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Can anyone hear me? Supply chain risks and cross-cutting impacts in the context of earthquakes

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ABSTRACT

Natural disasters, such as earthquakes, cause distinct and often severe risks to companies' operations and supply chains. This study examines these risks in the context of the devastating February 2023 earthquakes in Türkiye (measuring 7.7 Mw and 7.6 Mw). Empirical data were collected from 23 companies in the textile, food and beverage, and automotive sectors, representing companies across different supply chain tiers. Regarding direct supply chain risks, while well-established categories such as supplier and logistics risks and customer-related risks were observed, our findings emphasize the critical yet less recognized role of supply chain competence risks. Additionally, our results reveal that indirect risks, which are less recognized, can have far-reaching and often cascading effects. For indirect supply chain risks, we identify two newly emerging sub-dimensions: emotional and behavioral risks and humanitarian aid provided by companies. This research highlights the diverse fields, such as psychology (emotional and behavioral risks), civil engineering (building damage), and policy (political instability and governmental risks), that can indirectly disturb supply chains. This study also identifies cross-cutting risks in supply chains that span multiple categories, highlighting the interactions between different risk categories and leading to expanded effects. This study contributes to safety science by demonstrating the need to go beyond traditional supply chain risk categorizations to effectively assess and manage earthquake-specific supply chain risks, particularly in the context of a country with a developing economy.

1. Introduction

After disastrous earthquakes, search and rescue teams gather around collapsed buildings, count to three, and collectively shout, "Can anyone hear me?". This coordinated call generates a powerful and far-reaching sound intended to reach survivors trapped under the collapsed buildings, prompting them to respond if possible. The question serves not only as a practical rescue tool, but also as a grim indicator: if you hear this question echoing surroundings, it is a sign that you are witnessing a scene of significant destruction and human safety-related distress. Türkiye witnessed this in February 2023, when the country was struck by severe earthquakes that had devastating, large-scale effects on the people living in the area. The earthquakes in southeastern Türkiye and northern Syria drastically affected businesses and industries, impacting 4.5 million people and causing a total financial loss of approximately $119 billion (Cinar et al., 2023; Dündar, 2023). Türkiye was already facing economic challenges, and the earthquakes disrupted supply chains for essential resources and led to outbreaks of supply chain problems, also hindering industrial recovery (Cinar et al., 2023). Companies faced completely new supply chain risks and tried to keep operations running despite the chaos caused by the earthquake.

Supply chain management (SCM) process involves a series of unexpected force-majeure situations requiring rapid, accurate decisions (DuHadway et al., 2019; Finkenstadt and Handfield, 2021). Supply chain risk can be defined as "*any risks for the information, material, and product flows from the original supplier to the delivery of the final product for the end user*" (Jüttner et al., 2003). Supply chain risk should not be understood as an unwanted element of the supply chain; rather, it should be recognized as a process that needs to be understood and managed, involving the development and planning to strengthen the existing supply chain (Kähkönen and Patrucco, 2022; Yang et al., 2024).

Supply chains are often long and complex, encompassing a variety of suppliers across multiple supply chain tiers (Ateş et al., 2022; Bode et al., 2011). Lower-tier suppliers have been recognized as the riskiest, as they are often less visible and difficult to manage (Kähkönen et al., 2023;

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Villena and Gioia, 2018). Recognizing the suppliers and understanding the multi-tier nature provides better risk management opportunities, thereby strengthening the supply chain and enhancing supply chain resilience (Wang-Mlynek and Foerstl, 2020). In this study, we adopt this multi-tier approach, acknowledging that many risks are often realized in lower-tier suppliers. These suppliers are often characterized by higher levels of uncontrollability and a lack of information due to supplier capabilities (Villena and Gioia, 2018). Therefore, understanding these characteristics is essential for building more robust and resilient supply chains.

The research on supply chain risks and disruption has a long history, and the topic has been studied extensively from the traditional SCM perspective (Jüttner et al., 2003; Zsidisin, 2003; Hallikas et al., 2004). During the recent decade, research on sustainability-related risks has increased a lot as companies face risks that can be seen as connected to sustainability issues (Jüttner, 2005; Giannakis and Papadopoulos, 2016). Since 2020, when the COVID-19 pandemic hit the world, the number of supply chain risk and resilience studies has grown significantly (Kähkönen and Patrucco, 2022), but the focus in these studies has been on supply chain risks and disruptions caused by COVID-19 (Hofmann et al., 2018; Ali et al., 2022; Cheng et al., 2024; Garola et al., 2023; Hohenstein, 2022; Kähkönen et al., 2023; Mitręga and Choi, 2021; Nayal et al., 2024; Ramos et al., 2021; Sawyerr and Harrison, 2022). Natural disasters, such as earthquakes, however, cause a fundamentally different set of risks than pandemics, sustainability-related issues, or typical supply chain operation disruptions. Earthquakes often cause risks to human life and safety (Fiedrich et al., 2000), extensive damage to critical infrastructure and transportation networks, including roads, airports, and power systems, disrupting supply chains at multiple levels and requiring both immediate response and long-term recovery efforts (Wang and Yao, 2023). Manufacturing facilities are particularly vulnerable to earthquakes, which highly affects companies' operations (Matsuo, 2015). When a country with a developing economy experiences a natural disaster, the consequences might be even more severe and responses more vulnerable and critical. For example, Baharmand et al. (Baharmand et al., 2015) analyzed the impact of the 2015 earthquake in Nepal on supply chains and transportation infrastructure, and found significant vulnerabilities in continuity of operations. The current understanding of supply chain risks in countries with developing economies, especially in the context of earthquakes, is still limited (Aslam et al., 2020; Tukamuhabwa et al., 2017).

As a response to the above gap, to study the supply chain risks caused by an earthquake, we selected Türkiye as a representative of a country with a developing economy. Türkiye, as a middle-income country (SSHB, 2025), demonstrates the common safety challenges faced by low- and middle-income countries, where context-specific solutions remain limited (Karanikas et al., 2024). The February 2023 earthquakes in Türkiye were classified as the deadliest earthquakes in Türkiye's history by geological and medical researchers (Görmeli Kurt et al., 2023; Kusky et al., 2023; Tayfur et al., 2024; Uwishema, 2023), measuring 7.7 and 7.6 on the Richter scale (Cinar et al., 2023; Dündar, 2023). These twin earthquakes caused widespread damage and severe disruption across various industries (Onat et al., 2020). To adopt a cross-industry approach, we examined the food and beverage, automotive, and textile sectors, which were all affected by the earthquakes. Using the multiple case study method, we collected interview data from focal companies and their direct and lower-tier suppliers, located both in the earthquake area and across different parts of Türkiye, some of which are also geographically high earthquake-risk areas. We investigated the following two research questions: RQ1: *What are the main supply chain risks observed after earthquakes?* and RQ2: *How are these risks interrelated?*

Our study contributes to the literature in three ways. First, it advances disaster risk reduction research by providing a nuanced categorization of direct and indirect supply chain risks specific to earthquakes. Second, by bringing the psychological perspective to supply chain risk management, it recognizes the critical role of emotional and behavioral risks, which are often overlooked in traditional supply chain risk frameworks. The third contribution demonstrates the cross-cutting nature of these risks, showing how they can trigger cascading effects that disrupt entire supply chains. Overall, the study provides a more comprehensive understanding of the complex supply chain challenges faced by companies in the aftermath of natural disasters like earthquakes.

2. Theoretical background

2.1. Supply chain risk

The concept of risk is always context-specific and has been defined, for example, as the potential for loss or uncertainty, or probability/significance of a loss, and as the effects of uncertainty on objectives (Yates and Stone, 1994). Risk is a deviation from what is expected, and may be positive, negative, or both, which can give rise to opportunities or threats. It is typically characterized in terms of its sources, the potential events that may occur, their consequences, and the likelihood of those consequences. Supply chain risk, on the other hand, can be described as the likelihood of a disruptive event arising due to issues with individual suppliers or supply market conditions (Tayfur et al., 2024; Uwishema, 2023). These risks are multifaceted, encompassing political risks (Trkman and McCormack, 2009), economic uncertainties (Shafiq et al., 2017), delivery failures (Tummala and Schoenherr, 2011), sustainability challenges (Hofmann et al., 2018), missing workforce (Torabi et al., 2016), and infrastructure vulnerabilities (Wagner and Bode, 2008). Among these, catastrophic risks stand out due to their extreme and often immediate impact, arising from natural disasters such as earthquakes and floods, or human-induced crises like terrorist attacks and wars (Ho et al., 2015; Knemeyer et al., 2009; Tang, 2006; Wu et al., 2006). These large-scale disruptions pose severe challenges for supply chains, making them a critical area of focus in risk management strategies.

Supply chain risks can occur in many different forms and have diverse impacts (Zsidisin and Wagner, 2010), creating a need for clear identification and categorization. Understanding the types of risks allows companies to manage and reduce risks more effectively (Chopra and Sodhi, 2004). However, it is often difficult for companies to recognize the risk types and create risk categories that fit their specific situation (Pagell and Louis, 2019). Table 1 presents the main supply

Table 1
Main supply chain risk categories in previous research.

Classified supply chain risks	References
Delivery failures	(Pagell and Louis, 2019; Olson and Dash Wu, 2010; Abe and Ye, 2013)
Infrastructure vulnerabilities	(Shafiq et al., 2017; Bing et al., 2005; Presidency of Strategy and Budget of Turkiye, 2023; Son et al., 2011; Akkermans and Van Wassenhove, 2018)
Order volume fluctuation	(Chopra and Sodhi, 2004; Akkermans and Van Wassenhove, 2018)
Lack of supplier flexibility	(Sheffi and Rice, 2005)
Logistic problems	(Matsuo, 2015; Abe and Ye, 2013; Son et al., 2011; Yang, 2011)
Missing alternative supplier	(Akkermans and Van Wassenhove, 2018; Cole et al., 2017; Sheffi and Rice, 2005; Yang, 2011)
Missing supplier capacity risk	(Chopra and Sodhi, 2004; Cole et al., 2017; Rangel et al., 2015)
Missing communication with suppliers	(Görmeli Kurt et al., 2023; Cavinato, 2004)
Supplier bankruptcy	(Akkermans and Van Wassenhove, 2018)
Financial risks	(Chopra and Sodhi, 2004; Olson and Dash Wu, 2010; Yang, 2011)
Raw material crises	(Forbes and Wilson, 2018; Matsuo, 2015)
Supply base reduction	(Bing et al., 2005)
Inability to respond to customer demands	(Forbes and Wilson, 2018; Chopra and Sodhi, 2004)

chain risk categories identified in existing literature.

