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Article

Social sustainability and labor risk governance in Türkiye's construction sector: Evidence from social security data and prevention through design implications (2014–2024)

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Abstract: Social sustainability in high-risk labor sectors requires more than regulatory compliance. It depends on governance that can identify where severe and fatal occupational risks concentrate. This study examines Türkiye's construction sector between 2014 and 2024 using national social security data, assessing how accident burden, permanent disability, and fatal outcomes are distributed across construction subsectors. Drawing on Social Security Institution (SGK) records, the analysis evaluates occupational accident frequency, permanent disability, and fatal accident indicators from a policy-oriented, Prevention through Design-informed perspective. The contrast is notable. Although construction accounts for an average of 11.98 % of total insured employment, it produces 31.94 % of fatal occupational accidents, a fatal risk burden roughly 2.7 times its employment share. This burden is concentrated in the Construction of buildings subsector, where the share of sectoral fatalities rose from 51.90 % in 2014 to 63.04 % in 2024. Such patterns are shaped by informal employment, organizational fragmentation, subcontracting, macroeconomic shocks, and the spatial organization of worksites. By showing how social security data can reveal labor risk inequalities, the study contributes to sustainable social development research. It also demonstrates that data-based labor risk governance, read together with a Prevention through Design lens, is necessary for building equitable, targeted, and preventive occupational health and safety policy.

Keywords: social sustainability; sustainable social development; labor risk governance; labor risk inequality; social security data; occupational health and safety; Prevention through Design; Türkiye

1. Introduction

The construction sector carries a risk burden out of proportion to its size. It employs only a modest share of the global workforce, yet accounts for a disproportionately high share of occupational accidents and fatalities, with substantial human and economic costs [1]. The gap is clearest in industrialized countries, where construction makes up just 6 to 10 % of employment but is responsible for 25 to 40 % of fatal occupational accidents [2]. This pattern has been documented consistently across national contexts. As Lingard [3] observes, its persistence over decades reflects not merely weak regulation but deep-rooted features of the sector, including project-based organization, labor fragmentation, and the temporary nature of worksites, that repeatedly give rise to hazardous conditions. International data likewise show that accident rates in construction exceed the average for other sectors [4], and the sector is widely treated as a high-risk environment [5–7].

These accidents are not only isolated safety incidents. They also signal systemic disparities that bear directly on sustainable social development. The persistent and disproportionate burden of fatal and disabling injuries among construction workers points to unmet goals of decent work, labor equity, and safe working conditions, all central to sustainable development. Seen this way, social security data is more than administrative records. They offer an empirical basis for detecting inequalities in occupational risk, assessing governance performance, and guiding targeted, evidence-based policy. Linking these data to Prevention through Design frameworks can shift the focus from reactive accident monitoring toward a more proactive and socially responsive model of occupational health governance.

This high level of risk primarily stems from the combination of unsafe worker behaviors and unsafe working conditions [8]. However, occupational accidents cannot be explained solely by individual errors; rather, they should be understood within a multidimensional risk structure shaped by informal employment, precarious working conditions, labor force characteristics, and macro-level crises such as COVID-19 [9,10]. Supporting this perspective, Hoła and Nowobilski [11] show that enterprise structure and staff turnover are among the most significant determinants of accident rates in the construction industry. Their findings further indicate that production volume and macroeconomic decisions measurably affect the number of workers injured at construction sites, suggesting that accident risk is rooted in the sector's economic environment rather than arising solely from individual behavior.

In small-scale enterprises, low levels of institutionalization and inadequate occupational health and safety practices are among the key factors contributing to increased accident rates [12]. Vinberg [13] further confirms that, compared with larger enterprises, small-scale enterprises consistently exhibit higher occupational accident rates and poorer safety performance, attributing this pattern to limited financial resources, insufficient OSH inspections, the manager's limited interest in safety issues, and the absence of employee representation. In addition, characteristics of the labor force further increase the level of risk in the sector. In particular, migrant workers are often employed in more precarious jobs characterized by low wages, long working hours, and adverse working conditions, which increases their risk of occupational accidents [14]. A systematic review and meta-analysis by Lau et al. [15] confirms that migrant workers face a significantly higher risk of fatal workplace injury than local workers, a disparity attributed not to health differences but to structural determinants including precarious employment, inadequate safety protection, lower language proficiency, and undocumented employment status.

Construction activities have a complex production structure due to interdependent contractors and simultaneously conducted operations, and this raises the level of risk within the sector [5]. Romero et al. [16] show that construction activities are especially susceptible to occupational accidents because of the complexity and diversity of tasks carried out simultaneously or successively on the same site, and that subcontracting and the constantly changing nature of the work environment make systematic safety management difficult to achieve. In addition, employees are simultaneously exposed to multiple physical risks such as adverse weather conditions, high noise levels, working at heights, and chemical exposure [17]. Recent studies on these layers of physical risk report that falls from height, material handling, and the use of heavy machinery are the most frequently documented hazards across many sub-activity groups in the construction sector [18]. The NACE 41, 42, and 43 subgroups examined in this study represent fields of activity exposed to these hazards at different levels of intensity. Accordingly, subsectoral differentiation in overall accident frequency (AFI_1), permanent disability frequency (AFI_2), and fatal accident frequency (AFI_3) is analyzed in Section 3 and discussed in Section 4.

When this globally defined hazard pattern is examined in Türkiye's construction sector, sectoral risk concentration displays a similar structure. During the 2014–2024 period, although the sector's average share of insured employment was 11.98 %, its share of fatal occupational accidents remained at nearly three times this level, indicating a pronounced concentration of accident severity within the sector. This finding is consistent with the internationally documented pattern; Eurostat data indicate that the construction sector accounted for approximately 24 % of all fatal occupational accidents in the EU in 2023, a share substantially exceeding its proportion of total employment [19]. This disproportionate concentration is also consistent with previous national studies conducted in Türkiye [20,21]. It also shows that occupational accidents in the construction sector are distinguished from those in other sectors not only in terms of numerical concentration, but also with respect to their severe consequences [12].

The economic crisis has been shown to reduce occupational injury rates most markedly in the construction and industry sectors, a pattern attributed not to genuine safety improvements but to a form of labor market natural selection whereby economic contractions disproportionately eliminate the most vulnerable workers from employment [22]. This sensitivity of raw accident counts to macroeconomic conditions shows why occupational health and safety performance should be evaluated through exposure-normalized frequency indicators and within an international comparative framework.

Recent studies on Türkiye's construction sector have examined occupational safety and health through worker-level and organizational perspectives, focusing on safety leadership, employee morale, safety performance, and workplace stress among construction professionals [23,24]. Building on this body of literature, the present study shifts the analytical focus toward the population-level distribution of accident burden and severity across NACE Rev. 2 subsectors, complementing existing worker-level research with a subsectoral view of risk and intervention priorities.

Within this framework, the study aims to establish the structural risk profile of the sector from 2014 to 2024 by calculating AFI_1, AFI_2, and AFI_3 across NACE Rev. 2 subsectors using Social Security Institution (SGK) data [25], and to evaluate its international position through comparison with datasets from the ILOSTAT database of the International Labor Organization [26], the Bureau of Labor Statistics [27], and Eurostat [28]. In addition, the study offers an interdisciplinary perspective by examining the relationship between the accident pattern concentrated in the Construction of buildings segment (NACE 41) and spatial organization and work area layout.

2. Materials and methods

2.1. Data sources

This study draws on four main data sources. The primary source for Türkiye is the Statistical Yearbooks published by the Social Security Institution (SGK) for the period from 2014 to 2024. Despite the structural limitations of accident reporting systems in the construction sector, Bilir and Gürcanli [29] note that existing macro-level data provide an indispensable basis for understanding sectoral trends and for developing proactive occupational health and safety strategies. The ten-year dataset used here serves exactly this purpose, tracking how risk shifts across the sector over time. During the data collection process, data corresponding to NACE codes were compiled on an annual basis from the “Occupational Accidents and Occupational Diseases Statistics” and “Insured Persons and Workplaces Statistics” sections for the relevant years, resulting in a complete annual database. Each year, independent cross-validation was performed during the compilation process; any discrepancies identified were rechecked against the original tables in the respective yearbooks to ensure data integrity [25].

For the purposes of the analyses, the construction sector was defined as the aggregate of codes 41 (Construction of buildings), 42 (Civil engineering; hereafter referred to as ‘Non-building structures’ to emphasize the physical distinction from building construction), and 43 (Specialized construction activities) in the NACE Rev. 2 classification. This definition covered the three subsections under Section F (Construction) in Eurostat’s NACE Rev. 2 classification, and the same classification system was also used in SGK statistics [30]. Data corresponding to these NACE codes were extracted separately from SGK tables, and the analyses were conducted on the basis of the aggregated values. Employment data were obtained from the tables under the heading “Insured Persons and Workplaces Statistics.” For the national total, compulsory active insured persons within the scope of Article 4/1(a) were used, whereas for the construction sector, the aggregate of the relevant NACE codes was taken as the basis. Data on occupational accidents, permanent disability, and fatal occupational accidents were compiled from the relevant tables published under Law No. 5510. The analyses directly used both the national totals for Türkiye and the aggregate values of NACE codes 41, 42, and 43 for the construction sector. Although the International Labor Organization (ILO) recommends calculating accident rates based on total hours worked, total hours worked for the NACE 41, 42, and 43 subsectors are not regularly available for each year in SGK data for Türkiye. The number of insured employees was therefore used as the denominator, with indicator-specific multipliers applied as detailed in Section 2.2. This choice preserves the longitudinal consistency of the trend analysis for 2014 to 2024 and enables consistent comparisons within the national dataset. This approach may introduce a potential exposure bias: subsectors characterized by longer average working hours per employee (e.g., NACE 42 infrastructure works involving continuous or shift-based schedules) may have their frequency indicators relatively underestimated compared with subsectors operating closer to standard working-time norms. As a transparency measure, the annual AFI values presented in Section 3.5 allow readers to assess year-to-year variability directly. The consistently elevated construction-to-national ratios across all three indicators throughout the decade indicate that the main conclusions are robust to plausible variation in the choice of denominator.

The second data source used for international comparisons was obtained through Data Explorer, the online interface of the ILOSTAT database of the International Labor Organization (ILO). The dataset "Fatal occupational injuries per 100,000 workers by economic activity – Annual" was used, and the category "construction" was selected within the economic activity classification to obtain fatal occupational accident frequency values for the construction sector across countries. Country selection was based on two criteria: (1) the uninterrupted availability of fatal occupational accident frequency data for the construction sector in the ILOSTAT database for the period from 2014 to 2024; and (2) the inclusion of at least one country from each income group according to the World Bank income classification [31], including high income countries (Norway, Finland, Germany, and the United States), upper middle income countries (Argentina, Romania, and Panama), and a middle income country (Moldova). The countries selected based on these criteria are presented in Section 3.6 [26].

For the third data source, because data for the United States were unavailable in the ILOSTAT database for certain years (2019, 2020, 2021, and 2024), the missing years were supplemented using the Census of Fatal Occupational Injuries (CFOI) database of the Bureau of Labor Statistics (BLS) to preserve the continuity of the time series. Methodological compatibility between the two datasets was verified. To ensure comparability with the other datasets, the values obtained from BLS were first normalized to a frequency format per 100,000 employees and then rescaled to 1,000,000 employees in line with the common standard adopted in this study before being incorporated into the analysis [27].

As the fourth data source, the European Statistics on Accidents at Work [28] database, published by Eurostat, was used. This dataset presents occupational accident statistics for European countries within a standardized methodological framework and was included in the analysis to enhance the international comparability of fatal occupational accident indicators. Since fatal accident rates in the Eurostat database are defined per 100,000 employees, all values were rescaled to a per 1,000,000 employees' basis to ensure consistency with the other datasets used in this study. Eurostat data also served as a reference for checking the trend consistency of findings obtained from the ILOSTAT dataset [28].

All national and international online datasets used in this study (SGK, ILOSTAT, BLS, and Eurostat) were accessed between 19 March and 1 April, 2026.

