



A regional field study on employment problems caused by earthquakes in organized industrial zones

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ABSTRACT

This study addresses the limited enterprise-level evidence on how workforce mobility, living conditions, and production continuity interact in industrial areas after a major disaster. It examines the effects of the 6 February 2023 Kahramanmaraş earthquakes on employment and production continuity in Organized Industrial Zones (OIZs) in Adıyaman, Hatay, Kahramanmaraş, and Malatya, four of the provinces most severely affected. A qualitative multiple-case field study used criterion-based purposive sampling and semi-structured interviews with owners or authorized representatives of 214 enterprises: 50 in Adıyaman, 41 in Hatay, 50 in Kahramanmaraş, and 73 in Malatya. Interview accounts were interpreted together with field observations and descriptive eye-tracking material. The findings show that employment and production disruptions reflected not only physical damage but also workforce migration, housing shortages, transportation and infrastructure problems, and limited access to skilled labor. Although these pressures were shared, their relative importance differed across provinces. Workforce retention and return therefore depend on restoring employment opportunities alongside housing, transport, and social living conditions. The study proposes a flexible, province-sensitive OIZ planning framework integrating structural, human, operational, institutional, and social resilience.

1. Introduction

Natural disasters affect more than physical assets: they can disrupt production, infrastructure, supply chains, labor markets, and regional development long after the immediate event. Vulnerability is shaped by the capacity of communities and institutions to absorb and respond to these disruptions [1,2], while comprehensive loss assessment must include indirect and longer-term costs [3,4]. Türkiye's recurring disaster experience likewise shows the importance of examining social and economic consequences together with physical damage [5]. Local employment losses, sectoral wage changes, and interrupted business activity are therefore central to recovery [6–8].

At the macroeconomic level, disasters can influence growth through capital destruction, productivity, reconstruction, and institutional capacity. Their effects are heterogeneous rather than uniformly negative

or positive [9–12]. Reconstruction may embody newer technology, but any benefit depends on financing and implementation conditions [13]. Economic resilience accordingly concerns limiting output losses and accelerating recovery, not merely rebuilding assets [14]. Evidence from different countries also shows that labor-market responses vary with sectoral structure, exposure, and policy capacity [15–17].

These effects become more complex when workforce mobility is considered. Fatalities and injuries create direct labor losses, whereas damaged housing, interrupted services, and worsening living conditions can prompt outmigration. Migration may be an adaptive response to income loss, yet reconstruction employment can encourage staying or return; transnational and place-based ties further condition such decisions [18]. Studies of the Nepal and Wenchuan earthquakes show that disaster exposure can reshape labor mobility across sectors and over time [19,20]. Return decisions likewise reflect employment, property,

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housing assistance, infrastructure, services, and community ties rather than housing alone [21,22].

These relationships are critical in Organized Industrial Zones (OIZs), where production, infrastructure, firms, and workers are spatially concentrated. Earthquake losses can propagate through transportation networks and regional economies [23], while disrupted international supply chains transmit effects beyond the damaged area [24,25]. Emergency-service location and post-disaster logistics also influence operational recovery [26,27]. Studies of business continuity emphasize alternative production capacity, rapid restoration of infrastructure, and advance planning [28,29]. Critical services such as electricity, water, gas, and transportation can delay capacity recovery even where direct structural damage is limited [30].

Türkiye's seismic history shows that risk is geographically widespread and shaped by building stock, soil conditions, and exposed populations [5,31]. After the 2020 Samos earthquake, investigations in İzmir documented the importance of structural characteristics and local ground conditions [32]. The Mw 6.1 Sındırgı-Balıkesir earthquake of 10 August 2025 again highlighted continuing hazard in western Türkiye [33]. These experiences support treating resilience as the continuity of economic and social systems as well as structural safety.

The Mw 7.7 and Mw 7.6 earthquakes centered in Pazarcık and Elbistan on 6 February 2023 affected Adana, Adıyaman, Diyarbakır, Elazığ, Gaziantep, Hatay, Kahramanmaraş, Kilis, Malatya, Osmaniye, and Şanlıurfa. AFAD's update of 24 February reported 44,218 deaths and the evacuation of 528,146 people from the affected region [34,35]. Research on the sequence has since documented its multi-fault rupture dynamics [36], severe damage in both older and some newer reinforced-concrete buildings [37], the implications of structural alterations and retrofitting for reinforced-concrete safety [38], the vulnerability of masonry mosques and minarets in Hatay [39], and post-earthquake material deterioration and residual structural performance in reinforced-concrete buildings [40]. Together, these studies show that the disaster combined a complex seismic process with damage across different structural types. In the manufacturing base, losses of factories, machinery, inventories, housing, and infrastructure coincided with deaths, injuries, and worker migration. Employer–employee data indicate increased labor-market exits and interprovincial job mobility, together with weaker wage growth after exposure [41], while evidence from Nurdağı links re-employment to business continuity and community recovery [42]. Physical restoration alone therefore cannot secure production when workers lack housing, transport, education, healthcare, and other conditions required to remain or return.

Existing research often treats structural vulnerability, macroeconomic loss, labor-market adjustment, and disaster-induced migration separately. Enterprise-level studies that jointly examine workforce loss, return conditions, housing, social infrastructure, and production continuity in OIZs remain limited. This study addresses that gap using field evidence from 214 enterprises in Adıyaman, Hatay, Kahramanmaraş, and Malatya. It identifies post-earthquake employment and production challenges, examines the conditions shaping workforce migration and return, and develops policy recommendations for more resilient OIZs. Its contribution is to connect production, workforce, migration, housing, and social infrastructure within a single, province-sensitive framework.

2. Method

This study adopts a qualitative multiple-case field study design to examine the effects of the 6 February 2023 earthquakes on employment in Organized Industrial Zones (OIZs) in Adıyaman, Hatay, Kahramanmaraş, and Malatya. The primary aim of the study is to identify the employment-related challenges that emerged in OIZs following the earthquakes, to examine how these challenges are associated with workforce migration, housing conditions, infrastructure disruptions, and production processes, and to assess potential solutions that could support workforce retention and the return of displaced

workers to the affected region in the post-disaster period.

In line with this aim, the study seeks to address the following research questions:

RQ1. What are the main employment-related challenges faced by enterprises operating in Organized Industrial Zones (OIZs) following the 6 February 2023 earthquakes?

RQ2. How have workforce migration, housing conditions, infrastructure disruptions, and changes in labor supply following the earthquakes affected the continuity of employment and production in OIZs?

RQ3. What institutional, spatial, and social arrangements aimed at retaining the workforce in the affected region and supporting return migration could contribute to enhancing the resilience of OIZs in the post-disaster period?

A qualitative design was adopted because the research questions concern how enterprises experienced post-earthquake employment, migration, housing, infrastructure, and production processes, not only the numerical extent of loss. Such designs support context-sensitive examination of participants' experiences and meanings [43–45]. The study was organized as field research, with attention to the fit between the research questions, evidence, and claims [46]. Fig. 1 presents the field implementation and the role of each data-collection technique.

The interview, field-observation, and eye-tracking materials captured complementary aspects of the same phenomenon. Semi-structured interviews allowed enterprise representatives to explain employment, migration, housing, infrastructure, and production experiences in their own terms [47–49]. With consent, all interviews were audio-recorded, lasted approximately 23 min on average, and were conducted in an appropriate setting in each enterprise's administrative office. The researcher accompanying the interviewer recorded field observations, which the interviewer subsequently reviewed and confirmed. These notes documented the physical and operational context of participants' accounts. Eye tracking was used more narrowly to describe the distribution of visual attention across concepts shown during fieldwork. It did not measure preferences or attitudes and served only as contextual support for interview findings. Fig. 2 presents the procedure and an example stimulus.

Eye tracking was conducted with the same 214 participants using a Tobii X60 screen-based device sampling at 60 Hz, with recordings processed in Tobii Pro Lab. A nine-point calibration preceded each task and was repeated when gaze capture was incomplete or markedly deviated. Concepts derived from the interview framework were displayed at fixed locations for 10 s. No formal areas of interest (AOIs) were defined or statistically compared. The method has been used to describe overt visual attention in varied research settings [50–52], including consumer exposure and decision processes [53–55], attention and problem solving [56], advertising warnings [57], memory-related attention [58], and engagement [59]. Here, fixation count, total fixation duration, and heat maps were reviewed only as recording-level descriptive outputs [60–64]. They were not assigned to concepts for numerical comparison across concepts, provinces, or groups and were not used to infer attitudes, emotions, preferences, or causality.