2.2. Natural disaster supply chain risks

Natural disaster risks are defined as "*The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society, or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability, and capacity.*" (UNDRR, 2009). An earthquake is one type of natural disaster that wields a profound influence on supply chains, often triggering widespread disruptions that reverberate across industries and regions and cause extensive damage to critical infrastructure, including roads, bridges, ports, and warehouses (Atik, 2024; Matthias and Rafferty, 2023). Such destruction impedes the smooth flow of goods, causing delays and interruptions throughout the supply chain (Atik, 2024).

Earthquakes, regardless of their location, can cause similar damage depending on their magnitude (Natarajarathinam et al., 2009). However, the impact they have and the responses to them can vary significantly from country to country, often influenced by each nation's level of development. For example, earthquakes can damage critical infrastructure, such as gas, telecommunications, and electricity systems (Dasgupta et al., 2024; Yulianto et al., 2020), which in turn leads to supply chain breakdowns (Rangel et al., 2015; Cavinato, 2004; MacKenzie et al., 2024). Disruptions can trigger unexpected price increases, labor shortages, and humanitarian crises, as experienced before, for example, in the 2021 Haiti earthquake (Onat et al., 2020; Haiti Earthquake, 2021; OCHA, 2021). Studies on supply chain risks in the context of earthquakes consistently highlight their potential to cause severe economic implications and significant disruptions in supply chain operations. For instance, Carvalho et al. (2021) demonstrated that the Great East Japan earthquake resulted in a 0.47 percentage point decline in Japan's real GDP growth, underscoring the broader economic impact of such disasters. On the other hand, disruptions pose motivational challenges for supply chain managers. In the Türkiye earthquakes, labor shortages, humanitarian crises, and economic impacts were reported similarly to other major earthquakes (Atik, 2024; Eskalen, 2024). Table 2 shows some major earthquakes that have disrupted supply chains in the last two decades.

Earthquakes are sudden energy releases caused by tectonic stresses in the Earth's crust, and current technology cannot fully predict where and when an earthquake will occur (Akkermans and Van Wassenhove, 2018). Early earthquake warning systems can provide information just a few seconds before the earthquake begins, which is not enough to take all necessary safety actions. Therefore, understanding the risks created solely by earthquakes is significant. A critical point to recognize is also that different types of disasters impact businesses in different ways (Heger et al., 2008). For instance, research has shown that earthquakes have a different impact compared to other disasters, such as storms and floods (Abe and Ye, 2013). Moreover, supply chain risks are largely context and location-specific, and thus the nature of the incident and geographic location are highly determinant (Tukamuhabwa et al., 2017).

Many existing studies on supply chain risks and earthquakes have been conducted in the empirical context of developed economy countries, such as Japan (e.g., (Son et al., 2011; Carvalho et al., 2021; Fujimoto and Park, 2014; Smith et al., 2025; Norrman and Wieland, 2020)). However, responses to earthquakes can vary significantly from country to country and are often influenced by the level of development within each country. For instance, Natarajarathinam et al. (2009) state: *"A magnitude 7.2 earthquake in Japan in 2008 resulted in 12 deaths, whereas the same magnitude earthquake in Türkiye in 1999 caused more than 25.000 deaths"*. Many countries with developing economies, like Türkiye, are located in high earthquake-risk areas geologically, but the research on earthquakes in the context of these countries is still limited. According to Tukamuhabwa et al. (2017), in developing countries, the level of industry maturity, business practices, governance structures, and infrastructures are weaker when compared to developed countries, making the country's status a significant factor in exposure to different types of supply chain risks. Therefore, the research on earthquake impacts from developed countries are not fully applicable to developing economy countries. As most of the previous studies on the topic focus on the developed countries, there is a need to investigate the topic in the context of developing countries, and thus, this study uses Türkiye as an empirical context.

After the February 2023 earthquakes, beyond the physical damage, the disaster had severe psychological impacts on people. For example, post-traumatic stress disorder (PTSD) was observed in victims, severely affecting their decision-making abilities (Kaya et al., 2023). Another significant challenge was encountered in emergency supplies (Wu et al., 2024) and emergency health operations (Yumarni, 2018; Araneda et al., 2010). Some earthquake victims needed urgent transportation to hospitals, but damaged roads caused by the earthquake made this impossible. Additionally, certain patients required specific medications and vaccines, but the supply chain collapsed, and emergency supplies were not available. To ensure patients' survival, the use of air ambulances was considered, but it took three days for an air ambulance to reach the earthquake-affected region because of the damage (Koçer et al., 2024). Notably, the emotional and behavioral impact of the earthquake extended to individuals involved in supply chain operations, potentially compromising decision-making and resilience (Kaya et al., 2023). According to Altuntaş et al. (2023) several other challenges arose in the aftermath of the earthquake, including a lack of coordination, uncertainties, poor emotional management (e.g., dealing with anger, helplessness, and hopelessness), and an inventory of medical supplies. Their study highlights that crisis management and risk management skills are critical competencies for employees in such situations. Kaçar et al. (2024) also highlighted that the same earthquake significantly disrupted food supply chains, limiting the availability and capacity for food delivery, storage, preparation, and access.

3. Methodology

3.1. Research design

This study adopts a multiple case study method (Eisenhardt, 1989; Eisenhardt and Graebner, 2007). Interview data were collected following the 2023 earthquakes in Türkiye, focusing on textile, automotive, and food and beverage industries, as these sectors were among

Table 2
The biggest earthquakes in the last two decades.

Geographic location	Year	Magnitude	Death toll	Financial loss (billion $)	SC disruption	References
Indonesia	2006	6.3	5 800	3.1	Yes	(Gatignon et al., 2010; Yumarni, 2018)
Chile (Maule)	2010	8.8	521	30	Yes	(Araneda et al., 2010; Elnashai et al., 2010)
Japan (Tōhoku)	2011	9.1	13 392	199	Yes	(Matsuo, 2015; Fujimoto and Park, 2014; Smith et al., 2025)
Türkiye (Aegean Sea)	2020	7.0	117	0.4	Yes	(Onat et al., 2020; Mavroulis et al., 2022)
Haiti (Nippes)	2021	7.2	2 248	1.5–1.7	Yes	(2021 Haiti earthquake; OCHA, 2021; Shakibaei et al., 2024)
Türkiye (Kahramanmaras)	2023	7.8	45 089	119	Yes	(Cinar et al., 2023; Dündar, 2023; Tayfur et al., 2024; Koçer et al., 2024)

the most affected by the earthquakes (Olson and Dash Wu, 2010). The interview data includes a total of 40 interviewees from 23 companies; including 8 companies from the automotive sector (four focal firms, three tier 1 suppliers, one tier 2 supplier), 10 companies from the textile sector (five tier 1 suppliers, five tier 2 and tier 3 suppliers), and 5 companies from the food and beverage sector (one focal firm, two tier 1 suppliers, two tier 2 and tier 3 suppliers). A case study approach with multiple supply chain tiers enables us to identify patterns, relationships, and mechanisms across different cases. We follow the recommendation by Eisenhardt (1989), selecting between four to ten case companies in each sector to ensure the effectiveness and depth of the case study methodology. This helps to balance the need for comprehensive data with the practical considerations of managing complex, multi-tiered case studies (Machado et al., 2018).

3.2. Case selection and description of the research context

The Türkiye earthquake disrupted the logistics of vital resources like food, water, shelter, and medication, impacting humanitarian supply chains. It also severely affected industrial sectors, with manufacturing and production facilities facing major challenges, further hampering the nation's economic infrastructure. The earthquake also impacted neighboring countries, including Lebanon, Cyprus, Iraq, Israel, Jordan, Iran, and Egypt, underscoring the need for improved disaster preparedness and infrastructure resilience in the region (Cinar et al., 2023). Türkiye was facing economic challenges already before the earthquake, and the destruction and delayed response had negative effects on the industrial and economic sectors (Cinar et al., 2023; Jain, 2023).

Following severe earthquakes, industrial recovery may take several years, and the affected cities, which encompassed 10% of Türkiye's total national income, suffered significant disruptions from the supply chain perspective (Atik, 2024). Türkiye, already prone to seismic activity, has seen a noticeable increase in severe earthquakes since the devastating 1999 events. In earthquake risk regions, like Türkiye, companies face a higher probability of risks (Onat et al., 2020), and thus there is a need to more closely study these regions and develop stronger supply chain risk management strategies to prepare for future disasters.

3.3. Data collection

To collect empirical data, we contacted companies that were directly impacted by the earthquakes, including those that experienced significant economic losses during the February 2023 earthquakes and those that are at risk of future earthquakes. In 2023, the epicenter of the earthquake in Türkiye was Kahramanmaras city, which caused extensive destruction in the surrounding cities. Our study was conducted in both the epicenter and the neighbouring cities affected by the earthquake, as well as in companies located in regions identified by geological researchers as high earthquake-risk areas, including the Marmara (Erdik et al., 2004) and Aegean (Onat et al., 2020; Polat et al., 2008) regions.

Due to the sensitive nature of the research topic, ethical standards and data protection regulations were carefully followed. Before each interview, participants were informed about the aims of the study, the voluntary nature of their participation, and their right to withdraw at any time without any consequences. Explicit verbal or written consent was obtained from all participants for both participation and audio recording. Anonymity and confidentiality were strictly guaranteed: no company or individual names were disclosed, and any information that participants requested to remain confidential was excluded from the analysis and reporting. All interview data were securely stored on password-protected devices accessible only to the research team, and anonymized transcripts were used exclusively for research purposes. Table 3 shows information on the case companies and interviews.

Table 3
Interview information.