2.2. Calculation of accident indicators

In this study, the calculation of occupational accident frequency and severity indicators was based on the concepts and definitions established in the ILO Resolution concerning statistics of occupational injuries resulting from occupational accidents [32]. The overall accident frequency indicator (AFI_1) represents the number of occupational accidents per 100,000 employees per year; the permanent disability frequency indicator (AFI_2) represents the number of permanent disability cases per

1,000,000 employees per year; and the fatal accident frequency indicator (AFI_3) represents the number of deaths per 1,000,000 employees per year. The mortality rate (MR) was also calculated as the number of deaths per 100,000 employees and was used to monitor the ten-year trend.

AFI_1 = (Number of occupational accidents / Number of employees) × 100,000

AFI_2 = (Number of permanent disability cases / Number of employees) × 1,000,000

AFI_3 = (Number of deaths / Number of employees) × 1,000,000

MR = (Number of deaths / Number of employees) × 100,000

In the ILO [32] methodology, the denominator for the calculation of AFI_2 and AFI_3 is defined as total hours worked. However, since sector-specific data on total hours worked are not published in Türkiye's SGK statistics, the number of employees was used as the denominator for all indicators in this study. Similar studies on the construction sector in Türkiye have also adopted the same approach [33,34]. The incidence rate for AFI_1 was calculated per 100,000 employees, in accordance with the methodology adopted by ILOSTAT [35], the United Nations SDG 8.8.1 official metadata [36], and Eurostat's ESAW methodology [37]. The multiplier of 1,000,000 adopted for AFI_2 and AFI_3 serves to prevent decimal values given the low absolute frequency of permanent disability and fatal outcomes, and is consistent with the approach used in similar Turkish construction sector studies [33,34]. The mortality rate (MR), unlike AFI_3, uses a 100,000 multiplier and thus facilitates direct comparison with international databases [35–37]; it was therefore used alongside AFI_3 to monitor the ten-year trend. For international comparisons, AFI_3 fatal accident frequency values reported per 100,000 employees in the ILOSTAT, BLS, and Eurostat (ESAW) datasets were multiplied by 10 (i.e., converting from a per 100,000 to a per 1,000,000 basis) to align them with the 1,000,000 employee standard adopted for AFI_3 in this study.

2.3. Scope and limitations

SGK statistics cover only registered employment under Article 4/1(a), while informal workers, migrant workers, and employees working in workplaces that do not regularly pay insurance premiums remain outside the scope of the data. Within the overall pool of informal employment in Türkiye, the construction sector accounts for a 7.8 % share in the sectoral distribution of employment [38]. This suggests that precarious working practices, which are concentrated in the sector by its very nature, are only partially reflected in official accident and fatality data. The restriction of occupational accident statistics in administrative record systems to wage-earning employees leads to the substantial exclusion of informal sector workers, while underreporting remains a universal problem even where reporting systems are in place [39]. Based on estimates reported in the literature, underreporting rates in construction sector occupational accidents generally range between 20 % and 40 %, suggesting that the AFI values presented in this study should be interpreted as conservative lower-bound estimates of the actual accident burden [39,40]. Applying these bounds illustratively: if actual accident counts are 20 % higher than recorded (lower-bound scenario), the true AFI_1 for the construction sector in 2024 would be approximately

5226 rather than 4355; under a 40 % undercount (upper-bound scenario), it would reach approximately 6097. For fatal outcomes, where underreporting is thought to be lower given the mandatory notification requirements for workplace deaths in Türkiye, the bias is expected to be smaller but non-zero, particularly for informal workers who fall outside the SGK reporting system. These illustrative bounds do not alter the qualitative conclusions of the study (the construction sector's disproportionate share of severe outcomes is consistent across all reasonable underreporting scenarios), but they confirm that the absolute indicator values should be treated as lower estimates of the true accident burden. In Türkiye, it has also been documented that employers may postpone insurance procedures until the day an accident occurs, and that thousands of uninsured workers are never reflected in accident statistics [40]. This reinforces the assessment that SGK data underrepresent the actual accident burden of the sector. The direction of this underreporting bias is unlikely to be uniform across subsectors. Construction of buildings (NACE 41), which is dominated by small and micro-scale enterprises, individual employers, and multi-tiered subcontracting chains, is more exposed to informal employment practices than either non-building structures (NACE 42) or Specialized construction activities (NACE 43). Large-scale infrastructure projects within NACE 42 are typically subject to public procurement procedures and institutional oversight that impose stricter registration compliance, whereas NACE 41 residential and commercial building projects are more frequently executed through informal subcontracting arrangements in which workers may be registered only at the moment of an accident, or not at all [40]. This asymmetry implies that the AFI_1, AFI_2, and AFI_3 values reported for NACE 41 are likely subject to a larger downward bias than those for NACE 42, and that the true concentration of occupational risk within the building construction subsector is probably greater than the official figures indicate. Beyond this general methodological limitation, a number of scope choices were also made in shaping the analytical framework of the study. Three sub-activity groups were included in the analysis: Construction of buildings (NACE 41), Non-building structures (NACE 42), and Specialized construction activities (NACE 43). The main rationale for this distinction is that these groups involve different physical working environments, construction processes, and conditions of spatial organization. In particular, the interior construction processes within Construction of buildings (NACE 41) constitute a direct point of intersection with the built environment disciplines in terms of variables such as floor planning, spatial circulation, and work area layout.

This study adopts a population-level descriptive-comparative design to map the structural distribution of occupational risk across NACE Rev. 2 subsectors. The analysis focuses on identifying patterns of accident concentration, severity, and longitudinal change rather than testing individual-level causal relationships. This design is appropriate to the research aim, which seeks to clarify how occupational risk is distributed across Construction of buildings (NACE 41), non-building structures (NACE 42), and Specialized construction activities (NACE 43) at the macro level and to position Türkiye's construction sector within an international comparative framework. Since the indicators presented in this study are derived from complete population-level administrative records rather than probability samples, classical sampling error and confidence interval estimation are not directly applicable. The year-to-year variability in AFI_1, AFI_2, and AFI_3 values, as reported across Section 3.5, provides a transparent basis for assessing the stability of the observed patterns over time. As an additional transparency measure, the construction-to-national ratios reported in Section 3.5 show that the sector's elevated risk relative to the national level persisted in every year of the observation period, suggesting that the observed pattern is not driven by a single outlier year. Formal change-point analysis (e.g., join point regression or segmented interrupted time series) would provide additional statistical precision in quantifying the effect sizes of the 2018 currency crisis, the 2020 COVID-19 period, and the 2023 earthquake reconstruction phase, and is identified as a priority for future methodological development in Section 5.

In addition to national data limitations, international comparisons are subject to methodological constraints arising from differences in employment definitions, reporting systems, and the definition of fatal occupational accidents across countries. Although a substantial proportion of accidents in the construction sector is associated with the working environment, the equipment used, and organizational safety management, such variables cannot be directly observed in the available datasets, which may limit the extent to which comparative analyses reflect these risk components [41]. For example, in some countries the definition of a fatal occupational accident includes cases occurring within 30 days of the accident, whereas in others this period varies; this discrepancy limits the comparability of data compiled from administrative records across countries [36]. The COVID-19 pandemic in 2020 and the Kahramanmaraş earthquakes in 2023 also caused unusual fluctuations in the data for those years, and these periods are evaluated separately in the Results section. A fuller understanding of the sector's risk profile will require future mixed-methods research supported by qualitative data on accident causes. Hashmi et al. note that relying solely on realized accident and injury data, namely lagging indicators, reflects a reactive approach in the construction sector, and that leading indicators such as near-miss events should also be analyzed for proactive risk management [42]. The present study, which is limited to official statistics, could therefore be extended in future through field-based and technology-supported monitoring studies.

3. Results

In this section, the sector's ten-year occupational health and safety performance is analyzed across three sub-activity groups within the NACE Rev. 2 framework with respect to employment, accident volume, permanent disability, and mortality. Periods of observable macroeconomic and contextual disruption (the 2018 currency shock, the COVID-19 pandemic in 2020, the Kahramanmaraş earthquakes in 2023, and the wave of Syrian migration) are examined in the relevant subsections through a data-driven descriptive analysis. These periods are identified based on empirical patterns visible in the data rather than formal change-point modeling.

3.1. Employment figures, workforce analysis, and macroeconomic context

The ten-year trajectory of employment in the construction sector closely tracks macroeconomic processes. As shown in **Table 1**, the sector reached a historical peak of 2,083,438 insured employees in 2017, up from 1,875,929 in 2014. However, this upward trend was sharply disrupted by the currency crisis that struck Türkiye in 2018 and the subsequent slowdown in the housing sector. By 2019, employment had declined to 1,294,788, marking the lowest level of the decade. Over the same period, the sector's share of total employment in Türkiye fell from 14.17 % in 2014 to 9.05 % in 2019.

Table 1. Annual share of the construction sector in total employment in Türkiye [25].

Year	Türkiye Total 4/1-a	Share %	Construction Sector (NACE 41, 42, 43)	Share (%)
2014	13,240,122	100	1,875,929	14.17
2015	13,999,398	100	1,980,630	14.15
2016	13,415,843	100	1,887,099	14.07
2017	14,477,817	100	2,083,438	14.39
2018	14,229,170	100	1,601,184	11.25
2019	14,314,313	100	1,294,788	9.05
2020	15,203,423	100	1,587,666	10.44
2021	16,169,679	100	1,630,678	10.08
2022	17,332,991	100	1,808,486	10.43
2023	16,406,420	100	1,928,297	11.75
2024	16,602,868	100	1,991,728	12.00
Average	—	—	—	11.98

Figure 1 presents the ten-year employment trajectory of Türkiye and the construction sector. Although construction activities were partially affected by global restrictions during the COVID-19 pandemic period from 2020 to 2021, employment in the sector remained relatively stable at 1,587,666 in 2020 and began to recover, reaching 1,630,678 in 2021 and 1,808,486 in 2022. The most notable increase in sectoral employment was observed after the Kahramanmaraş, Pazarcık, and Elbistan earthquakes on 6 February 2023. At a time when total insured employment in Türkiye declined from 17,332,991 to 16,406,420, employment in the construction sector moved in the opposite direction, rising from 1,808,486 to 1,928,297. As a result, the sector's share of total employment in Türkiye increased from 10.43 % to 11.75 % (**Table 1**).

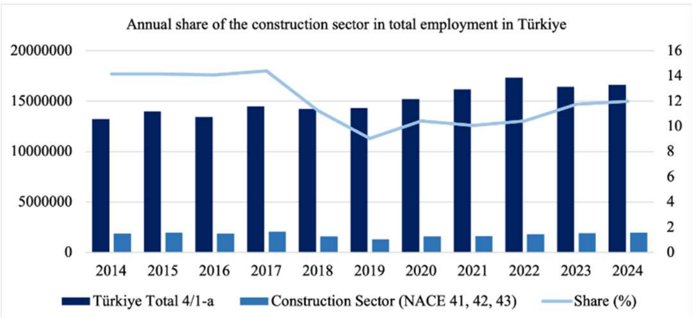

Figure 1. Trends in employment in Türkiye and the construction sector (2014–2024).

An examination of the distribution across sub-activity groups shows the dominance of the Construction of buildings (NACE 41) segment in sectoral employment. The share of this group within the sector increased from 63.34 % in 2014 to 68.93 % in 2024 (**Table 2**). This segment encompasses the construction of residential, office, and commercial buildings, as well as interior construction processes. Spatial organization variables (floor planning, spatial circulation, material storage points, and work area layout) fall directly within the scope of interior architectural design decisions. Because design decisions made during the planning of interior work areas may shape subsequent working conditions, and therefore patterns of accident risk, the dominance of NACE 41 underpins the interdisciplinary perspective of this study and suggests that the spatial design dimension of accident risk merits further investigation. In contrast, the share of the non-building structures segment (NACE 42), which mainly covers infrastructure-related works, declined from 18.05 % in 2014 to 15.66 % in 2024, while the share of Specialized construction activities (NACE 43) decreased from 18.61 % to 15.41 % over the same period (**Table 2**). This relative decline appears to stem from the disproportionate increase in NACE 41 employment, and the trend was calculated from the raw data reported in the SGK Statistical Yearbooks (2014–2024). The distribution of employment across the three subsectors is visualized in **Figure 2**.

Table 2. Number of employees and percentage distribution across construction subsectors by year [25].

