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Research Article

Comparison of Occupational Incidence Rates in Risky Sectors and Future Prospects

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Abstract

In this study, accidents that occurred between 2012 and 2022 in five different sectors where occupational accidents are common in Turkey were compared using internationally accepted parameters. Using the trend analysis, the number of occupational accidents, incidence rates, and accident frequency rates that may occur in the five sectors and in Turkey in 2023-2026 were calculated, and a future perspective was developed. Furthermore, a comparison was made between Turkey, the European Union (EU) in general, and some of the EU's developed and developing member countries. In Turkey, 2.29 out of every 100 employees experience an occupational accident each year. The mining and metal sectors have the highest risk of accidents. However, 9 out of every 100,000 workers in Turkey die as a result of occupational accidents. The frequency of fatal accidents in Turkey is significantly higher than the average of the 27 EU member states and other countries surveyed. Turkey loses five times more employees than the average of the 27 EU member countries, and ten times more than Germany, a locomotive country with a European Union-based industry. Trend analysis was used to estimate the number of occupational accidents, incidence rates, and accident frequency rates between 2023 and 2026 in Turkey based on 11 years of historical data.

Keywords

Occupational safety, occupational accidents, incidence rates, trend analysis.

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1. Introduction

In Turkey, material and moral losses from occupational accidents and diseases are increasing on a daily basis. According to the 2019 report by the International Labour Organization (ILO), annually, 300,000 workers die due to occupational accidents, 2.48 million workers succumb to occupational diseases, and 374 million workers suffer from non-fatal occupational accidents. Similarly, the ILO notes that these figures tend to increase each year. According to the 2021 data from the European Statistical Office (EUROSTAT), 3,347 people lost their lives in occupational accidents within the European Union (EU). Additionally, a total of 2,886,507 occupational accidents occurred in the 27 EU member states. In Turkey, based on the last 10 years of data from the Social Security Institution (SSI), an occupational accident happens every 2 minutes, and every 6 hours, a worker dies as a result of an occupational accident. Furthermore, in Turkey, every 2.5 hours, a worker becomes permanently disabled due to an occupational accident (Sekmen&Zengin, 2023).

Occupational accidents also lead to significant economic losses for countries. According to the ILO, the cost of occupational accidents and diseases to countries is estimated to range between 1% and 6% of a country's gross domestic product. This ratio is close to 1% in countries where occupational health and safety mechanisms are well-functioning, while it is around 6% in countries where the system does not work correctly (ILO, 2019). In the Turkish economy, occupational accidents and diseases result in an approximate income loss of 3 billion dollars (Yılmaz&Alp, 2016).

In the last 11 years in Turkey, a total of 14,838 fatal occupational accidents have occurred. Of these, 49.1% took place in the five sectors under evaluation. To reduce the number of fatal accidents in these sectors, it is crucial to conduct a more detailed analysis of the current situation and provide a forward-looking perspective. The purpose of this research is to compare occupational accidents that occurred between 2012 and 2022 in five different sectors (construction, mining, manufacturing, metal, and textile) where occupational accidents are common in Turkey, using internationally accepted parameters. The study used 11-year data to better understand changes in the sectors. Another goal of the study is to forecast accident statistics for the next four years in order to take a proactive approach to occupational accidents in the sectors. In this direction, incidence rates for the years 2023-2026 were estimated using trend analysis on data from the sectors. The study also aims to compare Turkey's incidence rates to those of other countries. In this regard, the incidence rates of the European Union, some of its member countries, and Turkey have been compared.

Accident analyses in the literature are typically conducted in a single sector. However, the studies did not provide a future perspective on incidence rates, which would allow businesses to take a preventative approach. For this reason, there is an important research gap both in comparing incidence rates in different sectors with each other and in revealing incidence rate perspectives for the future. Within the scope of the study, the calculation and comparison of incidence rates in 5 different sectors, trend analysis for the future, and comparison of incidence rates of Turkey with the European Union and some member countries in order to reveal Turkey's place in the international arena constitute the originality of the study by separating it from the studies in the literature. The statistical results obtained from this study are expected to provide significant benefits to employees, employers, and the government. Employees will be able to increase their occupational health and safety awareness by comparing accident statistics in their own sectors with those in other sectors. Employers will have the opportunity to compare their company’s accident rates with industry averages. The government, on the other hand, will be able to use the information on sectoral accident rates and future trends to determine the necessary measures to be taken in specific sectors.

2. Conceptual Framework

2.1. Occupational Safety in the Construction Industry

Incidence rates in the construction sector are a matter of international concern. In the UK, over the past 20 years, 27% of fatalities and 10% of major injuries have occurred in the construction sector (Asanka&Ranasinghe, 2015). Among all Asian countries, the construction sector in Hong Kong has the highest annual death rate, averaging 60.53 per 100,000 workers from 1999 to 2008 (Hamid et al., 2019). In 2005, there were 1,243 fatalities in the US construction sector, accounting for 21% of all fatal injuries in other sectors (Dong et al., 2010). When accidents related to construction in the US and Singapore are examined, it is observed that most fatalities occur in the 24-34 age group, accidents predominantly occur among skilled labor, and 50% occur immediately before break time (Ling et al., 2009). In Turkey, the accident and mortality rates in the construction sector are also high compared to other sectors. The mortality rate in the construction sector is around 27 per 100,000 workers. Based on the relevant statistics, it can be said that almost one in every three accidents resulting in death in Turkey occurs in the construction sector (Zengin, 2022).

While the construction sector constitutes approximately 5% of the total workforce, it accounts for about one-third of fatalities resulting from occupational accidents and nearly one-fifth of permanent disabilities caused by such accidents (Gözüak&Ceylan, 2021). The increasing world population over the last fifty years has led to the construction of high-rise buildings to meet the housing needs (Satır&Topraklı, 2023). Among the causes of fatal injuries in the construction sector are falls from height, being struck by objects, being caught in or between objects, and exposure to electricity (Hamid et al., 2019). Working at heights, one of the hazards in the construction sector, causes serious occupational accidents for construction workers globally (Nadhim et al., 2016).

Another factor influencing the occurrence of accidents in the construction sector is the scale of the firm (Zengin&Asal, 2020). To remain economically competitive and sustainable and to maximize profits, many small-scale contractors only implement basic safety measures during the implementation of construction projects and eliminate many important hazard prevention training programs. Therefore, when accidents in the construction sector are examined, it is observed that accidents mostly occur in small businesses. López et al. (2008) analyzed the impact of company size on the distribution of occupational accidents among 1,630,452 construction sector accidents that occurred in Spain between 1990 and 2000 and determined that companies with fewer than 25 employees had very high incidence rates.

Several studies have been conducted to investigate accidents in the construction sector. Based on SSI data, Özdemir and Serin (2022) analyzed occupational accidents and diseases in Turkey and found that fatal occupational accidents occur more frequently in the construction sector. Altın et al. (2017) classified occupational accidents caused by formwork and scaffolding in the construction sector in Turkey, identified their causes, and emphasized the impact of these accidents on the construction sector and the national economy. In their study, Yılmaz and Yıldırım (2022) evaluated occupational accidents that occurred in the last five years in order to reduce occupational accidents in the construction sector. Ceylan and Kaplan (2024) compared the number of fatalities and mortality rates due to occupational accidents between Turkey and the EU-27 countries. The study concluded that some fatal occupational accidents in Turkey were not recorded, and in comparison with the EU-27 countries, Turkey had the worst performance in terms of both the number of fatalities and mortality rates due to occupational accidents.