Triangulation occurred during interpretation [49,65]. Interview themes were compared with field observations and descriptive gaze patterns. Eye tracking neither generated themes nor independently validated the interviews. Agreement across materials was treated cautiously as contextual consistency, while differences were retained and interpreted in relation to each OIZ's physical, economic, and social conditions.

The 6 February 2023 earthquakes affected eleven provinces: Adana, Adıyaman, Diyarbakır, Elazığ, Gaziantep, Hatay, Kahramanmaraş, Kilis, Malatya, Osmaniye, and Şanlıurfa. Fig. 3 identifies all eleven provinces and highlights the four provinces included in this study—Adıyaman, Hatay, Kahramanmaraş, and Malatya—together with the selected Organized Industrial Zone (OIZ) cases. (See Fig. 4.)

During the planning stage of the study, the online enterprise lists of the relevant OIZs indicated that a total of 707 enterprises were operating

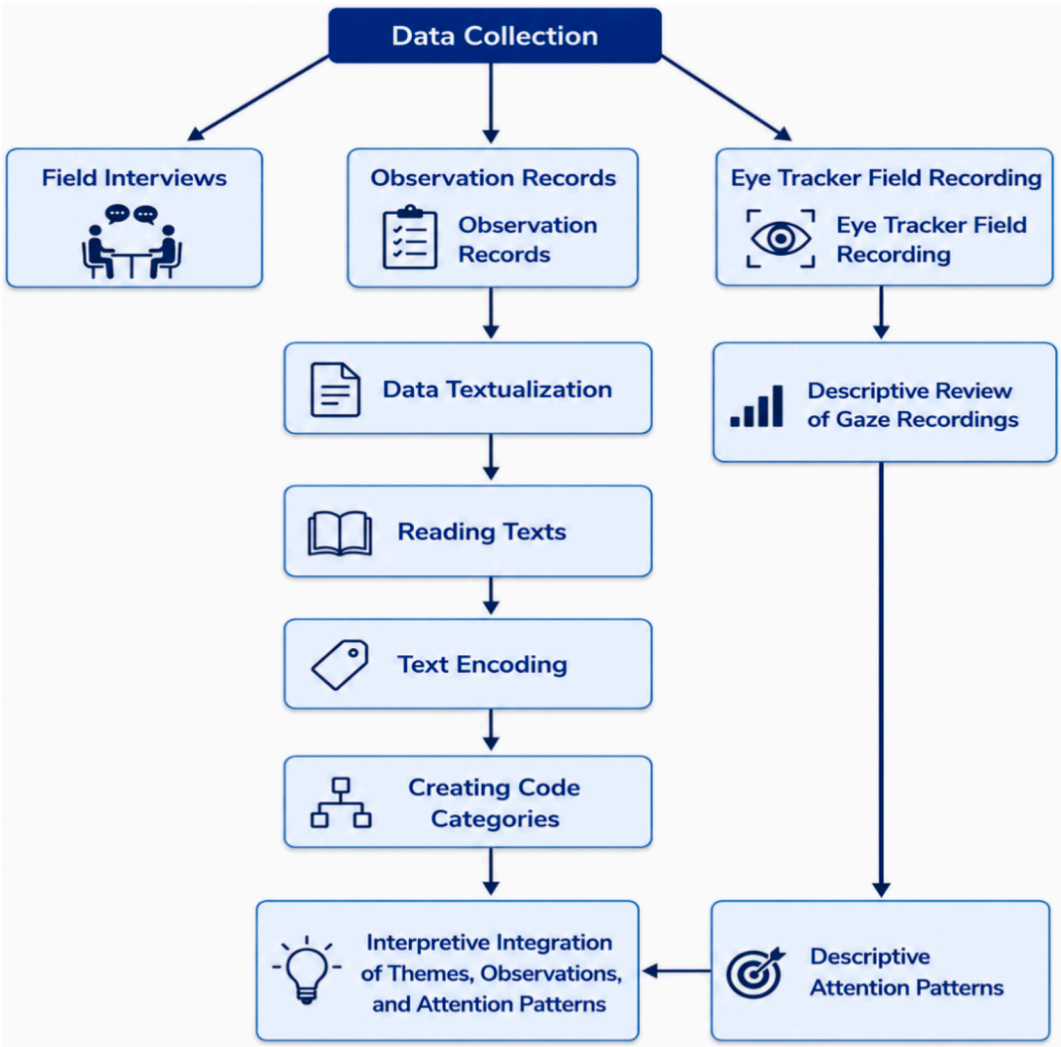


Fig. 1. Field Implementation and Data Collection Process.

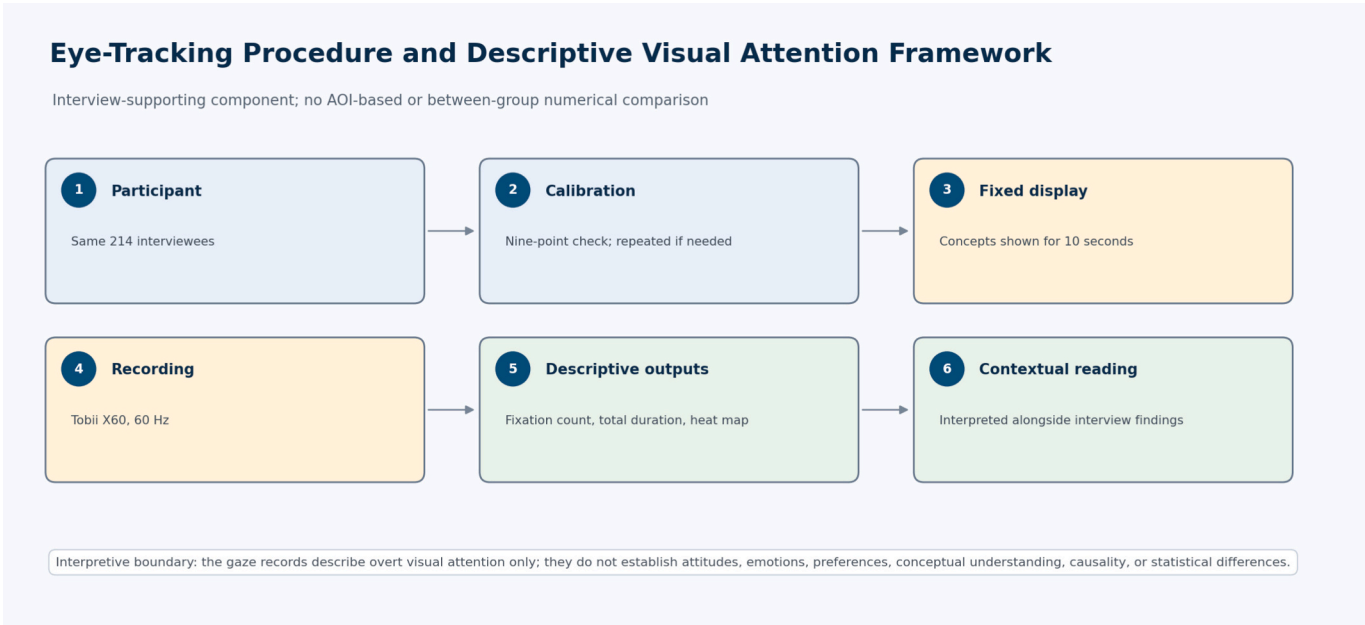
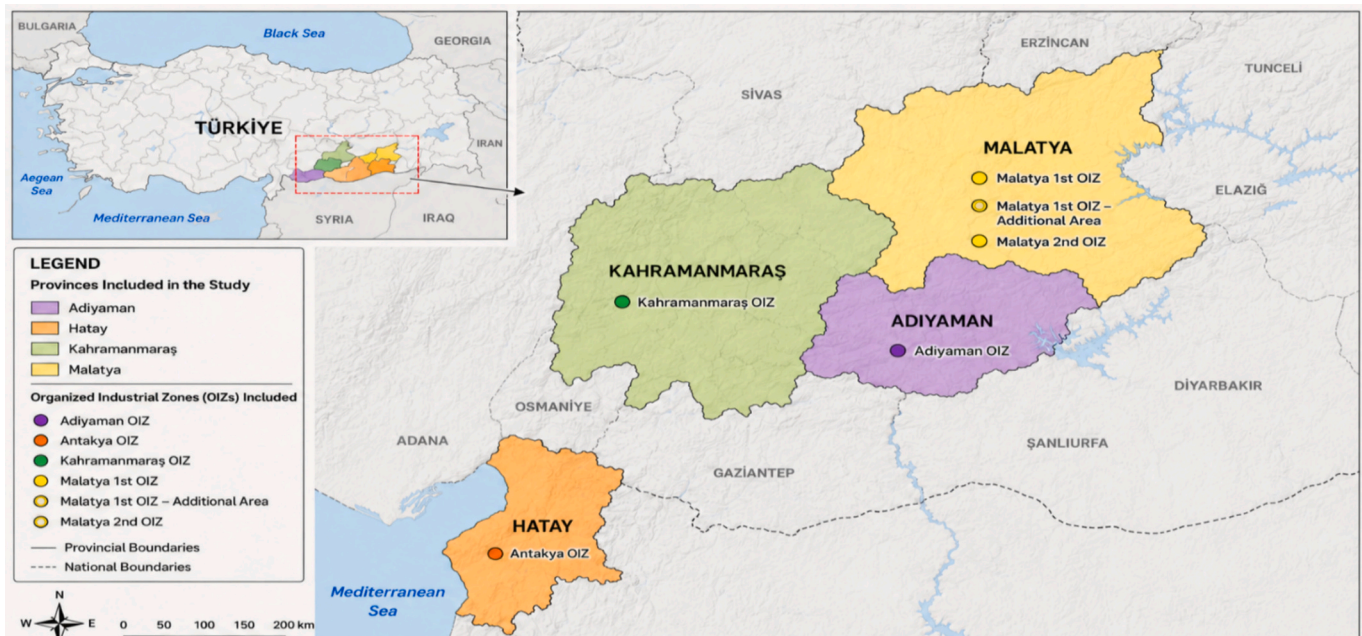


