PREDICTIVE MODELING OF WORK ACCIDENTS USING LAGGING SAFETY INDICATORS: PERSPECTIVES ON SOCIAL SECURITY TRANSFORMATION IN THE 21ST CENTURY

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Başvuru Tarihi: 23/04/2025 **Kabul Tarihi:** 23/05/2025

DOI: 0.21441/sosyalguvence.1682358 **Türü:** Araştırma Makalesi

Atıf: Tuna G. (2025), Predictive Modeling Of Work Accidents Using Lagging Safety Indicators: Perspectives On Social Security Transformation In The 21st Century, Sosyal Güvence Dergisi, 2025 (Özel Sayı), s. 299-346. doi: 10.21441/sosyalguvence.1682358

ABSTRACT

The 21st century has introduced complex and evolving risks that challenge the resilience and adaptability of social security systems. Among these, work accidents and occupational disabilities continue to pose persistent threats to labor force stability, income security, and long-term well-being. As technological transformations reshape the nature of work and global crises—such as the COVID-19 pandemic—expose vulnerabilities in workplace protections, the need to reassess and strengthen occupational risk frameworks becomes increasingly urgent. This article positions occupational risk management within the broader context of modernizing social security frameworks. It advocates for the integration of digital tools and predictive analytics into safety monitoring systems to enhance responsiveness to emerging labor market Dynamics, it examines the characteristics of lagging indicators in occupational health and safety, and includes reactive and proactive solutions, respectively. Using data on work accidents in Türkiye from 2013 to 2023, time series analysis, correlation analysis, Granger causality tests, and predictive models were developed. The relationships between lagging indicators and outcomes such as accidents and fatalities and their effects analyzed. The results underscore the significance of taking preventive actions to minimize accidents in the workplace and illustrate how lagging indicators can be utilized to guide upcoming safety initiatives. Lagging indicators can also serve as predictive tools when used proactively. These findings highlight the need for continuous monitoring and the importance of targeted interventions to improve occupational health and safety outcomes. By linking empirical findings to contemporary policy challenges—such as adapting to new employment models and mitigating inequalities—the study contributes to discussions on building resilient, inclusive, and future-ready social protection systems.

Keywords: Lagging Safety Indicators, Work Accidents, Occupational Health and Safety, Predictive Modeling.

GECİKMELİ GÜVENLİK GÖSTERGELERİYLE İŞ KAZALARININ TAHMİNLEMESİ: 21. YÜZYILDA SOSYAL GÜVENLİK DÖNÜŞÜMÜNE YÖNELİK PERSPEKTİFLER

ÖZ

21. yüzyıl, sosyal güvenlik sistemlerinin dayanıklılığını ve uyum kabiliyetini zorlayan karmaşık ve gelişen riskleri beraberinde getirmiştir. Bunlar arasında, iş kazaları ve iş göremezlik durumları, iş gücü istikrarı, gelir güvenliği ve uzun vadeli refah açısından, kalıcı tehditler oluşturmaya devam etmektedir. Teknolojik dönüşümler işin doğasını değiştirirken ve küresel krizler—örneğin COVID-19 pandemisi—işyeri koruma mekanizmalarındaki kırılganlıkları açığa çıkarırken, iş risklerinin yönetim çerçevelerini yeniden değerlendirme ve güçlendirme ihtiyacı giderek daha acil hale gelmektedir. Bu çalışma, mesleki risk yönetimini sosyal güvenlik çerçevelerinin modernizasyonu bağlamında konumlandırmaktadır. Dijital araçların ve tahminleme analitiklerin güvenlik izleme sistemlerine entegrasyonunu savunarak, ortaya çıkan iş gücü piyasası dinamiklerine daha duyarlı hale gelinmesini önermektedir, iş sağlığı ve güvenliğinde gecikmeli göstergelerin özellikleri incelemekte olup, sırasıyla reaktif ve proaktif çözümleri içermektedir. Türkiye'de 2013-2023 yılları arasındaki iş kazalarına ilişkin veriler kullanılarak zaman serisi analizi, korelasyon analizi, Granger nedensellik testleri ve tahmin modelleri geliştirilmiştir. Gecikmeli göstergeler ile kazalar ve ölümler gibi sonuçlar arasındaki ilişkileri ve bunların etkileri analiz edilmiştir. Sonuçlar, işyerinde kazaları en aza indirmek için önleyici eylemlerin alınmasının önemini vurgulamakta ve gecikmeli göstergelerin gelecekteki güvenlik girişimlerine rehberlik etmek için nasıl kullanılabileceğini göstermektedir. Gecikmeli göstergeler, proaktif bir şekilde kullanıldığında tahmin araçları olarak da işlev görebilir. Bu bulgular, iş sağlığı ve güvenliği sonuçlarını iyileştirmek için sürekli izlemenin gerekliliğini ve hedefe yönelik müdahalelerin önemini ortaya koymaktadır. Ampirik bulguları çağdaş politika zorluklarıyla—yeni istihdam modellerine uyum sağlama ve eşitsizlikleri azaltma gibi—ilişkilendirerek, çalışmanın dayanıklı, kapsayıcı ve geleceğe hazır sosyal koruma sistemlerinin oluşturulmasına yönelik tartışmalara katkı sağlamasını amaçlamaktadır.

Anahtar Kelimeler: Gecikmeli Güvenlik Göstergeleri, İş Kazaları, İş Sağlığı ve Güvenliği, Tahmini Modelleme.

INTRODUCTION

In the 21st century, social security systems are confronted with unprecedented challenges arising from demographic shifts, technological transformations, environmental risks, and global crises. Among these emerging concerns, occupational health and safety represent a critical yet often overlooked dimension of labor protection and income security. Work accidents not only threaten individual well-being but also impose significant economic and social costs, affecting productivity, healthcare expenditures, and long-term disability support systems.

Although workplace safety has improved in many sectors in recent years, new risks continue to emerge alongside evolving work structures—such as remote employment, flexible working arrangements, and automation-driven industrial processes. These changes necessitate a re-evaluation of traditional risk prevention mechanisms and highlight the importance of adaptable policy frameworks capable of effectively responding to changing occupational hazards.

This study contributes to this discourse by analyzing longitudinal data on work-related accidents and associated incapacity cases in Türkiye between 2013 and 2023. The research focuses on key indicators such as the number of insured individuals, fatal and non-fatal accident rates, and temporary and permanent incapacity claims. It highlights both the progress made in occupational safety management and the ongoing vulnerabilities in the system.

By situating empirical findings within the transformation of modern social security systems, this paper explores how current policies can be enhanced through digitalization, predictive analytics, and stronger regulatory enforcement. It argues that reducing occupational risks is not only essential for protecting worker health but also critical for ensuring the sustainability of future-oriented social security frameworks.

Occupational safety is considered a critical area for preventing work accidents and ensuring the well-being of employees.

OSH represents a comprehensive interdisciplinary domain dedicated to safeguarding the physical, psychological, and social welfare of employees across diverse professions. According to World Health Organization (WHO), this field encompasses the formulation and enactment of policies, procedures, and practices specifically designed to avert work-related injuries, illnesses, and fatalities (WHO, 2023). The principal aim of OSH is to establish a secure and health-promoting work environment wherein employees can execute their responsibilities devoid of undue risks to their health and safety.

As articulated by the International Labour Organization (ILO), OSH embodies a

proactive methodology for recognizing, assessing, and mitigating hazards present in the workplace (ILO, 2023). This proactive stance includes the management of risks linked to chemical exposures, ergonomic challenges, machinery operation, psychological stress, and environmental factors. An effective OSH framework incorporates legal statutes, educational initiatives, emergency preparedness protocols, and ongoing monitoring systems to guarantee adherence and efficacy.

The fundamental objective of occupational safety transcends mere accident and occupational disease prevention; it also seeks to cultivate a culture of proactive prevention and accountability among both employers and employees. In pursuing this objective, occupational safety enhances productivity, diminishes absenteeism, and nurtures a constructive organizational atmosphere (European Agency for Safety and Health at Work, 2021).

The function of OSH within the workplace is multifarious. Initially, it establishes a systematic framework for hazard identification and risk assessment. Subsequently, it mandates the provision of personal protective equipment (PPE), appropriate training, and emergency response mechanisms. Furthermore, it ensures compliance with both national and international labor standards as delineated by entities such as the ILO and the WHO.

Additionally, OSH plays an indispensable role in fostering psychosocial health by addressing concerns such as workplace harassment, excessive workloads, and job insecurity—elements that can drastically influence employee performance and retention.

Regarding contributions, efficacious OSH methodologies have demonstrated a capacity to diminish the prevalence of work-related injuries and illnesses, consequently leading to reduced healthcare expenditures and insurance premiums for employers (Centers for Disease Control and Prevention, 2021). Moreover, organizations that prioritize the safety of their workforce generally report elevated levels of employee morale, engagement, and loyalty. Viewed through a broader lens, robust OSH systems contribute to sustainable economic advancement by safeguarding human capital and alleviating the socioeconomic burden associated with occupational diseases.

The benefits of instituting comprehensive occupational safety protocols are both concrete and abstract. Concrete advantages encompass diminished absenteeism rates, lowered compensation claims, and enhanced operational efficiency. In contrast, abstract benefits include an improved corporate reputation, heightened employee trust, and alignment with global sustainability objectives, such as the United Nations' Sustainable Development Goals (SDGs), particularly SDG 8, which underscores decent work and economic development (United Nations, 2023).

In summary, occupational safety and health extends beyond mere regulatory compliance; it constitutes a strategic imperative for contemporary organizations. Its seamless integration into everyday operations signifies a commitment to ethical business practices and the long-term sustainability of the workforce. As the nature of work continues to transform—with the advent of new technologies, remote work configurations, and evolving labor dynamics—the necessity of sustaining rigorous OSH standards becomes increasingly vital in ensuring the well-being of all workers.

Leading indicators are at the heart of past events, while lagging indicators recognize opportunities while proactively demonstrating safety efforts. This study provides broad evaluation of growth on lagging indicators and effective model development to predict crashes.

1. Literature Review, Applications, and Challenges of Lagging Indicators

Lagging indicators serve as critical tools in understanding safety performance by focusing on past adverse events such as workplace accidents, injuries, and illnesses. These indicators provide retrospective insights, allowing organizations to measure the effectiveness of safety protocols and identify trends over time (Dale et al., 2017).

However, their reactive nature means they are limited in predicting future risks (Flin et al., 2000), making their integration with leading indicators essential for a comprehensive safety management framework (Zhou et al., 2008). In the subsequent sections, we explore their theoretical foundation, key studies, applications in policy, and challenges related to their use.

Theoretical insights into lagging indicators emphasize their role in validating safety performance and assessing compliance (Dale et al., 2017; Zwetsloot et al., 2013). Research has expanded on their methodological applications, introducing metrics such as severity-based indicators to enhance evaluation precision (Hinze et al., 2013). Their application in occupational safety policy highlights their utility in regulatory compliance and performance benchmarking (Hasle, 2014). Despite their value, challenges such as data accuracy and reliance on historical incidents limit their proactive utility (Goh & Zainuddin, 2017), underscoring the importance of combining lagging and leading indicators for a holistic approach to workplace safety management (Zhou et al., 2008; Neal & Griffin, 2006).

1.1. Theoretical Background and Definition of Lagging Indicators

Within the scope of OSH, lagging indicators are retrospective metrics that quantify past adverse events, such as workplace accidents, injuries, illnesses, and fatalities, thereby providing tangible data on safety performance outcomes (Manuele, 2009, p. 33). These indicators encompass measures like injury frequency and severity rates, lost time injury

frequency rates, workers' compensation claims, and incident counts, reflecting the effectiveness of existing safety protocols and highlighting areas necessitating improvement (Pawłowska, 2015, p. 284). By analyzing these metrics, organizations can identify trends and patterns in safety performance, facilitating the evaluation of historical safety outcomes and the development of strategies to mitigate future incidents (Shea et al., 2016, p. 130).