Year	Construction of Buildings NACE 41	Share %	Non-building Structures NACE 42	Share %	Specialized Construction Activities NACE 43	Share %
2014	1,188,281	63.34	338,606	18.05	349,042	18.61
2015	1,266,828	63.96	364,592	18.41	349,210	17.63
2016	1,194,432	63.29	368,923	19.55	323,744	17.16
2017	1,331,723	63.92	417,205	20.02	334,510	16.06
2018	974,030	60.83	335,685	20.96	291,469	18.20
2019	727,961	56.22	293,312	22.65	273,515	21.12
2020	986,439	62.13	312,310	19.67	288,917	18.20
2021	1,016,670	62.35	320,772	19.67	293,236	17.98
2022	1,141,742	63.13	345,523	19.11	321,221	17.76
2023	1,304,154	67.63	316,144	16.39	307,999	15.97
2024	1,372,945	68.93	311,842	15.66	306,941	15.41

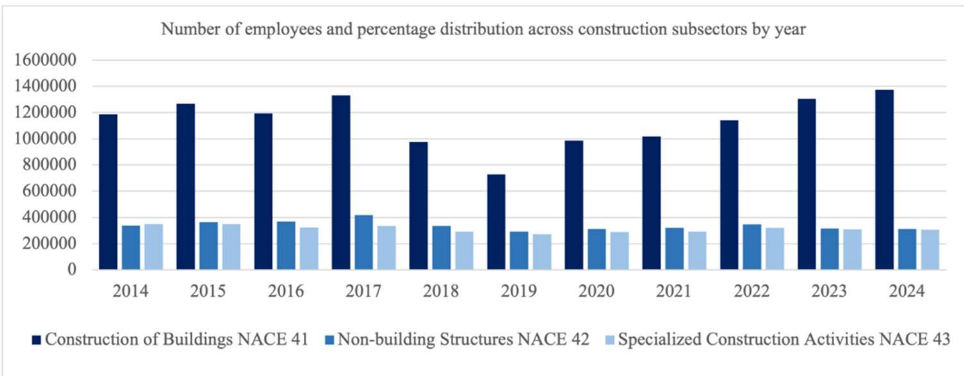

Figure 2. Distribution of employment across construction subsectors (NACE 41, 42, and 43).

The ten-year average share of the construction sector in compulsory insured employment in Türkiye was 11.98 % (**Table 1**), showing that employment volume in the sector fluctuated sharply in response to cycles of economic growth and contraction [43,44]. Over the past decade, economic disruptions, public health crises, and disaster-related events have directly affected employment and production dynamics in the sector, as evidenced by the sharp contraction during the 2018 currency crisis, the stabilization during the COVID-19 period, and the post-earthquake expansion in 2023 [43–45]. The difference of approximately 789,000 between the peak of 2,083,438 in 2017 and the trough of 1,294,788 in 2019 illustrates the magnitude of this volatility. Such rapid changes in employment volume increase worker turnover at the site level and constrain both the continuity of occupational health and safety training and the effectiveness of inspection mechanisms. This variability can also be read against previous research on job tenure and accident risk: employees with less than one month of experience have been reported to account for a disproportionately large share of occupational accidents [46].

3.2. Occupational accident volume, frequency trends, and sectoral risk concentration

The number of recorded occupational accidents in the construction sector increased from 29,699 in 2014 to 86,736 in 2024, representing an almost threefold rise over the ten-year period. The daily average number of accidents rose from 81 to 238, indicating a marked increase in the recorded accident burden. Since this increase may be associated with several factors, including the maturation of the reporting system, the expansion of construction activity, and possible changes in safety conditions, it warrants a more detailed examination of risk dynamics in the sector (**Table 3**). These trends are illustrated in **Figure 3**.

Table 3. Annual share of the construction sector in total occupational accidents in Türkiye [25].

Year	Türkiye total 4/1-a	Share %	Construction sector (NACE 41, 42, 43)	Share (%)	Daily average
2014	221,366	100	29,699	13.42	81.37
2015	241,547	100	33,361	13.81	91.40
2016	286,068	100	44,552	15.57	122.06
2017	359,653	100	62,358	17.34	170.84
2018	430,985	100	77,157	17.90	211.39
2019	422,463	100	47,701	11.29	130.69
2020	384,262	100	44,304	11.53	121.38
2021	511,084	100	58,107	11.37	159.20
2022	588,823	100	64,184	10.90	175.85
2023	681,401	100	82,111	12.05	224.96
2024	733,646	100	86,736	11.82	237.63
Average	—	—	—	13.37	—

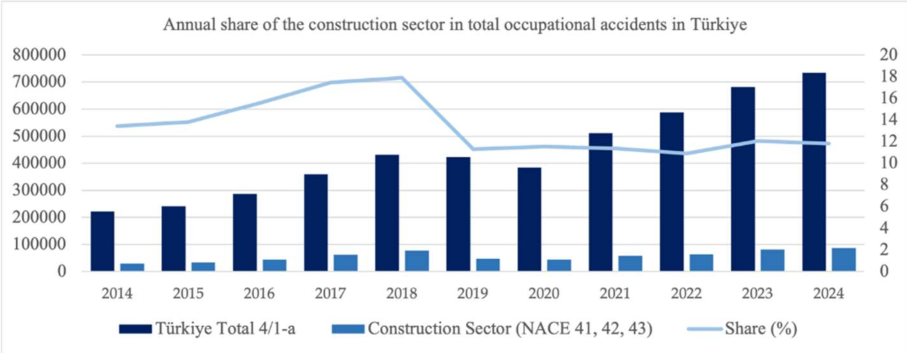

Figure 3. Distribution of occupational accidents in Türkiye and the construction sector (2014–2024).

Over the ten-year period, the construction sector accounted for an average of 13.37 % of total occupational accidents in Türkiye, indicating a persistently high share of the national occupational accident burden despite annual fluctuations (**Table 3**). This share peaked at 17.90 % in 2018 and declined to around 11 % during the economic downturn of 2019 and the subsequent COVID-19 period. The increase in the absolute number of accidents to 82,111 in 2023 and 86,736 in 2024 coincides with the post-earthquake reconstruction process, although the sector's share remained below the 2018 peak (**Table 3**).

When **Tables 3** and **4** are considered together, Construction of buildings (NACE 41) emerges as the primary locus of accident concentration within the sector. The share of this subgroup in sectoral accidents increased from 45.48 % in 2014 to 58.14 % in 2024, indicating that the upward trend observed over the ten-year period is structural and persistent. Among the factors that may underlie this concentration, subcontracting practices and short-term working conditions stand out. Related occupational health and safety concerns have also been documented in field-based research conducted among construction workers in Tekirdağ / Ergene [47]. The subsectoral distribution of occupational accidents is presented in **Figure 4**.

Table 4. Distribution and percentages of occupational accidents across construction subsectors by year [25].

Year	Construction of Buildings NACE 41	Share %	Non-building Structures NACE 42	Share %	Specialized Construction Activities NACE 43	Share %
2014	13,508	45.48	7675	25.84	8516	28.67
2015	15,065	45.16	7903	23.69	10,393	31.15
2016	20,159	45.25	9516	21.36	14,877	33.39
2017	34,791	55.40	20,676	32.92	6891	10.97
2018	41,759	54.12	27,639	35.82	7759	10.06
2019	25,551	53.56	15,927	33.39	6223	13.05
2020	23,949	54.06	14,225	32.11	6130	13.84
2021	32,131	55.30	18,318	31.52	7658	13.18
2022	35,636	55.52	20,198	31.47	8350	13.01
2023	45,996	56.02	26,523	32.30	9592	11.68
2024	50,429	58.14	26,106	30.10	10,201	11.76

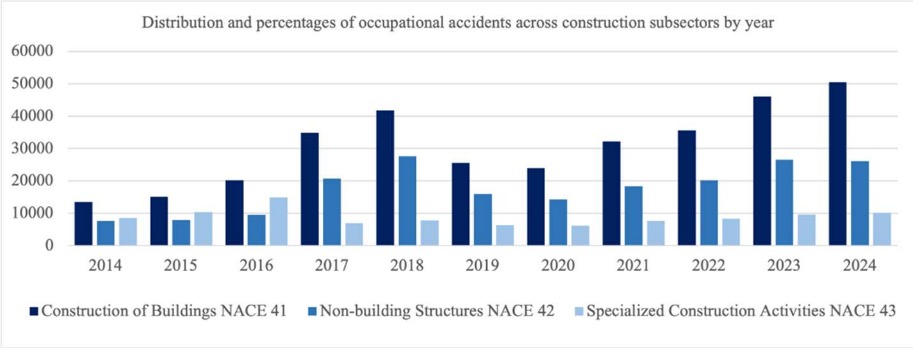

Figure 4. Distribution of occupational accidents across construction subsectors (NACE 41, 42, and 43) (2014–2024).

The share of non-building structures (NACE 42) in sectoral occupational accidents increased from 25.84 % in 2014 to between 32.92 % and 35.82 % in the period from 2017 to 2018, before declining to 30.10 % in 2024 (**Table 4**). This segment, which includes large-scale engineering structures such as roads, bridges, tunnels, and pipelines, shows a pattern in which accident risk appears to vary with project intensity. At the same time, it does not exhibit the type of structural concentration observed in NACE 41.

The share of Specialized construction activities (NACE 43) in sectoral occupational accidents declined sharply from its peak of 33.39 % in 2016 to 10.97 % in 2017, and further to 11.76 % in 2024. This discontinuity coincides with a reclassification in SGK reporting practices whereby accidents involving subcontracted workers on building construction sites were increasingly attributed to NACE 41 rather than NACE 43 from 2017 onward, as the main contractor's NACE code was applied to the workplace registration. This administrative reclassification, rather than a genuine safety improvement, appears to be the primary driver of the decline in NACE 43's share, and this limitation should be taken into account when interpreting subsectoral trends across the pre- and post-2017 periods (**Table 4**). This suggests that substantial limitations remain in the monitoring of sectoral safety performance through official statistical channels.

3.3. Permanent disability cases: A persistent indicator of accident severity

The number of permanent disability cases in the construction sector started at 404 in 2014, increased by 142.33 % in a single year to 979 in 2015, and rose to 1505 in 2017 (**Table 5**). This coincided with the highest level of insured employment in the ten-year period, reaching 2,083,438 in the same year (**Table 1**), as well as with the 62,358 occupational accidents documented (**Table 3**). The fact that informal employment, in which Syrian migrant workers are heavily concentrated, is not reflected in permanent disability cases suggests that official permanent disability statistics do not fully capture the actual severity burden. These trends are illustrated in **Figure 5**.

Table 5. Comparative distribution of permanent disability cases in Türkiye and the construction sector [25].

Year	Türkiye total 4/1-a	Share (%)	Construction sector (NACE 41, 42, 43)	Share (%)	Change (%)
2014	1421	100	404	28.43	—
2015	3433	100	979	28.52	+142.33
2016	4447	100	1450	32.61	+48.11
2017	3987	100	1505	37.75	+3.79
2018	3773	100	1328	35.20	−11.76
2019	4318	100	1586	36.73	+19.43
2020	3183	100	1078	33.87	−32.03
2021	3123	100	967	30.96	−10.30
2022	4085	100	1202	29.42	+24.30
2023	3358	100	1009	30.05	−16.06
2024	3626	100	1140	31.44	+12.98
Average	—	—	—	32.27	—

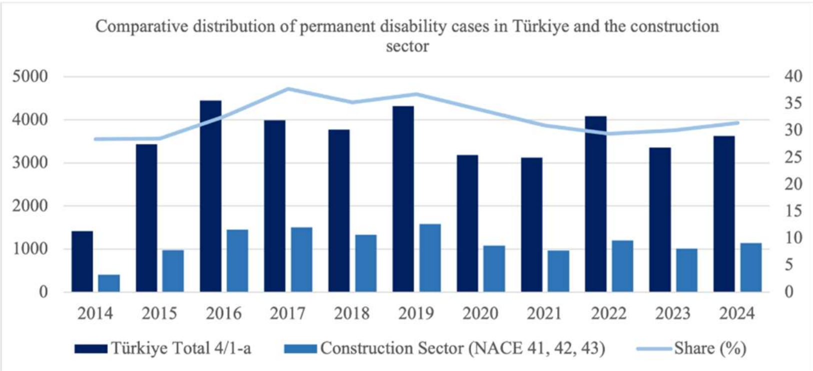

Figure 5. Distribution of permanent disability cases in Türkiye and the construction sector (2014–2024).