Fig. 2. Eye-tracking procedure and descriptive visual attention framework.



Eleven provinces affected by the 6 February 2023 earthquakes

Adana, Adiyaman*, Diyarbakır, Elazığ, Gaziantep, Hatay*, Kahramanmaraş*, Kilis, Malatya*, Osmaniye, Şanlıurfa

* Four study provinces; their selected OIZ cases are highlighted on the map.

Fig. 3. Earthquake-affected provinces and locations of the four study OIZ cases in Türkiye.

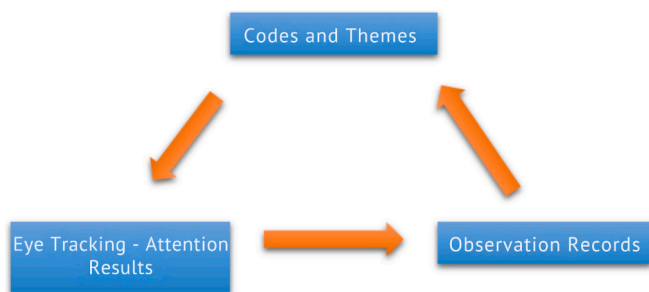


Fig. 4. Triangulation framework used in data analysis.

across the four provinces. In this context, to establish an initial sample size based on a quantitative reference, the finite population sample size formula, which is used when the population size is known, was applied [66].

The initial sample size was calculated using the following formula:

$$n = \frac{N \times t^2 \times p \times q}{[d^2 \times (N - 1) + t^2 \times p \times q]}$$

For a 95% confidence level, the calculation yielded an initial target sample of approximately 250 enterprises. This calculation was used as a benchmark for determining the scale of the fieldwork and was not regarded as the sole basis for claiming the statistical representativeness of the final sample. However, consultations with OIZ administrations before the fieldwork revealed that the existing enterprise lists did not fully reflect the current situation. Some enterprises remained on the lists despite having ceased operations, while multiple subsidiaries owned by the same enterprise owners were recorded as separate enterprises. Therefore, the lists were reassessed in collaboration with the OIZ administrations, resulting in the identification of approximately 321 enterprises considered eligible for inclusion in the field study.

Consistent with the qualitative multiple-case study design, a criterion-based purposive sampling approach was adopted for the selection of enterprises. The primary criteria for inclusion in the study were that enterprises were actively operating during the study period,

located within the OIZs included in the research, and primarily engaged in production activities.

During the fieldwork, a total of 257 of the enterprises identified for the study were contacted, and semi-structured interviews were completed with 214 enterprises. The main reasons why interviews could not be conducted with all contacted enterprises included the unwillingness of some enterprises to participate in the study and the fact that multiple subsidiaries owned by the same enterprise owners were listed as separate enterprises in OIZ records. Accordingly, the final analytical sample consisted of 214 enterprises. Table 1 presents the number of enterprises interviewed in each province and their sectoral distribution.

The interviews were conducted with enterprise representatives who had direct knowledge of the enterprises' employment structures, workforce mobility, and production processes before and after the earthquakes. Accordingly, the participants included enterprise owners/partners as well as individuals holding managerial or authorized positions, such as general managers, enterprise managers, human resources managers, production managers, and other comparable positions. Since the participants' organizational positions were not numerically coded according to a standardized classification in the field records, a quantitative distribution by position is not reported. Similarly, standardized information on enterprise size—categorized as micro, small, medium-sized, or large enterprises—was not recorded as a separate variable in the available field records. Therefore, no statistical distribution by enterprise size is reported. Consequently, the assessment of the sample was based primarily on the criteria of active operation, production orientation, and experience relevant to the research questions, rather than on enterprise size.

Sample adequacy was assessed through data saturation as well as the initial numerical benchmark. Accounts increasingly repeated themes concerning workforce loss, migration, housing, infrastructure, transportation, and production, and later interviews added little to the established categories (Charmaz, 2006, as cited in [44]). The 214-enterprise dataset was therefore considered adequate for its contextual diversity and analytical breadth. It is not claimed to statistically represent every enterprise in the four provinces.

Table 1
Distribution of the Sample by Province and Sector Group.

Province	OIZ(s) included	Enterprises (n)	Textiles & apparel	Food & agriculture	Construction materials	Metal & machinery	Other
Adıyaman	Adıyaman OIZ	50	29	6	9	2	4
Hatay	Antakya OIZ	41	4	12	11	13	1
Kahramanmaraş	Kahramanmaraş OIZ	50	32	0	6	9	3
Malatya	1st OIZ, 1st OIZ Additional Area, and 2nd OIZ	73	28	20	7	13	5
Total	–	214	93	38	33	37	13

All participants were informed about the purpose and procedures of the study before data collection, and informed consent was obtained prior to their participation in both the semi-structured interviews and the eye-tracking procedure. Ethical approval for this study was obtained from the Firat University Social and Human Sciences Research Ethics Committee. The study was reviewed and approved at the Ethics Committee meeting held on 30 May 2024 (Meeting No. 2024/11, Decision No. 10). The Ethics Committee unanimously determined that the study complied with the relevant ethical principles.

3. Data

Interview recordings were transcribed verbatim in Turkish and checked against the audio. Quotations used in the manuscript were translated into English with attention to meaning and context. The thematic component of narrative analysis focused on what participants said rather than the formal structure of their accounts [67,68]. Coding combined categories informed by the research questions with inductive codes for recurrent issues [69]. Two researchers coded manually; Python was used to organize material, verify counts, and generate descriptive summaries. For the descriptive co-occurrence networks, nodes represent recurrent terms or coded themes retained for each provincial corpus, and an edge indicates that two items occurred within the same sentence-level coding unit. Edge weight was based on the corresponding co-occurrence count and, where varied, controlled only visual prominence. Common function words, punctuation-only tokens, and duplicate variants were removed; labels were manually normalized, and only recurrent substantive items needed for a readable descriptive summary were retained. Layouts were generated in Python for legibility and carry no metric meaning; colors, where used, group related descriptive topics rather than statistically detected communities. In the simplified Kahramanmaraş map (Fig. 11), line widths are uniform and denote only the presence of a retained sentence-level co-occurrence. No network centrality, density, community-detection, or significance statistics were used. Consequently, spatial proximity or a visually stronger link is not interpreted as evidence of causal or cognitive association. Coding decisions were compared regularly and disagreements resolved by consensus; no formal inter-coder coefficient was calculated. The counted unit was a unique sentence assigned to a theme. A sentence was counted once within a theme but could enter multiple themes when it substantively addressed overlapping issues, so theme totals are not mutually exclusive.