However, the inherent reactive nature of lagging indicators means they document events post-occurrence, offering limited foresight into potential future incidents and underscoring the necessity for proactive safety measures (Manuele, 2009, p. 33). This limitation suggests that while lagging indicators are valuable for assessing past performance, they should be complemented with leading indicators to provide a comprehensive safety management approach that anticipates and prevents incidents before they occur (Pawłowska, 2015, p. 284).

1.2. Key Studies and Methodological Advances

The assessment of OSH performance has historically depended on lagging indicators, such as rates of injuries and illnesses, to evaluate safety results. Nevertheless, recent studies highlight the importance of combining both lagging and leading indicators to achieve a more holistic evaluation of safety performance. In a 2015 study, Pawłowska examined 60 companies to identify the types of indicators utilized for measuring OSH performance across various levels of organizational effectiveness. The study revealed that while compliance-related lagging indicators were commonly employed across all companies, those with higher OSH performance levels more frequently adopted leading indicators and monitored them regularly (Pawłowska, 2015, p. 284).

Further research by Hallowell et al. (2023) introduced a severity-based lagging indicator to enhance the measurement of safety performance. This method considers the seriousness of incidents, enabling a deeper and more meaningful analysis of safety outcomes that goes beyond simply counting the number of occurrences (Hallowell et al., 2023, p. 24). The research highlights the critical role of incorporating incident severity into safety metrics, aiming to enhance the effectiveness of safety management practices.

Additionally, a white paper by Underwriters Laboratories (UL) discusses the importance of combining leading and lagging indicators to effectively manage workplace health and safety risks. The article introduces a reporting framework designed to assess key safety components, emphasizing that combining both types of indicators promotes continuous enhancement in overall workplace safety initiatives (UL, 2013, p. 3).

These studies collectively highlight the evolution of safety performance measurement methodologies, advocating for a balanced approach that incorporates both lagging and

leading indicators. This integrated strategy enables organizations to not only assess past safety outcomes but also proactively identify and mitigate potential hazards, thereby enhancing overall safety performance.

1.3. Applications in Occupational Safety Policy

Lagging indicators are essential in occupational safety policy, serving as retrospective metrics that quantify past incidents such as workplace accidents, injuries, and illnesses (Manuele, 2009, p. 28). These metrics offer concrete data on safety performance results, allowing organizations to evaluate the efficacy of current safety protocols and pinpoint areas that require enhancement (Pawłowska, 2015, p. 284). Frequently used lagging indicators encompass injury frequency and severity rates, lost-time injury frequency rates, workers' compensation claims, and the total number of incidents (Shea et al., 2016, p. 131). By analyzing these metrics, organizations can identify trends and patterns in safety performance, facilitating the evaluation of historical safety outcomes and the development of strategies to mitigate future incidents (Yorio et al., 2020, p. 150).

However, the inherent reactive nature of lagging indicators means they document events post-occurrence, offering limited foresight into potential future incidents and underscoring the necessity for proactive safety measures (Manuele, 2009, p. 29). This limitation suggests that while lagging indicators are valuable for assessing past performance, they should be complemented with leading indicators to provide a comprehensive safety management approach that anticipates and prevents incidents before they occur (Pawłowska, 2015, p. 285).

Within the framework of occupational safety policy, lagging indicators are employed to assess the success of safety programs and adherence to regulatory requirements (Shea et al., 2016, p. 132). They provide quantifiable data that can be analyzed to identify patterns and areas for improvement (Yorio et al., 2020, p. 151). For instance, the Total Recordable Injury Rate (TRIR) is a common lagging indicator used to measure workplace safety performance (Manuele, 2009, p. 30).

Despite their widespread use, lagging indicators present challenges related to data reliability and analytical limitations (Pawłowska, 2015, p. 286). Their retrospective nature means they do not predict future incidents, and relying solely on them can lead to a reactive approach to safety management (Shea et al., 2016, p. 133). Additionally, underreporting of incidents can compromise data accuracy, making it difficult to assess true safety performance (Yorio et al., 2020, p. 152). Therefore, it is recommended to use lagging indicators in conjunction with leading indicators to develop a more proactive and comprehensive safety management strategy (Manuele, 2009, p. 31).

1.4. Challenges in Data Reliability and Analytical Limitations

In OSH, lagging indicators like injury and illness rates are frequently utilized to assess past performance outcomes. However, they have significant limitations in data reliability and analytical utility. One major issue is underreporting, where incidents are not consistently documented, leading to inaccurate data that hampers effective safety assessments (Makin & Winder, 2008, p. 655).

Additionally, lagging indicators provide a retrospective view, reflecting incidents that have already occurred, which limits their ability to predict future risks and necessitates the integration of leading indicators for a proactive safety approach (Pawłowska, 2015, p. 285). This reactive nature can result in delayed responses to emerging hazards, reducing the effectiveness of safety interventions.

Moreover, the reliance on lagging indicators may cause organizations to focus on compliance rather than fostering a proactive safety culture, as these metrics often emphasize meeting regulatory requirements over continuous improvement (Manuele, 2009, p. 30). This compliance-driven approach can hinder the development of innovative safety strategies and the identification of potential hazards before they result in incidents.

Furthermore, the variability in data collection methods and definitions across organizations complicates benchmarking and comparative analysis, making it challenging to establish industry-wide safety standards (Shea et al., 2016, p. 134). This inconsistency can lead to difficulties in assessing the true state of workplace safety and in implementing effective safety policies.

In conclusion, although lagging indicators play a crucial role in evaluating past safety performance, their shortcomings in terms of data reliability and predictive power underscore the importance of adopting a balanced strategy that integrates both leading and lagging indicators to improve occupational safety management.

2. Lagging Indicators of work accidents

The Social Security Institution of Republic of Türkiye (SGK) regularly publishes statistics on the sectoral distribution of insured individuals in Türkiye. These data are of great importance for OSH, economic analyses, policy development, and academic studies (Işık & Işıkhan, 2024). The sectoral insured statistics of the SGK are generally addressed under the following headings:

Data Sources and Collection Methods

The sectoral insured statistics of the SGK are obtained from the following sources:

- Insured Reporting System: Monthly reports submitted by employers to the SGK.
- Premium Payment Records: Classification based on the premium payment status of insured individuals.
- NACE (Nomenclature of Economic Activities) Rev. 2 Codes: Classification of sectors according to the NACE system, enabling sector-based analysis of the data.
- These data provide a comprehensive basis for analyzing issues such as workplace accidents, occupational diseases, and working conditions of insured individuals (Bayramlar, Ezirmik, İşsever & Bayramlar 2019).

Sectoral Distribution

In the statistics published by the SGK, insured individuals are generally classified into the following sectors:

- Agriculture and Forestry (NACE Section A): Activities related to agriculture, livestock farming, forestry, and fishing.
- Industry and Manufacturing (NACE Sections C-D): Covers mining, manufacturing, electricity and gas supply, water management, and waste disposal.
- Construction (NACE Section F): Building construction, infrastructure projects, and other construction services.
- Service Sector (NACE Sections G-U): Trade, transportation, communication, finance, education, health, tourism, and other services.

Since each sector has a different risk profile, this distribution is critically important for analyzing workplace accidents and occupational diseases (Eurostat, 2008).

Number of Insured Individuals and Trends

The annual reports of the SGK include the following information:

- Total Number of Insured Individuals: The number of active insured individuals (those paying premiums).
- Sectoral Distribution: The proportion of insured individuals working in each sector relative to the total.
- Gender Distribution: The ratio of male to female insured individuals.
- Age Groups: The distribution of young, middle-aged, and older insured individuals.

- Temporary and Permanent Workers: The ratio of temporary workers to permanent workers.

For example, since the construction sector is generally considered a high-risk industry, the proportion of insured individuals working in this sector and their workplace accident rates are closely monitored.

Workplace Accidents and Occupational Disease Statistics

The sectoral insured statistics of the SGK also play an important role in analyzing workplace accidents and occupational diseases:

- Workplace Accident Rates: The number and rates of workplace accidents in each sector (accidents per insured individual).
- Occupational Disease Rates: The distribution of occupational disease cases across sectors.
- Risk Analysis: Identification of high-risk sectors and the development of preventive policies.

The data we used is obtained from the Statistics of SGK for the calendar years of 2013–2023 (Sosyal Güvenlik Kurumu, 2025). In this study, work accident data of 4/a insured persons were discussed.

The NACE is an European industry-standard classification system that categorizes economic activities. It offers a systematic framework for organizing and analyzing economic data across various sectors and industries. Below is an in-depth academic explanation of NACE's economic methodology, its hierarchical organization, and its importance. The NACE system classifies economic activities into parts, sections, divisions, groups, classes, and subclasses, providing a detailed and structured approach to categorization. There are 21 parts, 88 sections, 272 groups, 615 classes and 2182 subclasses in NACE. NACE sections are coded consecutively from 1 to 99.

The NACE system is a robust and versatile tool for classifying economic activities. Its hierarchical structure allows for flexibility in analysis, from broad overviews to highly detailed investigations. By providing a standardized framework, NACE supports economic research, policy formulation, and business strategy development, making it indispensable for academics, policymakers, and practitioners alike (Eurostat, 2008).

Work accidents are unfortunate events that can have serious consequences for employees and their families. In Türkiye, work accidents are defined under Law No. 6331 on Occupational Health and Safety as incidents occurring at the workplace or during work-related activities that harm the physical or mental health of employees, or in severe cases,

result in fatalities (T.C. Resmi Gazete, 2012).

Compensation rights for work accidents in Türkiye include:

- Moral Compensation: For emotional and psychological suffering.
- Material Compensation: Covers economic losses like medical expenses and lost earnings.
- Loss of Work Capacity Compensation: For reduced earning potential due to injuries.
- Compensation for Deprivation of Support: For dependents of deceased workers (Özdemir & Yılmaz, 2018).

2.1 Number of insured having work accident

A comprehensive understanding of the incidence of work-related accidents among insured individuals is imperative for evaluating the effectiveness of occupational safety regulations and insurance frameworks. The term "number of insured having work accidents" pertains to the quantification of employees who have sustained injuries or illnesses attributable to occupational activities and are beneficiaries of a structured occupational injury insurance program. This metric functions as a lagging indicator, encapsulating historical incidents rather than forecasting prospective risks, yet it remains a vital parameter for appraising the overall impact of workplace accidents on both employers and insurance infrastructures (Hasle, 2014; Zwetsloot et al., 2013).

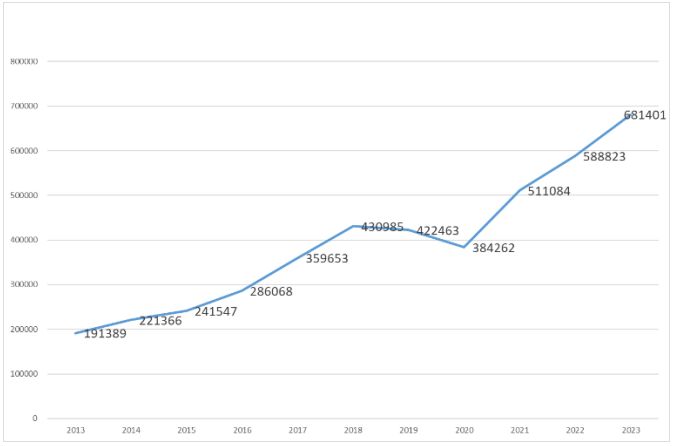
The monitoring of this statistic enables policymakers and organizations to: Analyze longitudinal trends in occupational injuries. Pinpoint sectors or occupations characterized by heightened risk. Assess the sufficiency and scope of insurance provisions. Guide prevention methodologies informed by historical incident trends.

