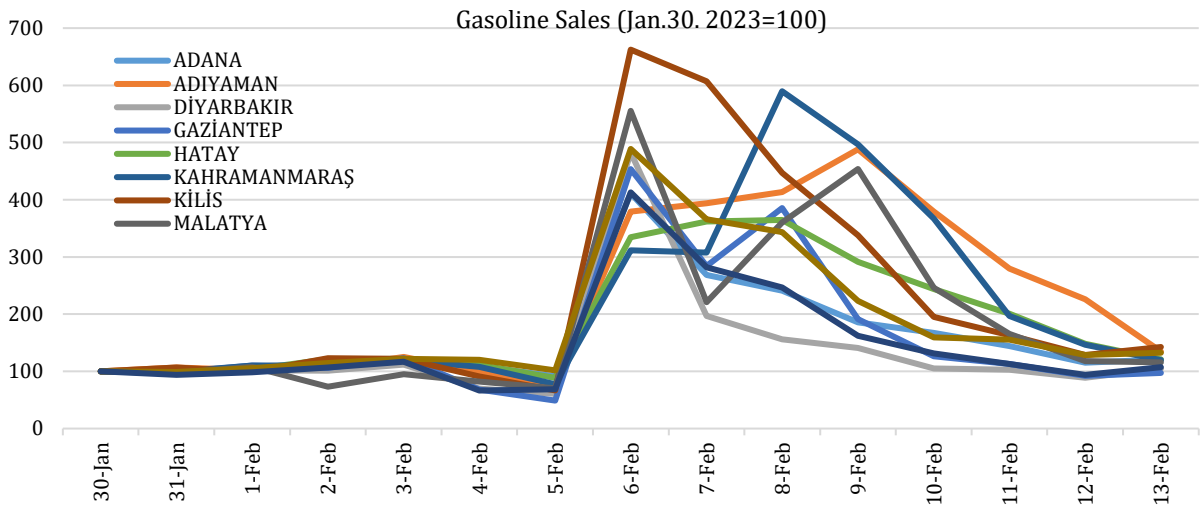

Figure 8: Gasoline sold at the stations in disaster zones before and after the quakes (**Source:** Authors' own elaboration based on the Turkish fuel monitoring system data)

Regarding the Turkish Statistical Institute's statistics, 3.14 million motor vehicles, corresponding to 11.9% of the total vehicles in Türkiye, are registered in disaster zones as of January 2023. 46.4% of these vehicles are automobiles and the fuel types consumed by these vehicles are gasoil (36.9%), LPG (35.1%) and gasoline (26.8%) (TUIK, 2023b). In light of these data, Figures 7 and 8, the gasoil and gasoline were primarily used for travel to other provinces.

When gasoil and gasoline sales submitted by the automation system to EMRA are examined to determine the effects of the earthquakes on the whole market, it was seen that quakes had ripple effects on the market and fuel sales not only in ten provinces but also in their neighbors were impacted drastically.