During interpretation, interview themes and sentence-level frequencies were compared with field observations and descriptive eye-tracking material [49,65]. Gaze distribution was considered only in relation to the fixed concept locations, and heat maps supported interpretation of interviews rather than numerical ranking or between-case comparison. Convergence was treated as contextual consistency, not causality or independent validation; divergence was retained as substantively informative.

4. Findings

The findings presented in this section are based on interviews conducted with representatives of 214 enterprises operating in selected

OIZs in Adıyaman, Hatay, Kahramanmaraş, and Malatya between October 2024 and June 2025. The field data indicate that the consequences of the earthquakes extended beyond direct physical and economic damage. Participants frequently emphasized the psychosocial effects of the disaster, workforce shortages, employee migration, and disruptions to production continuity as persistent challenges during the post-earthquake period. While direct economic losses can be quantified more readily, the interviews suggest that the indirect effects of the earthquakes are more difficult to measure and may persist over a longer period. In particular, workforce migration, labor shortages, and disruptions to production emerged as interconnected factors that complicated the recovery of enterprises and the regional economy. Quotations are identified by province; participant role or enterprise sector is reported only where it could be securely linked in the field record. Missing role-sector labels were not reconstructed retrospectively, so quotation coverage by enterprise type should not be inferred.

4.1. Findings for Adıyaman Province

Adıyaman, which had a population of 635,169 in 2022, was among the provinces severely affected by the earthquakes. According to International Organization for Migration (IOM, 2023) data, approximately 465,000 people were affected, of whom around 307,000 were displaced. A total of 1485 buildings collapsed, while more than 68,000 buildings were classified as unsafe, including 6108 designated for immediate demolition. Despite the extensive damage across the province, the Adıyaman OIZ experienced relatively limited physical damage, largely because of its location and the earthquake-resistant characteristics of its buildings. Nevertheless, enterprises operating in the OIZ faced substantial post-earthquake challenges, particularly workforce shortages, which continued to affect production during the study period. Interviews with representatives of 50 enterprises operating in the Adıyaman OIZ were analyzed to examine these employment- and production-related challenges.

As summarized in Fig. 5, the most frequently identified theme was “Decrease in employment volume/half-capacity,” which appeared in approximately 90 sentences. One participant illustrated the extent of the workforce decline as follows: “There were 260 of us working here before the earthquake; now there are only around 130.” This finding indicates that the substantial decline in labor supply constituted one of the main constraints on post-earthquake production capacity.

The second most frequently identified theme was “Lack of willingness to work/Comfort provided by the Community Benefit Program (TYP),” which appeared in approximately 70 sentences. Participants frequently perceived TYP as providing a form of “guaranteed income” that reduced incentives to seek regular employment. As one participant stated, “TYP allowed them to receive an income without working; now nobody wants to come to work.”

The third theme, “Effects of housing, rent, and container accommodation” (approximately 55 sentences), highlights the close relationship between housing conditions and employment. Participants indicated that access to government-provided container accommodation and reduced housing costs could influence workers’ incentives and decisions regarding their return to regular employment.

The fourth theme, “Shift to the construction sector/Effects of

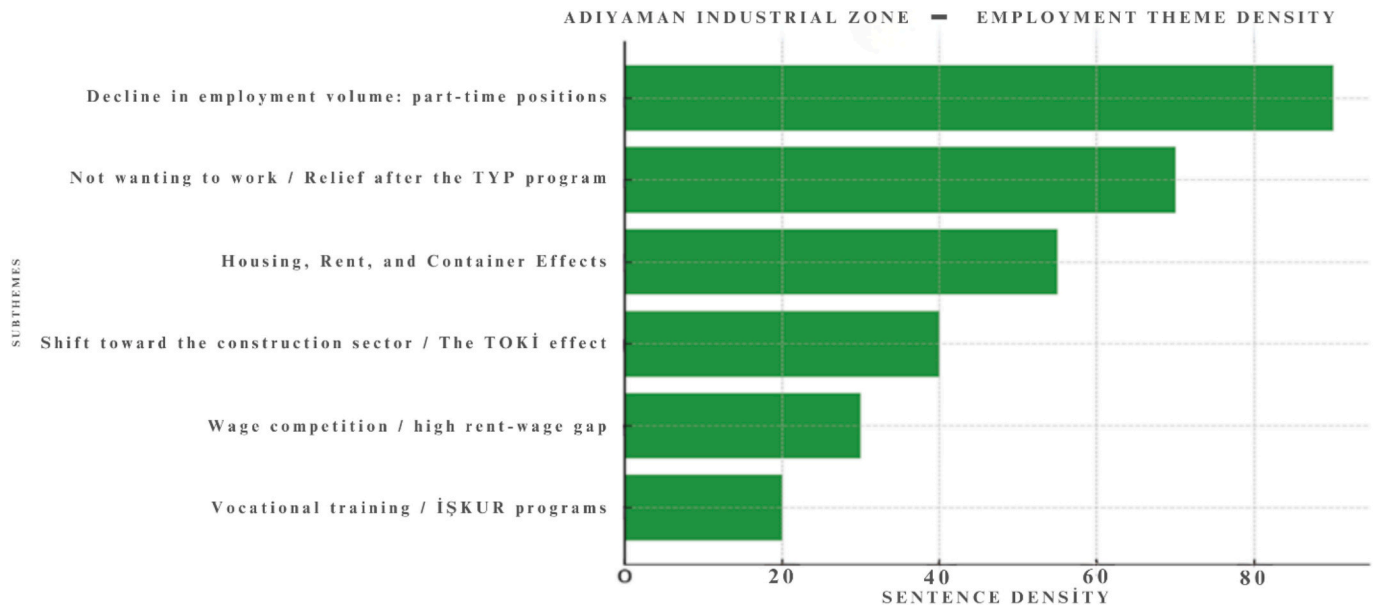


Fig. 5. Adiyaman OIZ: employment-related themes.

Housing Development Administration of the Republic of Türkiye (TOKİ) projects” (approximately 40 sentences), reflects the movement of workers from manufacturing to the construction sector. Participants associated this shift particularly with the comparatively higher short-term earnings available in TOKİ construction projects.

Two additional themes, “Wage competition and lack of incentives” (approximately 30 sentences) and “Inadequate vocational training” (approximately 20 sentences), point to broader structural challenges in the regional labor market. Participants also stated that vocational training programs provided by the Turkish Employment Agency (İŞKUR) did not adequately meet labor-market needs and that the minimum wage was insufficient relative to the post-earthquake cost of living.

The eye-tracking visualization for Adiyaman (Fig. 6) shows a dispersed pattern of visual attention across the fixed locations of the predefined concepts rather than a concentration in one part of the stimulus. This visual distribution is broadly consistent with the interview material, in which post-earthquake employment problems were described as interconnected rather than attributable to a single factor. Because no formal AOI-based or statistical comparison was conducted, the pattern is interpreted descriptively and does not establish the relative importance of individual concepts.

The accompanying thematic network likewise lacks a single dominant node and instead links several recurrent problem areas. Read

together with the descriptive eye-tracking pattern, this suggests that attention was distributed across employment, housing, infrastructure, and production concerns rather than consistently focused on one issue; it does not establish a cognitive hierarchy among these concerns.

The fixation heat map and the thematic frequency analysis therefore appear broadly consistent in depicting the Adiyaman findings as distributed across several interrelated problem areas. The substantive basis for the proposed multifaceted recovery approach, however, remains the interview and field-observation evidence concerning employment continuity, social support, housing, and infrastructure.

4.2. Findings for Hatay province

Hatay had a population of 1,686,043 prior to the earthquakes and was among the provinces most severely affected, particularly in districts such as Antakya, Kırıkhan, and Defne. Approximately 305,490 people in the province were affected by the earthquakes, of whom around 69,000 were displaced. According to official data, 215,255 buildings were classified as requiring immediate demolition, severely damaged, or completely destroyed. Hatay also represents an important manufacturing center in the region, with 23 large, 60 medium-sized, and 285 small enterprises. The province contains five OIZs, of which the Antakya OIZ was selected as the study site. The analyses presented below draw on interviews with representatives of 41 enterprises operating in the Antakya OIZ and examine the employment- and production-related challenges reported after the earthquakes.