2.2. Occupational Safety in Machinery Manufacturing and Metal Sectors

Machinery manufacturing sector and metal sector; machining methods (turning, milling, boring, cutting, grinding, etc.), sheet metal forming, pressing, hot or cold forging, welded joining, sintering, iron-steel manufacturing, ferro alloys, non-ferrous metals, especially aluminum and copper It covers the main industrial branches with wide application areas such as manufacturing.

Due to the dangers and hazards it entails, the metal and manufacturing industry is one of the risky industries that needs knowledge, skill, experience, and supervision. Injury to the back and upper extremities, harm to the eyes and body from exposure to toxic dust, gas, smoke, and other chemicals while processing metals, stress, noise, and vibration, harm from cutting and piercing tips, jamming, ionizing and infrared radiation, glare, and electrical hazards. Injuries, burns, repetitive strain injuries, musculoskeletal system issues, lung diseases, respiratory problems, skin disorders, and systemic toxic/toxin effects are among the illnesses that are frequently observed. Presses are used particularly frequently in the metal industry, which leads to workplace accidents that result in the loss of extremities like hands and fingers (Pehlivan&Usta, 2020). Within a year, 4.5% of workers in manufacturing jobs experience a occupational accident (Nenonen, 2011).

According to Saha et al. (2007) study, the metalworking industry's increased use of safety measures led to a decline in incidence rates. They said that accidents rise throughout the summer and on nights, that about 62% of accidents involve limbs, and that 40.9% of accidents result in superficial wounds like cuts and scrapes. They noted that incorrect motions and the usage of small tools accounted for 45.5% of the accident causes, and that machines were a factor in 62.5% of the incidents. Altunkaynak (2018) used statistical tools to evaluate the occupational accidents that occurred in the Turkish manufacturing sector in 2012 in order to identify the primary factors contributing to manufacturing injuries. According to the study, variables such as industry, height, age, experience, and time-of-day were significant predictors of accident frequency.

According to statistics from 2016, Yağımlı et al. (2017) found that the fabrication of fabricated metal goods had the greatest rate of occupational accidents, accounting for 20,616 of all accidents in the manufacturing industry. They mentioned the fact that it operates in fully automatic shifts, covers a large manufacturing area, and that technical faults and malfunctions regularly occur when dealing with machinery as reasons for this. The Turkish Employers Metal Industrialists' Union surveyed its members in 2016, and the results show that March had the largest number of occupational accidents. While the accident happened on Tuesdays as a day, it actually happened in the third working hour. It has been noted that 28% of accident workers have between 2-4 years of seniority in the workplace, 66% of them are married, and 48% are between the ages of 25 and 35 (Turkey Metal Industrialists Union, 2018). Another study done on workers in the metal industry found that 44% of workplace accidents were brought on by inadequate PPE use, 38% by negligence, and 18% by personal reasons including disregarding safety safeguards in machines and benches (Gülhan et al., 2012). By requiring metalworkers to wear eye protection, ocular injuries have been largely avoided in Norway (Bull, 2007). Aşkın and Öztürk (2022) statistically examined occupational accidents and occupational diseases among furniture sector workers. They found that furniture sector workers did not regularly use personal protective equipment, identified carelessness as the primary cause of accidents, and noted that accidents often occurred during cutting operations.

2.3. Occupational Safety in the Mining Sector

Despite significant developments in safety in the mining sector in recent years, accidents continue to occur, and mining remains one of the riskiest sectors worldwide. Coal mining is considered one of the riskiest industries globally (Khanzode et al., 2011). One of the factors that will contribute to reducing accidents in the mining sector is safety training for workers. Safety training plays a crucial role in informing workers about hazards in the workplace (Ghasemi et al., 2017). Training has a positive impact on reducing injuries that result in workforce loss (Kowalski et al., 2003). Ren et al. (2008) stated that safety training and education can increase workers' job competency and have a significant impact on reducing the severity of accidents. Ghasemi et al. (2017) also noted that experienced workers are less likely to engage in unsafe behaviors.

Arıtan and Ataman (2017) indicated in their study on open-pit mining that a significant portion of the accidents were preventable and primarily caused by worker errors. Bayraktar et al. (2018) examined occupational accident data in Turkey from 2002 to 2015, comparing the accident rates in the mining sector with those in other sectors. Their analyses revealed that, despite recent legal regulations, the mining sector continued to have a higher incidence rate compared to other sectors. At the conclusion of their study, they recommended abandoning small-scale mining, increasing the use of machinery, developing new safety measures specifically for mining, and conducting rigorous inspections. In his study, Koçali (2022) stated that to address occupational health and safety issues in the mining sector, integrated models involving external and internal organizational factors, socio-economic conditions, technological changes, safety culture, knowledge transfer, and team/workplace innovation should also be developed. Ceylan (2012), in his study using accident data from 2004 to 2010, noted that 46.4% of occupational accidents and 41.1% of fatal accidents in Turkey occurred in the construction, mining, and metal sectors. When examining other studies in the literature, it is observed that most major accidents in the mining industries occur due to a weak safety culture (Kowalski et al. 2007; Zhang et al. 2020).

2.4. Occupational Safety in the Textile Sector

The textile sector, along with agriculture, is one of the largest sectors in the world. It contributes significantly to countries in terms of employment and their economies. Despite its significant contribution to national economies, the textile industry harbors various risks that affect the health and safety of workers. These hazards can be categorized as mechanical, chemical, physical, physiological, and ergonomic risks (Kumar et al., 2014). Ergonomic risks, such as working in similar postures for extended periods, excessive repetitive movements, and working in incorrect postures, are the most commonly encountered risks (Aksüt et al., 2022). In the textile sector, various machines and equipment are used to convert raw materials into products. Workers are exposed to many mechanical risks caused by machines, such as crushing, flying debris, impact, friction, entanglement, cutting, and compression (Anitha Rajathi&Pavithra, 2017).

In his study, Kodaloğlu (2024) examined the effects of thermal factors, such as temperature and humidity, on occupational accident frequency. The results of the study revealed that accident frequency increases with high humidity and temperature values, while it decreases under ideal humidity and temperature conditions. Malik et al. (2010) stated that inadequate lighting, ventilation, high noise, and dust are the most significant risks in the textile sector. Workers are exposed to cotton dust during the processing and spinning of raw cotton. Cotton dust causes a work-related lung disease called byssinosis in workers. Due to exposure to other hazardous dust in the textile sector, workers also experience respiratory problems (Nafees et al., 2019). Additionally, it has been found that many textile facilities generate high levels of noise (Deepak Kumar &Muthukumar, 2018). Prolonged exposure to high-frequency noise can lead to serious health problems such as hearing loss, anxiety disorders, heart rate disturbances, decreased productivity, fatigue, absenteeism, discomfort, and hypertension (Sudha&Meenaxi, 2014).

In a study conducted by Yılmaz (2009), it was stated that the textile sector is one of the worst sectors in Turkey in terms of occupational health and safety. Yılmaz indicated that approximately 75% of the establishments operating in the textile sector are inadequate or partially adequate in terms of OHS, followed by the mining sector with 64.7% and the construction sector with 45.7%.