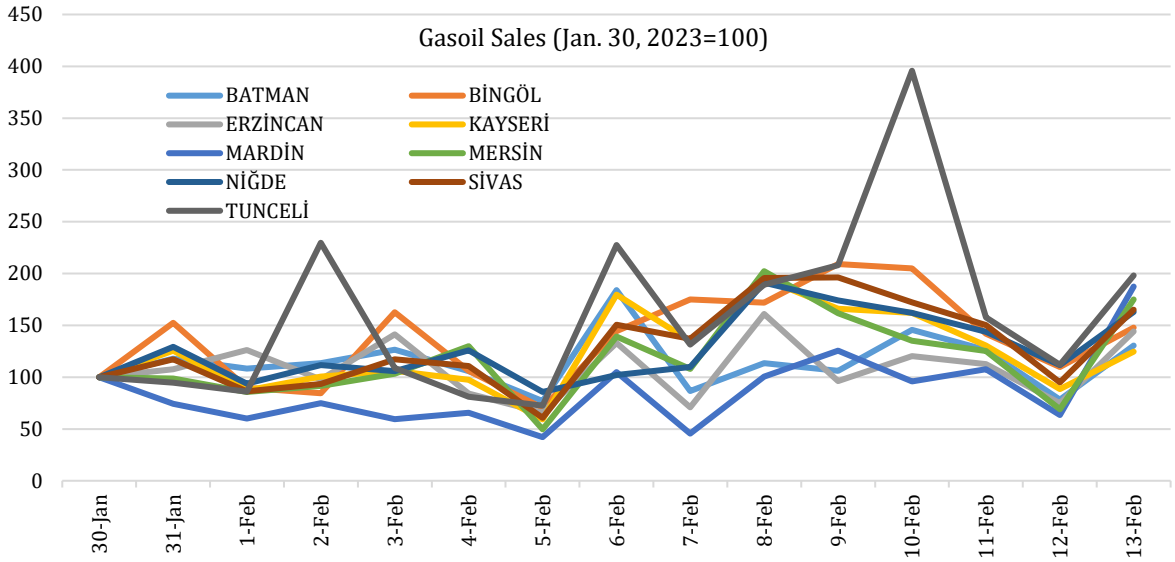

Fig. 9: Gasoil sold at the stations in the neighboring provinces of the disaster zones before and after the quakes (**Source:** Authors' own elaboration based on the Turkish fuel monitoring system data)

Figures 9 and 10 illustrate gasoil and gasoline sales in neighboring provinces of the earthquake-impacted zones before and after the quakes. As in the ten provinces affected by the earthquakes, gasoil

sales in the surrounding provinces (e.g. Tunceli, Kayseri, Batman, Sivas etc.) increased on the day of the earthquakes and their impacts lasted the following week.

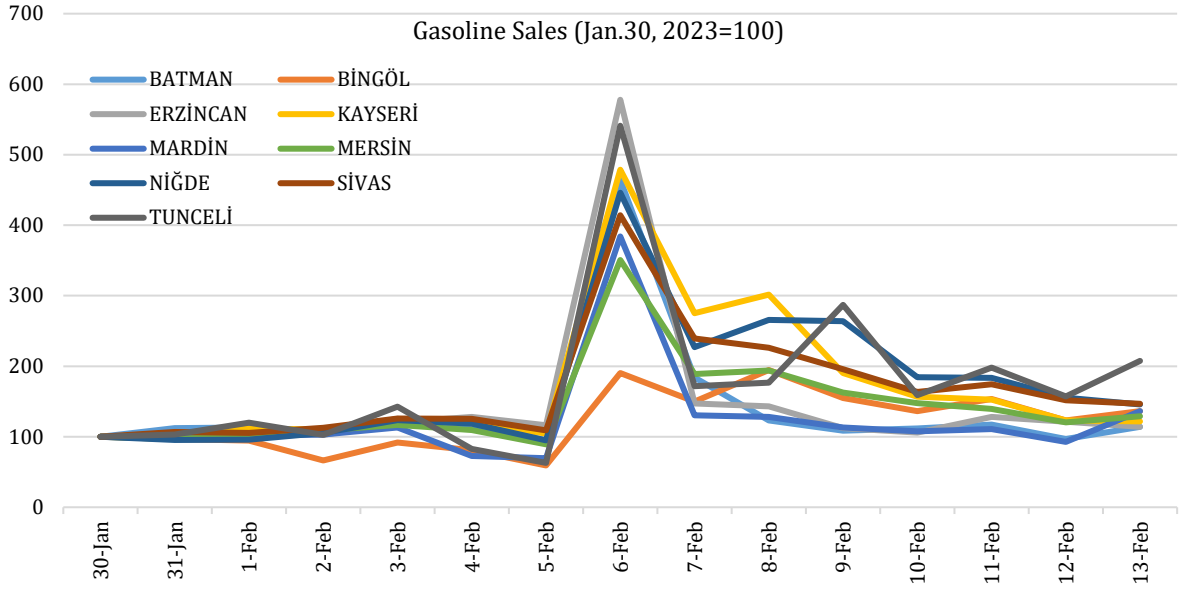

Fig. 10: Gasoline sold at the stations in the neighboring provinces of the disaster zones before and after the quakes **(Source:** Authors' own elaboration based on the Turkish fuel monitoring system data)