As shown in Fig. 7, the most frequently occurring terms were “earthquake,” “factory,” “worker,” “industrial zone,” “Antakya,” and “production.” The prominence of these terms suggests that the earthquake remained a central frame of reference in participants' accounts of post-disaster production and employment conditions. This relationship between physical damage and workforce loss is also reflected in participants' accounts. As two enterprise representatives stated:

“The machines were dislodged from their places during the earthquake, but the steel structures were unharmed.”

“We can't find any workers, because most people have moved elsewhere.”

Moderately frequent terms included “electricity,” “housing,” “migration,” “transportation,” “steel,” “rent,” “infrastructure,” and “container.” Their recurrence indicates that participants' concerns



Fig. 6. Adiyaman OIZ: eye-tracking fixation heat map.

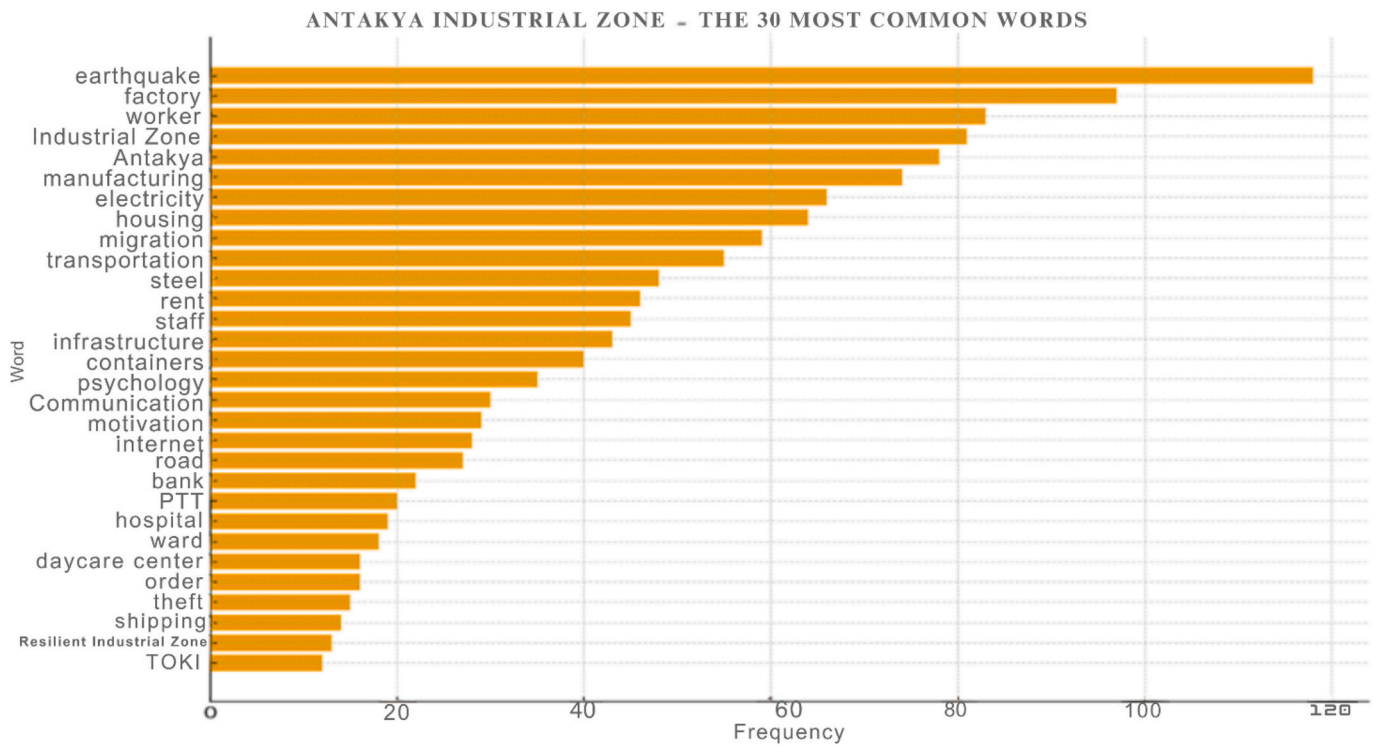


Fig. 7. Antakya OIZ: most frequent words in interviews.

extended beyond production-related issues to include living conditions, housing, and transportation infrastructure. In particular, frequent references to “container” accommodation highlight the continuing difficulties in accessing adequate housing, both across the province and in areas close to workplaces.

Other relevant but less frequently mentioned concepts included “bank,” “PTT (Turkish Postal Service),” “bus,” “nursery,” “order,” “theft,” and “earthquake-resistant OIZ.” Although less prominent, these concepts point to concerns regarding access to essential services, security, transportation, and social infrastructure during the post-earthquake recovery of the Antakya OIZ. The relatively low frequency of references to an “earthquake-resistant OIZ” may also reflect the comparatively limited physical damage sustained by the OIZ itself.

Fig. 8 shows that “Production and Infrastructure” (32%) and “Employment and Migration” (28%) were the two most prominent themes. Together, these themes demonstrate the interconnected nature of post-earthquake recovery in the Antakya OIZ: enterprises faced

continuing workforce shortages, while migration and reduced willingness to return constrained the recovery of labor supply. “Housing and Economy” (21%) emerged as an important link between these two dimensions, as rising rents and dependence on temporary container accommodation affected both workforce retention and production continuity. The “Social-Psychological” (10%) and “Governance” (9%) themes further highlight the importance of longer-term institutional resilience and improvements in social conditions.

The thematic network places the concepts “earthquake,” “migration,” “production,” and “labour force” near the centre of the web, with multiple descriptive co-occurrence links among them. The descriptive heat map in Fig. 9 displays visual concentration around corresponding predefined concepts. Read cautiously alongside the interview material, this pattern is consistent with participants’ descriptions of problems in the Antakya OIZ as mutually reinforcing rather than as a simple linear chain of cause and effect; it does not independently demonstrate the strength of those relationships.

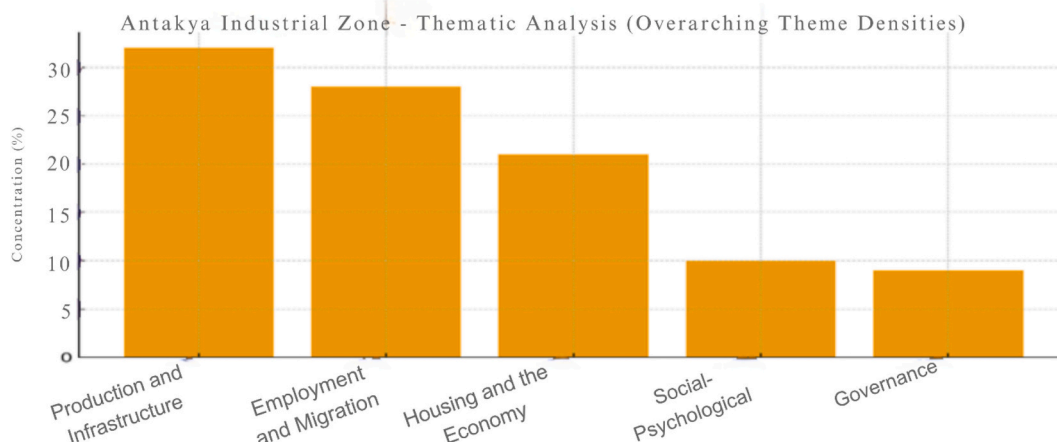


Fig. 8. Antakya OIZ: Thematic Analysis of Employment-Related Problems.



Fig. 9. Antakya OIZ: eye-tracking fixation heat map.

Participants commonly linked outmigration with lower production capacity and continuing employment difficulties. The descriptive visual pattern and the thematic frequency analysis point in a similar direction, but the inference that migration constrained production rests primarily on the recurring interview accounts rather than on the eye-tracking material alone.

4.3. Findings for Kahramanmaraş province

Kahramanmaraş had a population of 1,177,436 in 2022, prior to the earthquakes. According to the 2023 report of the Presidency of Strategy and Budget of the Republic of Türkiye, the province contained a total of 243,153 buildings, including 219,351 residential buildings and 12,358 buildings used as offices, public institutions, or for other purposes. Province-level damage assessments indicate that 99,326 buildings were severely damaged, destroyed, or designated for immediate demolition following the earthquakes. Kahramanmaraş and Hatay recorded particularly high levels of building damage compared with the other provinces examined. A preliminary damage assessment prepared by the Department of Earthquake Engineering at Boğaziçi University further reported that approximately 40% of the buildings in Kahramanmaraş were either destroyed or substantially damaged.