Figure 1 delineates the annual count of insured individuals who encountered work-related accidents throughout the designated study timeframe. The data demonstrates variations that may correlate with fluctuations in labor market conditions, enforcement of regulations, or cyclical economic patterns. Significantly, peaks within the figure may signify epochs of intensified industrial activity or inadequate preventive strategies, while declines may indicate advancements in workplace safety protocols or challenges related to underreporting.

This visual depiction offers a foundational comprehension of accident frequency among insured employees and facilitates further exploration into contributing determinants such as sector-specific hazards, compliance rates, and policy responses.

The Figure 1 below shows the number of insured having work accidents reported each year from 2013 to 2023.

Figure 1: Number Of Insured Having Work Accident, 2013-2023



As shown in Figure 1, the number of insured workers experiencing work accidents has generally increased over the years. Starting at 191,389 in 2013, the figure rose steadily to reach 681,401 in 2023. Notably, there was a temporary decline in 2020, likely due to pandemic-related restrictions that reduced industrial activity. However, the numbers rebounded sharply in subsequent years, indicating a return to higher-risk operational conditions. This upward trend highlights the growing need for enhanced safety protocols and preventive measures to mitigate workplace hazards effectively.

Fatal workplace accidents represent severe incidents that carry profound consequences for individuals, families, and entire industries. They underscore the need for robust occupational safety measures and regulations. Based on the data you provided earlier, the examination yielded discernible trends indicating elevated mortality rates within industries such as construction, manufacturing, and transportation/storage (Hale & Hovden, 1998). These industries often involve high-risk activities, which may explain the numbers. Some sectors, like education and information and communication, show relatively lower incidents, indicating safer environments or less hazardous operations (Reason, J. 1997). Efforts to mitigate workplace accidents include stricter compliance with safety standards, targeted training programs, risk assessments, and advancements in protective equipment (Khanzode, Maiti & Ray, 2012).

The provided data (Table-1) shows the number of work accidents across 21 economic activity parts classified under the NACE Rev. 2 system, spanning from 2013 to 2023. This analysis will focus on identifying trends, patterns, and insights regarding work accidents in different sectors over this period.

Table 1: Work Accidents, 2013-2023

Nace Rev.2 - 21 Parts	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Information and communication	224	340	421	543	833	912	1,005	867	854	1,119	1,221
Other service activities	2,640	2,028	1,856	1,991	1,380	1,655	1,559	1,319	1,418	1,609	1,977
Education	712	924	1,773	4,744	5,551	6,541	7,992	3,703	5,963	9,885	11,213
Production and distribution of electricity, gas, steam and air conditioning	795	1,274	1,815	1,760	3,206	3,651	3,954	3,790	4,865	5,989	6,346
Finance and insurance activities	190	225	320	347	469	483	562	313	348	568	711
Real estate activities	32	155	293	434	702	875	1,041	935	1,190	1,270	1,381
Activities of households as employers; activities of producing goods and services, undisclosed, by households for their own use	29	46	64	89	63	77	65	18	9	24	19
Administrative and support service activities	5,791	10,514	14,036	18,171	23,291	28,114	30,991	24,474	27,368	33,332	40,109
Manufacturing	97,027	111,153	117,520	131,896	159,815	183,288	182,623	179,165	243,302	268,620	304,864
Human health and social service activities	1,210	2,098	3,084	4,696	7,347	10,888	14,423	19,382	22,104	27,378	29,899
Construction	26,967	29,699	33,361	44,552	62,802	77,157	47,701	44,304	58,107	64,184	82,111
Public administration and defense; compulsory social security	128	108	227	377	483	1,398	2,219	2,392	3,699	4,436	4,695
Accommodation and catering activities	10,617	13,837	15,554	18,023	24,709	35,298	43,426	24,818	40,837	56,062	67,795
Culture, arts, entertainment, recreation and sports	232	274	312	404	448	850	1,407	676	609	874	1,050
Mining and quarrying	14,304	13,049	10,420	11,792	13,052	13,771	14,167	13,047	17,083	19,369	19,804
Vocational, scientific and technical activities	1,533	1,988	2,153	2,842	3,196	3,900	3,959	3,909	4,593	5,528	6,432
Water supply; sewerage, waste management and improvement activities	1,166	2,335	4,057	5,052	6,753	6,887	7,138	6,622	7,224	7,778	9,060
Agriculture, forestry and fishing	1,672	2,076	2,453	2,790	2,761	3,439	3,641	3,331	4,258	4,610	5,337
Wholesale and retail trade; repair of motor vehicles and motorcycles	9,898	11,768	13,330	16,470	21,135	25,552	25,837	25,995	34,259	36,678	41,614
Transportation and storage	16,212	17,465	18,491	19,087	21,643	26,229	28,733	25,188	32,973	39,490	45,739
Activities of international organizations and their representatives	10	10	7	8	14	20	20	14	21	20	24
Sum	191,389	221,366	241,547	286,068	359,653	430,985	422,463	384,262	511,084	588,823	681,401

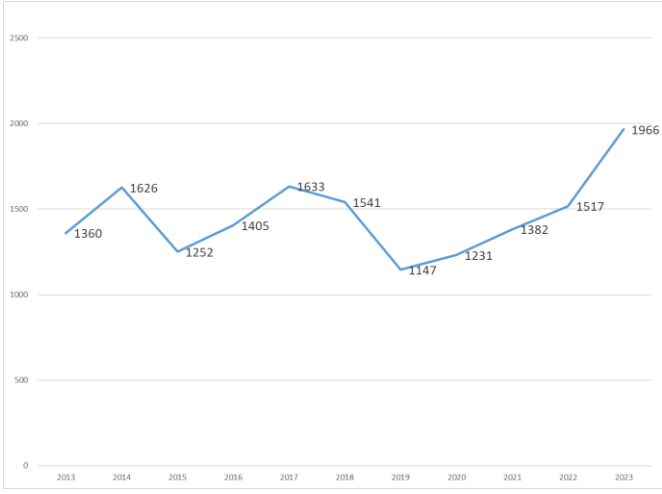
Source: Calculated by the author from the (SGK) 2013-2023 Work Accidents and Occupational Diseases Statistics Yearbook.

2.2 Number of fatal accident at work

Work-related fatalities are tragic occurrences that underscore the critical need for effective workplace safety measures. In 2022, the European Union recorded 3,286 work-related fatalities (Eurostat, 2024), with nearly a quarter of these incidents occurring in the construction sector (Lingard & Rowlinson, 2005). Globally, occupational accidents have significant human, social, and economic costs, and efforts to improve safety standards that are crucial (ILO, 2023).

This Figure 2 presents the annual number of fatal accidents at work from 2013 to 2023. The data shows fluctuations over time, with a notable increase in recent years. Starting from 1,360 in 2013, the number reached a peak of 1,966 in 2023, indicating a concerning upward trend.

Figure 2: Number Of Fatal Accident At Work, 2013-2023



Although some years saw declines (e.g., 2015 and 2019), the overall pattern suggests that fatal accidents remain a persistent issue, especially in high-risk sectors. This trend underscores the urgent need for stronger preventive measures and improved occupational safety policies.

The dataset presented in Table 2 illustrates the number of work-related fatalities across various main activity groups under NACE Rev. 2 (the 21 economic sections), covering the period from 2013 to 2023. The numbers indicate significant variations by sector and year. For instance:

- Construction consistently shows the highest numbers, peaking at 591 in 2018 and again reaching 552 in 2023.

- Manufacturing also has high numbers, with a sharp increase from 330 in 2022 to 492 in 2023.
- Transportation and Storage displays a steady increase over the years, reaching 347 in 2023.
- Mining and Quarrying had a spike in 2014 (382), but stabilized to 86 in 2023.
- Education and Information and Communication have relatively lower figures.

Table 2: Fatal Accidents At Work, 2013-2023

Nace rev.2 - 21 parts	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Information and communication	3	6	1	5	6	3	1	2	5	7	3
Other service activities	13	14	3	6	4	7	5	8	9	11	4
Education	3	3	5	9	11	9	6	1	3	9	8
Production and distribution of electricity, gas, steam and air conditioning	10	15	30	15	25	20	21	25	30	25	26
Finance and insurance activities	0	3	0	2	2	1	6	0	1	0	2
Real estate activities	1	1	3	3	8	7	6	7	10	12	12
Activities of households as employers; activities of producing goods and services, undisclosed, by households for their own use	1	0	1	0	2	0	0	0	0	0	1
Administrative and support service activities	43	68	67	84	93	79	70	62	59	54	79
Manufacturing	284	253	231	262	311	299	205	240	297	330	492
Human health and social service activities	8	1	7	10	11	7	6	15	12	21	26
Construction	521	501	473	496	587	591	368	347	386	422	552
Public administration and defense; compulsory social security	3	1	1	5	5	11	12	8	8	19	14
Accommodation and catering activities	17	28	33	34	45	45	32	43	55	49	72

Table 2 (Continued): Fatal Accidents At Work, 2013-2023

Nace rev.2 - 21 parts	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Culture, arts, entertainment, recreation and sports	0	1	2	3	3	1	2	1	3	1	4
Mining and quarrying	87	382	79	83	86	57	48	66	75	105	86
Vocational, scientific and technical activities	18	16	11	23	21	21	16	22	12	24	28
Water supply; sewerage, waste management and improvement activities	12	15	22	23	22	20	22	23	28	27	28
Agriculture, forestry and fishing	23	20	21	26	31	35	31	34	33	36	35
Wholesale and retail trade; repair of motor vehicles and motorcycles	82	79	71	91	96	104	74	86	99	105	147
Transportation and storage	230	217	190	225	264	224	216	241	257	260	347
Activities of international organizations and their representatives	1	2	1	0	0	0	0	0	0	0	0
Sum	1,360	1,626	1,252	1,405	1,633	1,541	1,147	1,231	1,382	1,517	1,966

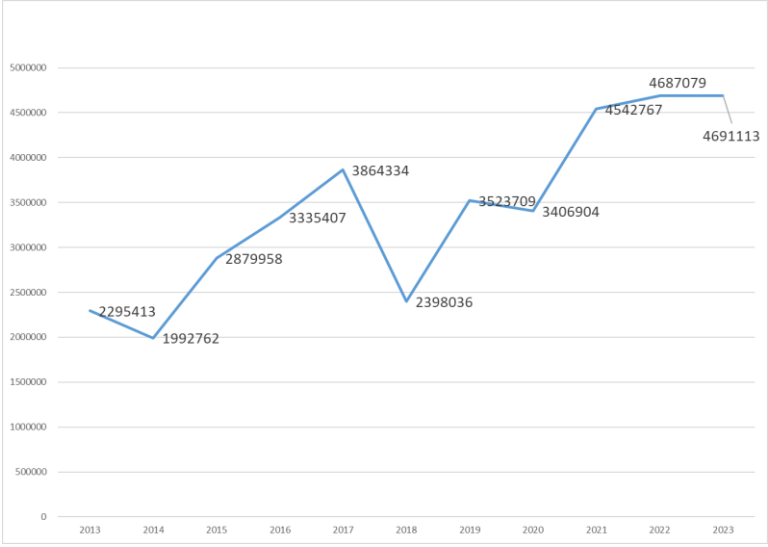
Source: Calculated by the author from the (SGK) 2013-2023 Work Accidents and Occupational Diseases Statistics Yearbook.

2.3 Days of Temporary Incapacity (Outpatient)

Days of temporary incapacity (outpatient) refer to the period during which an employee is unable to work due to a work-related injury or illness but does not require hospitalization (Akgündüz & Torun, 2018). In Türkiye, SGK provides compensation for such cases, typically covering two-thirds of the employee's daily earnings during the period of incapacity (Seyyar, 2015). This ensures financial support while the employee recovers (Demirbilek, 2017).