The trend of gasoline sales in the neighboring provinces presented in Figure 10 is similar to the trend given in Figure 8. On Feb. 6, 2023, the earthquakes catapulted gasoline sales, and all sales decreased significantly.

Future Implications of Earthquakes

After the destructive earthquakes on Feb. 6, 2023, the fuel market, one of the essential markets to support search and research activities, has gained importance. In Türkiye, one of the most active earthquake hotspots, many emergency plans have been implemented to save more lives and make the lives of the victims easier after quakes.

Türkiye is located between two major fault systems, the North Anatolian and East Anatolian Faults, which make the country vulnerable to an earthquake of magnitude 7 or stronger. Tracing back the history of the country, it has faced destructive earthquakes many times, and according to the analysis carried out by the National Disaster Mitigation Agency (BNPB), earthquakes in Türkiye have a repeated history (ANTARA, 2023).

There has been an ever-continuous rise in the number of earthquakes since 1990, as seen in Figure 11, focussing on the earthquake statistics between 1990 and Oct. 5, 2023. Although only 344 earthquakes were recorded in 1990, this number has increased to 65,011 as of Oct. 5, 2023. Considering the recurrence and exponential rise of earthquakes in Türkiye, these numbers are expected to continue.

In order to be prepared for future quakes, the Turkish government should develop an emergency response plan outlining also fuel supply and demand restraint measures by using the Turkish fuel monitoring system as a guide. These measures should be considered complementary to the search and research operations. These measures should be categorized as light- and heavy-handed measures in the fuel sector to guarantee ongoing fuel supply.

While light-handed fuel supply measures can include modeling current fuel supply by provinces and districts, diversification of alternative fuel supply routes by provinces and assessing/auditing resilience of existing oil infrastructure, heavy-handed fuel supply measures can consist of utilization of storage facilities that are not regulated by the PML after the earthquakes.