Kahramanmaraş is an important manufacturing center, particularly in the textile and apparel industries, with a production value exceeding USD 300 million. As of 2023, the Kahramanmaraş OIZ included 55 large, 92 medium-sized, and 301 small enterprises. The analyses presented below draw on interviews with representatives of 50 enterprises operating in the Kahramanmaraş OIZ and examine the employment- and production-related challenges reported after the earthquakes.

The keyword frequencies shown in Fig. 10 and the simplified descriptive map in Fig. 11 display recurring production, workforce, and

living-condition subthemes. Fig. 11 retains selected substantive terms only and is not a complete lexical network. Its links indicate the presence of sentence-level co-occurrence, not magnitude, causal importance, or a formal hierarchy. Read with the interviews, the pattern shows that production and workforce issues were often discussed within the same sentence-level units.

5. Employment and social dimensions

The retained labor-related terms form a descriptive cluster around workers, skills, and wages, while housing, containers, TOKİ, and transportation appear as a separate but connected set of living-condition concerns. This co-occurrence pattern is consistent with interview accounts linking skilled-worker retention to both employment conditions and everyday access constraints; it does not quantify the strength of those relationships.

6. Employment-related themes

Fig. 12 summarizes the thematic distribution and demonstrates the prominence of employment-related challenges in participants' post-earthquake accounts.

“Employment Volume (Numbers)” (≈290 Sentences).

“Employment Volume” was the most frequently identified theme, appearing in approximately 290 sentences. Participants repeatedly referred to declines in workforce numbers and to the limited return of employees following the earthquakes. These accounts indicate that, although production had partially recovered by the time of the field-work, employment levels in many enterprises remained below their pre-earthquake levels. As one enterprise representative explained: “We were unable to bring all of our employees back. Around ten to fifteen people left after the earthquake. Some had heavily damaged homes and were living in rented accommodation, so they preferred to stay outside the city. We had twenty-five employees before; now we have fifteen.” (Enterprise representative, Kahramanmaraş)

This pattern was not limited to smaller enterprises. A human resources manager from a large textile enterprise described a substantial initial decline in employment followed by a gradual but incomplete recovery: “We had approximately 1,400 employees before the earthquake. When we resumed operations after the earthquake, the number was around 700–800, and during the first week only about 200–300 employees returned to work. We have now recovered to approximately 1,200 employees.” (Human Resources Manager, textile sector, Kahramanmaraş).

“Loss of skilled workforce/migration/transfer” (≈120 sentences).

“Loss of skilled workforce/migration/transfer” appeared in approximately 120 sentences and emerged as another major employment-

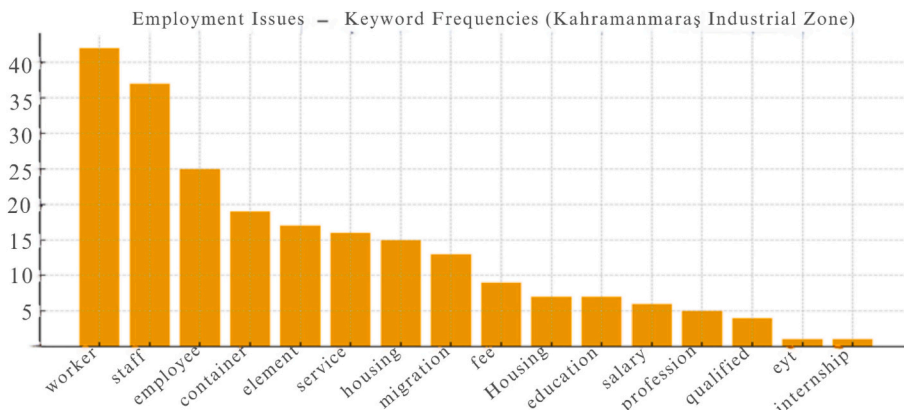


Fig. 10. Kahramanmaraş OIZ: keyword frequencies.

Kahramanmaraş OIZ: Selected Recurrent-Term Co-occurrence Map

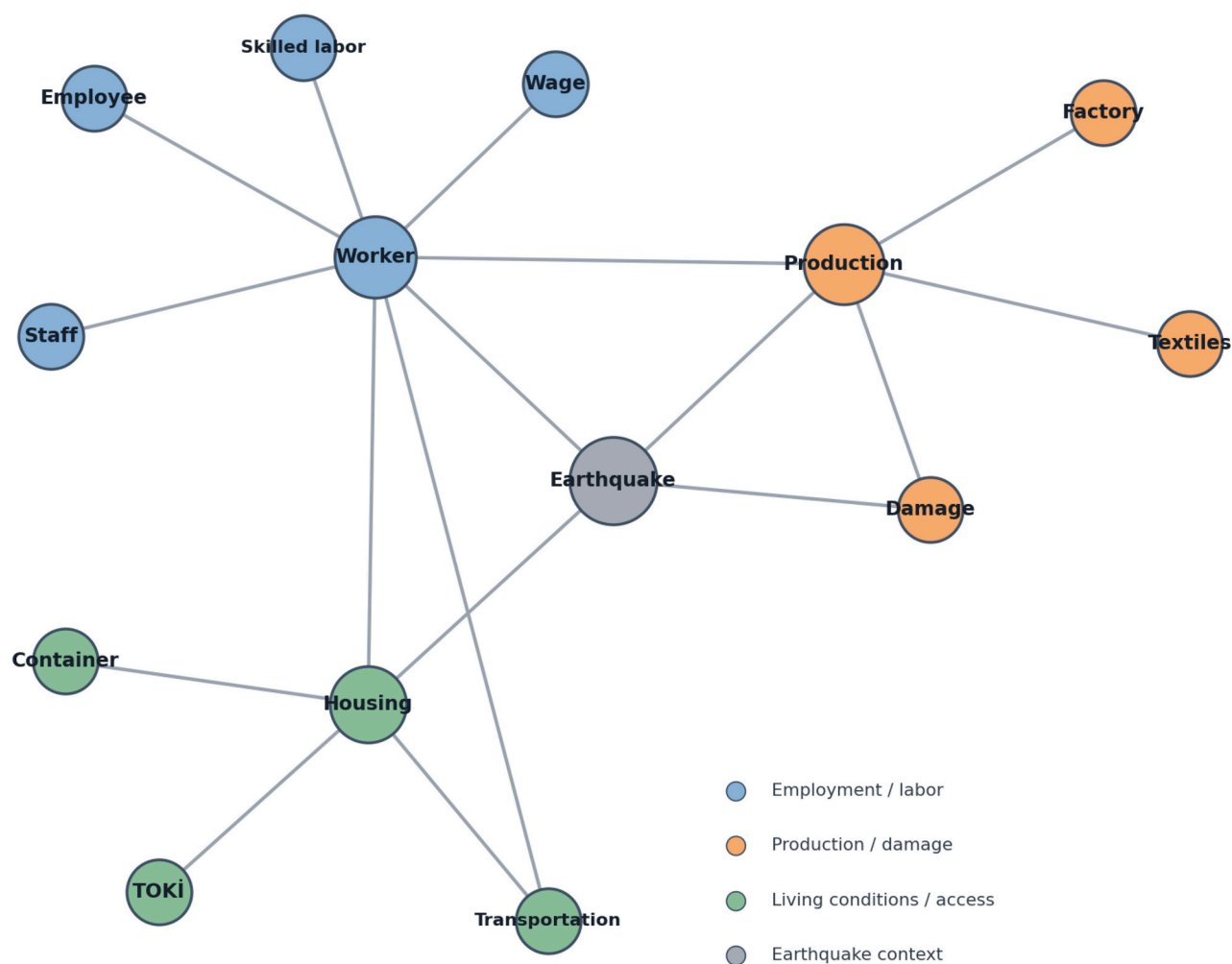


Fig. 11. Kahramanmaraş OIZ: selected recurrent-term co-occurrence map.