3. Theoretical Method

3.1. Data Collection

This study utilized 11 years of data (2012-2022) published by Turkey's Social Security Institution (SSI) for five sectors. The most recent SSI data was published in 2022, and the scope of the study includes estimations for the subsequent four years. This data collection improved in accuracy following the enactment of OHS Law No. 6331 in 2012 (Korkusuz et al., 2020). Businesses operating within the examined sectors were identified using the Economic Activity Classification (NACE), developed by the European Union statistical office. The codes used for each sector are as follows:

- Construction Sector: 41 (Building construction), 42 (Construction of non-building structures), 43 (Special construction activities)

- Machinery Manufacturing Sector: 25 (Manufacture of fabricated metal products), 28 (Manufacture of machinery and equipment not elsewhere classified), 29 (Motor vehicles, trailers, semi-trailers), 30 (Manufacturing of other transportation vehicles)
- Metal Sector: 24 (Basic metal sector)
- Textile Sector: 13 (Manufacture of textile products), 14 (Manufacturing of clothing)
- Mining Sector: 5 (Coal and Lignite Extraction), 6 (Crude Oil and Natural Gas Extraction), 7 (Metal Ore Mining), 8 (Other Mining and Quarries), 9 (Mining Support Service)

In determining the sectors examined in the study, the number of occupational accidents, fatal accidents, and the number of employed personnel were taken into consideration. The sectors analyzed in the study are among those in Turkey with the highest number of occupational accidents and fatalities over the last 11 years. The analyses revealed that the construction and mining sectors experienced approximately five times more occupational accidents compared to the national average, while the manufacturing sector had about three times more accidents. To reduce occupational accidents in Turkey, it is essential to develop preventive OHS approaches specifically targeting these sectors.

3.2. Statistical Definitions and Equations

Definitions of key statistical terms, such as accident frequency rates and mortality rates, were standardized at the 16th International Conference of Labor Statisticians in Geneva to provide a common language for occupational accident statistics (Ling et al., 2009). The following equations and their significance are provided:

The number of injuries per 100 workers employed in the relevant sector is used to determine accident (incidence) rates (Eq. 1), (Jo et al., 2017).

$$\text{Incidence Rates} = \frac{Total\ number\ of\ occupation\ injuries}{Total\ number\ of\ workers} x100 \quad (1)$$

The number of fatal accidents per 100,000 workers employed in the relevant sector is used to determine mortality rates (Eq. 2), (Choi et al., 2019).

$$\text{Mortality rates} = \frac{Total\ number\ of\ fatal\ occupation\ injuries\ per\ year}{Total\ number\ of\ workers} x100{,}000 \quad (2)$$

Accident Frequency Rate is defined as the number of occupational accidents per one million working hours worked in a year. In order to calculate the accident frequency rate, it is necessary to know the number of accidents and the total working hours in the relevant year (Eq. 3), (Arıtan&Ataman, 2017).

$$Accident\ Frequency\ Rate = \frac{Number\ of\ occupational\ accidents\ per\ year}{Total\ working\ hours\ in\ year} x1{,}000{,}000 \quad (3)$$

Accident Weight Rate refers to the number of days lost due to accidents in a given year. The number of lost days is calculated as (temporary incapacity periods) + (total of permanent incapacity degrees x 75) + (number of death cases x 7,500) (Eq. 4), (Balcı et al., 2013).

$$\text{Accident Weight Rate} = \frac{Total\ number\ of\ working\ days\ lost}{Total\ working\ hours\ in\ year} x1{,}000{,}000 \quad (4)$$

3.3. Trend/Regression Analysis

Trend analysis is a method utilized to forecast expected future conditions based on the assumption that past trends will continue (Mudelsee, 2019). This analytical approach is essential in various fields, including occupational safety, where understanding past accident patterns can inform future safety measures. The magnitude of a trend in a time series can typically be assessed through either parametric methods, such as linear regression, or non-parametric approaches. Both methodologies presume a linear trend within the time series data. Trend analysis is employed when there is an expectation that historical conditions will persist into the forthcoming forecast period.

A simple linear regression model is instrumental in predicting (forecasting) a dependent variable based on the influence of an explanatory (independent) variable. This model is particularly effective when a linear relationship exists between the independent and dependent variables (Yazğılı&Baykara, 2021). In the context of occupational accidents, regression analysis can be conducted with time as the independent variable and various dependent variables, such as accident numbers, incidence rates, or employee counts. For trend analysis to yield meaningful insights, the past must exhibit a consistent pattern, and it is essential that future conditions are a continuation of these historical trends.

The formula for trend analysis employed in this study is represented as follows:

$$y=mt+c \quad (5)$$

In Equation 5:

y represents the estimated value (dependent variable),
t is the time (independent variable),
c is the y-intercept, indicating where the trend line intersects the y-axis,
m denotes the slope of the trend line, reflecting the rate of change over time.

The effectiveness of the regression model is evaluated using the coefficient of determination (R^2), which quantifies how well the predicted values align with the actual data. This ratio, calculated as $R^2 = \frac{SSR}{SST}$ (Kasuya, 2019), compares the explained variation (SSR) to the total variation (SST). A R^2 value exceeding 0.7 is generally interpreted as indicating a strong effect size, suggesting a robust relationship between the variables (Moore, 2004). Within the scope of this study, the R^2 value was computed to determine the degree of fit between the predicted data and the actual observations.

4. Results And Discussion

While comparing the sectors in the study, analyses were made by using the ratio of the number of employees who had an accident or died to the total number of employees in the sector. Table 1 shows the number of occupational accidents and fatalities in five different sectors, compiled from Turkish Social Security Institution (SSI) statistics between 2012 and 2022 (Turkish social security institution, 2024). In general, it can be claimed that Turkey is experiencing an alarmingly high number of accidents and fatalities. In Turkey, the construction and machinery manufacturing sectors have a higher incidence rate than other sectors. In terms of the number of fatal accidents, the construction industry has ranked first in all years studied. The mining industry has the highest number of fatal accidents after the construction sector. As a result, more disasters occur in Turkey's construction industry each year than the Soma mine disaster.

Table 1. Number of occupational accidents and deaths on a sectoral basis in Turkey

Years	Construction sector		Machinery Manufacturing sector		Textile sector		Mining sector		Metal sector	
	Accident	Death	Accident	Death	Accident	Death	Accident	Death	Accident	Death
2012	9,209	256	11,515	36	5,970	18	9,960	44	4,938	10
2013	26,967	521	27,396	60	9,587	26	14,304	87	12,061	34
2014	29,699	501	31,765	62	14,627	21	13,049	382	12,357	14
2015	33,361	473	34,878	54	15,059	15	10,420	79	12,529	21
2016	44,552	496	38,591	39	17,550	37	11,792	83	13,081	30
2017	62,802	587	46,601	63	20,452	31	13,052	86	15,670	29
2018	77,157	591	52,282	73	25,220	33	13,771	57	17,403	43
2019	47,701	368	52,443	48	27,365	25	14,167	48	16,413	19
2020	44,304	347	51,449	42	25,464	24	13,047	66	15,782	32
2021	58,107	386	70,682	67	36,693	41	17,083	75	21,868	35
2022	64,184	422	78,616	83	41,644	32	19,369	105	22,775	32
Avg.	45,277	450	45,111	57	21,785	28	13,638	101	14,989	27

Source: Compiled from Turkey's SSI statistics.