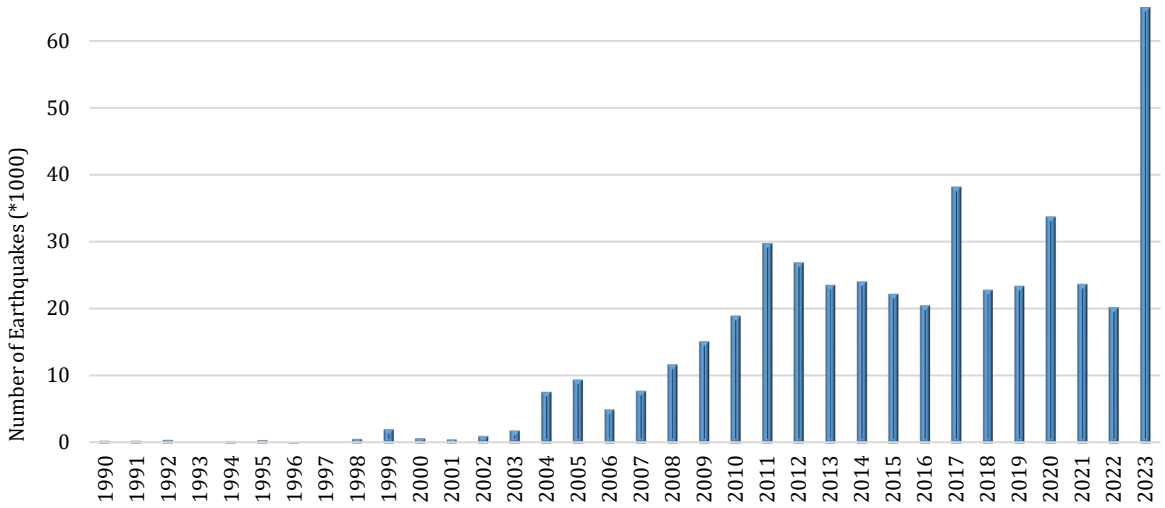

Fig. 11: Earthquake statistics in Türkiye between 1990 and Oct. 5, 2023. (**Source:** Disaster and Emergency Management Authority (AFAD, 2023))

For the demand side, light-handed measures can ensure sustainable data transmission and plan mobile fuel delivery systems by regions and provinces. Classification and limitation of individual and SAR equipment use should be implemented as a heavy-handed measure.

In light of the points mentioned earlier, Türkiye's objective must be to utilize the Turkish fuel monitoring system more efficiently and concoct an earthquake contingency plan

Conclusion

Türkiye, which has experienced many earthquakes throughout its history, woke up on the morning of Feb. 6, 2023, with the biggest of these disasters. The Kahramanmaras earthquakes, with magnitudes of 7.8 and 7.5, struck ten provinces in the southeastern part of Türkiye and led to significant destruction in these regions. The earthquakes caused more than 50,000 people to die and wound thousands. In addition to massive casualties, many infrastructures, cultural heritages, natural gas transmission pipelines, and public buildings such as hospitals and schools were severely destroyed. In the disaster zone, where life came to a standstill, besides humanitarian needs, administrative authorities had to focus on ensuring an uninterrupted fuel supply and take immediate action in case of a supply crisis. The fuel supply after the disaster was more critical to evacuate victims from the earthquake-affected zones and maintain SAR activities without disruption. At this point, Türkiye utilized its unique fuel monitoring system with the petrol stations and tank storage automation systems that had been implemented for many years mainly to monitor the activities in the fuel market to prevent fuel tax evasion and fuel smuggling.

These destructive earthquakes revealed how real-time fuel market data can be vital in a force majeure. Thanks to the data compiled from these systems, Turkish authorities could instantly determine the amount of fuel stocks in the facilities and stations and direct the fuel to the stations in the earthquake zones at need. They applied other alternatives for supplying fuel to the disaster zones while checking the stocks at neighborhood storage facilities, given that many railway lines, bridges, and tunnels were severely damaged.

In this study, gasoline and gasoil sales in and around the disaster zones between Jan. 30 and Feb. 13, 2023 and the stocks of these fuels on Feb. 6 and 7 were selected to assess the impacts of the quakes on the Turkish fuel market. The disproportionate effect of the quakes on the provinces was eliminated by rescaling of fuel sales data by taking sales on Jan. 30 as 100. Also, pre- and post-earthquake fuel stocks compared.

According to the data compiled from the station monitoring system, some provinces faced the threat of being out of stock for a few days after the earthquake. In relatively less damaged provinces, fuel sales increased on the day of the earthquake compared to the previous week's sales, indicating people's behavior in a chaotic environment with panic. On the contrary, in severely destroyed provinces, fuel sales, mainly for the gasoil, were stable, revealing the extent of the disaster since most of the stations in

these regions became already unusable. Many provinces faced the risk of running out of gasoline, which was an alarming situation that the authorities had to ponder while considering gasoline supply schemes for these regions.

Using data from the fuel monitoring system, Türkiye managed the possible fuel supply crisis in a contingency, even though this system was initially designed for different purposes. Since the country is prone to further earthquakes, building roadmaps and contingency plans is critical before such disasters. Concentrating on emergency action plans by making use of the available data and all possibilities and conducting case studies for possible earthquake zones is crucial in minimizing the destructive effects of such disasters in the fuel market.In possible earthquakes, e.g., Istanbul, the impacts can spread over the whole country, and fuel crisis management can be much more challenging for the authorities. Therefore, the results of this study are beneficiary for the public authorities. The area affected from the quakes is wide and consists of dozen of provinces. By using outcomes of this study, contingency plans can be organized by authorities to mitigate the impacts of upcoming earthquakes.