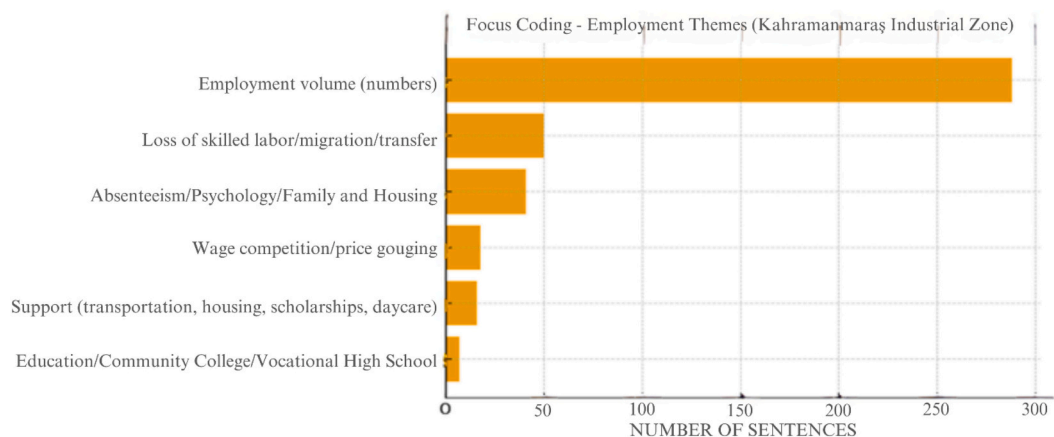


Fig. 12. Kahramanmaraş OIZ: Employment-Related Themes.

related theme. Participants frequently referred to the migration of skilled workers from the region and their movement to larger enterprises offering more favorable employment conditions. The outmigration of younger and technically skilled employees was perceived by

participants as a significant challenge to the long-term recovery of production capacity.

“Absenteeism/psychology/family-housing” (≈80 sentences).

The theme “Absenteeism/psychology/family-housing,” identified in approximately 80 sentences, reflects the continuing social and psychological dimensions of workforce disruption. Participants associated absenteeism with inadequate housing, family responsibilities, and psychological difficulties experienced after the earthquakes. These accounts indicate that employment continuity was influenced not only by workplace conditions but also by workers' broader post-disaster living and family circumstances.

The descriptive eye-tracking visualization for the Kahramanmaraş OIZ (Fig. 13) shows how visual attention was distributed across the predefined concepts presented in the stimulus.

Read alongside the thematic network, the fixation heat map displays visual concentration around migration, workforce loss, and production-related content. This is interpreted only as a descriptive attention pattern. In the absence of a formal AOI-based or statistical comparison, it is not treated as evidence of a cognitive hierarchy or a causal structure.

The most visible concentration in the heat map appears around the predefined “outward migration” concept region. In the interviews, migration was described not only as an effect of the earthquake but also as a factor associated with delays in the production chain, reduced capacity, and lower employment levels. The heat map does not establish that outward migration was more important than the other concepts; it provides a descriptive visual context for this recurring interview theme.

Secondary concentrations of visual attention appear around “Workforce loss and production,” “Delays to the production chain,” and “Infrastructure limitations.” Their proximity to the migration-related attention cluster is consistent with the qualitative finding that participants frequently connected production difficulties with human-capital loss as well as with physical and infrastructural disruption.

6.1. Findings for Malatya province

Malatya had a population of 812,580 in 2022. According to 2021 data, the province contained 345,536 residential buildings. Following the earthquakes, 71,519 buildings were classified as requiring immediate demolition, severely damaged, or completely destroyed, while 107,765 residential buildings sustained minor damage.

Malatya has three OIZs. The province's manufacturing sector comprises 7 large, 43 medium-sized, and 194 small enterprises. Fieldwork was conducted in the 1st OIZ, the 1st OIZ Additional Area, and the 2nd OIZ. Field observations indicated that the production facilities examined had sustained relatively limited physical damage from the earthquakes. The infrastructure, spatial layout, and structural characteristics of the buildings appeared to have contributed to limiting physical damage within the OIZs. The analyses presented below draw on interviews with representatives of 73 enterprises operating in these OIZs and examine the employment- and production-related challenges reported after the

earthquakes.

As summarized in Fig. 14, the interview findings show that the relatively limited physical damage to production facilities did not prevent significant disruptions caused by workforce loss. One enterprise representative described the direct relationship between skilled labor migration and production capacity as follows: “When a skilled employee migrates or leaves the enterprise, the machine operated by that employee stops, and consequently production is disrupted. At one point, we had lost approximately 75% of our capacity and were operating at only about 25%. Recruiting and training new employees to replace them took time.” (Enterprise representative, Malatya).

The descriptive heat map for Malatya (Fig. 15) displays visual concentration around “Workforce Loss and Production,” while attention appears more dispersed across the remaining predefined concepts. “Outmigration,” “Reverse Migration Potential,” and “Earthquake Resistant Buildings” are also visible in the distribution. Read alongside the interviews, this pattern provides descriptive context for participants' accounts linking workforce loss with infrastructure and production-chain difficulties and for their references to return and rebuilding. It is not used to rank the concepts statistically or to infer attitudes independently of the interview data.

Table 2 brings the four cases together and shows that labor-market disruptions following the earthquakes were common across all four provinces, although the nature and severity of these challenges varied across provinces. While labor shortages and migration emerged as shared regional challenges, the findings indicate that post-disaster recovery requires province-specific employment and workforce-retention policies rather than a uniform regional intervention.

7. Discussion

The findings show that employment and production disruption in OIZs cannot be explained by physical damage alone. Workforce loss, outmigration, housing shortages, transportation and infrastructure problems, wage competition, and limited skilled labor interacted across the four provinces. This accords with evidence that indirect losses persist through infrastructure, inputs, and business-continuity constraints [23,28–30] and with broader accounts of disaster costs and resilience [4,14]. The present cases add that workers' capacity to remain or return can constrain recovery even when industrial structures are usable.

The comparative analysis nevertheless reveals distinct provincial configurations. Adıyaman was marked by labor shortages, under-capacity production, housing problems, and competition from construction employment; Hatay by outmigration, housing, transportation, and return difficulties; Kahramanmaraş by the loss of skilled workers and production-chain disruption; and Malatya by relatively stronger expectations of return and reconstruction. Such variation is consistent with evidence that labor-market and migration responses differ by exposure, sector, and local opportunity [7,17,19,20,41]. Accordingly, the resilient-OIZ proposal is a shared regional framework, not an identical prescription: its priorities should reflect the conditions of each province.

The study contributes to industrial-resilience research by connecting production recovery, workforce mobility, housing, and social infrastructure. Previous studies have often examined physical and macro-economic loss separately from labor adjustment and migration [7,11,12,70,71]. Enterprise-level evidence from the four OIZs instead supports a multidimensional view in which structural, human, operational, institutional, and social capacities interact. This extends resilience beyond restoring productive assets to include the conditions required for workforce retention and return.

Read through a vulnerability lens, the results suggest that post-disaster industrial capacity is relational. A plant may remain operable, yet effective capacity can decline when workers cannot secure housing or reach the workplace. Vulnerability thus arises from the interaction between exposure and resources for absorbing disruption, not from

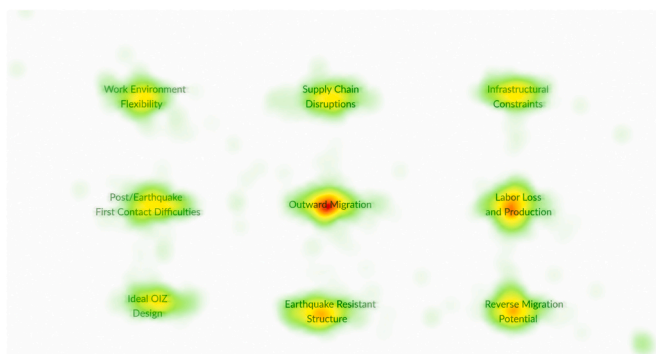


Fig. 13. Kahramanmaraş OIZ: Eye-Tracking Fixation Heat Map.