This Figure 3 illustrates the annual number of days of temporary incapacity (outpatient) due to work-related injuries from 2013 to 2023. The data reveal significant fluctuations over time, with an overall upward trend in recent years. Starting at 2,295,413 days in 2013, the number peaked at 4,691,113 days in 2023. Notable increases occurred between 2015 and 2017, followed by a dip in 2018 before rising again.

Figure 3: Days of Temporary Incapacity (Outpatient), 2013-2023



Despite some variability, the general pattern indicates a growing burden of temporary incapacity, highlighting the need for enhanced workplace safety measures and improved injury prevention strategies.

This metric serves as a critical indicator of the severity and frequency of work-related injuries requiring medical attention but not hospitalization.

A Table-3 indicates the "Days of Temporary Incapacity (Outpatient)" across various sectors (NACE's 21 economic parts) , based on NACE Rev. 2 main groups, from 2013 to 2023. The dataset provides insight into annual totals and trends over this decade.

Here are some highlights:

Sectoral Insights: The table categorizes data into sectors such as construction, health and social services, education, and many more. This allows for a detailed cross-sectoral analysis.

Yearly Trends: Temporary incapacity days have generally increased over the years, with 2023 reporting the highest total (4,691,113 days) among the given years.

Notable Changes:

- A significant rise between 2021 and 2022 suggests something noteworthy (e.g., policy changes, health trends, or societal shifts).
- Data from sectors like healthcare and construction might reveal which areas see the highest incidence rates.

Table 3: Days of Temporary Incapacity (Outpatient), 2013-2023

Nace Rev.2 - 21 PARTS	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Information and communication	2,556	2,032	3,711	4,579	5,020	2,732	5,916	6,023	5,422	5,430	4,838
Other service activities	26,827	15,708	20,405	20,732	17,962	9,294	13,551	12,257	14,697	12,645	13,999
Education	4,266	3,218	6,980	12,327	14,728	8,862	12,659	11,457	15,516	23,834	22,944
Production and distribution of electricity, gas, steam and air conditioning	9,388	9,818	16,819	17,968	29,761	18,706	29,496	30,991	35,420	40,560	38,543
Finance and insurance activities	1,334	572	1,118	1,116	1,985	881	1,096	1,306	1,215	2,233	1,598
Real estate activities	1,452	1,850	4,772	6,347	9,767	5,337	13,073	12,814	14,748	15,746	11,584
Activities of households as employers; activities of producing goods and services, undisclosed, by households for their own use	677	1,210	788	1,001	734	66	255	72	310	233	341
Administrative and support service activities	53,498	68,979	120,570	156,532	175,970	98,022	166,238	148,373	164,492	179,944	192,968
Manufacturing	1,172,623	1,061,485	1,450,765	1,609,213	1,856,756	1,163,552	1,795,312	1,785,312	2,417,477	2,490,653	2,492,481
Human health and social service activities	6,000	5,948	10,723	15,720	18,084	12,816	27,552	41,405	57,535	61,700	65,361
Construction	437,826	338,545	531,027	663,346	795,473	500,468	497,814	483,620	641,137	636,851	658,681
Public administration and defense; compulsory social security	1,145	889	3,609	4,718	4,378	6,442	17,975	20,707	31,689	33,524	32,712
Accommodation and catering activities	67,010	61,169	104,548	119,588	152,752	84,288	182,784	131,141	216,659	241,215	240,363
Culture, arts, entertainment, recreation and sports	2,761	2,801	5,290	5,771	5,171	4,461	5,249	3,665	6,458	7,031	7,277
Mining and quarrying	169,034	130,454	150,703	169,663	193,845	121,610	188,452	176,077	228,022	240,411	225,298
Vocational, scientific and technical activities	16,804	13,079	23,891	30,127	30,161	19,003	27,592	29,673	34,253	35,826	36,220
Water supply; sewerage, waste management and improvement activities	18,181	22,139	51,522	56,371	68,855	38,255	63,044	64,835	67,232	69,933	72,906
Agriculture, forestry and fishing	20,460	20,409	32,657	35,153	35,922	25,125	35,733	31,685	43,550	44,413	46,469

Table 3 (Continued): Days of Temporary Incapacity (Outpatient), 2013-2023

Nace Rev.2 - 21 PARTS	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Wholesale and retail trade; repair of motor vehicles and motorcycles	109,845	99,182	146,278	189,520	210,784	132,897	204,051	218,385	280,060	267,617	247,782
Transportation and storage	173,570	133,165	193,685	215,595	236,060	145,005	235,732	197,008	266,829	277,250	278,438
Activities of international organizations and their representatives	156	110	97	20	166	214	135	98	46	30	310
Sum	2,295,413	1,992,762	2,879,958	3,335,407	3,864,334	2,398,036	3,523,709	3,406,904	4,542,767	4,687,079	4,691,113

Source: Calculated by the author from the (SGK) 2013-2023 Work Accidents and Occupational Diseases Statistics Yearbook.

2.4 Days of Temporary Incapacity (Inpatient)

In Türkiye, temporary incapacity due to illness, work accidents, or maternity is covered by SGK. Employees who are hospitalized receive half of their daily earnings as compensation during their inpatient treatment. To qualify for temporary incapacity benefits, employees must have at least 90 days of SSI premium payments before the report date, except in cases of work accidents (Gürcanli & Müngen, 2013).

Employers are not legally required to pay for the first two days of sick leave unless stated in employment contracts or collective agreements. However, some companies voluntarily cover these days to prevent wage loss. The SGK starts paying temporary incapacity benefits from the third day of the report (Özkan & Yilmaz, 2018).

The Table-4 shows the Days of Temporary Incapacity (Inpatient) across various sectors over (NACE's 21 economic parts) the years 2013 to 2023, grouped under NACE Rev. 2 classifications. This dataset offers valuable insights into sector-specific trends in hospitalization-related incapacity.

Key Observations:

- Steady Increase in Administrative & Support Service Activities: This sector shows a continuous rise from 22,993 days in 2013 to 51,233 days in 2023, indicating either worsening workplace conditions or increased reporting.
- Significant Variability in Activities of Households as Employers: The values fluctuate dramatically, peaking in 2015 (11,854 days) and dropping sharply afterward.
- Manufacturing Sector's Gradual Growth: The number of incapacity days rises steadily, especially after 2018, suggesting either increased incidents or longer recovery periods.
- Construction Industry's High Levels: It remains consistently above 5,000

days, reinforcing the high-risk nature of this sector.

- Human Health & Social Service Activities: The data suggests continuous growth, possibly reflecting the impact of health crises or evolving working conditions in the sector.

Table 4: Days of Temporary Incapacity (Inpatient), 2013-2023

Nace Rev.2 - 21 PARTS	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Information and communication	42	62	178	57	101	67	165	130	112	169	132
Other service activities	939	503	534	658	903	323	481	335	487	610	613
Education	136	73	208	404	432	391	560	250	454	835	640
Production and distribution of electricity, gas, steam and air conditioning	514	1,014	1,235	1,894	2,091	1,541	2,044	1,932	1,380	1,899	1,954
Finance and insurance activities	40	11	18	19	91	36	24	89	21	57	59
Real estate activities	34	113	282	271	677	173	417	417	319	549	431
Activities of households as employers; activities of producing goods and services, undisclosed, by households for their own use	18	29	18	28	7	0	43	0	3	11	23
Administrative and support service activities	1,034	2,574	5,754	5,416	6,422	3,679	5,161	3,611	3,919	4,383	4,824
Manufacturing	22,993	31,491	44,851	40,657	45,525	31,085	40,228	33,560	43,902	48,911	51,885
Human health and social service activities	85	123	225	447	385	360	768	1,047	1,053	1,308	1,233
Construction	19,611	19,991	31,471	37,562	43,224	27,942	23,389	20,546	26,053	28,874	30,676
Public administration and defense; compulsory social security	2	36	203	258	228	457	786	491	725	935	1,033
Accommodation and catering activities	1,886	2,179	3,111	3,560	4,457	2,410	4,942	3,008	5,528	5,633	5,437
Culture, arts, entertainment, recreation and sports	85	179	146	245	443	465	191	95	149	167	250
Mining and quarrying	4,288	2,976	4,965	6,363	5,873	5,164	5,503	3,941	5,220	6,271	5,389
Vocational, scientific and technical activities	487	454	1,226	1,361	1,323	833	804	668	855	1,213	1,201
Water supply; sewerage, waste management and improvement activities	497	943	1,704	2,330	2,253	1,931	2,051	1,639	1,721	1,719	2,340
Agriculture, forestry and fishing	545	1,065	1,759	1,590	2,053	1,556	1,591	1,061	1,711	1,911	2,099

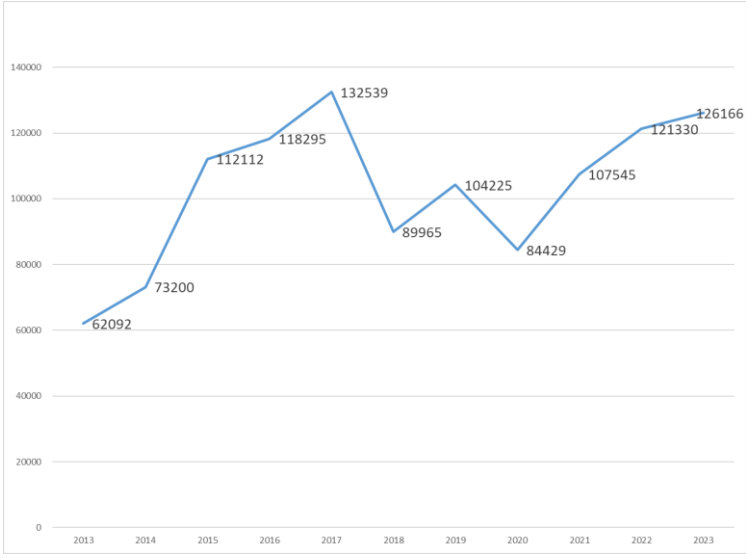
Table 4 (Continued): Days of Temporary Incapacity (Inpatient), 2013-2023

Nace Rev.2 - 21 PARTS	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Wholesale and retail trade; repair of motor vehicles and motorcycles	2,767	3,988	6,260	7,265	7,303	5,637	7,454	5,409	6,758	7,552	7,971
Transportation and storage	6,089	5,394	7,964	7,910	8,744	5,912	7,621	6,200	7,175	8,323	7,975
Activities of international organizations and their representatives	0	2	0	0	4	3	2	0	0	0	1
Sum	62,092	73,200	112,112	118,295	132,539	899,65	104,225	844,29	107545	121,330	126,166

Source: Calculated by the author from the (SGK) 2013-2023 Work Accidents and Occupational Diseases Statistics Yearbook.

This Figure 4 shows the annual number of days of temporary incapacity requiring inpatient care due to work-related injuries from 2013 to 2023. The data reveal fluctuations over time, with an overall upward trend in recent years. Starting at 62,092 days in 2013, the number peaked at 126,166 days in 2023. Notable increases occurred between 2015 and 2017, followed by a dip in 2018 before rising again. Despite some variability, the general pattern indicates a growing burden of severe work-related injuries requiring hospitalization.

Figure 4: Days of Temporary Incapacity (Inpatient), 2013-2023



Source: Calculated by the author from the (SGK) 2013-2023 Work Accidents and

Occupational Diseases Statistics Yearbook.

This metric is crucial for understanding the severity of workplace accidents that necessitate extended medical care, highlighting the need for improved safety measures and injury prevention strategies.

2.5 Insured Receiving Permanent Incapacity Income

In Türkiye, permanent incapacity income is provided to insured individuals who suffer a work accident or occupational disease that results in a lasting loss of earning capacity (Seyyar, 2015). SGK determines the degree of incapacity, and the compensation is calculated based on the insured's monthly earnings and incapacity percentage.