Lastly, this study, which sheds light on the challenges of meeting an urgent need following unexpected disasters, emphasizes the importance of conducting more sophisticated analyses on demand management and optimal resource allocation post-disaster.

Acknowledgment: *We would like to express our sincere gratitude to our Head of Department, Abdullah Ince for their support throughout the research process. We would also like to thank our Head of Group, Kağan Akın for encouraging us to conduct this challenging research. We also wish to thank Özgür Çakır for his invaluable guidance and providing technical advice. Finally, we are very grateful to Şeyma Burkan, who generously gave her time and effort to draw all the maps.*

Compliance with Ethical Standards Ethical responsibilities of Authors: *The author has read, understood, and complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors".*

Funding: *No funding was received by the authors.*

Conflict of Interest: *The authors declare that they do not have any conflict of interest.*

Change of Authorship: *The author has read, understood, and complied as applicable with the statement on "Ethical responsibilities of Authors" as found in the Instructions for Authors and is aware that with minor exceptions, no changes can be made to authorship once the paper is submitted.*

References

AFAD. (2023) *Earthquake Statistic*s, https://deprem.afad.gov.tr/event-statistics

ANTARA. (2023) *Turkey earthquake has a repetitive histor*y: BNPB'. https://en.antaranews.com/news/274218/turkey-earthquake-has-a-repetitive-history-bnpb

Artymiuk S, (2023) 'Turkey and Syria battle impact of 7.8-magnitude earthquake'. IRJ. https://www.railjournal.com/infrastructure/turkey-and-syria-battle-impact-of-7-8-magnitude-earthquake/

Başbug E, Karanci AN, Kalaycioglu S, Ozden AT, Caliskan I, and Ozaksehir G, 2015) From Emergency Response to Recovery: Multiple Impacts and Lessons Learned from the 2011 Van Earthquakes. *Earthquake Spectra*, pp. 527–540, Available: https://hdl.handle.net/11511/30470.

BDTIM. (2023) '2022 Yılı Deprem Harita, Grafik ve Tabloları'. http://www.koeri.boun.edu.tr/sismo/2/deprem-verileri/yillik-deprem-haritalari/2022-yili-deprem-harita-grafik-ve-tablolari/

BOTAS. (2023) *Crude Oil*. https://www.botas.gov.tr/pages/crude-oil/359

EMRA. (2023a) *Annual Petroleum Market Reports*. https://www.epdk.gov.tr/Detay/Icerik/3-0-107/yillik-sektor-raporu

EMRA. (2023b) *Petrol Piyasası Rafinerici Lisansları*. https://lisans.epdk.gov.tr/epvys-web/faces/pages/lisans/petrolRafineri/petrolRafineriOzetSorgula.xhtml

Gunasekera R, Ishizawa Escudero OA, Daniell JE, Pomonis A, Macabuag JLDC, Brand J, Schaefer A, 2023. G*lobal Rapid Post-Disaster Damage Estimation (GRADE) Report : February 6, 2023 Kahramanmaraş Earthquakes - Türkiye Report*' (English). Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/099022723021250141/P1788430aeb62f08009b2302bd4074030fb

IEA. (2021) *Turkey 2021 Energy Policy Review*. https://iea.blob.core.windows.net/assets/cc499a7b-b72a-466c-88de-d792a9daff44/Turkey_2021_Energy_Policy_Review.pdf

Jacobo J, (2023) *How regional fault lines led to such a destructive earthquake in Turkey, Syria*. ABC News. https://abcnews.go.com/International/regional-fault-lines-led-destructive-earthquake-turkey-syria/story?id=97005531.