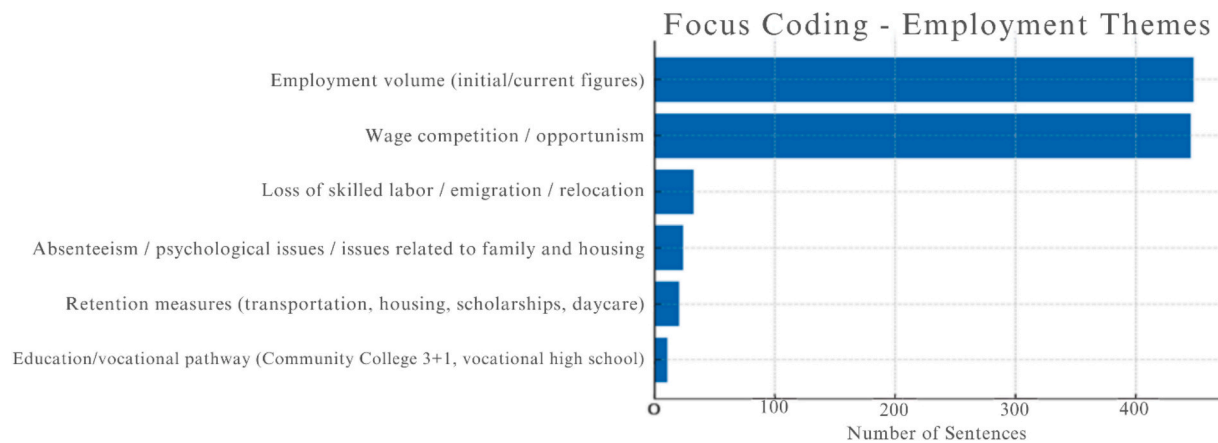


Fig. 14. Malatya OIZ: employment-related themes.



Fig. 15. Malatya OIZ: eye-tracking fixation heat map.

physical damage alone [1,2]. Across the cases, housing and mobility constraints were repeatedly connected to labor availability and production continuity. Although the evidence does not establish a single causal sequence, measures addressing only one component may leave connected constraints unresolved.

The provincial differences also show why return migration should not be assumed to follow automatically from reconstruction. Employment may encourage return, but decisions also depend on housing security, services, family needs, and confidence in local recovery. This accords with studies treating post-disaster mobility as an outcome of institutional and household conditions [19–21]. Malatya's relatively stronger return expectations, compared with the persistent mobility difficulties described in Hatay, illustrate this conditionality without proving that one recovery pathway is superior. The policy implication is coordination: employment incentives become more credible when housing, transport, education, and basic services recover alongside production. The resilient-OIZ proposal is therefore framed as a locally adapted coordination mechanism rather than a stand-alone construction project.

For OIZ planning, structural safety remains necessary but does not by itself retain or attract workers. Participants linked workforce continuity to secure housing, transportation, social infrastructure, services, and employer support. This parallels studies in which employment, housing assistance, restored infrastructure, services, and community ties jointly shape return and recovery [21,22] and evidence connecting re-employment with business and community recovery in Nurdagi [42]. The findings therefore support considering OIZs as integrated production-and-living systems, while recognizing that the relative importance of these components varies locally.

The findings also point to persistent shortages of skilled labor and to the importance participants assigned to cooperation among OIZs,

vocational high schools, technical colleges, and employment institutions. The Community Benefit Program (TYP) was frequently discussed, particularly in Adiyaman and Malatya, and some participants perceived it as competing with manufacturing for a limited workforce. This perception-based finding does not establish a causal effect of TYP on labor supply.

Housing and social facilities in or near OIZs should not be treated as a universal solution. Financing, governance, land use, eligibility, security, and worker dependence require safeguards; unequal access, rising land values, and the persistence of substandard temporary housing are also risks. Eligibility rules should consider household need and duration of residence without making housing security contingent solely on continued employment. Implementation therefore requires a flexible framework, clear responsibilities among governments, OIZ administrations, and firms, and adaptation to provincial conditions. Sustainable industrial recovery depends on rebuilding production together with the social and spatial conditions that enable people to work, remain, and return.

8. Conclusion

Across the four selected OIZ cases, the earthquakes disrupted employment through a combination of direct damage, workforce migration, housing and transport difficulties, infrastructure interruptions, and shortages of skilled labor. These pressures were shared, but their configuration varied: Adiyaman was marked by under-capacity production and competition from construction and temporary employment; Hatay by outmigration, housing, and transport constraints; Kahramanmaraş by skilled-worker loss and production-chain disruption; and Malatya by relatively stronger expectations of return. The findings therefore support a common regional framework but not a uniform intervention or generalization to all earthquake-affected industrial areas.

The policy implication is that restoring factories should be coordinated with secure housing, transport, basic services, vocational training, and business-continuity arrangements. Participants' accounts also suggest that the Community Benefit Program (TYP) should be aligned more closely with regional industrial labor needs. This perception-based result does not establish that TYP caused manufacturing labor shortages; it indicates a need to monitor whether temporary public-employment programs unintentionally compete with recovery-critical sectors and, where appropriate, to design transition mechanisms into regular OIZ employment.

The resilient-OIZ proposal should consequently be understood as a flexible planning framework rather than a standardized residential model. Implementation requires clear responsibilities for central and local government, OIZ administrations, and firms, together with

Table 2
Comparative Overview of Employment-Related Challenges Across the Four Provinces.

Employment-related issue	Adıyaman	Hatay	Kahramanmaraş	Malatya
Labor shortage	Very high – sharp decline in employment levels; enterprises operating at approximately half capacity.	High – labor shortages caused production interruptions and difficulties in maintaining operations.	Very high – employment levels remain substantially below pre-earthquake levels.	High – employment levels remain a major concern despite partial recovery in production.
Loss of skilled labor	Skilled workers shifted particularly toward higher-paying employment in construction and TOKİ projects.	Migration contributed to the loss of workers, including skilled personnel.	The loss and migration of skilled and technical personnel emerged as one of the most critical concerns.	Skilled labor loss, migration, and transfers to other enterprises emerged as major employment-related concerns.
Outmigration	Workforce loss and outmigration were closely associated with reduced production capacity.	Central issue – outmigration was perceived as a major factor contributing to employment and production problems.	Central issue – migration was perceived as a major factor contributing to declining employment and production.	Migration was an important concern but was perceived as more reversible than in Kahramanmaraş and Hatay.
Housing problems	Container accommodation, rent levels, and housing conditions were associated with workers' willingness to work.	Rising rents, temporary container accommodation, and access to housing near workplaces affected employment continuity.	Housing shortages, family responsibilities, and accommodation problems contributed to absenteeism.	Post-earthquake housing shortages and rising costs strongly affected workforce retention and employment continuity.
Wage competition	Manufacturing enterprises competed with higher-paying employment opportunities in construction and TOKİ projects.	Economic pressures accompanied migration and labor scarcity.	Enterprises competed for a limited supply of workers and frequently offered wages above the minimum wage.	Wage competition and rising costs emerged as prominent employment-related concerns.
Transportation problems	Infrastructure limitations were present but comparatively less prominent.	Transportation and infrastructure emerged as recurrent concerns.	Enterprises used employee transportation services as a workforce-retention mechanism.	Limited transportation to OIZs increased enterprises' dependence on employer-provided transportation services.
Psychological/social factors	Uncertainty, social vulnerability, and changing work motivation affected labor participation.	Social and psychological issues emerged as a distinct thematic category.	Trauma, family responsibilities, and psychological difficulties contributed to absenteeism.	Psychological and family-related concerns continued to affect attendance and workforce retention.
Production disruptions	Labor shortages resulted in reduced production capacity and idle machinery.	Production was temporarily halted or reduced because of labor shortages.	Workforce loss was associated with production-chain delays and reduced capacity.	Workforce loss, infrastructure limitations, and production-chain delays remained interconnected.
Vocational training needs	Vocational schools and İŞKUR training programs were perceived as insufficient to meet workforce needs.	Vocational training needs were less prominent than migration, housing, and infrastructure issues.	Participants emphasized the long-term need for vocational high schools, technical colleges, and the development of a skilled workforce.	Strengthening the transition from vocational education to employment emerged as an important long-term labor-market need.
Perceived reverse migration potential	Recovery was characterized more by continuing vulnerability and uncertainty than by expectations of return migration.	Reverse migration was considered important for the future recovery of production.	Migration was more frequently perceived as permanent, particularly among skilled workers.	Participants expressed cautious but comparatively stronger expectations of workforce return and regional rebuilding.

safeguards concerning finance, land use, housing eligibility, security, and worker dependence. Future research could test these relationships across additional OIZs using longitudinal employment and return-migration data.

CRedit authorship contribution statement

Haluk Yaman: Funding acquisition, Data curation. **Ertuğrul Buğra Orhan:** Software, Resources. **Nil Çokluk:** Writing – original draft. **Murat Sezik:** Conceptualization. **Ahmet Hikmet Zabun:** Project administration.

Ethics statement

This study was conducted in accordance with ethical standards.

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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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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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