Key Aspects of Permanent Incapacity Income:

- Full vs. Partial Incapacity: If an individual is fully incapacitated, they receive 70% of their monthly earnings as income (Özkan & Yilmaz 2018). For partial incapacity, the amount is adjusted based on the percentage of lost earning capacity (Demirbilek, 2017).
- Additional Support: If the insured requires constant care, the income rate may increase to 100%.
- Survivor Benefits: If an insured person receiving permanent incapacity income passes away, their dependents may be eligible for survivor benefits (Gürcanli & Müngen, 2013).

The Table-5 presents the number of insured individuals receiving permanent incapacity income across different economic sectors from 2013 to 2023, classified under NACE Rev. 2 (NACE's 21 economic parts)

Key Observations & Trends:

- Sharp Increase in 2015 & 2016: The total number of insured individuals receiving incapacity income jumped significantly, rising from 1,421 in 2014 to 3,433 in 2015, and peaking at 4,447 in 2016. This suggests major shifts—possibly policy changes or increased reporting mechanisms.
- Gradual Decline After 2017: While numbers remained high in 2017 and 2019, there was a noticeable drop in 2020 (3,183), which coincides with the pandemic and possible disruptions in reporting or eligibility assessments.
- Sector-Specific Patterns:
    - Manufacturing, Construction & Mining consistently report higher incapacity cases, reflecting high-risk working conditions.

- Education & Finance have relatively low numbers, indicating less hazardous work environments.
- Transportation & Storage shows consistent reporting across the years, likely due to road-related work accidents.

Table 5: Insured receiving permanent incapacity income, 2013-2023

Nace rev.2 - 21 parts	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Information and communication	6	2	5	6	7	7	3	8	3	8	4
Other service activities	25	13	28	40	5	20	18	17	10	11	17
Education	4	2	9	27	14	28	24	27	17	21	22
Production and distribution of electricity, gas, steam and air conditioning	15	7	36	38	29	35	31	26	32	40	33
Finance and insurance activities	0	1	0	3	2	6	3	1	2	3	4
Real estate activities	1	0	9	3	7	6	18	23	15	21	13
Activities of households as employers; activities of producing goods and services, undisclosed, by households for their own use	0	0	2	5	0	1	1	1	1	2	0
Administrative and support service activities	31	22	95	135	116	166	176	141	124	159	140
Manufacturing	721	592	1,371	1,648	1,443	1,260	1,410	1,035	1,100	1,514	1,225
Human health and social service activities	7	1	7	12	5	16	8	14	26	19	23
Construction	459	404	979	1,450	1,505	1,328	1,586	1,078	967	1,202	1,009
Public administration and defense; compulsory social security	0	0	2	3	8	6	13	7	21	19	13
Accommodation and catering activities	28	29	91	84	85	105	111	98	118	139	110
Culture, arts, entertainment, recreation and sports	31	12	1	23	1	7	8	6	7	4	9
Mining and quarrying	78	106	195	273	167	143	166	124	136	177	123
Vocational, scientific and technical activities	21	22	29	33	36	43	44	46	30	37	42
Water supply; sewerage, waste management and improvement activities	19	22	57	78	44	50	50	44	40	50	37
Agriculture, forestry and fishing	19	14	40	57	61	46	67	36	35	53	58
Wholesale and retail trade; repair of motor vehicles and motorcycles	79	70	193	225	217	241	236	208	207	290	256

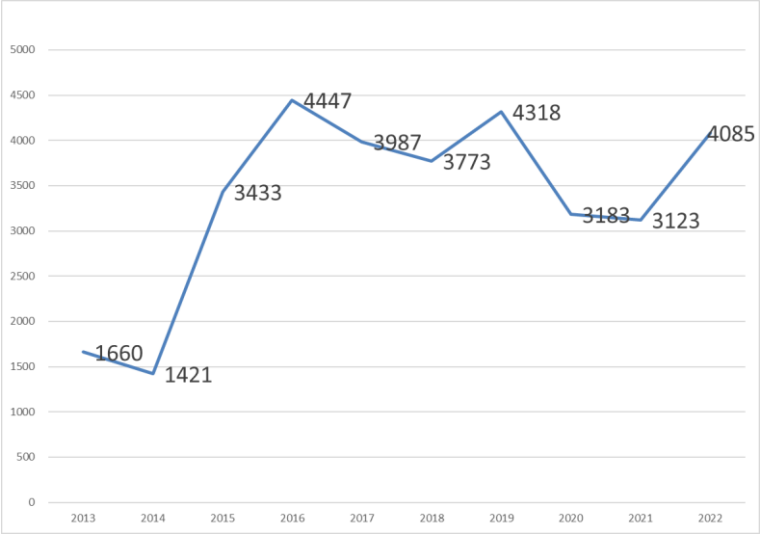
Table 5 (Continued): Insured receiving permanent incapacity income, 2013-2023

Nace rev.2 - 21 parts	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Transportation and storage	108	88	235	261	232	259	345	243	232	316	220
Activities of international organizations and their representatives	8	14	49	43	3	0	0	0	0	0	0
Sum	1,660	1,421	3,433	4,447	3,987	3,773	4,318	3,183	3,123	4,085	3,358

Source: Calculated by the author from the (SGK) 2013-2023 Work Accidents and Occupational Diseases Statistics Yearbook.

This Figure 5 presents the annual number of insured workers who received permanent incapacity income due to work-related injuries from 2013 to 2023. The data show fluctuations over time, ranging from a low of 1,421 in 2014 to a peak of 4,447 in 2016.

Figure 5: Insured Receiving Permanent Incapacity Income, 2013-2023



Source: Calculated by the author from the (SGK) 2013-2023 Work Accidents and Occupational Diseases Statistics Yearbook.

The trend indicates variability in the incidence of severe occupational injuries resulting in long-term disability. While there was a notable increase in the mid-period, the numbers have since shown signs of stabilization. This metric reflects the lasting impact of workplace accidents and highlights the importance of preventive safety strategies.

2.6 Number of Insured

As of the latest available data (up to 2023), the number of insured individuals in

Türkiye under SGK has been steadily increasing due to factors such as population growth, formalization of employment, and legal requirements for mandatory insurance. Below is a detailed breakdown of the number of insured individuals in Türkiye.

From 2013 to 2023, the number of insured individuals across NACE's 21 economic sectors (as shown in Table-6) will be analyzed in relation to Temporary Disability Days. This comparison aims to identify trends in the increase or decrease of insured persons within each sector, classified according to NACE Rev.2. It will also help in understanding accident patterns in relation to the size of the work. The total number of insured individuals will serve as the basis for calculating key metrics such as the Accident Frequency Rate.

Table 6: Number of insured, 2013-2023

Nace rev.2 - 21 parts	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Information and communication	171,375	194,196	203,013	200,551	214,605	202,699	227,803	216,214	247,630	284,867	279,095
Other service activities	363,894	211,778	214,921	215,944	221,667	223,903	230,640	227,335	235,566	256,634	238,261
Education	502,169	567,716	697,049	759,780	536,294	597,877	632,093	617,998	701,985	739,176	679,358
Production and distribution of electricity, gas, steam and air conditioning	104,789	92,984	93,975	100,688	105,934	103,221	111,754	109,439	116,618	123,476	118,800
Finance and insurance activities	164,762	168,042	171,678	166,347	163,210	160,637	159,474	163,132	170,818	182,761	176,821
Real estate activities	34,545	86,388	99,098	109,391	123,113	130,954	139,198	158,606	163,940	174,890	155,854
Activities of households as employers; activities of producing goods and services, undisclosed, by households for their own use	22,720	37,466	32,740	25,537	19,468	15,583	12,575	6,287	13,417	20,257	26,065
Administrative and support service activities	1,031,096	1,343,751	1,556,158	1,487,966	1,609,983	1,587,882	1,528,612	1,356,802	1,380,300	1,474,524	1,472,962
Manufacturing	3,476,261	3,580,914	3,578,737	3,519,638	3,668,237	3,631,873	3,774,496	4,099,082	4,433,585	4,668,933	4,244,244
Human health and social service activities	288,869	319,208	347,335	356,524	408,831	580,315	644,332	923,354	942,576	1,017,516	899,531
Construction	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	1,928,297
Public administration and defense; compulsory social security	8,696	18,005	45,728	63,981	130,970	198,895	220,782	274,216	299,901	332,874	271,373
Accommodation and catering activities	674,263	777,818	818,244	801,494	863,837	895,147	962,505	867,061	1,011,717	1,106,144	1,093,783
Culture, arts, entertainment, recreation and sports	80,537	67,429	70,212	68,733	70,499	73,613	79,725	71,938	75,697	84,409	82,212
Mining and quarrying	144,168	132,318	131,859	132,490	140,660	137,332	134,327	141,692	152,184	158,968	146,115
Vocational, scientific and technical activities	573,932	594,805	620,566	626,821	651,301	648,223	640,814	676,980	692,826	747,293	689,679

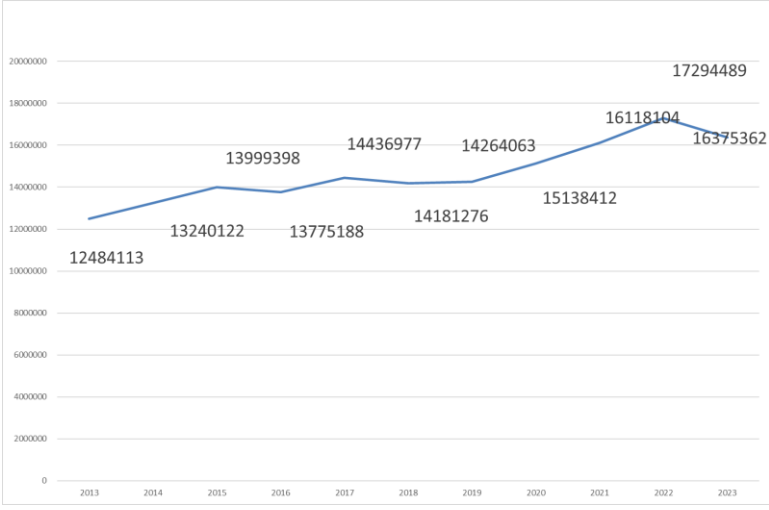
Table 6 (Continued): Number of insured, 2013-2023

Nace rev.2 - 21 parts	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Water supply; sewerage, waste management and improvement activities	76,202	108,480	122,756	118,892	129,691	115,394	114,946	116,992	126,636	133,540	128,943
Agriculture, forestry and fishing	135,684	151,557	218,999	147,670	155,619	147,534	141,678	160,548	168,086	185,314	163,848
Wholesale and retail trade; repair of motor vehicles and motorcycles	1,865,544	2,029,081	2,114,129	2,121,116	2,260,590	2,249,155	2,289,031	2,406,440	2,504,172	2,674,963	2,514,033
Transportation and storage	911,034	878,537	877,435	859,962	874,911	875,525	919,811	951,802	1,044,965	1,114,652	1,061,522
Activities of international organizations and their representatives	3,631	3,720	4,136	4,564	4,119	4,330	4,679	4,828	4,807	4,812	4,566
Sum	12,484,113	13,240,122	13,999,398	13,775,188	14,436,977	14,181,276	14,264,063	15,138,412	16,118,104	17,294,489	16,375,362

Source: Calculated by the author from the (SGK) 2013-2023 Insured and Work Place Statistics Yearbook.

This Figure 6 displays the annual count of individuals covered under occupational injury insurance between 2013 and 2023. It provides a contextual baseline for interpreting trends in work-related accidents relative to the size of the insured workforce.

Figure 6: Number of Insured, 2013-2023



Source: Calculated by the author from the (SGK) 2013-2023 Insured and Work Place Statistics Yearbook.