According to Table 1, the number of accidents and fatalities in 2013 was at least twice as high in the machinery manufacturing, textile, and mining sectors, and about three times higher in the construction and metal sectors than in 2012. The most significant development to explain such a large increase is Occupational Health and Safety Law No. 6331, which was published in 2012. The implementation of the relevant law resulted in a significant decrease in unregistered employment and unrecorded occupational accidents, which has been documented in statistics (Çavdar et al., 2022). The fact that the number of accidents continues to rise despite existing legal arrangements shows that the expected benefits have not been realized.

Table 2 displays the number of employees as well as the calculated accident and fatality rates for the assessed sectors from 2012 to 2022, based on Turkey's SSI statistics. As of 2022, the five sectors evaluated employ an average of 25.4 percent of Turkey's workforce. Among the five sectors, construction employs the most people. Although the number of occupational accidents and fatalities in the construction sector is higher than in other sectors, when accident and fatality rates per employee are considered, the construction sector outperforms some other industries. This is important evidence that comparing sectors using internationally recognized parameters, rather than just numbers, yields more accurate results.

Table 2. Incidence and mortality rates information by sectors

	Years	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Avg.
Construction sector	Number of Workers	1,789,487	1,849,942	1,875,929	1,980,630	1,887,099	2,083,438	1,601,184	1,294,788	1,587,666	1,630,678	1,808,486	1,762,666
	Incidence Rates	0.51	1.46	1.58	1.68	2.36	3.01	4.82	3.68	2.79	3.56	3.55	2.64
	Mortality Rates	14	28	27	24	26	28	37	28	22	24	23	26
Machinery Manufacturing sector	Number of Workers	679,920	726,078	728,584	754,531	768,148	789,787	778,309	798,514	880,712	948,864	1,020,367	806,710
	Incidence Rates	1.69	3.77	4.36	4.62	5.02	5.90	6.72	6.57	5.84	7.45	7.70	5.42
	Mortality Rates	5	8	9	7	5	8	9	6	5	7	8	7
Textile sector	Number of Workers	884,967	918,496	941,349	903,743	875,383	916,118	938,187	1,010,045	1,068,986	1,176,964	1,222,609	986,986
	Incidence Rates	0.67	1.04	1.55	1.67	2.00	2.23	2.69	2.71	2.38	3.12	3.41	2.13
	Mortality Rates	2	3	2	2	4	3	4	2	2	3	3	3
Mining sector	Number of Workers	141,387	144,168	132,318	131,859	132,490	140,660	137,332	134,327	141,692	152,184	158,968	140,671
	Incidence Rates	7.04	9.92	9.86	7.90	8.90	9.28	10.03	10.55	9.21	11.23	12.18	9.65
	Mortality Rates	31	60	289	60	63	61	42	36	47	49	66	73
Metal sector	Number of Workers	164,795	159,842	151,253	149,301	145,268	168,084	162,481	163,275	175,994	191,351	198,262	166,355
	Incidence Rates	3.00	7.55	8.17	8.39	9.00	9.32	10.71	10.05	8.97	11.43	11.49	8.92
	Mortality Rates	6	21	9	14	21	17	26	12	18	18	16	16

Source: Compiled from Turkey's SSI statistics.

Figure 1 depicts the change in occupational incidence rates by sector and in Turkey as a whole. Turkey experienced an average of 337,501 accidents over the last eleven years. The five sectors evaluated accounted for 41.7% (140,798) of the accidents. While the calculated incidence rates for the textile sector are comparable to Turkey's average incidence rates, the incidence rates for the other four sectors are significantly higher. The average annual incidence rate in Turkey between 2012 and 2022 is 2.29. According to this rate, 2.29 out of every 100 employees in Turkey experience an accident each year. In 5 sectors - 11-year average incidence rate is 5.75. This finding indicates that the risk of an accident in the five sectors studied is approximately 2.5 times higher than in Turkey in general. Mining and metals are the sectors with the highest incidence rates in Turkey. According to 11-year average data, 9.6 out of every 100 mining employees and 8.9 in the metal sector were involved in an accident.

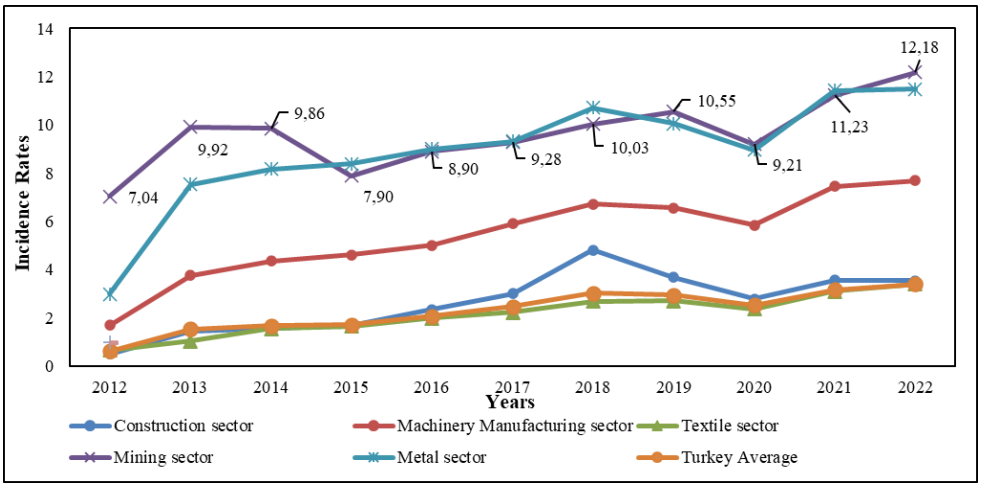

Figure 1. Occupational incidence rates by years in sectors

Figure 2 depicts the change in mortality rates across sectors and in Turkey as a whole. In Turkey, 1,349 fatal accidents occur annually on average. Five sectors accounted for 49.1% (663) of the fatal accidents. The mortality rate represents the number of fatal accidents per 100,000 employees. In Turkey, nine out of every 100,000 employees die. When the average of the five sectors evaluated in Turkey is calculated, the mortality rate rises by three times to 25. In terms of sectors, the textile sector (average 3) and the machinery manufacturing sector (average 7) have lower mortality rates than Turkey's overall average, whereas the metal sector (average 16), construction sector (average 26), and mining sector (average 73) have higher mortality rates. In 2014, the Soma mine disaster claimed the lives of 289 out of every 100,000 workers in the mining industry.