Supply chain	Case company	Company role	Position of the informants	Focal firm/ Tier
Automotive SC	A_FF_1	Car producer	Product risk responsible	FF
	A_FF_2	Truck producer	Purchasing manager, Buyer	FF
	A_FF_3	Car producer	Purchasing director, Purchasing manager	FF
	A_FF_4	Commercial vehicle producer	Purchasing manager	FF
	A_T1_1	Car tire producer	Supply chain director	Tier 1
	A_T1_2	Shock absorber producer	Deputy general manager	Tier 1
	A_T1_3	Spare parts producer	Supply chain director	Tier 1
	A_T2_1	Rubber bush producer	Business development resp.	Tier 2
Textile SC	T_T1_1	Apparel producer	Sustainability manager	Tier 1
	T_T1_2	Apparel producer	Executive board manager	Tier 1
	T_T1_3	Apparel producer	Sustainability manager	Tier 1
	T_T1_4	Apparel producer	Sustainability manager	Tier 1
	T_T1_5	Apparel producer	Purchasing manager	Tier 1
	T_T2_1	Fabric producer	Purchasing director	Tier 2
	T_T2_2	Fabric producer	Purchasing director	Tier 2
	T_T2_3	Fabric producer	Executive board manager	Tier 2
	T_T2_4	Fabric producer	Purchasing director	Tier 2
	F_T3_2	Packing materials	Executive board manager	Tier 2&3
Food and beverage SC	F_FF_1	Snack product producer	Purchasing director	FF
	F_T2_1	Pistachio producer	Purchasing manager	Tier 2
	F_T2_2	Pistachio producer	Executive board manager	Tier 2
	F_T3_1	Packing materials	Purchasing director	Tier 3
	F_T3_2	Packing materials	Executive board manager	Tier 3

3.4. Data analysis

The interviews were recorded and transcribed, resulting in a dataset consisting of 639 pages. NVivo qualitative data analysis software was used for data coding. For data analysis, we used two-step coding (Gioia et al., 2013) and built the analysis on previous studies on risk categorizations and classifications (Tang, 2006; Rangel et al., 2015; Kleindorfer and Saad, 2009; Vahidi et al., 2018). Previous research shows that risks can have both direct (Ho et al., 2015) and indirect effects (Sawik, 2022; Kaliani Sundram et al., 2016) on supply chains. Previous research was followed, and risks were classified and categorized as direct and indirect supply chain risks. *Direct supply chain risks* refer to factors that immediately impact the supply chain, creating a negative influence on the effectiveness of its operations. An example of direct supply chain risks can be the missing stocks in the warehouse after an earthquake or the lack of alternative suppliers. These are directly linked to the supply chain and pose a direct risk to supply chain operations. The second category, *indirect supply chain risks*, stems from various contextual influences outside core supply chain activities. While indirect risks do not directly stem from day-to-day supply chain operations, they can still cause significant negative effects. Indirect risks can be both

organizational or external factors, such as employee risks or regulatory risks. Table 4 shows data coding.

Primary risk categories, classified in parallel with the risk classification system outlined by Rangel et al. (2015), serve as overarching categories. The sub-risk categories offer a more granular examination of these main risk categories, providing a detailed exploration of the associated risks. Finally, the *supply chain risk impact* category categorizes risks according to their effect on the supply chain from the following perspectives:

- Upstream: Risk impacts related to suppliers,
- Downstream: Risk impacts related to customers and demand,
- Internal: Associated risk impacts with processes or resources within the organization,
- Macro: External, broader risk impacts that affect the whole system.

Table 4
Data coding, risk and sub-risk, and impact dimensions.

Risk type	Primary risk category	Sub-risk category	Impact
Direct SC risks	Supplier and logistics risks	Supplier availability risk	Upstream impact
		Supplier preparedness risk	Upstream impact
		Supply shortage	Upstream impact + Macro impact
		Logistic problems	Macro impact
		Missing communication with suppliers	Upstream impact
		Financial risks	Upstream impact
	Customer-related risks	Customer-induced order volume fluctuations	Downstream impact
		Failure to meet customer demand	Downstream impact
		Customer-specific production requirements	Downstream impact
		Customer quality standards compliance	Downstream impact
		Production flow problem	Downstream impact
		Line stoppage	Downstream impact
	SC competence risks	Managerial problems in SC	Upstream impact
		Low standards in the hiring process	Internal impact
		Low purchasing education level	Internal impact
		Non-qualified employees	Internal impact
Indirect SC risks	Emotional and behavioral risks	Emotional and psychological risks	Macro impact
		Behavioral and social risks	Macro impact
	Human resource and workforce-related risks	Retirements	Internal impact
		Migrations	Internal impact
		Quitting job	Internal impact
		Communication breakdown with employees	Internal impact
		Very high working hours	Internal impact
	Humanitarian aid provided by companies	Self-recovery delay due to aid involvement	Internal impact
	Infrastructure and facility risks	Building damage	Macro impact
		Energy and water crises	Macro impact
		Maintenance problems after the earthquake	Internal impact
		Data loss	Internal impact
		Missing information flow	Internal impact
	Regulatory and compliance risks	Court closure due to earthquake	Macro impact
		Inspection problems after the earthquake	Macro impact
		Insurance problems	Macro impact
		Unethical behavior	Macro impact
	Policy risks	Governmental risks	Macro impact
		Political instability	Macro impact

(SC): Supply Chain

3.5. Validity and reliability

We followed Eisenhardt (1989) and Yin (2009) to ensure the validity and reliability of the study. Construct validity was established by using multiple data sources, including interviews with 40 informants across 23 companies, spanning various supply chain tiers and industries. The triangulation of data sources allowed for a comprehensive understanding of supply chain risks and minimized potential biases. To enhance internal validity, a rigorous two-step coding process was applied during the data analysis phase, utilizing NVivo software to systematically categorize and classify the risks based on established frameworks from prior literature. Within-case and cross-case analyses were conducted to identify patterns and relationships. A firm-level analysis was conducted to identify the risks in each company, and then the results were analyzed between companies within the industries. Next, a cross-case analysis was conducted to find differences and similarities across the supply chains in different industries (Eisenhardt and Graebner, 2007). To maintain external validity, the study included companies from both regions severely impacted by the 2023 Türkiye earthquake and regions that were not affected by the earthquake but where the earthquake risk is high (such as the Marmara region, Aegean region, and Eastern Anatolia of Türkiye). This helps to ensure that the findings can be generalized to similar contexts of earthquake risk regions. Reliability was ensured through consistent and replicable data collection methods, including detailed documentation of interview protocols, standardized interview questions (see Appendix A), and clear procedures for data coding and analysis. A case study database was developed to document all research steps, including raw data, coding processes, and analytical frameworks. Additional quotes related to risk categories are provided in Appendix B.

4. Results

The empirical analysis of Türkiye's automotive, textile, and food and beverage supply chains reveals that, despite being affected by the same devastating earthquake in February 2023, the impact and associated risks differed to some extent. The following sections provide a detailed description of the key direct and indirect risks observed, along with their respective sub-categories.

4.1. Direct risks

4.1.1. Supplier and logistics risks

Supplier and logistics risks are one of the main direct risks as they can severely affect supply chains. As defined earlier, direct supply chain risks refer to factors and risks that immediately impact the supply chain, creating a negative influence on the effectiveness of operations. Building upon the supplier and logistics risks identified in previous studies (Table 1), we classified these into six subcategories in the context of earthquakes: *supplier availability risk, supplier preparedness risk, supply shortage risk, missing communication with suppliers, logistic problems,* and *financial risks,* having impacts on both upstream and macro levels (see Table 4).

"Supplier availability risk" includes problems caused by reducing the supplier base, the lack of alternative suppliers, and supplier bankruptcy, which negatively affect suppliers' ability to meet demand after an

earthquake. Supplier availability has a significant upstream impact on the supply chain because it can directly disrupt the flow of raw materials and components from suppliers, affecting production. The reduction of the supplier base refers to the elimination of suppliers from the supplier base and is often seen as a strategy or key performance index (KPI) to improve purchasing power. The results show that companies should have alternative suppliers because after the earthquake, many main suppliers faced damage and could not continue their operations, leading alternative suppliers to become crucial in ensuring continuity. Earthquakes can also trigger financial challenges, leading to supplier bankruptcy and thus disrupting the supply chain. 13% of the case companies faced bankruptcy risk after the earthquake, and the analysis shows that this risk was the most common in the textile sector.

"Our customers initially requested that we reduce the number of suppliers to work with a more compact group, fearing that an increased number of suppliers would become unmanageable. However, after the earthquake, we realized that reducing suppliers may not be the best approach." T_T1_1
"In a crisis time, the need for alternative suppliers becomes critical; however, we removed these suppliers from our supplier pool for supplier base reduction, and it was a big problem for us because we lacked alternative suppliers when it's needed." F_MP_1
"The CEO of our company passed away in the earthquake, and the company sustained physical damage. Due to the significant financial losses, the board of directors convened. Some voted to "continue operations," while others voted to "file for bankruptcy and shut down the company." However, since we still had outstanding installment loans, filing for bankruptcy would have been a painful process." F_T2_1

The second risk category under Supplier and logistics risk is "*Supplier preparedness risks*". This category emphasizes the significance of not only taking reactive measures after an earthquake occurs but also proactively preparing suppliers for earthquakes. Given that Türkiye is located in a seismically active region, with 92% of its territory in earthquake zones, it is critical to be prepared in advance. This risk means that suppliers do not have sufficient plans or resources to handle earthquake-related challenges, there is a lack of awareness or understanding of earthquake risks, and failure to take necessary actions. Our findings show that some companies refuse to prepare for earthquakes proactively and prefer reactive risk management. Results also show that some suppliers are not fully aware of the risks of earthquakes they might face.

"We never thought about what we would do if an earthquake occurred and affected us. Honestly, I have no idea what kind of risks I would face." A_T2_1
"There are significant losses during an earthquake, and when everyone is focused on their own survival, it's understandable that the company wouldn't be a priority. For this reason, we don't dedicate much time to earthquake preparations or substantial investments before an earthquake. Instead, if we survive after the earthquake, we plan to create an action plan based on the conditions that arise after the earthquake." A_T1_2

After the earthquake, some companies conducted audits for their suppliers, but the follow-ups failed. Conducting audits is important, but it is crucial to require suppliers to address the identified gaps and have a follow-up on actions.

"After the earthquake, many actions were requested by our customers. However, 5–6 months later, all follow-ups were forgotten. No one asked us what we had improved or how much progress we had made. We spent 20–30 days wearing ourselves down with this stress, and then we acted as if nothing had happened." A_T1_2

The third identified category under Supplier and logistics risk is *"Supply shortage"* which has four dimensions: *raw material crises, missing supplier capacity, lack of supplier flexibility*, and *stolen or missing stocks and goods*. Following the earthquake, logistics disruptions triggered a raw material crisis. Some materials were buried under collapsed buildings, stock levels were insufficient to sustain production, and damaged transportation routes delayed deliveries. When a supplier was not affected by an earthquake, other suppliers who were impacted tried to place orders with the unaffected supplier simultaneously, which resulted in a lack of production capacity for that supplier. This occurred particularly for automotive Original Equipment Manufacturers (OEMs) relying on high-capacity suppliers for large-scale production. Many companies also faced physical damage, which highlighted the role of supplier flexibility in adapting to changing conditions. Supplier flexibility allows effective coordination of supply chain activities during and after the earthquake. Our findings show that, especially in small suppliers in lower tiers, infrastructure and production equipment were damaged, leading to a lack of flexibility. Situations of stolen or missing stocks and goods referring to inventory losses due to looting, theft, or displacement during the earthquake were also identified. The stolen goods are often factory inventory, directly disrupting the supply chain.