Over the observed period, the number of insured individuals increased from

12,484,113 in 2013 to a high of 17,294,489 in 2022, indicating a general expansion in coverage or labor force participation. However, a decline was recorded in 2023, with the total falling to 16,375,362 possibly reflecting economic or policy-related changes affecting employment or insurance registration. This trend is essential for normalizing accident data over time and offers valuable context for assessing the real impact of workplace safety measures across the years.

2.7 Death rate, work accident rate, and fatal accident rate

In the literature, accident severity rate, accident frequency rate and accident likelihood rate indicators recommended by the European Community Statistical Office (EUROSTAT) are widely used in the quantitative analysis and comparison of accident data (Işık & Işıkhan, 2024).

This Table-7 provides a valuable quantitative comparison of workplace risks across different economic activities, using the NACE Rev. 2 classification system (NACE's 88 economic sectors). The inclusion of death rate, work accident rate, and fatal accident rate across sectors allows for a structured analysis of occupational hazards.

It's particularly useful in identifying high-risk industries, such as agriculture, mining, and manufacturing, where fatal accident rates tend to be elevated. These insights can inform workplace safety strategies, regulatory policies, and predictive modeling approaches for improving occupational safety.

Table 7: Death Rate, Work Accident Rate, And Fatal Accident Rate, 2013-2023 Average

Classification of Economic Activities (NACE Rev. 2)		Rates (2013-2023 average)		
NACE Code	**Sections Description**	**Death Rate**	**Work Accident Rate**	**Fatal Accident Rate**
01	Crop and animal production, hunting and related service activities	16.08	2,198.48	731.45
02	Forestry and logging	22.64	1,192.20	1,899.20
03	Fishing and aquaculture	23.93	3,850.56	621.39
05	Mining of coal and lignite	129.60	24,881.35	520.88
06	Extraction of crude petroleum and natural gas	17.45	3,770.03	462.96
07	Mining of metal ores	44.75	5,915.06	756.63
08	Other mining and quarrying	61.73	3,802.27	1,623.57
09	Mining support service activities	28.66	6,090.94	470.51
10	Manufacture of food products	7.23	4,465.67	161.98
11	Manufacture of beverages	6.30	3,147.15	200.29
12	Manufacture of tobacco products	5.56	2,752.09	202.02
13	Manufacture of textiles	4.96	4,453.03	111.29
14	Manufacture of wearing apparel	1.52	1,048.76	145.16
15	Manufacture of leather and related products	5.09	1,361.78	373.62

Table 7 (Continued): Death Rate, Work Accident Rate, And Fatal Accident Rate, 2013-2023 Average

Classification of Economic Activities (NACE Rev. 2)		Rates (2013-2023 average)		
NACE Code	**Sections Description**	**Death Rate**	**Work Accident Rate**	**Fatal Accident Rate**
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	14.28	5,078.60	281.22
17	Manufacture of paper and paper products	8.15	5,597.61	145.69
18	Printing and reproduction of recorded media	4.45	1,824.57	243.97
19	Manufacture of coke and refined petroleum products	9.36	2,054.66	455.70
20	Manufacture of chemicals and chemical products	9.42	4,172.37	225.76
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	2.97	3,260.17	91.15
22	Manufacture of rubber and plastic products	6.82	5,780.07	117.97
23	Manufacture of other non-metallic mineral products	21.34	6,545.12	326.11
24	Manufacture of basic metals	17.61	10,024.40	175.66
25	Manufacture of fabricated metal products, except machinery and equipment	8.99	6,291.14	142.85
26	Manufacture of computer, electronic and optical products	4.14	3,381.20	122.59
27	Manufacture of electrical equipment	5.90	5,717.65	103.25
28	Manufacture of machinery and equipment n.e.c.	9.44	5,859.39	161.16
29	Manufacture of motor vehicles, trailers and semi-trailers	4.14	5,842.76	70.79
30	Manufacture of other transport equipment	7.78	9,257.60	84.07
31	Manufacture of furniture	5.62	3,862.53	145.41
32	Other manufacturing	2.36	1,786.47	132.03
33	Repair and installation of machinery and equipment	11.34	3,487.12	325.32
35	Electricity, gas, steam and air conditioning supply	20.48	3,168.80	646.28
36	Water collection, treatment and supply	13.34	1,585.52	841.40
37	Sewerage	20.73	3,066.29	676.04
38	Waste collection, treatment and disposal activities; materials recovery	19.56	5,954.89	328.47
39	Remediation activities and other waste management services	10.26	3,267.92	313.97
41	Construction of buildings	23.95	2,486.60	963.06
42	Civil engineering	36.24	4,662.47	777.27
43	Specialised construction activities	26.92	2,592.91	1,038.19
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	5.06	1,132.79	446.72
46	Wholesale trade, except of motor vehicles and motorcycles	6.29	859.68	731.87
47	Retail trade, except of motor vehicles and motorcycles	2.84	1,135.32	250.00
49	Land transport and transport via pipelines	34.06	1,517.33	2,244.69
50	Water transport	46.67	2,066.53	2,258.15
51	Air transport	6.12	4,843.90	126.38
52	Warehousing and support activities for transportation	10.98	5,208.79	210.72
53	Postal and courier activities	9.42	4,501.85	209.33
55	Accommodation	6.37	5,077.89	125.41
56	Food and beverage service activities	3.95	3,004.49	131.30

Table 7 (Continued): Death Rate, Work Accident Rate, And Fatal Accident Rate, 2013-2023 Average

Classification of Economic Activities (NACE Rev. 2)		Rates (2013-2023 average)		
NACE Code	**Sections Description**	**Death Rate**	**Work Accident Rate**	**Fatal Accident Rate**
58	Publishing activities	1.96	230.79	850.34
59	Motion picture, video and television programme production, sound recording and music publishing activities	1.68	501.49	335.01
60	Programming and broadcasting activities	1.79	318.77	560.22
61	Telecommunications	5.27	543.18	970.25
62	Computer programming, consultancy and related activities	0.91	241.70	375.52
63	Information service activities	1.33	441.65	301.36
64	Financial service activities, except insurance and pension funding	0.91	348.54	259.82
65	Insurance, reinsurance and pension funding, except compulsory social security	1.83	147.54	1,237.62
66	Activities auxiliary to financial services and insurance activities	0.52	115.17	449.10
68	Real estate activities	5.09	603.79	842.56
69	Legal and accounting activities	0.78	47.27	1,651.84
70	Activities of head offices; management consultancy activities	2.70	732.19	368.38
71	Architectural and engineering activities; technical testing and analysis	5.55	648.34	856.59
72	Scientific research and development	0.66	1,075.08	61.20
73	Advertising and market research	2.65	744.25	355.80
74	Other professional, scientific and technical activities	3.76	351.81	1068.51
75	Veterinary activities	2.10	2,382.82	87.95
77	Rental and leasing activities	8.35	685.33	1,218.37
78	Employment activities	5.67	2,787.01	203.51
79	Travel agency, tour operator and other reservation service and related activities	6.47	388.87	1,664.36
80	Security and investigation activities	5.28	1,061.31	497.80
81	Services to buildings and landscape activities	5.11	2,392.70	213.55
82	Office administrative, office support and other business support activities	3.49	937.53	371.79
84	Public administration and defence; compulsory social security	4.66	1,080.83	431.50
85	Education	0.95	839.10	113.56
86	Human health activities	1.95	2,390.24	81.70
87	Residential care activities	1.84	1,027.29	178.85
88	Social work activities without accommodation	0.82	247.39	330.03
90	Creative, arts and entertainment activities	2.79	408.23	682.59
91	Libraries, archives, museums and other cultural activities	2.44	757.70	321.54
92	Gambling and betting activities	1.16	163.88	709.22
93	Sports activities and amusement and recreation activities	2.71	1,099.99	245.98
94	Activities of membership organisations	2.50	164.36	1,521.30
95	Repair of computers and personal and household goods	4.36	1,220.90	357.19
96	Other personal service activities	2.91	750.71	387.33

Table 7 (Continued): Death Rate, Work Accident Rate, And Fatal Accident Rate, 2013-2023 Avarage

Classification of Economic Activities (NACE Rev. 2)		Rates (2013-2023 average)		
NACE Code	**Sections Description**	**Death Rate**	**Work Accident Rate**	**Fatal Accident Rate**
97	Activities of households as employers of domestic personnel	1.82	82.92	2,197.80
98	Undifferentiated goods- and services-producing activities of private households for own use	7.92	2,540.76	311.53
99	Activities of extraterritorial organisations and bodies	8.30	348.61	2,380.95
	Grand Avarage	9.96	2,677.52	371.84

Source: Calculated by the author from the (SGK) 2013-2023 Work Accidents and Occupational Diseases Statistics Yearbook.

In Türkiye average (2013-2023):

- Death rate is 9.956139424 and 9.95 out of 100,000 people die. 05- Mining of coal and lignite is in first place with a crude death rate of 129.6023159. There (Table 8) are 23 sectors above the average.

Table 8: Sectors Above The Death Rate Average

Classification of Economic Activities (NACE Rev. 2)			Rates (2013-2023 average)
Number	**NACE Code**	**Sections Description**	**Death Rate**
1	05	Mining of coal and lignite	129.60
2	08	Other mining and quarrying	61.73
3	50	Water transport	46.67
4	07	Mining of metal ores	44.75
5	42	Civil engineering	36.24
6	49	Land transport and transport via pipelines	34.06
7	09	Mining support service activities	28.66
8	43	Specialised construction activities	26.92
9	41	Construction of buildings	23.95
10	03	Fishing and aquaculture	23.93
11	02	Forestry and logging	22.64
12	23	Manufacture of other non-metallic mineral products	21.34
13	37	Sewerage	20.73
14	35	Electricity, gas, steam and air conditioning supply	20.48
15	38	Waste collection, treatment and disposal activities; materials recovery	19.56
16	24	Manufacture of basic metals	17.61
17	06	Extraction of crude petroleum and natural gas	17.45
18	01	Crop and animal production, hunting and related service activities	16.08
19	16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	14.28

Table 8 (Continued): Sectors Above The Death Rate Average

Classification of Economic Activities (NACE Rev. 2)			Rates (2013-2023 average)
Number	NACE Code	Sections Description	Death Rate
20	36	Water collection. treatment and supply	13.34
21	33	Repair and installation of machinery and equipment	11.34
22	52	Warehousing and support activities for transportation	10.98
23	39	Remediation activities and other waste management services	10.26
		Grand Avarage	9.96

Source: Calculated by the author from the (SGK) 2013-2023 Work Accidents and Occupational Diseases Statistics Yearbook.

- Work Accident Rate is 2,677.520198 and 2,677.52 people have an accident out of every 100,000 insured. 05- Mining of coal and lignite is in first place with Work Accident Rate 24,881.3508. There (Table 9) are 36 sectors above average.