Over the ten-year period, the construction sector accounted for an average of 32.27 % of all permanent disability cases nationwide (**Table 5**). Set against its 11.98 % share of employment (**Table 1**) and 13.37 % average share of occupational accidents (**Table 3**), this figure shows that the sector carries a permanent disability burden about 2.7 times greater than its employment share. This burden is especially consequential because permanent disability can remove workers from employment or substantially reduce their work capacity, capturing a severity dimension that is not visible in accident counts alone. Previous studies in Türkiye have likewise reported that permanent disability cases are concentrated in construction, with sectoral proportions ranging from approximately 19 % to 32 % [21,34]. The 32.27 % value reported in this study indicates that this concentration remains at the upper end of previously documented national patterns.

At the sub-activity group level, permanent disability cases became increasingly concentrated in Construction of buildings (NACE 41). The sectoral share of this segment rose from 57.18 % in 2014 to 70.88 % in 2024 (**Table 6**). Over the same period, NACE 41's share of sectoral employment increased from 63.34 % to 68.93 % (**Table 2**). Although the disability share did not exceed the employment share in every year, its upward movement and its 2024 level point to a growing severity burden within this segment. This pattern shows that accidents in building construction should be assessed not only by frequency but also by the severity of their outcomes. In building construction environments, high-severity accident mechanisms such as falls, crush injuries, and cave-ins may be associated with physical workspace conditions, including transition points between floors, unguarded floor openings, and narrow circulation corridors. Directly testing this relationship, however, requires field studies that measure these spatial variables. This interpretation is also consistent with previous research showing that the complex, fragmented, and temporary nature of construction projects makes it difficult to standardize safety procedures and can reduce the effectiveness of risk controls applied only during implementation [48]. The subsectoral distribution of permanent disability cases is presented in **Figure 6**.

Table 6. Distribution and percentages of permanent disability cases across construction subsectors by year [25].

Year	Construction of Buildings NACE 41	Share %	Non-building Structures NACE 42	Share %	Specialized Construction Activities NACE 43	Share %
2014	231	57.18	58	14.36	115	28.47
2015	569	58.12	213	21.76	197	20.12
2016	909	62.69	300	20.69	241	16.62
2017	964	64.05	312	20.73	226	15.02
2018	861	64.83	290	21.84	177	13.33
2019	1029	64.88	357	22.51	200	12.61
2020	669	62.06	243	22.54	166	15.40
2021	620	64.12	204	21.10	143	14.79
2022	774	64.39	253	21.05	175	14.56
2023	689	68.29	195	19.33	125	12.39
2024	808	70.88	179	15.70	153	13.42

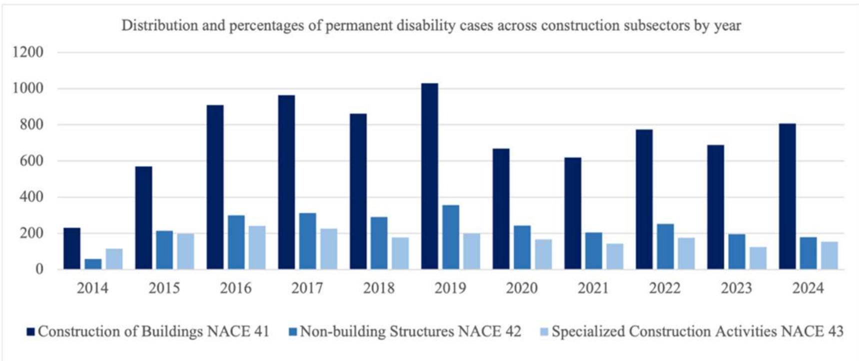

Figure 6. Distribution of permanent disability cases across construction subsectors (NACE 41, 42, and 43) (2014–2024).

By 2024, the share of permanent disability cases had declined to 15.70 % in NACE 42 and 13.42 % in NACE 43 (**Table 6**). This decline may reflect relative improvement in these segments, changes in employment intensity, or shifts in subsectoral attribution. In contrast, the rising share observed in NACE 41 indicates that the severity burden became more concentrated in building construction over the ten-year period.

3.4. Fatal occupational accidents and mortality rate: Evidence of persistent severity concentration

Between 2014 and 2024, the number of fatal occupational accidents in the construction sector ranged from 347 in 2020 to 591 in 2018. Over the same period, the sector accounted for an average of 31.94 % of all fatal occupational accidents nationwide (**Table 7**). This proportion is nearly three times the sector's 11.98 % share of insured employment (**Table 1**) and closely parallels the 32.27 % share observed in permanent disability cases in Section 3.3. Construction workers therefore faced a fatal accident burden about 2.7 times greater than would be expected from the sector's employment share, with the construction to national ratio ranging from 2.2 in 2014 to 3.5 in 2019 This pattern is also consistent with recent Türkiye focused studies. An analysis based on SGK data from 2018 to 2022 shows that the number of fatal occupational accidents declined from 591 to 422; nevertheless, approximately one third of occupational fatalities still occurred in the construction sector [49]. The same study also reported that workers with lower job experience had a higher probability of being involved in an accident. These trends are illustrated in **Figure 7**.

The most pronounced increase in fatal risk within the ten-year observation window occurred in 2018. In that year, the construction sector recorded 77,157 occupational accidents and 591 fatalities, with the latter representing the highest fatality count of the decade (**Table 3**, **Table 7**). Although the number of insured employees declined from 2,083,438 in 2017 to 1,601,184 in 2018, fatalities increased from 587 to 591, and the mortality rate rose from 28.17 to 36.91 (**Table 1**, **Table 7**). This pattern indicates that fatal risk intensified relative to registered employment in 2018, rather than simply reflecting changes in workforce size.

In 2020, while the number of insured employees increased from 1,294,788 to 1,587,666, the number of fatalities declined from 368 to 347, and the mortality rate fell to 21.86, the lowest value of the decade (**Table 7**). The decline in fatalities despite rising employment suggests that the 2020 data reflect a pattern consistent with the slowdown in activity during the COVID-19 period. Other conditions changing simultaneously may also have contributed to this outcome. Evidence from the U.S. construction sector points to a similar pattern: during the COVID-19 pandemic, occupational accidents declined compared with previous years, but this decline was associated not only with improvements in safety practices, but also with changes in work arrangements and a reduction in inspection activities [50].

With the acceleration of the reconstruction process following the 2023 Kahramanmaraş earthquakes, employment increased from 1,808,486 to 1,928,297. In parallel, the number of fatalities rose from 422 to 552, and the mortality rate increased from 23.33 to 28.63 **(Table 1, Table 7)**. In 2024, while employment growth continued, the number of fatalities remained at 552, and the mortality rate declined slightly to 27.71. Since the mortality rate remained higher in both years than during the pandemic period (21.86) and in 2022 (23.33), the data suggest that the post-earthquake expansion of construction activity coincided with a renewed increase in fatal risk. The subsectoral distribution of fatal occupational accidents is presented in **Figure 8**.

Table 7. Fatal occupational accidents, sectoral share, and mortality rate in Türkiye and the construction sector [25].

Year	Türkiye total 4/1-a	Share %	Construction Sector (NACE 41, 42, 43)	Share (%)	Mortality rate*
2014	1626	100	501	30.81	26.71
2015	1252	100	473	37.78	23.88
2016	1405	100	496	35.30	26.28
2017	1633	100	587	35.95	28.17
2018	1541	100	591	38.35	36.91
2019	1147	100	368	32.08	28.42
2020	1231	100	347	28.19	21.86
2021	1382	100	386	27.93	23.67
2022	1517	100	422	27.82	23.33
2023	1966	100	552	28.08	28.63
2024	1897	100	552	29.10	27.71
Average	—	—	—	31.94	—

* Mortality rate: Number of fatalities per 100,000 employees.

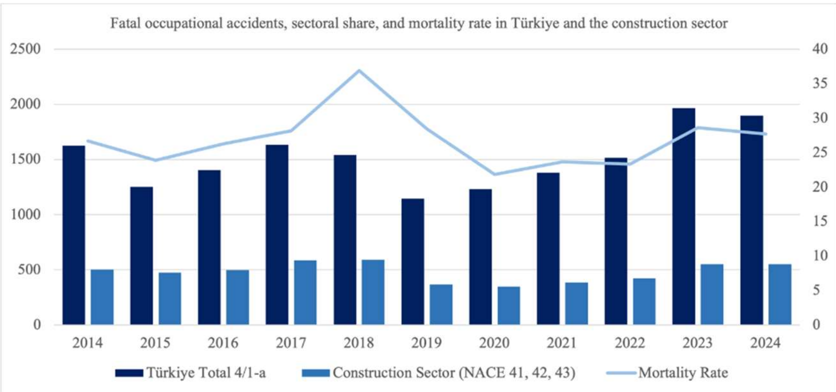

Figure 7. Trends in fatal occupational accidents and mortality rate in Türkiye's construction sector (2014–2024).

In the sub-activity group analysis, the share of fatalities in NACE 41 increased from 51.90 % to 63.04 %, while the share of NACE 42 declined from 28.54 % to 25.00 % and that of NACE 43 from 19.56 % to 11.96 % (**Table 8**). These changes indicate that fatal occupational accidents in the construction sector became more concentrated in building construction activities over the ten-year period. This trend is consistent with the patterns observed in the employment, accident, and permanent disability data.

Table 8. Distribution and percentages of fatal occupational accidents across construction subsectors by year [25].

Year	Construction of Buildings NACE 41	Share %	Non-building Structures NACE 42	Share %	Specialized Construction Activities NACE 43	Share %
2014	260	51.90	143	28.54	98	19.56
2015	239	50.53	124	26.22	110	23.26
2016	239	48.19	130	26.21	127	25.60

Table 8. (*Continued*).

Year	Construction of Buildings NACE 41	Share %	Non-building Structures NACE 42	Share %	Specialized Construction Activities NACE 43	Share %
2017	340	57.92	158	26.92	89	15.16
2018	360	60.91	162	27.41	69	11.68
2019	207	56.25	105	28.53	56	15.22
2020	199	57.35	98	28.24	50	14.41
2021	214	55.44	106	27.46	66	17.10
2022	248	58.77	91	21.56	83	19.67
2023	316	57.25	120	21.74	116	21.01
2024	348	63.04	138	25.00	66	11.96

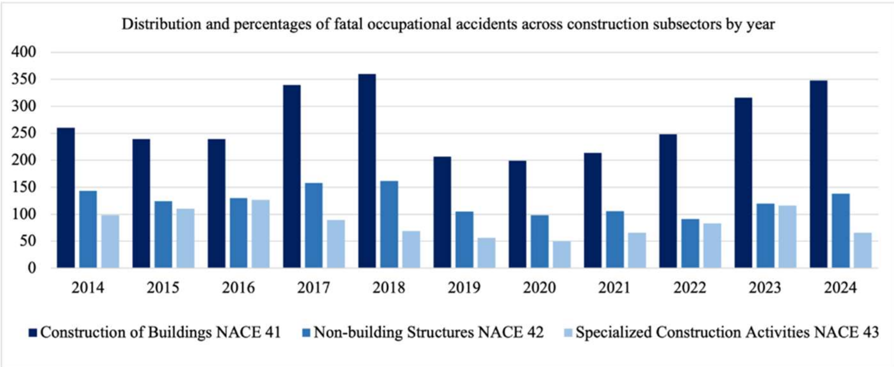

Figure 8. Fatal occupational accident distribution across construction subsectors (NACE 41, 42, and 43) (2014–2024).

3.5. Accident frequency indicators by subsector

3.5.1. Overall accident frequency indicator (AFI_1)

The overall accident frequency indicator (AFI_1) measures occupational accidents per 100,000 employees and normalizes accident counts by employment volume. A low number of accidents in a specific work item does not necessarily mean a low probability of fatal outcomes; for this reason, frequency indicators need to be read together with severity indicators [51]. In this study, AFI_1 is interpreted alongside AFI_2 and AFI_3 to distinguish accident frequency from permanent disability and fatality risk.