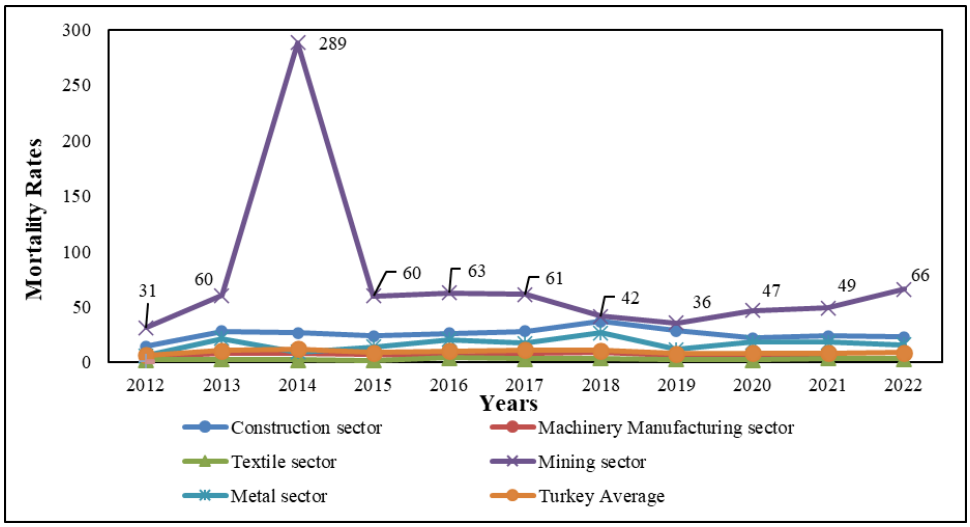

Figure 2. Mortality rate distribution by sector

Table 3 provides the number of accrued premium days and the calculated accident frequency rates for the sectors evaluated between 2012 and 2022. According to Table 3, there are 22 accidents per 1,000,000 work hours on average in five sectors, compared to Turkey's average of 8.8 accidents. Among the five sectors, the mining and metal sectors have the highest accident frequency rates. In the mining sector, there are approximately 5 times more accidents compared to the national average, while in the metal sector, there are approximately 4 times more accidents.

Table 3. Accident frequency rates of sectors

Years	Construction Sector		Machinery Manufacturing Sec.		Textile Sector		Mining Sector		Metals Sector	
	Total Premium Day	Accident Freq. Rate	Total Premium Day	Accident Freq. Rate	Total Premium Day	Accident Freq. Rate	Total Premium Day	Accident Freq. Rate	Total Premium Day	Accident Freq. Rate
2012	577,899,063	1.99	219,574,175	6.56	285,792,296	2.61	45,659,687	27.27	53,219,094	11.60
2013	603,082,714	5.59	236,702,065	14.47	299,430,501	4.00	46,998,894	38.04	52,108,632	28.93
2014	601,939,290	6.17	233,784,613	16.98	302,055,647	6.05	42,457,578	38.42	48,533,352	31.83
2015	631,295,158	6.61	240,495,078	18.13	288,054,094	6.53	42,028,015	30.99	47,587,383	32.91
2016	619,823,294	8.98	252,300,502	19.12	287,522,156	7.63	43,516,734	33.87	47,713,708	34.27
2017	651,083,882	12.06	246,812,042	23.60	286,291,054	8.93	43,956,892	37.12	52,527,017	37.29
2018	563,344,193	17.12	273,832,274	23.87	330,082,113	9.55	48,317,485	35.63	57,165,652	38.05
2019	443,858,702	13.43	273,733,914	23.95	346,247,619	9.88	46,047,852	38.46	55,971,348	36.65
2020	462,200,014	11.98	256,392,150	25.08	311,202,320	10.23	41,249,257	39.54	51,235,228	38.50
2021	525,006,175	13.83	305,579,156	28.91	378,930,339	12.10	48,996,513	43.58	61,606,557	44.37
2022	617,298,554	13.00	348,286,397	28.22	417,318,557	12.47	54,261,253	44.62	67,673,649	42.07
Avg.	567,953,249	9.78	262,499,306	20.81	321,175,154	8.18	45,771,833	37.05	54,121,965	34.23

Source: Compiled from Turkey's SSI statistics.

In Figure 3, the change in accident frequency rate over the years is depicted. According to the 11-year change in accident frequency rate, it is evident that the accident frequency rate is rapidly increasing both nationally and in the five sectors evaluated. Over the 11-year period, there has been a 412% increase in the accident frequency rate nationwide, while an average increase of 317% has been observed in the five evaluated sectors. The sector with the highest change is the construction sector with a 553% increase. The accident

frequency rate, which was 1.99 in 2012, reached 13.00 in 2022. The consistent increase in the accident frequency rate both nationally and in the evaluated sectors is an important indicator of the seriousness with which occupational health and safety measures are being taken.

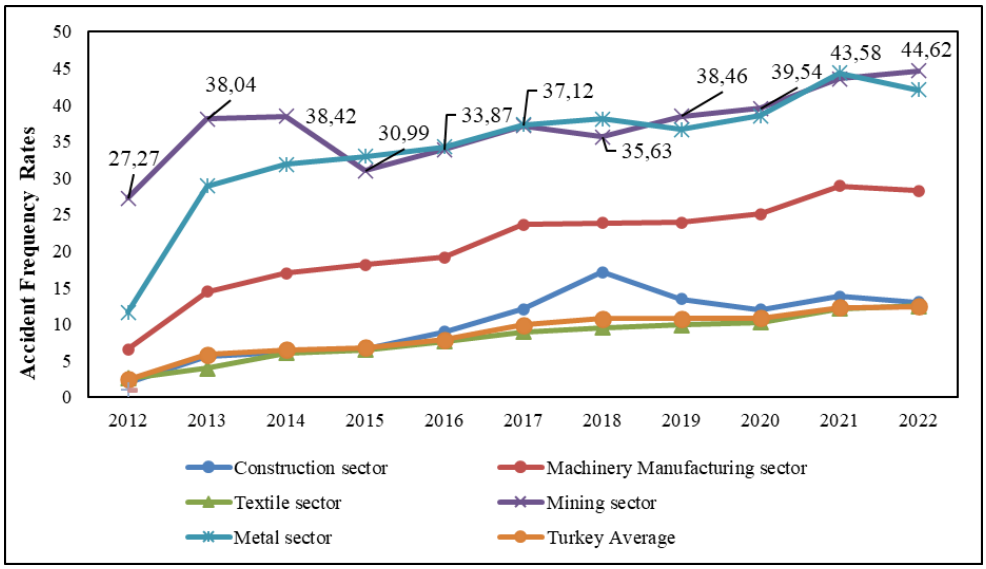

Figure 3. Accident frequency rates distribution by sector

Table 4 provides the temporary disability periods (days) and calculated accident weight rates for the sectors evaluated between 2012 and 2022. Accordingly, an average of 641 days per year has been lost due to work-related accidents nationwide, while an average of 1,714 days has been lost in the five sectors evaluated. Sectorally, the sector with the highest loss due to occupational accidents is the mining sector, with an average of 3,924 days lost per year.