Table 9: Sectors Above The Work Accident Rate Average

Classification of Economic Activities (NACE Rev. 2)			Rates (2013-2023 average)
Number	NACE Code	Sections Description	Work Accident Rate
1	05	Mining of coal and lignite	24,881.35
2	24	Manufacture of basic metals	10,024.40
3	30	Manufacture of other transport equipment	9,257.60
4	23	Manufacture of other non-metallic mineral products	6,545.12
5	25	Manufacture of fabricated metal products, except machinery and equipment	6,291.14
6	09	Mining support service activities	6,090.94
7	38	Waste collection, treatment and disposal activities; materials recovery	5,954.89
8	07	Mining of metal ores	5,915.06
9	28	Manufacture of machinery and equipment n.e.c.	5,859.39
10	29	Manufacture of motor vehicles, trailers and semi-trailers	5,842.76
11	22	Manufacture of rubber and plastic products	5,780.07
12	27	Manufacture of electrical equipment	5,717.65
13	17	Manufacture of paper and paper products	5,597.61
14	52	Warehousing and support activities for transportation	5,208.79
15	16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	5,078.60
16	55	Accommodation	5,077.89
17	51	Air transport	4,843.90

Table 9 (Continued): Sectors Above The Work Accident Rate Average

Classification of Economic Activities (NACE Rev. 2)			Rates (2013-2023 average)
Number	**NACE Code**	**Sections Description**	**Work Accident Rate**
18	42	Civil engineering	4,662.47
19	53	Postal and courier activities	4,501.85
20	10	Manufacture of food products	4,465.67
21	13	Manufacture of textiles	4,453.03
22	20	Manufacture of chemicals and chemical products	4,172.37
23	31	Manufacture of furniture	3,862.53
24	03	Fishing and aquaculture	3,850.56
25	08	Other mining and quarrying	3,802.27
26	06	Extraction of crude petroleum and natural gas	3,770.03
27	33	Repair and installation of machinery and equipment	3,487.12
28	26	Manufacture of computer. electronic and optical products	3,381.20
29	39	Remediation activities and other waste management services	3,267.92
30	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	3,260.17
31	35	Electricity. gas. steam and air conditioning supply	3,168.80
32	11	Manufacture of beverages	3,147.15
33	37	Sewerage	3,066.29
34	56	Food and beverage service activities	3,004.49
35	78	Employment activities	2,787.01
36	12	Manufacture of tobacco products	2,752.09
		Grand Avarage	2,677.52

Source: Calculated by the author from the (SGK) 2013-2023 Work Accidents and Occupational Diseases Statistics Yearbook.

- Fatal Accident Rate is 371.8418047 and 371.84 out of every 100,000 accidents are fatal. 99-Activities of extraterritorial organizations and bodies is in first place with a Fatal Accident Rate of 2,380.952381. There (Table 10) are 40 sectors above average.

Table 10: Sectors Above The Fatal Accident Rate Average

Classification of Economic Activities (NACE Rev. 2)			Rates (2013-2023 average)
Number	**NACE Code**	**Sections Description**	**Fatal Accident Rate**
1	99	Activities of extraterritorial organisations and bodies	2,380.95
2	50	Water transport	2,258.15
3	49	Land transport and transport via pipelines	2,244.69
4	97	Activities of households as employers of domestic personnel	2,197.80
5	02	Forestry and logging	1,899.20
6	79	Travel agency, tour operator and other reservation service and related activities	1,664.36
7	69	Legal and accounting activities	1,651.84
8	08	Other mining and quarrying	1,623.57

Table 10 (Continued): Sectors Above The Fatal Accident Rate Average

Classification of Economic Activities (NACE Rev. 2)			Rates (2013-2023 average)
Number	**NACE Code**	**Sections Description**	**Fatal Accident Rate**
9	94	Activities of membership organisations	1,521.30
10	65	Insurance. reinsurance and pension funding. except compulsory social security	1,237.62
11	77	Rental and leasing activities	1,218.37
12	74	Other professional. scientific and technical activities	1,068.51
13	43	Specialised construction activities	1,038.19
14	61	Telecommunications	970.25
15	41	Construction of buildings	963.06
16	71	Architectural and engineering activities; technical testing and analysis	856.59
17	58	Publishing activities	850.34
18	68	Real estate activities	842.56
19	36	Water collection. treatment and supply	841.40
20	42	Civil engineering	777.27
21	07	Mining of metal ores	756.63
22	46	Wholesale trade. except of motor vehicles and motorcycles	731.87
23	01	Crop and animal production. hunting and related service activities	731.45
24	92	Gambling and betting activities	709.22
25	90	Creative. arts and entertainment activities	682.59
26	37	Sewerage	676.04
27	35	Electricity. gas. steam and air conditioning supply	646.28
28	03	Fishing and aquaculture	621.39
29	60	Programming and broadcasting activities	560.22
30	05	Mining of coal and lignite	520.88
31	80	Security and investigation activities	497.80
32	09	Mining support service activities	470.51
33	06	Extraction of crude petroleum and natural gas	462.96
34	19	Manufacture of coke and refined petroleum products	455.70
35	66	Activities auxiliary to financial services and insurance activities	449.10
36	45	Wholesale and retail trade and repair of motor vehicles and motorcycles	446.72
37	84	Public administration and defence; compulsory social security	431.50
38	96	Other personal service activities	387.33
39	62	Computer programming. consultancy and related activities	375.52
40	15	Manufacture of leather and related products	373.62
		Grand Avarage	371.84

Source: Calculated by the author from the (SGK) 2013-2023 Work Accidents and Occupational Diseases Statistics Yearbook.

These metrics are crucial for identifying trends, comparing sector-specific risks, and informing policy decisions. Predictive modeling tools can be used to predict accident trends based on these indicators. That could yield valuable insights into seasonality effects and risk mitigation strategies.

3. METHODOLOGY

The analysis of NACE's 88 economic sectors was conducted using data from 2013 to 2023. The dataset includes key metrics such as the number of insured

individuals who experienced work-related accidents, the number of fatalities resulting from such accidents, the number of days of temporary work incapacity (both in general and during hospitalization), the count of permanent work incapacity cases, the total number of insured persons, mortality rates, work accident rates, and fatal accident rates.

Methods: Data Analysis and Statistical Modeling

In this study, variables such as accidents, fatalities, and disability days were analyzed using statistical methods including data preprocessing, time series analysis, correlation analysis, causality analysis, and predictive modeling. Below, each method is explained in detail along with its theoretical foundation and potential applications.

3.1. Data Preprocessing

Data preprocessing plays a crucial role in enhancing data quality and streamlining the analysis process (Little, Rubin, 2019). The following operations were performed during this stage:

Error Removal

Errors in the data (e.g., missing values, outliers, or incorrectly entered data) were identified and corrected. Missing data were handled using various techniques such as mean, median, or K-Nearest Neighbors (KNN) imputation. Outliers were detected using Interquartile Range (IQR) or Z-score methods (Aggarwal, 2015).

Formatting Digital Columns

Ensuring that the data was in the appropriate format was critical for analysis. For example, date information was converted to the "YYYY-MM-DD" format, numerical data were standardized, and categorical data were encoded. These steps were implemented using tools like Python's pandas library and R's dplyr package (Çelik & Başar, 2020).

Annual Aggregation

The data were grouped on an annual basis to enable more meaningful analyses. For instance, total accident counts, fatalities, and disability days were calculated for each year. This step laid the groundwork for time series analysis.

3.2. Time Series Analysis

Time series analysis is a technique employed to investigate how data evolves and changes over time. In this study, trends in accidents, fatalities, and disability days across years were investigated (Box, Jenkins, Reinsel & Ljung, 2015).

Key Analysis Steps

- Trend Analysis: The overall trend of accidents over the years (increase or decrease) was evaluated. Linear regression or moving average methods

were used for this purpose.

- Seasonal Variations: Differences in accidents across seasons were examined. For example, traffic accidents may increase during summer months.
- Autocorrelation Analysis: The relationship between the data and its past values (autocorrelation) was measured. This helped in applying ARIMA (AutoRegressive Integrated Moving Average) models (Hyndman & Athanasopoulos, 2021).

Application Examples

- ARIMA Model: An ARIMA model was developed to predict the future trajectory of accidents.
- Decomposition: The data were decomposed into trend, seasonal, and random components for better interpretability (Özmen & Yılmaz, 2018).

3.3. Correlation Analysis

Correlation analysis is a statistical technique used to assess the strength and nature of the relationship between variables. In this study, correlations between leading and lagged indicators were evaluated (Cohen, West & Aiken, 2003).

Pearson and Spearman Correlations

Pearson Correlation Coefficient: Used to measure linear relationships. For example, the relationship between accidents and fatalities was evaluated using the Pearson coefficient (Taylor, 1990). • Spearman Correlation Coefficient: Used to measure non-linear relationships, especially preferred for ranked data (Myers et al., 2010).

Lagged Correlations

Lagged correlations show how the relationship between variables changes over time. For example, the relationship between accident rates from the previous year and current fatality rates was examined (Box-Steffensmeier & Tomlinson, 2000).

3.4. Causality Analysis

Causality analysis is employed to identify cause-and-effect relationships between variables. In this study, the Granger Causality Test was utilized (Granger, 1969).

Granger Causality Test

The Granger Causality Test evaluates the extent to which one variable is useful in forecasting another. For instance:

- The question, "Does a rise in accidents result in an increase in fatalities?" was examined.
- The analysis was conducted using Python's statsmodels library or R's lmtest package.

Assumptions and Limitations

- The data must be stationary. If not, differencing methods are applied to make the data stationary (Lütkepohl, 2005).
- Causality does not imply absolute cause-and-effect but rather a statistical relationship.

3.5. Predictive Modeling

Predictive modeling is used to forecast future values based on historical data. In this study, linear regression models were developed for accidents and fatalities (Montgomery, Peck & Vining, 2012).

Linear Regression

Linear regression is a technique used to uncover the relationship between a dependent variable (e.g., fatalities) and one or more independent variables (e.g., number of accidents, season, etc.) (Hastie, Tibshirani & Friedman, 2009).The model is defined as:

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\epsilon \quad (1)$$

Where:

Y: Dependent variable (fatalities)

$X_1, X_2, \ldots$: Independent variables (number of accidents, season, etc.)

$\beta_0, \beta_1, \ldots$: Model coefficients

ϵ: Error term

Model Evaluation

The performance of the model was assessed using the following metrics: R-Squared (R^2): R^2 measures the proportion of variance in the dependent variable that is explained by the independent variables in the model (Aydın & Kaya, 2020). It ranges from 0 to 1, where:

0.00–0.30 : Weak explanatory power

0.31–0.50 : Moderate fit

0.51–0.70 : Good fit

0.71–0.90 : Very good fit

0.91–1.00 : Excellent fit

Generally, for an acceptable predictive model in scientific research, an R^2 value greater than 0.80 is considered favorable, indicating that the model explains a large portion of the variability in the data (Montgomery, Peck & Vining, 2021). Mean Absolute Error (MAE): MAE quantifies the average magnitude of errors in predictions without considering their direction (Aydın & Kaya, 2020). It is calculated as the average of absolute differences between predicted and observed values. Smaller MAE values indicate higher accuracy. Since MAE treats all errors equally, it provides a balanced view of overall error magnitude.

Root Mean Squared Error (RMSE): RMSE reflects the standard deviation of the residuals (prediction errors), placing greater weight on larger errors due to the squaring process (Aydın & Kaya, 2020). Like MAE, lower RMSE values are preferable. However, because RMSE penalizes large errors more heavily, it is especially useful when large prediction errors are particularly undesirable.

In summary, higher R^2 values indicate better model fit, while lower MAE and RMSE values suggest greater predictive accuracy. These metrics should be interpreted collectively to provide a comprehensive assessment of model performance.

4. RESULTS

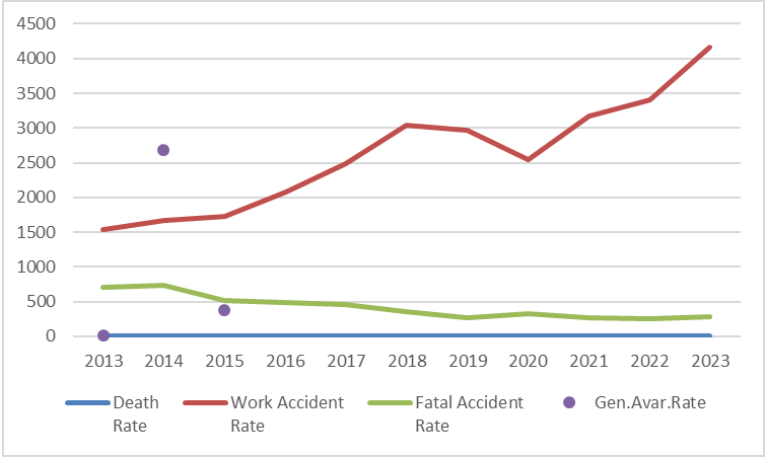
The data we used is obtained from the Statistics of SGK for the calendar years of 2013–2023.