In 2014, the overall accident frequency indicator (AFI_1) for the construction sector (1583.16) remained slightly below the national level (1671.93). From 2016 onward, however, the construction-to-national ratio exceeded 1, reaching 4818.75 in 2018, or 1.59 times the national value of 3028.88 (**Table 9**). This value corresponds to the 77,157 cases recorded in the same year (**Table 3**). In 2019, the construction sector's AFI_1 decreased to 3684.08, and in 2020 it fell further to 2790.51, the lowest value of the ten-year period. During the same period, the number of occupational accidents declined to 47,701 and 44,304, respectively; this decrease in AFI_1 is consistent with the reduction in accident numbers **(Tables 3** and **9**). From 2021 onward, both the number of occupational accidents and AFI_1 increased again, reaching 58,107 and 3563.36, respectively, and rising further to 82,111 and 4258.21 in 2023 (**Tables 3** and **9**).

By the end of the observation period, the construction sector's AFI_1 was 4354.81, slightly below the national AFI_1 of 4418.79, reducing the construction-to-national ratio to 0.99 in 2024 (**Table 9**). Compared with 2014, the national value increased from 1671.93 to 4418.79, while the construction sector value rose from 1583.16 to 4354.81. These changes correspond to increases of approximately 2.65 to 2.75 times over the ten-year period. Taken together, the figures indicate that accident frequency did not show sustained improvement either nationwide or in the construction sector (**Table 9**). The AFI_1 values reported in Table 9 are visualized in **Figure 9**.

Table 9. Overall accident frequency indicator (AFI_1) in Türkiye and the construction sector (per 100,000 employees).*

Year	Türkiye total 4/1-A	Construction sector (Nace 41, 42, 43)	Construction sector türkiye total ratio
2014	1671.93	1583.16	0.95
2015	1725.41	1684.36	0.98
2016	2132.31	2360.87	1.11
2017	2484.17	3014.34	1.21
2018	3028.88	4818.75	1.59
2019	2951.33	3684.08	1.25
2020	2527.47	2790.51	1.10
2021	3160.76	3563.36	1.13
2022	3397.12	3549.05	1.04
2023	4153.26	4258.21	1.03
2024	4418.79	4354.81	0.99

* Derived from the employment data presented in **Table 1** and the occupational accident data presented in **Table 3**.

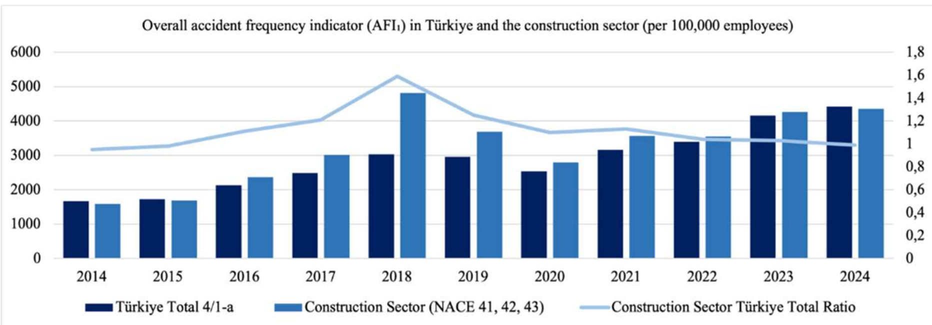

Figure 9. Trends in the overall accident frequency indicator (AFI_1) in Türkiye and the construction sector (2014–2024).

The construction-to-national AFI_1 ratio for the 2014 to 2024 period is presented in **Figure 10**. The figure shows how the construction sector's overall accident frequency indicator changed relative to the national level over time.

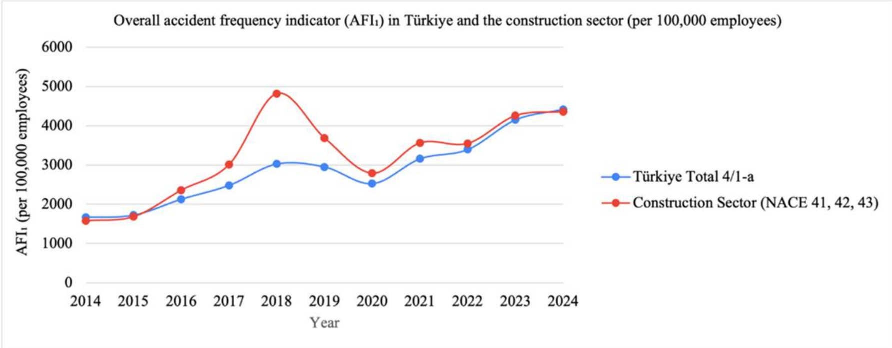

Figure 10. Construction to national ratio for the overall accident frequency indicator (AFI_1) (2014–2024).

3.5.2. Permanent disability frequency indicator (AFI_2)

In 2019, while the number of permanent disability cases increased from 1328 to 1586, AFI_2 rose from 830 to 1225 **(Tables 5 and 10)**. During the same period, the number of insured employees declined from 1,601,184 to 1,294,788 **(Table 1)**. The combination of rising case numbers and a shrinking employment base led to a sharper increase in AFI_2 than would be expected from the absolute increase in cases alone.

Between 2020 and 2024, the AFI_2 values for the construction sector ranged from 524 to 679, with the sector's ratio to the national level remaining in the 2.6 to 3.2 range (**Table 10**). The ratio of AFI_1 in the construction sector to the national level increased from 0.95 in 2014 to 0.99 in 2024, while both AFI_1 values rose by approximately 2.65 to 2.75 times over the ten-year period. In contrast, the same ratio for AFI_2 increased from 2.0 in 2014 to 2.6 in 2024, indicating that the risk of accidents resulting in permanent disability in the construction sector remained substantially above the national level (**Tables 9** and **10**). Although the AFI_1 values for the construction sector and the national level increased at similar rates, the persistent excess of permanent disability risk in the construction sector raises the question of how the sector's risk profile is reflected in terms of fatal accidents. This question is addressed in the following section through the fatal accident frequency indicator (AFI_3).

Table 10. Permanent disability frequency indicator (AFI_2) values (per 1,000,000 employees). *

Year	Türkiye Total 4/1-a	Construction Sector (NACE 41, 42, 43)	Construction sector türkiye total ratio
2014	108	216	2.0
2015	246	495	2.0
2016	332	769	2.3
2017	276	723	2.6
2018	266	830	3.1
2019	302	1225	4.1
2020	210	679	3.2
2021	194	593	3.1
2022	236	665	2.8
2023	205	524	2.6
2024	219	573	2.6

* Derived from the employment data presented in **Table 1** and the permanent disability data presented in **Table 5**.

The AFI_2 values reported in **Table 10** are visualized in **Figure 11**, and the construction-to-national ratio is presented separately in **Figure 12**.

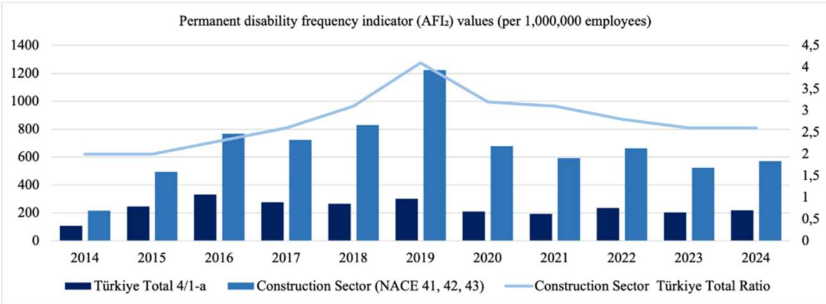

Figure 11. Trends in the permanent disability frequency indicator (AFI_2) in Türkiye and the construction sector (2014–2024).

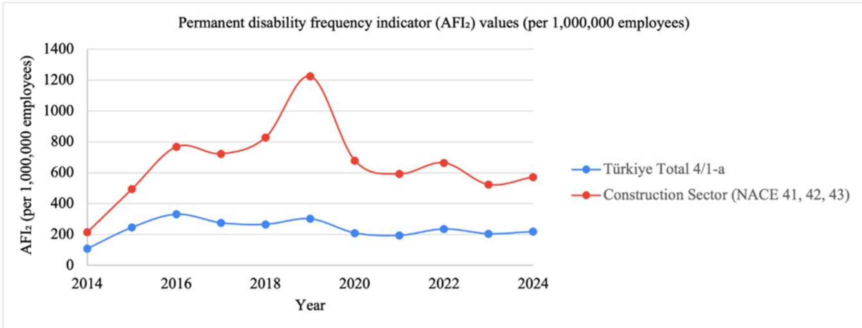

Figure 12. Construction to national ratio for the permanent disability frequency indicator (AFI_2) (2014–2024).

3.5.3. Fatal accident frequency indicator (AFI_3)

The fatal accident frequency indicator (AFI_3) represents the number of fatalities resulting from occupational accidents per 1,000,000 employees and serves as an occupational health and safety performance indicator that normalizes the absolute number of fatalities and the mortality rate reported in **Table 7** by employment volume. Throughout the ten-year period, the construction sector's AFI_3 did not fall below the national level in any year, with the ratio ranging from 2.2 in 2014 to 3.5 in 2019 **(Table 11)**.

In 2018, the construction sector's AFI_3 reached its peak value of 370 over the ten-year period, corresponding to 3.4 times the national level of 109. This value is consistent with the 591 fatalities and the mortality rate of 36.91 reported in **Table 7 (Tables 7 and 11)**. While the ratio for AFI_2 rose sharply to 4.1 in 2019, the corresponding ratio for AFI_3 increased only to 3.5. The decline in the absolute number of fatalities from 591 to 368 **(Table 7)** indicates that the fatal burden decreased in 2019, even though the risk of permanent disability increased markedly **(Tables 5, 7, and 11)**. Between 2020 and 2024, the construction sector's AFI_3 values ranged from 219 to 287, while its ratio to the national level remained between 2.4 and 2.8 **(Table 11)**. When AFI_1, AFI_2, and AFI_3 are considered together based on the 2024 data, a clear pattern emerges: the ratio for AFI_1 declined to 0.99, whereas the corresponding ratios remained at 2.6 for AFI_2 and 2.4 for AFI_3. These findings indicate that, although accident frequency in the construction sector converged toward the national level, the risks of permanent disability and fatal occupational accidents remained substantially above the national level throughout the ten-year period. The comparative position of this risk profile is examined in the following section through data from SGK, ILOSTAT, Eurostat, and BLS.

Table 11. Fatal accident frequency indicator (AFI_3) values (per 1,000,000 employees).*

Year	Türkiye total 4/1-a	Construction sector (NACE 41, 42, 43)	Construction sector türkiye total ratio
2014	123	268	2.2
2015	90	239	2.7
2016	105	263	2.5
2017	113	282	2.5
2018	109	370	3.4
2019	81	285	3.5
2020	81	219	2.7
2021	86	237	2.8
2022	88	234	2.7
2023	120	287	2.4
2024	115	278	2.4

* Derived from the employment data presented in **Table 1** and the fatal occupational accident data presented in **Table 7**.

The AFI_3 values reported in **Table 11** are visualized in **Figure 13**, and the construction-to-national AFI_3 ratio is presented in **Figure 14**.

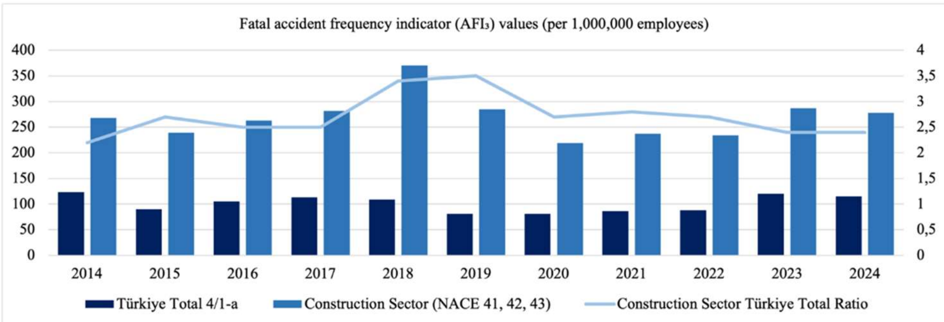

Figure 13. Trends in the fatal accident frequency indicator (AFI_3) in Türkiye and the construction sector (2014–2024).