"Although our factory wasn't severely damaged, we faced delays in resuming production due to our suppliers' limited capacity." A_OEM_4
"In the textile industry, supplier flexibility is achieved through contract manufacturing; however, the flexibility of such suppliers (sub-contractors) is limited because they are small workplaces. Those suppliers located in earthquake-affected regions faced significant challenges after the earthquake." T_T1_3

The earthquake also created many logistic risks. The destruction of Hatay airport's runway halted air logistics (Yilmaz and Balcikoca, 2025) while damaged roads became unusable (Sabah, 2023) (see Fig. 1). A massive fire at Iskenderun Port further crippled transportation (Paone, 2023). As a result, air, land, and sea logistics were largely damaged, leading to the collapse of logistical networks and thus directly affecting supply chain operations with macro-level impacts.

"After the earthquake, almost all roads were closed, and it was impossible to use the roads for transportation. Many companies couldn't send or receive any orders." T_T2_2

"Missing communication with suppliers" is also one type of Supplier and logistics risk. Communication after an earthquake is critical, but we identified cases where suppliers avoided communicating or providing information to customers after the earthquake.

"Some of our suppliers are hesitant to communicate with us after the earthquake and do not want to share details. For instance, if the supplier has an issue with their subcontractor, they may not want to disclose it to me openly. At this point, I can only clarify that I am asking in good faith to manage the risk and avoid making any comments regarding costs. A_OEM_1

The last category under the Supplier and logistics risks is *"Financial risks"* which refers to suppliers increasing the prices due to unexpectedly increased raw material or labor costs and delayed payments after the earthquake. Increased labor and raw material costs also led to a rise in suppliers' costs, leading to higher prices.

"After the earthquake, yarn prices in the city suddenly increased by more than 50% without any apparent reason." T_T2_1
"Labor costs have also risen significantly since the earthquake. Currently, it is difficult to find workers willing to work for 1.5 to 2 times the minimum wage. Our hidden costs have increased substantially. For instance, we needed to produce a product after the earthquake, which normally takes two days, but it took us four months. This was due to numerous unexpected costs and the damage sustained by suppliers." F_T3_1

Another issue was the delay in payments due to operational disruptions caused by the earthquake. This resulted in upstream risks, where suppliers, especially those in Europe, faced payment delays that affected their operations.

"We had some difficulties with payment to some suppliers, for example, those in Europe, where delayed payments are very risky. We couldn't pay

Fig. 1. Roadway and airport condition after the earthquake in Hatay / Türkiye (Yilmaz and Balcikoca, 2025; Sabah, 2023).

the invoices because all our colleagues in finance and accounting had left their laptops at home when they ran out during the earthquake in a hurry. It wasn't allowed to enter houses anymore after the earthquake, so they couldn't get their laptops and make payments." A_OEM_4

4.1.2. Customer-related risks

Downstream parts of the supply chains were also affected by the earthquakes. We found six dimensions under customer-related risk: *customer-induced order volume fluctuations, failure to meet customer demands, customer-specific production requirements, customer quality standards compliance, production flow problems,* and *line stoppages.* The first risk we identified is *"customer-induced order volume fluctuations"*. The interviews revealed that many customers in the earthquake-affected region had to cancel all orders due to their inability to continue production, resulting in stock accumulation for the suppliers and significantly increasing their inventory holding costs.

"After the earthquake, our customers' demands decreased from 50,000 to 10,000, which was impossible for us to accept. We requested them not to make changes in the next three weeks, but the orders changed for next week" A_T1_2

The second risk is identified as *"failure to meet customer demand"*. After the earthquake, some customers requested official reports proving that companies could meet their demands and continue operations, but many companies could not fulfill the requirements:

"After the earthquake, our customers immediately requested our building damage report to understand whether the building was moderately damaged or completely collapsed. However, it could take up to four months to get this report, and we couldn't provide it to our customers because the process took too long. Naturally, they didn't want to take any risks to ensure the supply chain wasn't disrupted, so they tried to work with their alternative suppliers." T_T2_3

A third risk is *"customer-specific production requirements",* which refers to the challenges that arise when relying on customized or specialized production processes. Our findings indicate that this risk was commonly observed in the automotive sector, where production often depends on customer-specific molds and equipment. This makes it difficult to quickly switch suppliers, creating a dependency that can result in a halt in production.

"You can't just get and transport production molds in one or two days. In the place you're moving them to, you should accept that molds can be broken, and your production can totally stop. This means a financial loss for us. Since it's tailored production, I have no alternative options for this." A_OEM_4

The fourth risk, *"customer quality compliance risk"*, refers to the failure of customers to receive products that meet the required quality and standards. Our findings indicate that because of the earthquake, some supplier warehouses collapsed, but to avoid production stoppages, customers adopted the approach of "send goods if available." In this case, goods were extracted from the collapsed buildings without quality inspection, and damaged products were sent to customers. Customers received products with quality defects and had to invest additional labor to inspect them.

"We didn't want to stop our customers, and we sent the finished products to the customers as much as we could recover from the rubble. However, there were quality issues with those." T_T2_3

The fifth risk, "*production flow problem*" refers to extended timelines and complex approval steps to resume production or recover from the earthquake. Making timely decisions after the earthquake is crucial, but our findings show that the standard production flow procedures prevent agile decision-making during the earthquake. Many approvals were required from different management levels, and obtaining approval for a new supplier could even take up to a year according to procedures. However, after the earthquake, there was no time, highlighting the need for faster, force-majeure frameworks to expedite decision-making.

"Now, in food businesses, we have certain rules. For example, if you don't purchase from a supplier for a year, you need to go through the approval process again, as there might have been changes in their production process." F_MP_1

"No component is put into operation without going through a specific approval process. Even the simplest parts, like a steel component, require certain tests and trials need to be conducted. These trials usually take a minimum of one year." A_OEM_1

Finally, one of the most undesirable customer-related risks is "*production line stoppage*". Our findings show that after the earthquake, production stopped in many suppliers and affected the downstream supply chain. Out of the 23 companies, eight experienced production stoppages after the earthquake, some being long and severe:

"It has been 16 months since the earthquake, and our production lines are still stopped. Construction is still ongoing in the building, but the line stoppage has been continuing for 16 months." T_T2_4

4.1.3. Supply chain competence risks

The third main category of direct supply chain risks is *"Supply chain competence risks"*, which has four sub-dimensions: *managerial problems, low standards in the hiring process, low purchasing education level*, and *non-qualified employees*. These risks arise from both managerial and operational levels and are categorized into upstream and internal risks.

The first sub-risk category we identified is *"managerial problems"*. While previous studies assume managerial presence in crisis, our findings highlight an overlooked issue: the absence of managers due to an earthquake. For example, case company F_T2_1 had a situation where their purchasing manager passed away in the earthquake, leading to the loss of supply chain decision-making authority.

> *"Our manager passed away in the earthquake after being trapped under the collapsed building. At that moment, I froze completely. I had no idea what to say to anyone, how to act, what decisions to make, or how to manage the supply chain. This was the responsibility of our manager, but he was no longer there." F_T2_1*

Second, *"low standards in the hiring process"* constitutes another type of risk. The workforce in the earthquake-affected region dramatically decreased, as many left to seek safety and stability elsewhere. Companies operating in the region were forced to revise their hiring practices and to hire employees for supply chain positions without requiring supply chain expertise, and to be content with low standards in the hiring process.

> *"Before the earthquake, we had many criteria when hiring buyers. After the earthquake, the workforce available became so limited that now our hiring criteria are just whether they have completed their military service or if they don't look like psychopaths. In short, we are hiring everyone without considering qualifications because we have no choice." F_T3_1*

The third sub-risk, *"low purchasing education level"*, stems from the insufficient formal training and academic background of purchasing employees and can lead to slower problem-solving and suboptimal decision-making, particularly in high-pressure situations like natural disasters. In earthquakes where rapid responses are essential, a lack of formal education in purchasing and SCM hampers the efficiency and effectiveness of the workforce.

> *"Just like how muscles in the body develop, supply chain skills develop in a similar way. The people who come to us are not graduates from supply chain departments at universities. I wish universities had a department dedicated to supply chain education in Türkiye, and we could hire graduates from there. But in the current situation, our employees know supply chains only as much as we have taught them in the factory." A_OEM_2*
>
> *"The level of supply chain education gives you the speed of solving the problem and increases the chances of making the right decisions. This is exactly what you need after earthquakes." T_T2_3*

Finally, the fourth sub-risk is *"non-qualified employees"*. The remaining workforce after the earthquake lacked the essential supply chain qualifications and expertise needed in managing critical tasks, such as international purchasing. Non-qualified employees are interconnected with the low hiring standards and employees leaving the region.

> *"After the earthquake, we needed to hire a buyer to handle international purchasing. We couldn't even find a buyer who could speak English. How can international purchasing operations be managed by someone who doesn't speak English? It's impossible. Probably all qualified buyers have already left and immigrated." T_T2_2*

4.2. Indirect supply chain risks

4.2.1. Emotional and behavioral risks

Indirect supply chain risks can be defined to stem from various contextual influences outside core supply chain activities, and whilst those are not directly involved in day-to-day operations, they can cause a significant negative impact on supply chains. *"Emotional and behavioral risks"* are not commonly recognized in supply chain literature, but can indirectly affect decision-making, potentially leading to supply chain disruptions. In fact, we found that this was the most observed risk across all sectors in our case. Behavior and social interactions play a sensitive role in post-earthquake environments. Emotional and behavioral risks are considered to have macro-level impacts due to their potential to induce widespread and far-reaching consequences across organizations, industries, and societies. When individuals are influenced by emotional or psychological factors, these can significantly affect collective behaviors and decision-making. Such risks can lead to suboptimal decisions, reduced organizational efficiency, and disruptions in coordination and communication, thereby amplifying the impact at a systemic level. We further divide emotional and behavioral risks into two subcategories such as *emotional and psychological risks*, and *behavioral and social risks*.