Johnson T, (2023) 'Infrastructure damage highlights severe impact of Turkey and Syria earthquakes'. https://www.newcivilengineer.com/latest/infrastructure-damage-highlights-severe-impact-of-turkey-and-syria-earthquakes-13-02-2023/.

Khare A, He Q, Batta R, (2020) Predicting gasoline shortage during disasters using social media. *Or Spectrum*, 42, 693-726. https://doi.org/10.1007/s00291-019-00559-8

Kalafat D, Zulfikar, AC, Akcan SO (2021) Seismicity of Turkey and Real-Time Seismology Applications in Determining Earthquake Hazard. Acad*emic Platform J. Natural Hazar. & Disaster Manag.* **2**(2), 96-111. doi: 10.52114/apjhad.1039670.

MSF. (2023) *People's needs stack up months after earthquake in Türkiye.* https://www.msf.org/humanitarian-needs-stack-months-after-earthquake-t%C3%BCrkiye

NEMC. (2017) 'List of big earthquakes 1900-2004'. http://www.koeri.boun.edu.tr/sismo/2/deprem-bilgileri/buyuk-depremler/

Oz FK, (2023) *50,783 people confirmed dead in Türkiye earthquakes*. AA. https://www.aa.com.tr/en/turkiye/50-783-people-confirmed-dead-in-turkiye-earthquakes/2878735#:~:text=A%20total%20of%2050%2C783%20people,country's%20interior%20minister%20said%20Saturday.

Platt S, Drinkwater BD, (2016) Post-earthquake decision making in Turkey: Studies of Van and İzmir, Int. J. Disaster Risk Reduc., **17**, 220-237, https://doi.org/10.1016/j.ijdrr.2016.03.010.

Rubenstone J, (2023) *Uneven Code Enforcement Seen in Earthquake-Damaged Buildings in Turkey. ENR.* https://www.enr.com/articles/55904-uneven-code-enforcement-seen-in-earthquake-damaged-buildings-in-turkey

SBO. (2023) T*ürkiye Earthquakes Recovery and Reconstruction Assessment.* https://www.sbb.gov.tr/wp-content/uploads/2023/03/Turkiye-Recovery-and-Reconstruction-Assessment.pdf

Suziki Y, (2012). Disaster-Relief logistics with limited fuel supply. *J. Business Logistics*, **33**(2), 145-157. https://doi.org/10.1111/j.0000-0000.2012.01047

TUIK. (2023a) *The Results of Address Based Population Registration System*. 2022. https://data.tuik.gov.tr/Bulten/Index?p=The-Results-of-Address-Based-Population-Registration-System-2022-49685&dil=2#:~:text=The%20population%20residing%20in%20T%C3%BCrkiye,million%20575%20thousand%20441%20people

TUIK. (2023b) *Road Motor Vehicles, December 2022*. https://data.tuik.gov.tr/Bulten/Index?p=Motorlu-Kara-Tasitlari-Aralik-2022-49436#:~:text=T%C3%BCrkiye'de%202022%20y%C4%B1l%C4%B1%20sonu,ya%C5%9F%2014%2C8%20olarak%20hesapland%C4%B1

Turkish Ministry of Health. (2023) *Bakan Koca, Deprem Bölgesinde Son Durumu Değerlendirdi*. https://www.saglik.gov.tr/TR,94749/bakan-koca-deprem-bolgesinde-son-durumu-degerlendirdi.html

USGS. (2023a) *Significant Earthquakes* (2023) https://earthquake.usgs.gov/earthquakes/browse/significant.php

USGS. (2023b) *Tectonic Map of Turkey*. https://www.usgs.gov/media/images/tectonic-map-turkey-region

Yalta AT, Yalta AY, (2016) The dynamics of fuel demand and illegal fuel activity in Turkey. E*nergy Economics*, **54**, 144-158. https://doi.org/10.1016/j.eneco.2015.11.026