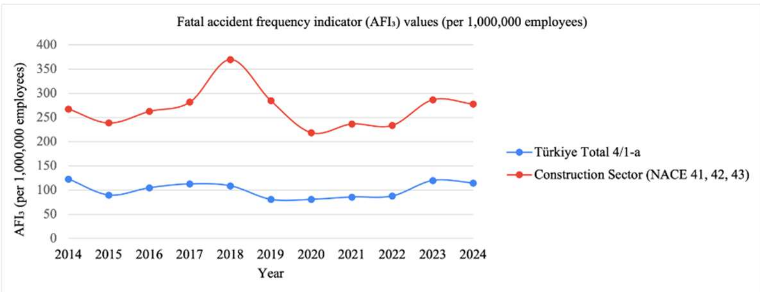

Figure 14. Construction to national ratio for the fatal accident frequency indicator (AFI_3) (2014–2024).

3.6. International comparison of the construction sector in Türkiye

The AFI_3 values calculated in the previous section established the fatal accident risk profile of Türkiye's construction sector relative to the national level. Here that profile is evaluated within an international framework drawing on the Social Security Institution (SGK), the ILOSTAT dataset of the International Labor Organization (ILO), the U.S. Bureau of Labor Statistics (BLS), and Eurostat's European Statistics on Accidents at Work (ESAW) database [25–28]. **Table 12** shows that AFI_3 values for Türkiye's construction sector ranged from 219 to 370 over the 2014–2024 period, whereas the corresponding values stayed within 15 to 36 for Norway, 11 to 53 for Finland, and 26 to 43 for Germany. Türkiye therefore appears to face a higher level of fatal occupational accident risk than several comparator countries, particularly high-income ones. These cross-country differences should be read with caution, since countries vary in how they define a fatal accident, in the scope of workers covered, and in the completeness of reporting systems; part of the observed gap may reflect measurement divergence rather than genuine differences in underlying risk. The fuller treatment of these definitional and reporting differences is given in Section 4.1 [52].

Table 12. Fatal accident frequency indicator values in the construction sectors of selected countries, based on SGK / ILOSTAT / BLS / Eurostat (per 1,000,000 employees).

Year/ country	Argentina	Romania	Moldova	Türkiye	Panama	Norway	Germany	USA	Finland
2014	155	177	378	268	77	36	43	164	53
2015	128	146	447	239	10	26	38	161	19
2016	164	143	145	263	17	33	31	162	50
2017	133	139	367	282	10	28	36	151	11
2018	117	97	256	370	11	15	35	160	26
2019	117	144	447	285	15	33	26	97	37
2020	116	98	124	219	2	29	36	91	22
2021	141	95	272	237	1	36	32	91	15
2022	117	99	289	234	29	32	29	96	22
2023	120	85	124	287	1	24	29	96	11
2024	134	—	540	278	3	—	—	92	—
Reference	Ilostat [26]	Ilostat [26] / eurostat [28]	Ilostat [26]	Sgk [25]	Ilostat [26]	Ilostat [26] / eurostat [28]	Ilostat [26] / eurostat [28]	Ilostat [26] /bls [27]	Ilostat [26] / eurostat [28]

The values in **Table 12** and **Figure 15** were derived from rates defined per 100,000 employees in the ILOSTAT, BLS, and Eurostat ESAW datasets and rescaled to a per 1,000,000 basis (multiplying by 10) to match the standard used for AFI_3 in this study and to present low-frequency events more legibly. Once converted, the Eurostat ESAW values track the ILOSTAT-based values closely for Germany, Finland,

and Romania, which indicates that the two sources agree on trends and that the comparison does not depend on the choice of database [26,28]. Against the lower fatal accident frequencies of the high-income countries noted above, higher values appear in Argentina (116 to 164) and Romania (85 to 177), placing Türkiye within the high-risk band of the comparison group.

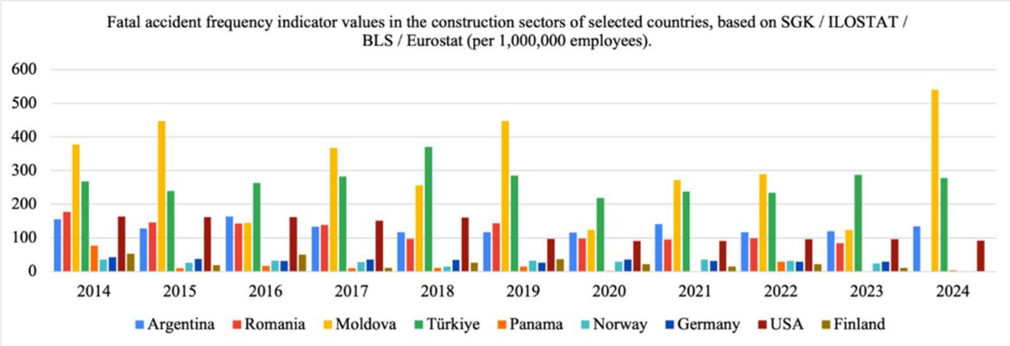

Figure 15. International comparison of fatal accident frequency indicator (AFI_3) values in selected construction sectors (2014–2024).

4. Discussion

4.1. Macroeconomic disruptions, structural risk, and data limitations

The indicators used in cross-country comparisons of fatal occupational accident rates are generated under different data collection and calculation conditions in each country, which limits their direct comparability [52]. By "differences," we refer specifically to variation in how a fatal occupational accident is defined (e.g., whether death must occur within 24 h, 30 days, or 1 year of the incident), which categories of workers fall within the scope of national reporting systems, and the administrative and notification procedures through which accidents are recorded. By "causal conclusions," we mean that the observed differences in AFI_3 values across countries cannot be attributed to specific institutional, regulatory, or behavioral factors (inspection capacity, enforcement stringency, or safety culture), because the datasets used do not permit controlled cross-national comparisons in which such factors are held constant. The comparisons presented here therefore identify relative risk levels and trend differences rather than definitive causal conclusions. The persistently high AFI_3 values observed for Türkiye, which ranged from 219 to 370 across the 2014–2024 period and consistently exceeded those of high-income comparator countries (**Table 12**), point to the need for a closer examination of risk dynamics within the sector. This pattern is not unique to Türkiye: research in contexts with comparable macroeconomic volatility suggests a broader structural relationship between economic growth cycles and construction fatality dynamics, whereby changes in production volume and growth rates influence accident outcomes more than the absolute level of economic activity alone [53,54].

Occupational accidents in Türkiye's construction sector rose nearly threefold between 2014 and 2024, even as employment fluctuated sharply. Employment contraction did not lower accident risk; risk intensity per employee appears to have risen under sustained production pressure. The 2018 currency crisis is the clearest case:

despite an approximately 23 % fall in insured employees, occupational accidents kept rising and the mortality rate climbed from 28.17 to 36.91. Evidence for 2010 to 2019 points the same way, with severe-outcome cases staying high through swings in accident numbers, which indicates that risk concentration in the sector is structural rather than cyclical [21]. The international literature also documents that the pressure for rapid construction during post-disaster reconstruction can systematically erode occupational health and safety conditions [45].

The mortality rate rose to 28.63 during the accelerated reconstruction after the 2023 Kahramanmaraş earthquakes, showing how existing vulnerabilities surface in periods of crisis. Reconstruction in Türkiye draws heavily on unregistered labor [55], which likely deepens the gap between recorded and actual accident burden. Migrant workers are underrepresented in official records elsewhere too, owing to reporting deficiencies [15,56], and the thin comparative evidence on this group suggests a broad problem rather than an isolated case [57]. The pattern holds in the SGK data, where the accident burden of informal and migrant workers stays largely invisible. A comparative study in Türkiye found migrant workers' occupational safety perception markedly lower than that of domestic workers, with the widest gap in construction [58]; a cross-sectional study of Syrian refugee workers in the south found that all participants were unregistered, 57.2 % had experienced a work accident, and long hours, low pay, and absent vocational training were common [55]. Economic fluctuation alone cannot account for the sector's risk pattern: informal employment and data gaps are part of it, and the datasets used here should be read accordingly.

4.2. Structural gaps in occupational health and safety legislation and inspection capacity

The persistently elevated AFI_2 and AFI_3 values in Türkiye's construction sector suggest that the expansion of occupational health and safety legislation under Law No. 6331 has not produced a proportional reduction in accident severity. As **Tables 10** and **11** show, construction-sector disability and fatality risks remained above the national average throughout the 2014–2024 period, with the construction-to-national AFI_2 ratio rising from 2.0 in 2014 to 2.6 in 2024 and the AFI_3 ratio holding between 2.2 and 3.5 across the decade. Formal regulatory expansion alone therefore appears insufficient to address risk conditions embedded in the sector's organization, particularly in fragmented, subcontracting-based environments. Previous studies in Türkiye report that occupational health and safety is still treated as a regulatory obligation or cost item rather than a long-term institutional investment [49], and international evidence likewise shows that regulatory compliance does not translate into effective risk control where implementation capacity remains weak [59,60]. The gap between legislative intent and field-level safety performance thus reflects deficiencies that are built into the sector rather than incidental to it.

Inspection gaps identified in earlier research have not been followed up systematically in later years, which points to the persistence of the problem [40]. More recent evidence indicates that the institutional maturity of inspection mechanisms remains limited and that subcontracting and informal employment are still widespread [61]. On sites dominated by multi-layered subcontracting, and especially in small enterprises, risk assessment is rarely carried out effectively, so occupational health and safety practice stays at a formal level [62]. The international literature reports the same unevenness: resource and technical-capacity constraints in small and medium-sized enterprises weaken inspection and implementation [63], which makes contractors' efficient use of limited safety investment all the more necessary [64]. Because the dataset does not capture informal and migrant workers directly, these components of risk cannot be measured quantitatively; the heavy concentration of Syrian workers in informal, low-skilled jobs further complicates the sector's risk profile [65]. Limited inspection capacity, widespread informal employment, and multi-layered subcontracting may all bear on the AFI_2 and AFI_3 gaps between Türkiye and the comparator countries in **Table 12**, though, as noted above, the data do not permit causal claims. Within this structure, accountability is diluted across subcontracting layers with no formally assignable liability, and field-level implementation lags behind the legislation even where it exists, consistent with evidence that safety performance depends on top-management commitment, implementation consistency, and training [66].

4.3. Risk concentration in building construction (NACE 41): Spatial and design dimensions

Ten-year data show that risk is concentrated in the Construction of buildings segment (NACE 41). The share of fatal occupational accidents in this segment rose from 51.90 % in 2014 to 63.04 % in 2024, so risk is not spread evenly across the sector but builds up in specific fields of activity. Construction is therefore better understood not only as a technical production activity but as a layered process of spatial organization. The literature likewise shows that hazards vary by project type, with some risks shared across subsectors and others concentrated in particular activity types [18]. Calculated separately for NACE 41 from the employment data in **Table 2** and the fatality counts in **Table 8**, the fatal accident frequency indicator (AFI_3) reaches about 253.5 per 1,000,000 employees in 2024, against a national AFI_3 of 115 (**Table 11**). The concentration of fatal outcomes in NACE 41 is thus not merely a function of its size; it reflects a fatality rate well above the national workforce.

Specific accident mechanisms and work items make this concentration clearer. In one study, the five leading accident types accounted for 84.1 % of all fatalities, while five principal work items (excavation, reinforced concrete works, masonry, plastering and painting, and roofing) accounted for 70.8 % of total accidents [29]. Analyses of the Chinese construction sector likewise find that falls alone make up as much as 47.8 % of accidents, one of the sector's dominant risk areas [67]. The pattern points to exposure level, set by the type of work and where it is carried out, as a key driver of accident severity.

The risks in building construction cannot be traced to implementation-stage errors alone; work organization and design decisions are also implicated. Safe work depends on processes being designed and organized from the outset, yet in small enterprises the shortage of qualified personnel often leaves this at the level of formal documentation [62]. Design- and planning-stage decisions are, in this sense, part of how risk is produced on site.