Table 4. Accident weight rate information for sectors

Years	Construction Sector		Machinery Manufacturing Sec.		Textile Sector		Mining Sector		Metals Sector	
	Temporary incapacity periods (Days)	Accident Weight Rate	Temporary incapacity periods (Days)	Accident Weight Rate	Temporary incapacity periods (Days)	Accident Weight Rate	Temporary incapacity periods (Days)	Accident Weight Rate	Temporary incapacity periods (Days)	Accident Weight Rate
2012	309,441	778	218,806	544	94,072	186	173,404	2144	91,828	798
2013	457,437	1134	345,793	690	137,264	217	173,322	2730	152,657	1339
2014	358,536	1045	302,675	643	135,715	178	133,430	9534	139,804	904
2015	562,498	1254	442,249	926	160,366	228	155,668	3541	177,320	1684
2016	700,908	1554	492,500	899	179,882	365	176,026	4071	188,489	2140
2017	838,697	2381	561,094	1574	202,291	474	199,718	4662	227,146	2779
2018	528,410	3940	341,591	1981	128,043	558	126,774	4999	126,442	3679
2019	521,203	1883	520,821	763	232,592	286	193,955	2471	206,195	1397
2020	504,166	1518	520,010	710	210,339	257	180,018	2919	206,699	1566
2021	667,190	1375	695,224	763	316,732	298	233,242	2825	281,744	1574
2022	665,725	1302	724,302	786	313,820	275	246,682	3264	285,387	1485
Avg.	555,837	1,651	469,551	934	191,920	302	181,113	3,924	189,428	1,759

Source: Compiled from Turkey's SSI statistics.

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Figure 4 presents the year-on-year changes in accident weight rate. All sectors except for the Textile sector have an accident weight rate above the Turkish average. Generally, there has been an increase in accident weight rates over the years, with a particularly significant increase in all sectors in 2018 compared to the previous year.

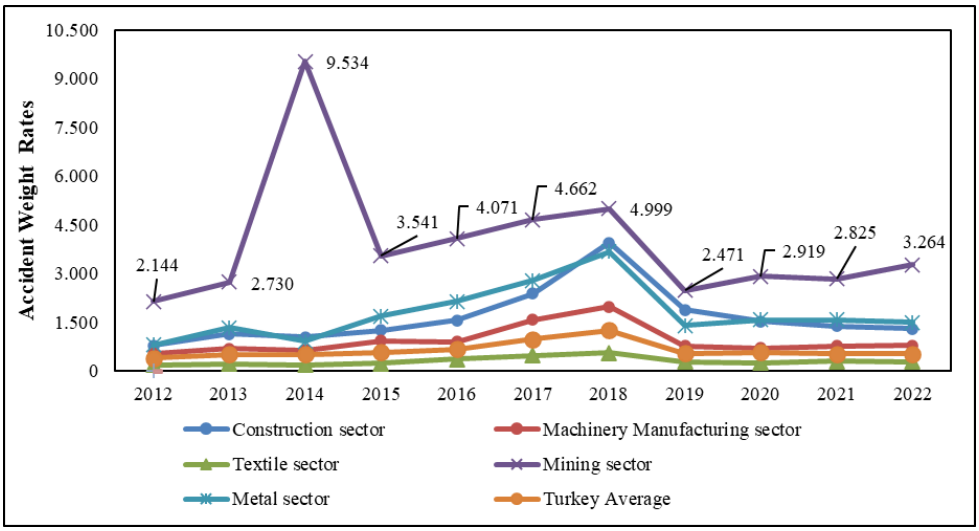

Figure 4. Accident weight rates distribution by sector

Figure 5 depicts the estimated number of occupational accidents and R^2 values for 2023-2026, as calculated from 11 years of data. In the 11-year time frame evaluated across the five sectors, an average of 140,798 accidents occur, while nationally, 337,501 accidents occur. Without taking necessary measures, it is estimated that the number of accidents will increase by 82% over the next 4 years, reaching an annual average of 256,097 (R2=0.9475) in the five sectors, and by 98% nationally, reaching 667,772 accidents (R2=0.9746). It is expected that the textile sector will experience the highest increase in the number of accidents over the next 4 years. Accordingly, the average annual number of accidents in the textile sector, which was 21,785 from 2012 to 2022, is estimated to increase by 110% to an annual average of 45,756 between 2023 and 2026, based on trend analysis. When examining the increases in accident numbers in other sectors, it is anticipated that they will increase by 93% in the machinery manufacturing sector, 76% in the construction sector, 69% in the metal sector, and 34% in the mining sector.

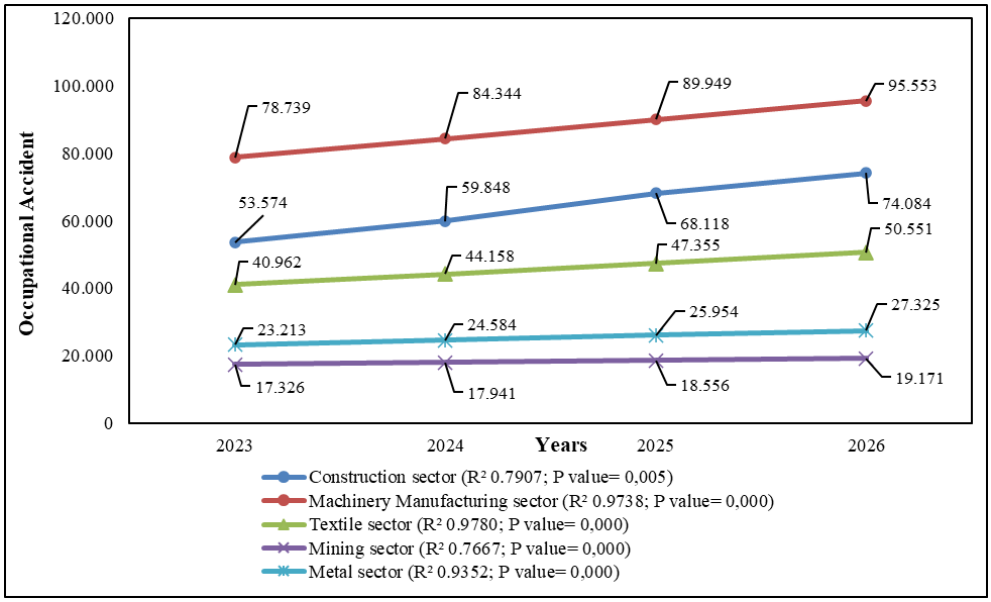

Figure 5. Occupational accident trend between 2023 and 2026 on a sectoral basis

In Figure 6, predictions of accident frequency rates for the years 2023-2026 in the evaluated sectors using 11 years of data are provided. The R^2 values calculated for the sectors are generally above 80%. This indicates that the predictions fit well to the linear curve, demonstrating that the estimated data align well with the linear trend.

The general trend of accident frequency rates in the sectors is increasing, as shown in Figure 6. Over the 11 years where actual data from the five sectors were considered, there were an average of 13.9 accidents per 1,000,000 work hours annually. This number is projected to increase by 138% over the next four years, reaching an annual average of 33.13 accidents (R^2=0.9695). Similarly, in

Turkey as a whole, the annual average accident frequency rate, which is currently 8.77, is estimated to increase by 77% to 15.56 between 2023 and 2026 (R^2=0.9746).