Emotional and psychological risks arise when individuals experience intense emotional distress, such as grief from deaths and losses, demotivation, shock, or a sense of helplessness. Emotional and psychological states can lead to faulty decisions, potentially causing bigger problems in supply chains. The 2023 Türkiye earthquake resulted in 44,218 deaths and thousands of injuries (Tayfur et al., 2024), leading people to suffer immense loss. Those who experienced tragedies became deeply sensitive to issues of death and loss, which affected their work in supply chains. After the earthquake, work-related issues became less important when people focused only on surviving:

> *"After the earthquake, there is something called emotional impact. We called the supplier, and they said, "The person responsible for your company passed away in the earthquake," or they answered the phone and said, "I lost my family, let's talk about work later." T_T2_2*
>
> *"After the earthquake, everyone was like a ghost. It was as if they had buried the living people under the ground too, such a helplessness, such a demotivation." A_T1_2*

The decision-making was also affected by fate and luck beliefs that stem from the notion that earthquake risks and outcomes are determined by fate, luck, or divine will, and therefore impacts of the disaster cannot be avoided. This led to a feeling that precautions may be useless, as the outcome is seen as destined to happen:

> *"We still couldn't accept what happened in the earthquake. This was a test from God, there's nothing to be done." F_T3_2*
>
> *"You can't take many precautions against an earthquake because you can't escape destiny; if an earthquake happens, it happens." A_OEM_3*

Many earthquake victims experienced the first shock as cognitive paralysis. Drozdibob et al. (2023) called this a 'stagnation phase'. Our results show that many companies experienced a period of shock and stagnation for several days after the earthquake, and were able to focus on their suppliers, customers, and factories only several days after the earthquake:

> *"I am the manager of this company, but after the earthquake, I went into shock. I was just standing outside in the cold, doing nothing. I couldn't think of anything. I completely forgot my work, and I even forgot my wife." F_T3_2*

The findings show that experienced trauma can severely impair the ability to function in the workplace. Research in the field of psychology indicates that mental health problems, such as emotional traumas already been observed in previous earthquakes in Türkiye (Kowalski and Kalayjian, 2001). Additionally, PTSD is highly common among Türkiye of the February 2023 earthquakes survivors (Kaya et al., 2023). Our findings indicate that psychological disorders can have a significant macro impact on SCM. PTSD presents an indirect risk to the supply chain by negatively affecting the well-being of employees and decision-

making processes. For instance, employees may be unable to focus on supply chain tasks, avoid returning to the office, or even refuse to work on night shifts due to the earthquake that happened at night before. These emotional disturbances can lead to significant disruptions within the supply chain or poor judgments, or a failure to act promptly in critical supply chain situations. Psychological impacts can affect communication and collaboration across teams, and the lack of emotional intelligence in addressing these challenges exacerbates supply chain vulnerabilities, making it harder to recover from the disaster.

"When we go into those buildings, when we open that door, we still feel scared. Nothing had really changed; it was an extraordinary earthquake, unseen before. In this earthquake, we lost our CEO. I don't know if you can see, but there's his photo in the back." F_T2_1
"We still can't find workers for the night shift, because the earthquake happened at night, and people are still afraid at night, and don't want to come to work." F_T2_2
"In the first week, I also had losses, and I couldn't come to work. I lost my brother's children and his wife; I had to be at the rubble site. It took six days to reach them, and we buried our loved ones. Then it occurred to me that the people at work might need me and that I was a manager there." T_T2_4

The data reveal the extreme emotional and psychological distress experienced by the purchasing employees:

"The next morning, we went for the autopsy to identify our manager. They didn't let me in because the bodies inside were in very bad condition. Let me tell you this, people were carrying bodies in the back of cars, using their own vehicles and motorcycles. Everyone was completely losing their mind. Even the families couldn't recognize the bodies, not even for the funeral; the emotions and psychology at that moment were truly uncontrollable. I couldn't control anything." F_T2_1

This shows uncontrollable emotions reflecting a psychological crisis, which is common after traumatic events such as earthquakes (Kaya et al., 2023). Intense emotional distress can have long-term effects, potentially leading to PTSD and making it difficult for individuals to restore a sense of stability and control in their lives. Overall, the emotional attributes negatively affected decision-making in the supply chains (Burkhardt et al., 2023), and significant cognitive overload and stress experienced by employees created logistical confusion and compromised financial accuracy.

"I used to visit our late CEO's cemetery every day at lunchtime, as it was nearby. I'd ask him about customer pricing and strategies, and his spirit guides me. Imagine telling a customer, 'I'm at the cemetery, I'll get back to you later.' It's heartbreaking. You've made a sale to a customer, but nothing really matters anymore. The earthquake didn't just destroy buildings; it shattered us, our identities, and our values." F_T2_1
"After the earthquake, people's psychology was shattered; they struggled with concentration and decision-making. Product defects increased significantly, many incorrect invoices were issued, vehicles transporting raw materials went to the wrong locations, faulty contracts were made, and we even observed processing errors in financial statements." F_T3_2

The second subcategory in emotional and behavioral risk is *behavioral and social risk,* which refers to the potential disruptions of the employee's behavior and societal relationships, stemming from factors like migration behaviors, work-life conflicts, avoiding contact with earthquake victims, and behavioral responses that may harm brand reputation and social trust. The results show that people were avoiding contact with earthquake victims, which stems from ethical concerns and emotional discomfort, and this affected the ability to communicate with suppliers and customers, creating communication gaps:

"The biggest difficulty after the earthquake was that, while people were dealing with such a huge disaster and their losses, we had to somehow ask what would happen to our shipments. But honestly, we were very hesitant and embarrassed to ask about our order situation." F_MP_1
"For 15 days after the earthquake, people didn't say a word. On the other hand, people were suffering and dealing with their lives, and it wasn't possible to ask them for raw materials. Honestly, we were even hesitant to call and ask if they needed anything or how we could help. For a while, we didn't even call them at all." T_T1_5

Findings also indicate that the managers faced significant work-life conflicts when employees tried to balance work obligations with personal fears and emotional strain, leading to the psychological burden of navigating conflicting priorities:

"We slept in a car. The earthquake continued all night, and the car was shaking. It felt like we were constantly on top of the sea, swaying, but we still had to go to work. Because one way or another, we had made commitments to people, and we had a delivery schedule. There is a life, a reality, and we need to carry it on. Personally, if you ask me, leaving my family behind and coming to work was extremely difficult for me. I thought to myself, what if there's another big earthquake and I can't be with them. I would blame myself for the rest of my life." A_OEM_4

The findings also show that companies' behavior during the earthquake can expose them to brand reputation risk. Harland et al., (2003) categorize this type of behavioral risk as reputational risk, the reputation being closely tied to a company's actions and behaviors (Eckert, 2017). Companies' actions can lead to public criticism and accusations of prioritizing financial concerns over humanitarian needs, and in addition to affecting the brand value, these can disrupt downstream operations.

"During the earthquake, one food company suffered damage. However, the public, which was the company's customer base, began a boycott, citing that the company only cared about money and didn't even distribute their produced provisions to earthquake victims after the earthquake. The survivors of the earthquake are still not buying the company's products and are continuing the boycott. As a result, this naturally led to brand damage for this company." T_T2_1

After an earthquake, migration serves as a behavioral coping strategy for those who feel their current location is no longer secure and socially supportive. Both internal and international migration as immediate responses were found, with people moving to safer cities within Türkiye and some relocating abroad. This disrupted local labor markets, supply chains, and economic stability.

"Many employees moved after the earthquake and went to safer cities to feel safer." T_T1_4

4.2.2. Human resource and workforce-related risks

The earthquake created significant human resource and workforce-related risks affecting internal operations and organizational stability. This includes issues related to *retirements, migrations, quitting jobs, communication breakdowns with the employees,* and *very high working hours*. This creates effects mainly internally, but if the problem spreads across organizations, it can escalate to a broader macro-level threat.

After the earthquake, *retirements, migrations, and quitting jobs* led to human capital risks after the earthquake. In some cases, supply chain employees opted to quit their jobs or retire earlier because they found it difficult to cope with the challenging post-earthquake conditions. This highlights the loss of valuable human capital and expertise during a crisis, which can disrupt organizational functions indirectly and hinder recovery efforts.

"After the earthquake, 7 out of 9 department managers retired. I'm uncertain how to find replacements for them." T_T2_2
"After the earthquake, nearly 400 of our employees decided to migrate, creating a serious workforce risk for us. We simply didn't have enough people left to keep operations running." F_T3_2

"Some of our female employees decided not to work anymore after the earthquake and wanted to be with their families at home. This led to the loss of labor, particularly among women." F_T2_1

Another significant challenge was *communication breakdowns with employees*. Companies sent surveys, calls, and messages to employees to check on their well-being, but received little to no responses. These communication issues exacerbated the internal risks, as companies struggled to manage both their workforce and relationships with suppliers during the crisis.

"After the earthquake, we couldn't reach our own employees with calls or messages. The phones didn't even work. It was a very stressful period." A_OEM_4

Employees faced *very high working hours* compared to pre-earthquake conditions, driven by increased workloads, limited staff, and the urgent need to restore operations. Despite official regulations limiting work hours, many reported being forced to work beyond the legal limits, which added strain to the workforce and raised concerns about long-term health and productivity.

"Working rule says no one can be made to work more than 11 h, and there's a fine for exceeding that, but that's not how it works. After the earthquake, we ended up working all day and night. Some people sign out after 11 h as if they've left but kept working, being told, "I'll pay you for it." T_T1_3

4.2.3. Humanitarian aid provided by companies

After the earthquake, many companies provided humanitarian aid (Smith, 2023), particularly when government and NGO assistance was delayed or insufficient. Türkiye was caught unprepared for this earthquake because during the critical first 72 h after the earthquake, there were various disruptions both in terms of meeting individual needs and in delivering aid to the affected regions (Aydin, 2023). Due to delayed organized aid, earthquake victims faced, for example, a risk of hypothermia, but companies in the region reacted and provided food, heating, tents, and other assistance to employees and earthquake victims. While this showed corporate solidarity, it delayed the companies' recovery, as their focus shifted to distributing aid rather than resuming production. As a result, the supply chain was significantly impacted due to the inability of suppliers to quickly return to production.