The literature groups the causes of construction accidents under four headings: personnel, environment, equipment, and management, whose interaction raises the likelihood of an accident [68]; accidents are shaped not only by site-specific factors but by environmental conditions as well [11]. This suggests that high-severity mechanisms may be tied to physical spatial conditions, such as transition points between floors, unguarded floor openings, and narrow circulation areas, though testing the link directly would require field studies that measure these variables. Among high-severity mechanisms, falls from height are prominent, bound up with risky activities, individual characteristics, site conditions, organizational factors, and equipment such as scaffolding and ladders [69], and they rank among the leading causes of fatality in the sector [70]. Musculoskeletal strain and the use of personal protective equipment also affect accident probability [71]. Accident severity is therefore shaped by the interaction of spatial conditions, work organization, worker exposure, and protective practice, which places design and planning at the center of how risk is generated. The Prevention through Design (PtD) approach addresses this by reducing occupational health and safety risks at the early design stage [72], although PtD uptake in practice remains limited and designer awareness is often insufficient [73]. Behm [74] provides empirical support for the design–outcome link, finding that 42 % of construction fatalities in the United States traced to identifiable design-phase factors and concluding that many could have been prevented through upstream design intervention. Gambatese et al. [75] further show that designing for worker safety is both feasible and practical, placing hazard elimination at the design stage at the top of the hierarchy of controls.

The descriptive findings of this study indicate that risk is concentrated in NACE 41. The study does not, however, contain mechanism-level injury data (falls from height, struck-by, or caught-in / between classifications) disaggregated by NACE subsector, which would be needed to map specific accident types directly onto design-stage intervention points. The SGK administrative dataset reports accident counts and outcomes but no injury mechanism codes at the subsectoral level. The PtD implications developed here are therefore grounded in the observed concentration of fatal and disabling outcomes within the building construction subsector, but they remain a design-oriented interpretive framework rather than a mechanism-level empirical mapping. The mechanisms by which spatial design decisions affect accident severity warrant systematic field-based investigation, measuring spatial variables such as circulation geometry, floor opening density, and access-route layout. The effectiveness of Prevention through Design interventions across high-risk work items, including excavation, reinforced concrete works, and roofing, likewise requires direct empirical evaluation. The NACE 41 concentration documented here is consistent with the design-linked fatality patterns reported by Behm [74] and Gambatese et al. [75]: Both point to the design and planning phase as the primary leverage point for reducing severity. The concentration in building construction is, on this reading, not only an implementation-stage failure but a sign that design-phase intervention has been systematically absent.

Social security data, then, should be treated not only as retrospective records of accidents but as evidence for labor risk governance. Read together with Prevention through Design principles, they help identify where severe occupational risk concentrates and where prevention should be prioritized, linking statistical evidence, design-oriented prevention, and sustainable labor policy.

5. Conclusions

The risk profile of Türkiye's construction sector between 2014 and 2024 is defined by a divergence that conventional sectoral safety narratives do not capture. Overall accident frequency (AFI_1) converged toward the national level over the decade, yet permanent disability frequency (AFI_2) and fatal accident frequency (AFI_3) remained 2.6 and 2.4 times the national level, respectively, in 2024. The sector's 31.94 % share of all fatal occupational accidents against an 11.98 % share of insured employment is not a residual statistical asymmetry; it is a stable structural feature reproduced over a decade marked by currency contraction, pandemic disruption, and post-disaster reconstruction. Severity, not frequency, is the binding occupational health and safety constraint in the sector.

This severity is concentrated in a single subsector. The share of fatal occupational accidents in Construction of buildings (NACE 41) rose from 51.90 % to 63.04 % between 2014 and 2024, while its share of permanent disability cases increased from 57.18 % to 70.88 % over the same period. Both shifts outpace the parallel rise in NACE 41's employment share (63.34 % to 68.93 %), so the subsector accumulates accident severity faster than it expands in employment. Non-building structures (NACE 42) and Specialized construction activities (NACE 43) do not reproduce this pattern. The locus of the sector's occupational risk is therefore identifiable, narrow, and persistent, and it coincides with the subsector in which spatial organization, circulation geometry, and work area layout are most actively shaped during production.

Treating the NACE 41 concentration as a design-stage problem rather than an implementation-stage one reframes the policy response, and three interventions follow. First, Prevention through Design must operate as a binding requirement at the project planning phase rather than an advisory principle, with spatial organization, circulation areas, temporary structures, and transition points evaluated against occupational health and safety criteria before construction begins; severity reduction at the design stage is not interchangeable with hazard control during execution. Second, inspection capacity must be reallocated according to the observed risk distribution: micro-scale enterprises within NACE 41 carry a fatality burden that general-purpose inspection regimes do not address, and the persistence of high AFI_2 and AFI_3 ratios across regulatory cycles shows that uniform inspection coverage misallocates limited enforcement resources. Third, the accountability structure of subcontracting must be tightened so that occupational health and safety responsibility is contractually assignable across multi-tiered project hierarchies, especially during periods of accelerated construction in which informal employment expands.

The study's method reinforces the credibility of these conclusions. Cross-validation across SGK, ILOSTAT, BLS, and Eurostat (ESAW) places Türkiye consistently within the high-risk band of the international comparison group, whichever source database is used. That the trend converges across these independent datasets is itself a finding: the pattern reported here is not an artifact of national reporting practice but a measurable and persistent feature of the sector. Within the limits of administrative data, which exclude informal and migrant workers and so underestimate the true accident burden, the figures presented here should be read as a lower bound on the risk faced by construction workers in Türkiye.

The policy implication is therefore direct. As long as occupational health and safety interventions in the Turkish construction sector are designed around the average sectoral worker rather than the disproportionately exposed building construction worker, the divergence between frequency and severity indicators will persist. The evidence developed here identifies where the burden concentrates, when it intensifies, and at which stage of the production cycle it can be reduced. Acting on it is a precondition for any meaningful improvement in fatality and disability outcomes in Türkiye’s building construction projects.

Overall, this study shows that the systematic analysis of social security data can offer more than a statistical account of occupational accidents. Read through social sustainability, labor risk inequality, and Prevention through Design, such data can serve as an evidence base for identifying where workers are most vulnerable and for guiding more equitable occupational health governance. In high-risk sectors such as construction, this matters for sustainable social development because it links accident prevention with decent work, labor equity, and the long-term protection of human capital.

Future research should address several gaps left by this study. First, field-based investigations incorporating spatial variables (circulation geometry, floor opening density, and access-route configurations on NACE 41 sites) are needed to examine how physical site conditions shape accident severity. Second, mixed-methods research integrating qualitative evidence on accident causation, near-miss incidents, and worker-level risk perceptions would complement the macro-level trends reported here. Third, studies that reach informal and migrant worker populations through primary data collection are needed for more complete estimates of the occupational accident burden in Türkiye’s construction sector. Fourth, future analyses should apply formal change-point or segmented interrupted time series regression to the disruption periods identified here (the 2018 currency crisis, the 2020 COVID-19 period, and the 2023 Kahramanmaraş earthquakes) to quantify effect sizes and distinguish genuine shifts in accident risk from compositional changes in the workforce. Fifth, if sector-specific working-hours data become available at the NACE subsector level through the Turkish Labour Force Survey, a sensitivity analysis using hour-based denominators would show how differences in working-time intensity affect the AFI values reported here. Sixth, mechanism-level injury data (falls from height, struck-by, caught-in/between) disaggregated by NACE subsector would allow accident types to be mapped empirically onto design-stage interventions, moving the Prevention through Design framework in this study from inference to direct evidence-based guidance.

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Abbreviations

AFI_1	Overall Accident Frequency Indicator
AFI_2	Permanent Disability Frequency Indicator
AFI_3	Fatal Accident Frequency Indicator
BLS	Bureau of Labor Statistics
CFOI	Census of Fatal Occupational Injuries
COVID-19	Coronavirus Disease 2019
ESAW	European Statistics on Accidents at Work
ILO	International Labour Organization
MR	Mortality Rate
NACE	Statistical Classification of Economic Activities in the European Community
PtD	Prevention Through Design
SGK	Social Security Institution

References

1. Liao C-W, Perng Y-H. Data mining for occupational injuries in the Taiwan construction industry. Safety Science. 2008; 46(7): 1091–1102. doi: 10.1016/j.ssci.2007.04.007
2. International Labour Office (ILO). Facts on Safety at Work. ILO; 2005. Available online: https://www.ilo.org/media/319841/download (accessed on 19 March 2026).
3. Lingard H. Occupational health and safety in the construction industry. Construction Management and Economics. 2013; 31(6): 505–514. doi: 10.1080/01446193.2013.816435
4. Heredia Morante RA, del Río Merino M, Ros Serrano A. The accident rate in the construction sector: a work proposal for its reduction through the standardization of safe work processes. Buildings. 2024; 14(8): 2399. doi: 10.3390/buildings14082399
5. Pinto A, Nunes IL, Ribeiro RA. Occupational risk assessment in the construction industry—overview and reflection. Safety Science. 2011; 49(5): 616–624. doi: 10.1016/j.ssci.2011.01.003
6. Occupational Safety and Health Administration (OSHA). Construction Industry: OSHA Standards. U.S. Department of Labor; 2018. Available online: https://www.osha.gov/doc/index.html (accessed on 19 March 2026).

7. National Institute for Occupational Safety and Health (NIOSH). Directory of NIOSH Construction Resources. Centers for Disease Control and Prevention (CDC); 2018. Available online: https://www.cdc.gov/niosh/construction/about/index.html (accessed on 19 March 2026).
8. Chi S, Han S, Kim DY. Relationship between unsafe working conditions and workers' behavior and impact of working conditions on injury severity in U.S. construction industry. Journal of Construction Engineering and Management. 2013; 139(7): 826–838. doi: 10.1061/(ASCE)CO.1943-7862.0000657
9. İncili FZ, Aysan Ü. The effect of the COVID-19 pandemic on employment and working conditions of Syrians under temporary protection (in Turkish). Manas Journal of Social Studies. 2023; 12(1): 209–223. doi: 10.33206/mjss.1053958
10. Yıldırım O, Altunoğlu MK, Geyik Yıldırım S. Factors affecting occupational health and safety of Syrian migrant workers (in Turkish). Kafkas University Journal of the Institute of Social Sciences. 2023; 31: 267–287. doi: 10.56597/kausbed.1245396
11. Hoła B, Nowobilski T. Analysis of the influence of socio-economic factors on occupational safety in the construction industry. Sustainability. 2019; 11(16): 4469. doi: 10.3390/su11164469
12. Çavuş A, Taçgın E. Classification and investigation of causes of occupational accidents in the construction sector in Turkey (in Turkish). Academic Platform - Journal of Engineering and Science. 2016; 4(2): 13–24. doi: 10.21541/apjes.63338
13. Vinberg S. Occupational safety and health challenges in small-scale enterprises. Industrial Health. 2020; 58(4): 303–305. doi: 10.2486/indhealth.58_400
14. Moyce SC, Schenker M. Migrant workers and their occupational health and safety. Annual Review of Public Health. 2018; 39: 351–365. doi: 10.1146/annurev-publhealth-040617-013714
15. Lau K, Aldridge R, Norredam M, et al. Workplace mortality risk and social determinants among migrant workers. The Lancet Public Health. 2024; 9(11): e935–e949. doi: 10.1016/S2468-2667(24)00226-3
16. Romero Á, González MdlN, Segarra M, et al. Mind the gap: Professionalization is the key to strengthening safety and leadership in the construction sector. International Journal of Environmental Research and Public Health. 2019; 16(11): 2045. doi: 10.3390/ijerph16112045
17. Mohammed YD, Shamsul BMT. A study pattern of construction occupation disease and nationality of the workers. International Journal of Advanced Engineering and Management Research. 2017; 2(3): 784–797.
18. Pamidimukkala A, Kermanshachi S. A review on construction safety: Hazards, mitigation strategies, and impacted sectors. Buildings. 2024; 14(2): 526. doi: 10.3390/buildings14020526
19. Eurostat. Accidents at work statistics. Statistics Explained. European Commission. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Accidents_at_work_statistics (accessed on 19 March 2026).
20. Bilim A, Çelik ON. General assessment of occupational accidents in the construction sector in Turkey (in Turkish). Niğde Ömer Halisdemir University Journal of Engineering Sciences. 2018; 7(2): 725–731. doi: 10.28948/ngumuh.444760
21. Ceylan H, Kaplan A, Bekar M. High-risky sectors in terms of work accidents in Turkey. International Journal of Engineering Research and Development. 2022; 14(1): 45–57. doi: 10.29137/umagd.937910
22. de la Fuente VS, Camino López MA, Fontaneda González I, et al. The impact of the economic crisis on occupational injuries. Journal of Safety Research. 2014; 48: 77–85. doi: 10.1016/j.jsr.2013.12.007
23. Selcuk E, Gundes S. Workplace stress among construction professionals: The influence of demographic and institutional characteristics. Buildings. 2025; 15(24): 4460. doi: 10.3390/buildings15244460
24. Slil E, Iyiola K, Alzubi A, Aljuhmani HY. Impact of safety leadership and employee morale on safety performance: the moderating role of harmonious safety passion. Buildings. 2025; 15(2): 186. doi: 10.3390/buildings15020186
25. Sosyal Güvenlik Kurumu (SGK). Statistical Yearbooks 2014–2024 (in Turkish).
26. International Labour Organization (ILO). ILOSTAT — Statistics on Safety and Health at Work. Available online: https://ilostat.ilo.org/topics/safety-and-health-at-work/ (accessed on 19 March 2026).
27. U.S. Bureau of Labor Statistics (BLS). Census of Fatal Occupational Injuries (CFOI), 2019–2024. Available online: https://www.bls.gov/iif/oshsum.htm (accessed on 19 March 2026).
28. Eurostat. European Statistics on Accidents at Work (ESAW), 2014–2024. Available online: https://ec.europa.eu/eurostat (accessed on 19 March 2026).
29. Bilir S, Gürcanlı GE. A method for determination of accident probability in the construction industry. Teknik Dergi. 2018; 29(4): 8537–8561. doi: 10.18400/tekderg.363613