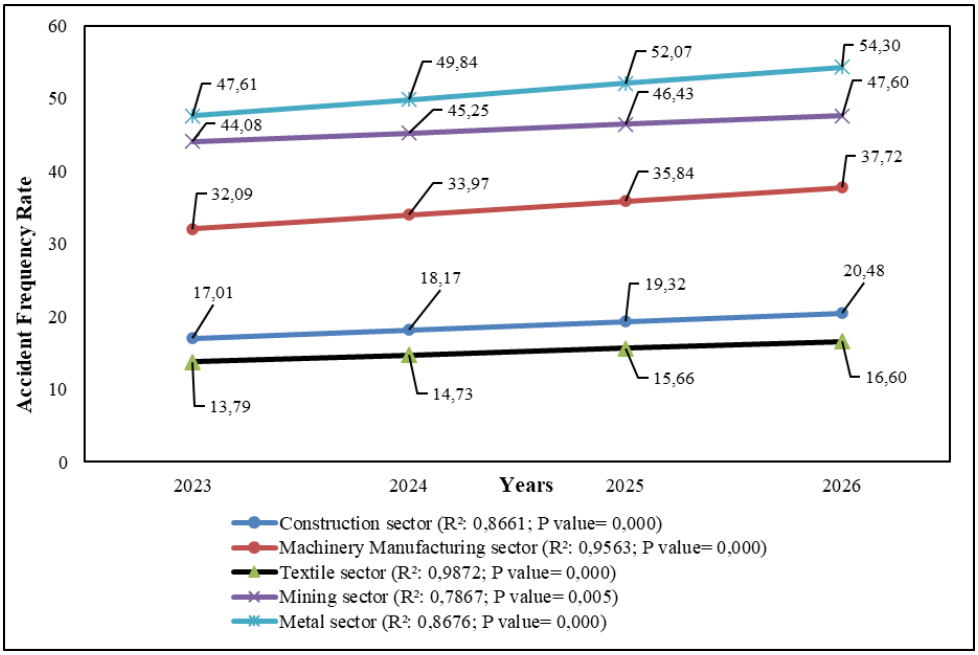

Figure 6. Accident frequency rate trend between 2023 and 2026 on a sectoral basis

In Figure 7, predictions of incidence rates for the years 2023-2026 in the evaluated sectors using 11 years of data are provided. Within the evaluated sectors, it is expected that the number of accidents will increase the most in the Construction sector over the next four years. Accordingly, while there were an average of 10.07 accidents per 1,000,000 work hours annually in the Construction sector from 2012 to 2022, it is projected to increase by 86% to an annual average of 18.75 accidents between 2023 and 2026 based on trend analysis. When examining the increases in accident frequency rates in other sectors, it is anticipated that they will increase by an annual average of 85% in the Textile sector, 66% in the Machinery Manufacturing sector, 49% in the Metal sector, and 23% in the Mining sector.

Between 2012 and 2022, on average, 3.62 out of every 100 workers in the five evaluated sectors and 2.29 out of every 100 workers nationwide were exposed to accidents. According to the trend analysis, it is estimated that the incidence rate in Turkey will increase by 78% to 4.08 (R^2=0.9501) between 2023 and 2026, and in the five sectors, it will increase by 140% to 8.70 (R^2=0.8745). Among the sectors, it is expected that the increase in incidence rates over the next 4 years will be highest in the Textile and Construction sectors. Accordingly, it is forecasted that the number of employees affected by accidents will increase by 87% in the Textile and Construction sectors between 2023 and 2026. When examining the annual average increase in incidence rates in other sectors, it is estimated to increase by 69% in the Machinery Manufacturing sector, 50% in the Metal sector, and 25% in the Mining sector. Since the R^2 values of the accident weight rate and mortality rate parameters used in comparing sectors in the study are very low, the trend analysis results have not been shared.

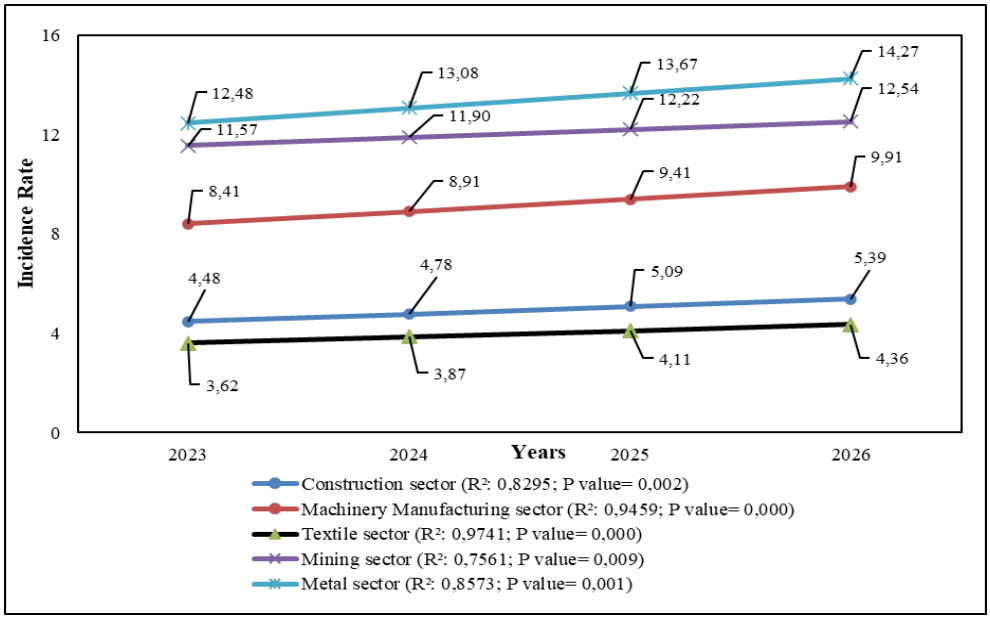

Figure 7. Incidence rate trend between 2023 and 2026 on a sectoral basis

The accident frequency rates and mortality rates in Turkey have been compared with selected EU countries. Accident frequency rates were calculated considering the number of accidents per 100,000 workers. Since the most recent data available from Eurostat, the data-sharing platform for EU countries, is from the year 2021, the comparison was made for the years between 2012 and 2021.

Figure 8 presents the accident frequency rates for Turkey and selected EU countries. In Turkey, between 2012 and 2021, the annual average number of workers exposed to accidents per 100,000 workers was 2,179, while it was 3,254 in France, 2,039 in Denmark, 1,799 in Germany, 1,345 in Italy, 72 in Romania, and the average for the 27 EU member countries was 1,635 (Eurostat Non-fatal Accidents, 2021; Eurostat Fatal Accidents, 2021). After the enactment of Law No. 6331 on Occupational Health and Safety in Turkey, accurate accident data began to be collected, resulting in an increase in accident frequency rates. Particularly after 2016, Turkey's accident frequency rates surpassed those of many EU countries. However, it is noteworthy that while France's accident frequency rates are nearly double the EU average, countries like Romania report very low accident frequencies, with an average of 72.