"We saw that the aid reaching the public was insufficient, so we delayed our company's recovery. During that period, we tried to support our employees by providing and distributing essential items such as food, shelter, tents, blankets, clothing, and water." T_T1_4
"In the first stage, the only thing that came to mind before our own production was providing shelter for our employees. We postponed our company recovery because shelter was a huge problem, and it still is. The weather was cold; it was winter. For this, we wanted to turn a building owned by our partners into a place where 300–400 people could take shelter." T_T2_4

Many companies first focused on the humanitarian supply chain and humanitarian aid, and only after ensuring the safety of people, the focus went back to factories and supply chain operations:

"We prioritized earthquake victims' needs, not our company recovery. We set up a shelter within the factory. Meals were provided, rooms were arranged, and the necessary facilities were set up. That place was also full. We tried to turn the factory into a home for the people because there were no tents or food outside. After ensuring the safety of the people, we looked at the situation analysis reports weeks later. We checked things like how much stock we had from each supplier, and whether we could continue production or not." A_OEM_4

4.2.4. Infrastructure and facility risks

"Infrastructure and facility risks" pose significant challenges for companies (Rangel et al., 2015). This risk group includes sub-risk dimensions *of building damage, energy and water crises, and maintenance problems*, which severely disrupt the supply chain indirectly by halting production and delaying transportation. Building damage creates macro impacts because buildings and facilities are unusable and non-operational. Energy crises also create macro impacts, creating disruptions in natural gas, electricity, and water supplies and severely hindering production and employee welfare.

"In our factory, only the administrative building collapsed, while other buildings remained standing, but all were in unusable condition." T_T2_4
"Our natural gas was cut off for 15 days. Without natural gas, we couldn't proceed with production. On the other hand, the weather was −10 °C at the time, and without natural gas, there was no heating." F_T2_2
"The whole city remained in darkness for 4 months, with no electricity. Our employees leave work and go home, but there is no electricity at home. This is not how crisis management works." F_T3_1

Maintenance problems after the earthquake often require specialized repairs that are delayed by logistical constraints, such as damaged airports or safety concerns, causing even further delays in recovery:

"Our production machines are very sensitive to vibrations. If the machines move, the production axis shifts, and all the settings are ruined. We would need to reset all the settings from scratch, but we couldn't do this ourselves; a team from abroad should have come. However, with the airport and roadways damaged and thousands of people dead, how could we bring a team from abroad? The team didn't want to come due to safety concerns." F_T3_2

4.2.5. Regulatory and compliance risks

Risks related to "*regulatory and compliance"* issues were also found to affect supply chains and operations after the earthquake. These arise mainly from *court closure due to the earthquake, inspection problems after the earthquake, insurance problems and unethical behaviors*. For example, in the provinces where a state of emergency was declared following the earthquake by the Turkish Ministry of Justice and Declaration (2023) judicial processes were suspended, and courts were closed, and thus, companies were not able to file claims about insurance, which resulted in delays in insurance compensation. This impacted supply chains because of financial risks due to the delayed payments.

"We decided to take an insurance company to court because we disagreed with their decisions, but the courts were closed, and they only reopened 10 months after the earthquake. Meanwhile, we needed legal assistance." F_T3_1
"Since July 2023 (1,5 years after the earthquake), I have not received insurance compensation. Everything has been done to avoid paying the amount, citing nonsensical excuses and deductions. Because of this reason, I couldn't pay my supplier invoices for a while" T_T2_4

Companies faced challenges in damage inspection decisions because of the lack of clear guidelines on damage assessment, determined by the government's responsibilities. Some unethical behaviors also emerged after the earthquake, with cases of relying on personal connections and favoritism, leading to unethical practices and corruption.

"My factory wasn't destroyed. It sustained damage and was initially reported as moderately damaged. However, no one knows the criteria that were used." T_T2_1
"Some of the requests from customers had no enforceable implications for us. For example, they asked for building usage permits, construction licenses, and fire department reports. However, if you don't have these reports, you can't get them unless you use connections at the municipality.

You need to have someone pull strings for you to get these reports." T_T1_1

4.2.6. Policy risks

The results indicate that risks related to "*governmental and political instability*" were also observed. As the primary authority responsible for disaster risk reduction and mitigation, the government has the primary responsibility for implementing measures to reduce disaster risk and is expected to implement measures for effective environmental planning, enforce building regulations, and provide support to the earthquake victims (Oral et al., 2015). It has also been found that *political instability* can disrupt supply chain operations in the context of earthquakes (Olson and Dash Wu, 2010; Dasgupta et al., 2024).

"The government's earthquake crisis management is essentially nonexistent, but because the volunteers and companies have gone above and beyond, we are still standing because we provided humanitarian aid as companies." T_T1_4

"The government needs to step up. Companies did more than their best, but the government was not here. People are living under tough conditions and high prices. Many prices have risen after the earthquake. We can understand the increase in housing costs, but beyond that, the costs for food and textiles have also surged dramatically." T_T2_4

"The approach of Turkish politics after the earthquake should be examined. The decisions they made, how the aid was provided, and most importantly, the effectiveness of these actions need to be questioned. For example, a lot of food and medicine were sent here, but we have a serious labor force problem, which was completely ignored, and policies were not adjusted in this regard." A_T2_1

4.3. Overall results

4.3.1. Cross-sector analysis

When comparing the sectors of automotive, textile, food and beverage, and the risks that the companies in those sectors faced (see Appendix C), the results show that the automotive sector is highly vulnerable to emotional and psychological risks. The second most prevalent risk in the automotive sector is financial risk within the supply chain. In the aftermath of an earthquake, financial instability and increased operational costs significantly undermine the sector's capacity to maintain financial stability. Deficiencies in supply chain competence, such as low purchasing education level and non-qualified employees, further impair effective risk management within automotive companies. Supplier availability and supplier preparedness are significant risks in this sector, especially in post-disaster contexts. Logistical problems, including road damage, bridge collapses, and port fires, have had a negative impact on the automotive supply chain. Furthermore, this sector is highly sensitive to governmental policies that affect the sustainability of its operations. Finally, the industry's reliance on specialized production requirements, such as unique tools and processes, intensifies its dependence on specific suppliers. This dependency intensifies vulnerability in post-earthquake scenarios, where supplier operations may be severely disrupted.

The textile sector was the most affected by emotional and behavioral risks, financial risks, low purchasing education level, governmental risks, and non-qualified employees. The most common risk in the textile sector was emotional and psychological risks, highlighting the critical importance of safeguarding employees' mental well-being in a post-earthquake environment. Financial risks among suppliers and rising costs further strained companies. Low purchasing education levels and non-qualified employees are common risks in the textile sector. This sector also became more sensitive to policy risks. Many textile companies contributed to humanitarian supply chain efforts, which caused delays in their own production. Overall, production stoppages and inadequate disaster preparedness were widespread among textile suppliers. The textile sector faced many direct supply chain risks, but also many indirect risks were notable.

The food and beverage sector faced significant challenges, particularly due to behavioral and social risks, and this negatively affected decision-making. The increased demand for essential food supplies led to rising raw material costs, further creating financial risks. Low purchasing education level created a challenge in managing the risks in a post-earthquake environment. Many food and beverage companies experienced extensive building damage. This sector was also highly sensitive to governmental policies and struggled with policy-related uncertainties. Like the textile sector, food and beverage companies shifted their focus to humanitarian supply chains, leading to delays in their production and an extended recovery period. Overall, the food sector was affected by direct risks but also highly affected by indirect risks, such as emotional and behavioral risks. It also faced significant risks related to infrastructure and facility damage, underscoring its vulnerability to both operational and external environmental factors.

Finally, analysis within the emotional and behavioral risk category revealed that the textile and food and beverage sectors were uniquely impacted, as they simultaneously exhibited both sub-risk categories: emotional and psychological risks, and behavioral and social risks. Notably, the emotional and psychological risks sub-risk category emerged as the most prevalent risk in both the automotive and textile sectors. Financial risks in the supply chain followed as the second most prevalent risk across all sectors, reflecting widespread economic vulnerability. The third most common risk in all sectors, low purchasing education level, further compounds risk management problems, especially in the post-earthquake phase. Due to extensive building damage caused by the earthquake, the automotive and food and beverage sectors were particularly exposed to significant risks. Overall, governmental risks were observed across all sectors.

4.3.2. New risk typology: Cross-cutting risks and cascading impacts

The analysis of the extensive interview data enabled us to recognize that even though supply chain risks in previous research are typically classified into separate categories, such as direct and indirect supply chain risks, many risks are interconnected and interact with each other. By examining the interconnectedness of risk categories, we were able to identify a phenomenon of *cross-cutting risks*. Cross-cutting risks are risks that are inherently interrelated, have the potential to generate macro or indirect risks, and carry distributional impacts (Street, 2017; Klein and Ruark, 2017). While these risks have not been studied in the existing literature, cross-cutting risks can be found, for example, as integral components of NASA's risk management frameworks (Klein and Ruark, 2017) or in the context of climate change risk. Table 5 presents an analysis of the identified cross-cutting risks and their interactions with other risk sub-categories.

For instance, emotional and psychological risks have a significant impact on decision-making and managerial problems. The emotional responses of supply chain employees can trigger consequences and upstream impact, influencing broader organizational dynamics. Another example is logistical problems and risks that impacted the availability of raw materials because suppliers did not receive raw materials due to road damage, which in turn caused issues for customers. The shortage of raw materials led to an increase in raw material prices, creating financial impact where the original problem related to logistics and macro impact started to spread downstream and upstream, creating impacts there. This shows that one risk can escalate and compound the overall impact, creating a more significant and complex risk landscape. Thus, recognizing these interrelations is important because they highlight the need for comprehensive risk management strategies that also consider the cascading effects of various impacts within the supply chain.

Fig. 2 illustrates how cross-cutting risks are interrelated and cascade in supply chains based on the patterns identified in our empirical data. Cross-cutting risks (Fig. 2 black boxes; Table 5 first column) can trigger or influence other risks across different parts of the supply chain. As

Table 5
Cross-cutting risks and impacts.