30. Eurostat. NACE Rev. 2: Statistical Classification of Economic Activities in the European Community. Publications Office of the European Union; 2008. Available online: https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF (accessed on 19 March 2026).
31. World Bank. World Bank Country and Lending Groups. 2024. Available online: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups (accessed on 19 March 2026).
32. ILO. Resolution Concerning Statistics of Occupational Injuries Resulting from Occupational Accidents; Sixteenth International Conference of Labour Statisticians; October 1998; Geneva, Switzerland. Available online: https://www.ilo.org/global/statistics-and-databases/standards-and-guidelines/resolutions-adopted-by-international-conferences-of-labour-statisticians/WCMS_087528/lang--en/index.htm (accessed on 19 March 2026)
33. Ceylan H. Analysis of occupational accidents in the construction sector in Turkey (in Turkish). International Journal of Engineering Research and Development. 2014; 6(1): 1–6. doi: 10.29137/umagd.346068
34. Gözüak MH, Ceylan H. Analysis of occupational accidents in the construction sector in Turkey in the context of occupational health and safety: An overview of current trends (in Turkish). Journal of Health Academics. 2021; 8(2): 133–143.
35. ILOSTAT. Description of Occupational Safety and Health Statistics. International Labour Organization. Available online: https://ilostat.ilo.org/methods/concepts-and-definitions/description-occupational-safety-and-health-statistics (accessed on 19 March 2026).
36. UN Statistics Division. SDG Indicator 8.8.1 Metadata. United Nations; 2026. Available online: https://unstats.un.org/sdgs/metadata/files/Metadata-08-08-01.pdf (accessed on 19 March 2026).
37. Eurostat. Glossary: Incidence Rate for Accidents at Work. European Commission. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary: Incidence_rate_for_accidents_at_work (accessed on 19 March 2026).
38. Öçal M, Şenel D. Regional analysis of informal employment in Turkey (in Turkish). Çalışma ve Toplum. 2021; 2(69): 1201–1232.
39. ILO. Statistics on Occupational Safety and Health: General Report. In: Proceedings of the 21st International Conference of Labour Statisticians; October 11–20, 2023; Geneva, Switzerland. Available online: https://www.ilo.org/media/250396/download (accessed on 19 March 2026).
40. Gürcanlı GE, Müngen U, Akad M. Construction equipment and motor vehicle related injuries on construction sites in Turkey. Industrial Health. 2008; 46(4): 375–388. doi: 10.2486/indhealth.46.375
41. Betsis S, Kalogirou M, Aretoulis G, Pertzinidou M. Work accidents correlation analysis for construction projects in Northern Greece 2003–2007: a retrospective study. Safety. 2019; 5(2): 33. doi: 10.3390/safety5020033
42. Hashmi F, Hassan MU, Zubair MU, et al. Near-miss detection metrics: an approach to enable sensing technologies for proactive construction safety management. Buildings. 2024; 14(4): 1005. doi: 10.3390/buildings14041005
43. Tanyılmaz K, Karahan M. Development and construction sector: the case of Turkey (in Turkish). Ardahan University Journal of the Faculty of Economics and Administrative Sciences. 2021; 3(1): 62–68. Available online: https://izlik.org/JA87WW59LZ (accessed on 19 March 2026).
44. Artekin AÖ. Examination of the relationship between the construction sector, employment and economic growth in Turkey: GMM approach (in Turkish). Selçuk University Journal of the Vocational School of Social Sciences. 2023; 26(2): 491–503. doi: 10.29249/selcuksbmyd.1382436
45. Carrasco S, O'Brien D. Build back safely: evaluating the occupational health and safety in post-disaster reconstruction. Sustainability. 2023; 15(9): 7721. doi: 10.3390/su15097721
46. Tuganishuri J, Yum S-G, Adhikari MD, Oh T-K. Analysis of the severity and cause and effect of occupational accidents in South Korea. Sustainability. 2023; 15(20): 15058. doi: 10.3390/su152015058
47. Yüksel A, Günaydın D. Attitudes of construction sector employees towards occupational health and safety: A study in Tekirdağ/Ergene district (in Turkish). Sosyal Güvence. 2022; 11(21): 810–839. doi: 10.21441/sosyalguvence.1028086
48. Al-Humaidi H, Tan F. Construction safety in Kuwait. Journal of Performance of Constructed Facilities. 2010; 24(1): 70–77. doi: 10.1061/(ASCE)CF.1943-5509.0000055
49. Bilim A. Demographic analysis of occupational safety in the construction sector: strategies and insights for risk reduction. Buildings. 2025; 15(4): 528. doi: 10.3390/buildings15040528

50. Ko C-H, Abdulmajeed HA. Improving construction safety: lessons learned from COVID-19 in the United States. Sustainability. 2022; 14(12): 7137. doi: 10.3390/su14127137
51. Jeong J, Jeong J. Comparative analysis of degree of risk between the frequency aspect and probability aspect using integrated uncertainty method considering work type and accident type in construction industry. Applied Sciences. 2022; 12(3): 1131. doi: 10.3390/app12031131
52. Shim Y, Jeong J, Jeong J, et al. Comparative analysis of the national fatality rate in construction industry using time-series approach and equivalent evaluation conditions. International Journal of Environmental Research and Public Health. 2022; 19(4): 2312. doi: 10.3390/ijerph19042312
53. Li C, Wang X, Wei C, et al. Analysis of the correlation between occupational accidents and economic factors in China. International Journal of Environmental Research and Public Health. 2021; 18(20): 10781. doi: 10.3390/ijerph182010781
54. Liang Q, Fung IW. The impact of macroeconomic and industrial fluctuation on fatalities of construction workers in China. Journal of Safety Research. 2019; 70: 149–158. doi: 10.1016/j.jsr.2019.06.004
55. Acar O, Kurt B, Koyu OA, et al. Difficult working conditions of migrant workers: An example of an industrial area in south of Türkiye. ESTUDAM Public Health Journal. 2025; 10(1): 42–49. doi: 10.35232/estudamhsd.1563793
56. Hargreaves S, Rustage K, Nellums LB, et al. Occupational health outcomes among international migrant workers: A systematic review and meta-analysis. The Lancet Global Health. 2019; 7(7): e872–e882. doi: 10.1016/S2214-109X(19)30204-9
57. Alruwaili M, Carrillo P, Soetanto R, Munir F. Occupational accidents, injuries, and associated factors among migrant and domestic construction workers in Saudi Arabia. Buildings. 2024; 14(9): 2714. doi: 10.3390/buildings14092714
58. Öztürk M. A comparison of occupational safety perceptions among domestic and migrant workers in Turkey. Sustainability. 2023; 15(21): 15245. doi: 10.3390/su152115245
59. Fernández-Muñiz B, Montes-Peón JM, Vázquez-Ordás CJ. Occupational accidents and the economic cycle in Spain 1994–2014. Safety Science. 2018; 106: 273–284. doi: 10.1016/j.ssci.2016.02.029
60. Baykuş N, Chadee AA, Yalçın N, Azamathulla HM. Role of the regulation framework in occupational safety in construction excavation works—a survey analysis in Turkey. Safety. 2024; 10(4): 87. doi: 10.3390/safety10040087
61. Yıldırım N, Gultekin D, Tilkici D, Ay D. An institutional system proposal for advanced occupational safety and labor standards in the Turkish construction industry. International Journal of Environmental Research and Public Health. 2022; 19(22): 15113. doi: 10.3390/ijerph192215113
62. Gunduz M, Laitinen H. Construction safety risk assessment with introduced control levels. Journal of Civil Engineering and Management. 2018; 24(1): 11-18. doi: 10.3846/jcem.2018.284
63. Mixafenti S, Moutzouri A, Karagkouni A, et al. Assessment of occupational health and safety management: Implications for corporate performance in the secondary sector. Safety. 2025; 11(2): 44. doi: 10.3390/safety11020044
64. Aydinli S, Alboga Ö, Oral M, Erdis E. A multi-dimensional construction safety risk optimization model. Buildings. 2025; 15(6): 985. doi: 10.3390/buildings15060985
65. Aksu E, Erzan R, Kırdar MG. The impact of mass migration of Syrians on the Turkish labor market. Labour Economics. 2022; 76: 102183. doi: 10.1016/j.labeco.2022.102183
66. Yoon SJ, Lin HK, Chen G, et al. Effect of occupational health and safety management system on work-related accident rate and differences of occupational health and safety management system awareness between managers in South Korea's construction industry. Safety and Health at Work. 2013; 4(4): 201–209. doi: 10.1016/j.shaw.2013.10.002
67. Wang Y, Liu C, Xu H, et al. Analysis of the causes of falling accidents on building construction sites in China based on the HFACS model. Buildings. 2025; 15(9): 1412. doi: 10.3390/buildings15091412
68. Li Z, Zhang Y. High-altitude fall accidents in construction: A text mining analysis of causal factors and COVID-19 impact. Modelling. 2025; 6(4): 124. doi: 10.3390/modelling6040124
69. Nadhim EA, Hon C, Xia B, et al. Falls from height in the construction industry: A critical review of the scientific literature. International Journal of Environmental Research and Public Health. 2016; 13(7): 638. doi: 10.3390/ijerph13070638
70. Pereira F, González García MN, Martins JP. An evaluation of the technologies used for the real-time monitoring of the risk of falling from height in construction—systematic review. Buildings. 2024; 14(9): 2879. doi: 10.3390/buildings14092879
71. Kayastha R, Kisi KP. Assessing factors affecting fall accidents among Hispanic construction workers: Integrating safety insights into BIM for enhanced life cycle management. Buildings. 2024; 14(9): 3017. doi: 10.3390/buildings14093017

72. Samsudin NS, Khalil N, Mohammad MZ, et al. An ontology to represent the Prevention through Design (PtD) concept in Integrated Project Delivery (IPD) in the construction industry from an architectural perspective. Buildings. 2023; 13(5): 1128. doi: 10.3390/buildings13051128
73. Al-Bayati AJ, Bazzi K, Karakhan AA, Jensen E. Clearing the path: overcoming barriers to Prevention through Design (PtD) utilization in the US construction industry. Safety. 2024; 10(3): 74. doi: 10.3390/safety10030074
74. Behm M. Linking construction fatalities to the design for construction safety concept. Safety Science. 2005; 43(8): 589–611. doi: 10.1016/j.ssci.2005.04.002
75. Gambatese JA, Behm M, Hinze JW. Viability of designing for construction worker safety. Journal of Construction Engineering and Management. 2005; 131(9): 1029–1036. doi: 10.1061/(ASCE)0733-9364(2005)131: 9(1029)