4.1 Time Series Analysis

The time series analysis uncovered the following trends:

- Accidents: A notable rise in the number of accidents was recorded from 2013 to 2023, signaling a growing risk over the years.
- Fatalities: No clear trend was observed in the number of fatalities, suggesting a stabilization or lack of significant change in this variable.
- Accident-to-Fatality Ratio: While the accident rate increased, the fatality rate decreased, signaling a potential reduction in the severity of accidents. This could be attributed to improvements in safety measures, medical response times, or vehicle safety technologies.

Figure 7: Trends in Accidents and Fatalities Rates (2013–2023)



4.2 Correlation Analysis

The correlation analysis uncovered the following relationships (Table-11):

Temporary Disability Days and Accidents: A strong positive correlation of (r=0.732)was identified, suggesting that higher accident rates are linked to an increase in the number of temporary disability days. This suggests that prolonged recovery periods may reflect the severity or frequency of accidents.

- Number of Employees and Accidents: A robust positive correlation of (r=0.907)was observed, indicating that a rise in the total number of employees is closely tied to an increase in accident occurrences. This finding highlights the need for enhanced safety protocols in workplaces with growing employee numbers.
- Hospitalized Days and Accidents : The correlation coefficient between hospitalized days and total accidents is very close to zero (r = -0.021), indicating a negligible relationship . This suggests that the number of hospitalized days does not significantly influence the overall accident rate. However, it is important to note that while the correlation is weak, hospitalized days may still be relevant for understanding severe injuries requiring hospitalization, which could be captured by other metrics such as fatality rates.
- Hospitalized Days and Fatalities : A moderate negative correlation (r = -0.367) was found between hospitalized days and total fatalities. This suggests that as the number of hospitalized days increases, there tends to

be a slight decrease in the number of fatalities. While this correlation is statistically significant, its practical interpretation requires caution. It could imply that more serious injuries leading to hospitalization are being managed effectively, reducing the likelihood of fatal outcomes. Alternatively, it might reflect differences in how injuries are classified or reported across severity levels. These findings provide leadings indicators into the interplay between various occupational safety. While temporary disability days and employee numbers strongly correlate with accident rates, the relationship between hospitalized days and fatalities offers a nuanced perspective on injury severity and management practices.

Table 11: Correlation Coefficients Between Variables

Variable	Total Accidents	Total Fatalities
Temporary Disability Days	0.73	0.24
Hospitalized Days	-0.021	-0.37
Total Employees	0.91	0.30

4.3 Granger Causality Test

The results of the Granger causality test are as follows:

- Temporary Disability Days: Temporary disability days did not exhibit a significant causal relationship with accidents, suggesting that these variables are not directly linked in a predictive manner.
- Total Number of Employees: A significant causal effect on accidents was observed with a one-period lag ($p = 0.0115$). This indicates that changes in workforce size can predict future accident rates, underscoring the importance of proactive safety measures as workforce expands.

Table 12: Granger Causality Test Results.

Variable Pair	Lag 1 p-value	Lag 2 p-value	Interpretation
Temporary Disability Days → Total Accidents	0.837	0.9442	No Granger causality at either lag (p-values > 0.05).
Total Employees → Total Accidents	0.0115	0.1036	Significant Granger causality at Lag 1 (p-value < 0.05), but not at Lag 2 (p-value ≥ 0.05)

4.4 Predictive Modeling

The performance of predictive models for accidents and fatalities is summarized below:

- Accident Prediction Model: The model achieved an R2 value of 0.61,

indicating moderate success in predicting accident rates. While the model captures a significant portion of variance, there is room for improvement by incorporating additional variables or using more advanced modeling techniques.

- Fatality Prediction Model: The model yielded a negative R2 value of -1.35, demonstrating poor predictive performance. This suggests that fatalities are influenced by factors not included in the current model, such as external conditions (e.g., weather, road infrastructure) or non-linear relationships.

While the current study employed linear regression, more complex models for modeling accident-related outcomes, future research could explore more advanced analytical techniques to further improve predictive performance. For instance:

- Logistic Regression: If the outcome variable is binary (e.g., accident occurrence: yes/no), logistic regression can be used to estimate the probability of an event based on predictor variables (Hosmer et al., 2013). This approach may offer better insights when the dependent variable is categorical.
- Machine Learning Models: Techniques such as Random Forest and Artificial Neural Networks (ANN) have shown strong performance in handling complex, non-linear relationships within large datasets (Zhang & Zhou, 2021).

These models require minimal assumptions and can automatically detect interactions among predictors, making them promising tools for occupational safety forecasting (Kuhn & Johnson, 2013).

Incorporating these alternative modeling strategies in future studies may enhance the accuracy and robustness of predictions, particularly when dealing with high-dimensional or unstructured safety data.

5. DISCUSSION

The analysis of trends in work-related accidents and incapacities between 2013 and 2023 provides critical insights relevant to the evolving landscape of social security in the 21st century. Although the total number of insured individuals increased during this period, the rise in reported work accidents indicates systemic shortcomings in current preventive strategies and enforcement mechanisms. This suggests that expanding coverage alone is insufficient without parallel improvements in workplace safety culture and risk-based prevention strategies.

The burden of fatal accidents and the increasing incidence of temporary and

permanent disabilities reflect the multifaceted structural problems faced by social security systems today. These issues become even more complex due to labor market transformations, sector-specific risk disparities, and varying levels of regulatory effectiveness. The notable increase in incapacity days carries socioeconomic consequences not only at the individual level but also in terms of pension planning, social insurance sustainability, and workforce productivity.

The findings of this study directly support growing calls to strengthen social security systems through digital transformation and the adoption of early warning mechanisms. Technologies such as real-time monitoring, predictive modeling, and automated reporting can significantly improve proactive interventions in high-risk sectors, laying the groundwork for next-generation social protection frameworks. Work accidents not only lead to individual health losses but also impose a substantial economic burden on public social security systems. In this context, the development of data-driven early warning and predictive models emerges as a critical preventive strategy to ensure the long-term sustainability of these systems. The model proposed in this study aims to contribute to both the protection of worker health and the reduction of systemic risk by enabling the anticipation and prevention of occupational accidents. Accordingly, the study exemplifies how 21st-century social security systems can evolve to address emerging risks through innovative and evidence-based solutions.

The results of this study offer significant insights into the dynamics of accidents, fatalities, and associated factors:

- Increasing Accident Rates: The upward trend in accidents over the study period highlights the need for targeted interventions. Factors such as increased traffic volume, urbanization, or occupational risks may contribute to this trend.
- Stable Fatality Rates: The lack of a clear trend in fatalities, despite rising accident rates, suggests improvements in post-accident care or accident severity mitigation. This aligns with prior research emphasizing the role of medical advancements and safety technologies (e.g., airbags, automatic braking systems).
- Correlation Insights: The robust positive correlation between the number of employees and accidents highlights the critical need for enhanced workplace safety measures. Organizations with growing workforces should prioritize safety training and risk management.
- Granger Causality Findings: The causal relationship between workforce size and accidents emphasizes the need for scalable safety measures. As

organizations expand, safety protocols must evolve to address new risks.

- Model Limitations: While the accident prediction model performed moderately well, the fatality prediction model's poor performance indicates the complexity of fatality determinants. Future studies should explore non-linear relationships and incorporate external variables such as weather conditions, road quality, and socioeconomic factors.

Furthermore, the observed sectoral and demographic inequalities in accident outcomes across the analyzed years indicate the need for more equitable, targeted, and inclusive redesign of social security policies. The accelerated shift toward digitalization and flexible work models during the pandemic has urgently highlighted the necessity of restructuring social security systems to include informal and remote workers.

CONCLUSION AND RECOMMENDATIONS

This study provides a comprehensive statistical analysis to understand the relationships between accidents, fatalities, and disability days. The findings offer valuable insights for policymakers and decision-makers, highlighting key areas for intervention and improvement. Below, we summarize the main conclusions and provide actionable recommendations for future research and practice.

Key Conclusions

1. Causal Relationships Between Variables: The results of the Granger causality test revealed that accidents have a statistically significant effect on fatalities. This highlights the critical importance of targeting accident rates as a key strategy for reducing fatality numbers.
2. Predictive Modeling for Future Trends: Predictive models developed in this study showed moderate success in forecasting accident rates (R^2=0.605). However, the poor performance of the fatality prediction model (R^2= −1.35) highlights the complexity of factors influencing fatalities and the need for more sophisticated approaches.
3. Severity Reduction in Accidents: While the number of accidents increased over the study period, the fatality rate decreased. This suggests improvements in mitigating the severity of accidents, potentially due to advancements in safety measures, medical response times, or vehicle technologies.

Table 13: Comparison Between Models

Metric	Total Accidents	Total Fatalities
MSE	10,543,240,061.89	15,150.08
R^2 Score	0.61	-1.35

Total Accidents: The model has moderate predictive power ($R^2 = 0.605$), but the high MSE indicates room for improvement.

Total Fatalities: The model performs poorly ($R^2 < 0$), suggesting that the current approach is ineffective for predicting fatalities.

Recommendations

In light of the findings, the following recommendations are suggested:

1. Proactive Monitoring and Early Warning Systems

Temporary disability days should be continuously monitored as leading indicators to serve as an early warning system for accident prevention. As Dyreborg (2009) suggests, lagging indicators such as disability days can also function as predictive tools when used proactively. Implementing real-time monitoring systems could help identify emerging risks and enable timely interventions.

2. Enhanced Workplace Safety Training

The significant positive correlation between the number of employees and accidents emphasizes the necessity for comprehensive workplace safety measures. Organizations experiencing workforce growth should prioritize intensive safety training programs to minimize accident risks. Regular audits and updated safety protocols can further reinforce these efforts.

3. Development of More Effective Prediction Models

To improve the accuracy of fatality prediction models, future studies should incorporate additional variables such as weather conditions, traffic density, road infrastructure, and socioeconomic factors. To capture non-linear relationships and improve predictive performance, advanced machine learning techniques like Random Forest or Gradient Boosting could be further explored.

Future Research Directions

While this study provides valuable insights, several avenues for future research remain:

- Incorporation of External Variables: Including external factors such as weather, road conditions, and economic indicators could improve the explanatory power of predictive models.
- Exploration of Non-linear Relationships: Advanced statistical methods

and machine learning algorithms should be tested to better capture complex relationships between variables.

- Longitudinal Studies: Conducting longitudinal studies across multiple regions or industries could offer a more comprehensive perspective on accident dynamics and inform more generalized policy recommendations.

In conclusion, this study highlights the critical role of data-driven approaches in tackling occupational safety challenges. By implementing the recommendations outlined above, stakeholders can work towards reducing accident rates, mitigating their consequences, and ultimately improving societal well-being.

Also in the study demonstrates that, despite an expanding insured workforce and increased awareness of occupational health and safety issues, work-related accidents and their associated incapacities have continued to rise over the past decade. These trends reveal persistent vulnerabilities in current risk management practices and underscore the urgency of reinforcing social security systems against evolving occupational hazards.

In the context of rapid technological change and shifting employment structures, traditional reactive approaches to workplace safety are no longer sufficient. The data suggest that effective policy responses must incorporate greater use of digital monitoring, predictive modeling, and real-time intervention strategies. Furthermore, the observed inequalities in accident severity and recovery outcomes point to the need for more equitable access to preventive training, medical care, and compensation mechanisms.

As global crises like pandemics and environmental disruptions expose weaknesses in existing safety nets, this research calls for a rethinking of occupational risk policies within broader social security frameworks. Strengthening resilience requires not only responding to current challenges but also anticipating future risks through innovation, regulation, and inclusive policy design.

By contributing empirical evidence, this article supports the development of next-generation, technology-enabled social security systems capable of safeguarding worker well-being in an increasingly complex and uncertain world.

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