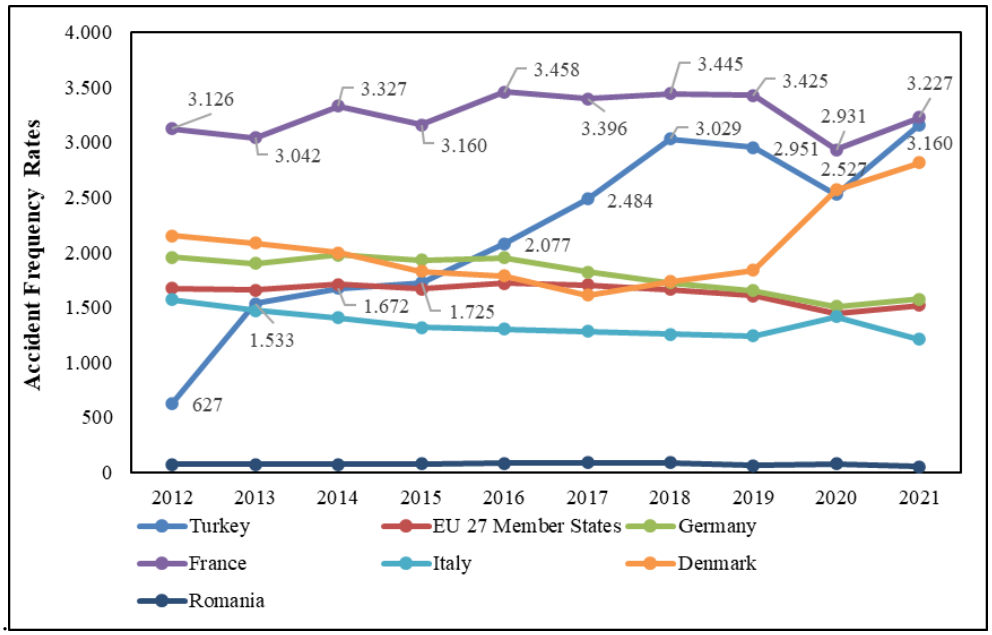

Figure 8. Occupational accident frequency rates for Turkey and selected EU countries

Figure 9 illustrates the fatality rate per 100,000 workers. The fatality rate in Turkey is approximately five times higher than the average of the 27 EU member countries. Between 2012 and 2021, in Turkey, the annual average number of workers who lost their lives per 100,000 workers was 9.53, while it was 4.52 in Romania, 2.88 in France, 2.43 in Italy, 1.32 in Denmark, 0.94 in Germany, and 1.87 in the average of the 27 EU member countries. In this context, in Turkey, the number of workers who lost their lives is five times higher than the average of the 27 EU member countries and ten times higher than Germany, which is a leading country in industry within the European Union. Additionally, in Turkey, the number of workers who lost their lives is even double that of Romania. The fact that

both the accident frequency rates and the mortality rates are significantly high in Turkey is an important evidence indicating the necessity of taking much more serious measures regarding occupational health and safety.

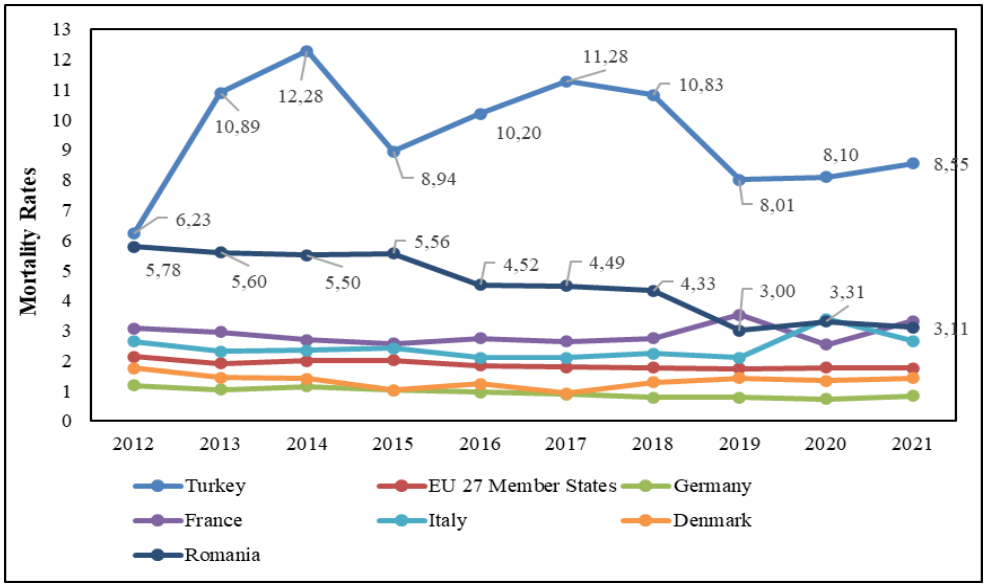

Figure 9. Mortality rates for Turkey and selected EU countries

Turkey's accident parameters are also higher compared to Middle Eastern countries. The incidence rate in Turkey between 2012 and 2022 has been calculated as 22.9 per 1,000. In a study conducted in Iran between 2001 and 2005, this rate was calculated as 3.8 per 1,000 (Ghods et al., 2009). The incidence rate for Middle Eastern countries was calculated as 9 per 1,000 in 2006 (Shafieian et al., 2007).

In Turkey, between 2012 and 2022, the average accident frequency rate and accident weight rate in the construction sector were calculated as 10.88 and 1,739, respectively. In a study conducted by Soltanzadeh et al., the average accident frequency rate and accident weight rate in the construction sector were calculated as 4.71 and 216, respectively (Ahmad et al., 2016).

5. Conclusions

Within the scope of the study, accident data that occurred in five different sectors where accidents are frequently observed between 2012 and 2022 were analyzed using internationally accepted parameters. Based on the analysis conducted, comparisons were made among the sectors themselves and with the overall data for Turkey. Through trend analysis, the projected numbers of accidents, incidence rates, and accident frequency rates for the years 2023-2026 were calculated for the five sectors and for Turkey as a whole, providing a perspective for the future. Additionally, a comparison was made between Turkey and some developed and developing countries that are members of the European Union.

Over the past eleven years, an average of 337,501 accidents occurred nationwide in Turkey. Of these accidents, 41.7% (140,798) occurred in the five sectors under evaluation. The sectors with the highest risk of accidents are the Mining and Metal sectors. On average, 1,349 fatal accidents occur annually in Turkey. Of these fatal accidents, 49% (663) occurred in the five evaluated sectors. When examining the overall mortality rates in Turkey, it is observed that 10 out of every 100,000 workers lose their lives. However, when looking at the average of the five evaluated sectors, the mortality rate increases by approximately 2 times to 17.

The data on fatal accident frequency in Turkey indicates significantly higher rates compared to the average of the EU 27 member countries and the other countries included in the comparison. In Turkey, workers are losing their lives at a rate five times higher than the average of the EU 27 member countries and ten times higher than Germany, which is a leading industrial country within the European Union.

Accidents in Turkey primarily stem from worker errors. Therefore, integrating technological advancements capable of mitigating individual errors into sectors would offer a significant advantage in reducing potential accidents. The trend analysis conducted utilized data spanning 11 years. In subsequent studies, employing longer-term datasets would enhance the accuracy of predictions for the estimated years.

In future studies, similar parameters can be calculated for different sectors not analyzed within the scope of the current study, allowing for comparisons with the sectors analyzed in the present study. Since the Social Security Institution (SSI) has published data up to the year 2022, the data used in the current study only covers up to 2022. Once SSI releases updated data, the study can be repeated to assess changes in sectoral trends. In the current study, future projections were conducted using simple linear regression. In future

studies, various methods such as exponential, linear, logarithmic, polynomial, and moving average techniques can be calculated and compared individually to determine the trendline used for predictions. Additionally, in the current study, Turkish data was compared with European Union data by aggregating all NACE codes. Eurostat provides sectoral data, enabling comparisons between Turkish and European Union data at a sectoral level. Consequently, in future studies, Turkish data can be compared with European Union data at a sectoral level using Eurostat's sectoral data retrieval feature.

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