Cross-cutting Risks	Quotes	Triggered Sub-Risks	Cross-cutting impact
Financial risk	*"…We couldn't pay the invoices because all colleagues in finance and accounting left their laptops at home when they ran away during the earthquake in a hurry…" A_OEM_4* *"…In addition to raw materials, energy, and other expenses, labor costs are also increasing all our overall costs…" T_T2_4* *"Labor costs have also risen significantly since the earthquake." F_T3_1* *"… yarn prices in the city suddenly increased more than 50% without any apparent reason…" F_T3_1* *"Due to the significant financial losses, the board of directors convened. Some voted to "continue operations," while others voted to "file for bankruptcy and shut down the company". F_T2_1*	Missing communication with suppliers, supply shortage, supplier availability risks, migrations, energy and water crisis	Upstream impact, internal impact, macro impact
Supplier availability risk	*"The CEO of our company passed away in the earthquake, and the company sustained physical damage. Due to the significant financial losses, the board of directors convened. Some voted to "continue operations," while others voted to "file for bankruptcy and shut down the company." However, since we still had outstanding installment loans, filing for bankruptcy would have been a painful process." F_T2_1*	Financial risk, emotional and psychological risk	Macro impact
Governmental risk	*"The government's earthquake crisis management is essentially nonexistent, but because the volunteers and companies have gone above and beyond, we are still standing because we provided humanitarian aid as companies." T_T1_4*	Self-recovery delay due to aid involvement	Macro impact
Migrations	*"…We couldn't even find a buyer who can speak English… Probably all qualified buyers have already left and immigrated." T_T2_2*	Non-qualified employees	Internal impact
Supplier preparedness risk	*"There are significant losses during an earthquake, and when everyone is focused on their own survival, it's understandable that the company wouldn't be a priority. For this reason, we don't dedicate much time to earthquake preparations." A_T1_2*	Behavioral and social risk, emotional and psychological risk	Macro impact
Behavioral and social risk	*"Many employees moved after the earthquake and went to safer cities to feel safer." T_T1_4*	Migrations, financial risk	Internal impact, upstream impact, macro impact
Self-recovery delay due to aid involvement	*"We saw that the aid reaching the public was insufficient, so we delayed our company's recovery. During that period, we tried to support our employees by providing and distributing essential items such as food, shelter, tents, blankets, clothing, and water." T_T1_4*	Financial risk	Macro impact
Missing information flow	*"Suppliers share details with us (customers) as they want to share, not what they need to share. They are hiding behind reasons like cost confidentiality; they do not communicate potential impact or information we need to know." A_OEM_1*	Financial risk, supplier preparedness risk, failure to meet customer demand	Upstream impact, downstream impact
Building damage	*"…Construction is still ongoing in the building, but the line stoppage has been continuing for 16 months." T_T2_4* *"…The company had to completely withdraw from the shirting fabric division and canceled all its orders." T_T2_2* *"When the supplier's building is damaged, there is a risk that they may demand higher prices from us*	Line stoppage, supplier availability risk, financial risk	Downstream impact, macro impact

(*continued on next page*)

Table 5 (*continued*)

Cross-cutting Risks	Quotes	Triggered Sub-Risks	Cross-cutting impact
	(the customer), which constitutes a financial risk." A_OEM_1		
Logistic problems	*"After the earthquake, almost all roads were closed, and it was impossible to use the roads for transportation. Many companies couldn't send or receive any orders." T_T2_2*	Financial risk, supply shortage	Macro impact, downstream impact, upstream impact

Fig. 2 shows, supplier availability risk and financial risk appear as two of the most central and highly connected risks. Both can be triggered by other risks, and at the same time, they can initiate further risks, spreading the impact across the supply chain. This shows their key role in the connectedness of risks.

5. Discussion and conclusions

This study explored the main supply chain risks that can be caused by earthquakes and the types and categorization of these risks. The results also highlight the multifaceted nature of supply chain risks and impact, emphasizing the interconnectedness of risks.

5.1. Theoretical contributions

This research has three key theoretical contributions. First, it offers a comprehensive categorization of supply chain risks resulting from the earthquakes, distinguishing between *direct* and *indirect supply chain risks*. The second key contribution is the incorporation of a psychological perspective, highlighting the importance of *emotional and behavioral risks* in the context of supply chains, and discussing the effects of earthquake-induced risks from the psychological approach. The third key contribution is introducing the concept of *cross-cutting risks*, which can have far-reaching impacts on both supply chains and their broader environments.

On direct supply chain risks, our study contributes especially to the findings of the significant role of the *purchasing and supply chain competence* during natural disasters such as earthquakes. While previous research (see Table 1) has mainly focused on operations-related supply chain risks, the impact of missing competencies of those managing these operations has received less attention. Our results illustrate that the purchasing education level plays a crucial role during and after the crisis. For example, many managers tragically lost their lives during the earthquake, which left uneducated buyers in confusion and unable to make decisions, leading to managerial problems. This highlights the importance of formal purchasing and supply chain educational programs, as they provide the essential knowledge and skills for effective risk management and recovery.

While direct supply chain risks are more frequently studied in existing research, indirect risks that stem from factors outside core supply chain activities and are not directly involved in day-to-day supply chain operations have received comparatively less attention. This research makes a significant contribution by highlighting this often overlooked type of risk, as it can have significant impacts in the aftermath of earthquakes. The results show that the indirect risks caused by emotional and behavioral factors significantly influence decision-making within the supply chain. Following the earthquake, PTSD was prevalent in the affected regions (Mavroulis et al., 2022; Koçer et al., 2024). Current psychological research indicates that untreated PTSD can, over time, lead to critical mental disorders (OConghaile and DeLisi, 2015). The failure to identify and treat PTSD among supply chain employees in the earthquake-affected regions can increase the future risks in the whole supply chain, for example, if people with untreated PTSD hold managerial positions. The literature shows that psychological disturbances can negatively impact decision-making processes, and we found that the likelihood of poor decision-making increased after the earthquake. Prior literature has not extensively explored the intersection of psychology and SCM. This underscores the novelty of this study because we show that a more comprehensive understanding of how psychological factors influence decision-making processes and behaviors within the supply chain contexts is needed.

The psychological approach also provides valuable insights into suppliers' behavior and its broader impacts. The findings show that suppliers tend to prioritize complex, long-term actions over simpler, more immediate steps in earthquake preparedness. Rather than implementing straightforward measures like training suppliers, developing crisis management plans, or establishing emergency inventories, suppliers often focus on large-scale initiatives, such as restructuring the entire supply chain or rebuilding facilities. Building on Frega (2014)'s research about bridging pragmatism and perfectionism, it becomes evident that these two approaches offer contrasting strategies for addressing supplier preparedness risks. Perfectionist tendencies in suppliers often manifest as a preference for large-scale, costly solutions such as rebuilding facilities. While such measures may be necessary in the long term, they are expensive and can delay more immediate preparedness actions. In contrast, pragmatism encourages suppliers to take smaller, more immediate, and cost-effective steps, such as developing crisis management plans. This approach ensures that suppliers are not paralyzed by the perceived financial constraints of preparedness, allowing them to begin building resilience right away. Pragmatism

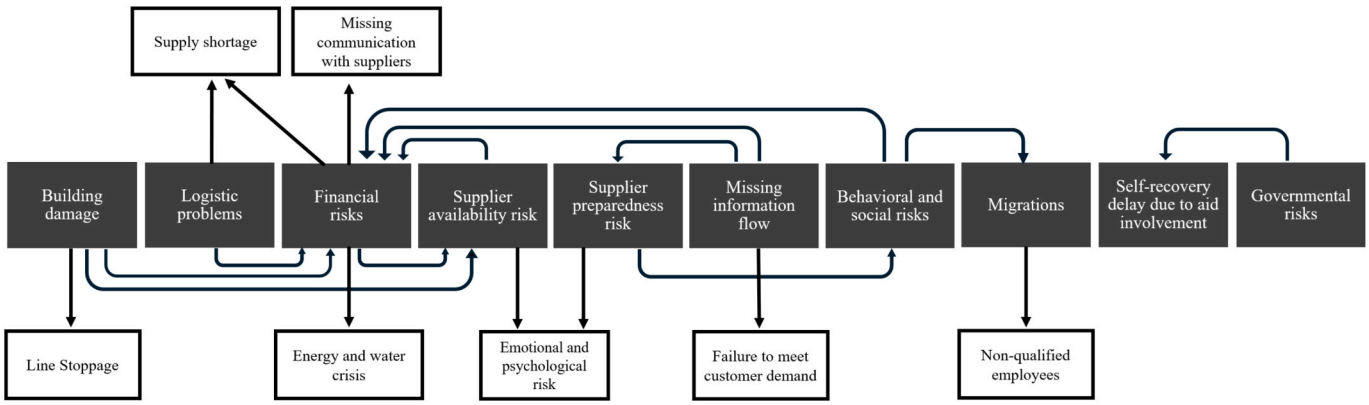

Fig. 2. Identified patterns between cross-cutting risks.

emphasizes addressing the most pressing needs while maintaining flexibility for future adaptation. Therefore, in the context of earthquake preparedness, a pragmatic approach, focused on practical and achievable actions, enables suppliers to act swiftly and effectively, without being hindered by the pursuit of perfection, which could delay necessary interventions.

This study also contributes by introducing the concept of *cross-cutting risks* in the context of the supply chain. Cross-cutting risks are risks where interconnectedness creates impact and cascading effects not only on the internal company level but on the supply chain and macro level. For example, our findings show that supply shortages are not caused by one single factor but can be the result of several interconnected issues. The original problem might not be the supply shortage itself caused by the lack of raw material, but the shortage might be caused by, for example, raw materials being buried under collapsed warehouses or logistical problems caused by delayed deliveries because of damaged roads. This highlights that supply shortages after the natural disaster and other catastrophic events are not only about supplier failures but also about the physical destruction of materials and transport routes. Another example of cross-cutting risk comes from supplier capacity. Suppliers who did not suffer damage faced a sudden overload of orders because damaged suppliers were unable to respond to demand. This created capacity bottlenecks and unexpected pressure on these suppliers. Prior studies often describe unaffected suppliers as safe alternatives during crises (Son et al., 2011; Křenková et al., 2023), but our findings show that they can quickly become overwhelmed, which adds a new layer to our understanding of supply chain risks considering supplier capacity. Looting and theft were also widespread after the Türkiye earthquake, directly affecting factory inventories and worsening supply shortages. While looting is often discussed in disaster management studies, it has not been deeply explored in the supply chain field. Our study highlights that stolen stock is not just an internal security issue but a serious supply chain risk that needs more attention in the literature.

Our results on cross-cutting risks expand existing discussions on supply chain risks and offer a more complete view of how single risks, such as supply shortages, develop in extreme situations and how the impacts may cascade on various levels. Our findings on sector-specific differences illustrate the uneven distribution of vulnerabilities across different industrial sectors and highlight the need for tailored, industry-specific resilience strategies that also account for shared, cross-cutting risks across supply chains.

5.2. Managerial implications

Managerially, our results highlight the significance of taking a wider perspective to supply chain risk management under sudden natural disaster events like earthquakes. Our results show that companies need risk management strategies and plans where the interrelations of the risks are recognized. Risks are cross-cutting, and impacts are cascaded in supply chains, but with proper risk management plans, companies could be able to break the cascading effects and mitigate risks. Managers should also be aware that the impact of earthquakes on employees' mental and emotional well-being should not be underestimated in the supply chain context. Managers must acknowledge that supply chain employees may be mentally affected by disasters, which can influence decision-making processes and increase the likelihood of errors. Ensuring that employees receive adequate mental health support and maintain their overall well-being is significant. Furthermore, companies should recognize the critical role of education in purchasing and supply management. The ability of supply chain employees to make timely and successful decisions under pressure heavily depends on their understanding, knowledge, and expertise. A lack of knowledge might lead to poor decision-making, resulting in challenges that are difficult for managers to resolve. Thus, companies should be aware that investing in the education and training of employees is vital for building stronger supply chain risk management capabilities. Finally, when creating an emergency plan, managers should not assume they will always remain part of the scenario. The system should be designed in a way that it remains operational even if some key persons or managers are lost. Thus, the risk management plan for natural disasters and similar large-scale disruptions should be extensive and, in addition to operational risks, cover also the strategic and managerial risks.

5.3. Limitations and future research

While this study provides valuable insights into supply chain impact during earthquakes, it is geographically limited to Türkiye, and the findings may not be fully applicable to other regions with different risk profiles. However, the generalizability of the results extends beyond companies purely operating in earthquake-prone regions. Even if the company itself is not located near an active fault line, the vulnerability of a critical supplier in a high-risk seismic zone can result in significant operational disturbances. In today's global economy, major industries such as textiles, food and beverage, and automotive heavily rely on suppliers based in countries like China, Japan, India, Indonesia, and Türkiye, all of which are exposed to significant earthquake risk. This highlights the importance of integrating geophysical risk considerations into supply chain risk management, regardless of a company's own geographic location.

Future research should explore these findings across different countries and disaster scenarios other than earthquakes. Additionally, further studies could investigate the long-term effects of emotional and behavioral impact on supply chains, as well as examine supply chain resilience and its development, for example, by applying the dynamic capability view that would enable the perspective of responding to change.

CRediT authorship contribution statement

Seray Mirasçı: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Anni-Kaisa Kähkönen:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Melek Akın Ateş:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

The interview protocol

- What strategies does your company use to manage procurement impact, especially against natural disasters like earthquakes?
- How do you assess the impact of your suppliers' geographical locations on procurement and supply chain impact? Which areas of Türkiye are more vulnerable?
- What methods or metrics do you use to categorize your supplier-related impact?
- As an OEM company, how do you plan to respond quickly in crisis situations?
- In case of impact like supplier bankruptcy or production disruptions due to natural disasters, what backup supply sources are you considering? Do you have any plans for that?
- What steps are you taking to make your suppliers more resilient, particularly regarding supplier diversity and business continuity planning?
- Can you evaluate how well your suppliers prepare for crises, such as having backup production capacity or emergency plans?
- How are you improving collaboration and communication strategies for supplier resilience? Do you regularly work on crisis scenarios with your suppliers?
- What are the most important lessons learned about supplier resilience and continuous improvement?
- How do you monitor supplier performance with metrics or indicators related to supplier resilience?
- Can you describe any instances where your suppliers took proactive measures to mitigate impact or improve their performance without your direct intervention?
- Do you have supplier agreements or contracts that encourage or require suppliers to proactively manage and communicate potential impact?
- Were any of your facilities directly affected by the 2023 Türkiye-Syria earthquakes?
- Were any of your lower-tier suppliers directly affected by the Türkiye-Syria earthquakes?
- Have you or lower-tier suppliers encountered any production shortages?
- What types of products are manufactured by the suppliers that have been affected?
- Are the products produced by the suppliers affected by the earthquake on your critical component list?
- Do you have any facilities near the red-marked earthquake regions in Fig. A1?
- Do you have any lower-tier suppliers near the red-marked earthquake regions in Fig. A1?
- Do you have critical components produced in the earthquake regions by lower-tier suppliers?
- Do you face a purchasing or supply chain risk if an earthquake happens in the red regions?

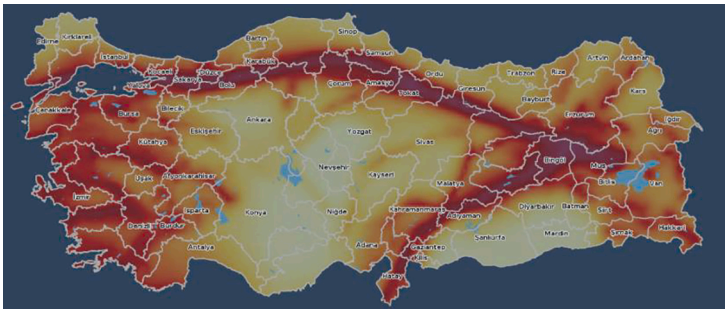

Fig. A1. Türkiye Earthquake Risk Map

Appendix B

Additional quotes for primary and secondary risk categories (see Table B1).

Table B1
Additional quotes for risk categories.

Primary risk category	Secondary risk category	Quote
Supplier and logistics risk	Supplier preparedness risk (missing action following supplier audits)	"Our customer requested supplier earthquake compliance reports during the audit. According to these reports, one of our suppliers' buildings was found to be non-compliant with earthquake standards and posed a risk of collapse in the event of an earthquake. It was recommended that the building be reinforced. We shared this report with our customer. Despite the building being non-compliant, no action was requested from us regarding the reinforcement. When we asked if they wanted us to take action, they initially responded that they were waiting for feedback from the U. S. A few months later, communication was cut off, and they stopped responding to our emails." T_T1_1
Supplier and logistics risk	Supplier preparedness risk (lack of understanding of earthquake impact and missing earthquake preparedness among suppliers)	"The risk of earthquakes is still not a well-understood issue in Türkiye. With every major earthquake, we suffer significant losses, but we tend to forget and move on without taking action. Not only earthquakes, even for floods, fires, or landslides, we don't have any plans in place. If we survive, we'll figure it out afterward". A_OEM_1
Supplier and logistic risk	Supply shortage (stolen or missing goods and stocks)	"A lot of materials were stolen from our factory after the earthquake. When people saw that the building had collapsed, thieves went in and stole the materials. …

(*continued on next page*)

Table B1 (*continued*)

Primary risk category	Secondary risk category	Quote
		Strange is that not only thread and fabric were stolen, but someone even stole a washing machine." T_T2_2
Customer-related risks	Production flow problems	"For example, as the purchasing manager, I have a certain level of approval authority. I can approve up to a certain limit. I know we can purchase this, but beyond that, we always have to go through a series of approval stages. We need to obtain written approvals to ensure that, in case of audits in the future, we won't face any issues in the audits. This is how we proceed" A_OEM_2
Emotional and behavioral risks	Emotional and psychological risk (deaths and losses)	"One of our suppliers' CEO passed away. The owner of the company died because the building he lived in collapsed. The company wasn't affected in terms of production, but it was seriously impacted in terms of management. Even if just one person, especially if they hold a crucial position in management, is affected, it can still influence the company's operations." F_MP_1
Emotional and behavioral risks	Emotional and psychological risks (emotional attributes)	"My husband, my mother, and my sister all lived in one room together. I couldn't even enter my own bedroom for 4 months. When I did go into the room, I felt like I was going to be swallowed up or killed. We were living in one room of the house and couldn't go to the others. It's hard to overcome this psychology. I can understand people don't want to work on night shifts." F_T2_1
Emotional and behavioral risks	Emotional and psychological risks: (fate and luck believing)	"We (Turkish people) have a fate-driven mentality. We struggle with earthquakes, but in a way that is a gift from God, even though we have many precautions, they won't work because you can't take precautions against God. But we are always able to act quickly. We have learned to live with crises." T_T1_5
Human resources and workforce-related impact	Communication problems with staff	"We sent a survey to our suppliers and employees asking if they were okay after the earthquake, but neither the suppliers nor our employees wanted to respond to it." A_OEM_1
Humanitarian aid provided by companies	Self-recovery delay due to aid involvement	"We bought a truckload of tents so that our own staff could have a place to stay. However, even the materials we purchased couldn't reach us; the authorities seized the truck and redirected it to another city. After a long discussion, we were finally able to bring the tents we had purchased with our own money to this location." T_T2_
Humanitarian aid provided by companies	Self-recovery delay due to aid involvement	"As a factory, we stopped our production and organized the aid efforts; we prepared meals, set up tents, and worked to keep our employees alive." F_T2_2
Infrastructure and facility risks	Energy and water crises	"After the earthquake, the electricity was cut off. However, the industry needs electricity both for production and to provide shelter for employees. We had to wait for 4 days and then start working with generators because there was no electricity." T_T1_4
Infrastructure and facility risks	Energy and water crises	"There was an issue with the water pipes, and all the water flowed murky for 3–4 months. I was using that water in the production process. We tried to filter the water, but it didn't work, causing a quality issue on the products." T_T2_4
Infrastructure and facility risks	Building damage	"One of our suppliers, which produced shirting fabrics, had its building completely collapse. The building was entirely destroyed and in very poor condition. The company had to completely withdraw from the shirting fabric division and canceled all its orders. They are currently operating in different industries, but they were unable to save the shirting fabric division." T_T2_2
Infrastructure and facility risks	Building damage	"When the supplier's building is damaged, there is a risk that they may demand higher prices from us (the customer), which constitutes a financial risk." A_OEM_1

Appendix C

The main risk category order in each sector (see Table C.1).

Table C1
Main risk categories in the case sectors.

Primary risk category	Sub-risk category	Sectors		
		Automotive	Textile	Food and beverage
(I) Emotional and behavioral risks	Emotional and psychological risks	1	1	5
	Behavioral and social risks		9	1
(D) Customer-related risks	Customer-specific production requirements	10		
	Customer-induced order volume fluctuations		10	
	Line stoppage		8	6
(D) Supplier and logistics risks	Financial risk	2	2	2
	Supplier availability risk	5		
	Supplier preparedness risk	6	7	
	Logistic problems	7		
(D) Supply chain competence risks	Low purchasing education level	3	3	3
	Non-qualified employees	9	5	8
(I) Infrastructure and facility risks	Missing information flow	4		
	Building damage			4
(I) Policy risks	Governmental risks	8	4	7
(I) Regulatory and compliance risks	Inspection problems after the earthquake			10
(I) Humanitarian aid provided by companies	Self-recovery delay due to aid involvement		6	9

(D): Direct supply chain risks, (I): Indirect supply chain risks.

Data availability

The data that has been used is confidential.

The authors are unable to share the data due to company confidentiality restrictions.

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