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PREFACE

It is our great pleasure to present the *Proceedings of the 22nd International May Conference on Strategic Management*, a collection of contributions that reflect the dedication, creativity, and scholarly excellence of our academic and professional community.

We would like to express our sincere gratitude to all authors who have contributed their time, knowledge, and enthusiasm to this conference. This year, we are especially proud to highlight that the proceedings include contributions from authors representing more than 30 countries, underscoring the international character and growing impact of the conference. The diversity of topics and perspectives presented here highlights the importance of collaboration and continuous dialogue in addressing contemporary challenges.

We extend our deepest appreciation to our main sponsor, the Ministry of Science, Technological Development and Innovation, for its invaluable support and commitment to advancing research and innovation. We are also grateful to our gold sponsors, Zijin Mining and Zijin Copper, whose generous contributions have significantly supported the successful organization of this conference. In addition, we would like to thank our exhibition partner, MDPI, for their collaboration and engagement in promoting academic exchange.

We also extend our appreciation to the reviewers and members of the organizing committee, whose dedication and careful work ensured the quality and success of the conference. Their efforts have been essential in maintaining high academic standards and in bringing this publication to fruition.

Finally, we thank all attendees for their engagement and for fostering a stimulating and supportive environment. We hope that these Proceedings will serve as a valuable resource and inspiration for future research, collaboration, and innovation.

Thank you!!

Editors

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STRATEGIC MANAGEMENT**



OCCUPATIONAL INJURIES AND WORKPLACE SAFETY IN EUROPEAN COUNTRIES: A K-MEANS CLUSTER ANALYSIS

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Abstract: Occupational injuries remain a significant issue in European countries, affecting both worker safety and broader socio-economic outcomes. This study groups European countries into homogeneous categories based on workplace injury levels from 2014 to 2023. The analysis uses secondary data from Eurostat, including indicators on fatal and non-fatal workplace accidents within aggregated sectors: agriculture, industry and construction (excluding mining), and business economy services. To achieve the research objective, K-means cluster analysis was applied after data standardisation using Z-score normalisation. The results show substantial variability in occupational injury levels across countries, with particularly high dispersion for non-fatal injuries. The clustering identifies two distinct groups of countries, representing relatively safer and less safe working environments. While most countries show consistent classification across both fatal and non-fatal injury models, a significant number display discrepancies, suggesting that these indicators capture different aspects of workplace safety.

Keywords: Workplace safety, European countries, fatal injuries, non-fatal injuries.

1. INTRODUCTION

Occupational injuries, also known as occupational accidents, have occurred throughout human history. However, over time, high-income countries have made significant progress in reducing occupational injuries, despite the increasing complexity of modern work environments. In these countries, including the United States, European Union (EU) member states, Japan, Australia, New Zealand, and Singapore, the focus within occupational safety and health has gradually shifted. The health aspect of workplace safety has become increasingly important relative to the traditional safety component. This transition reflects structural and organisational changes in advanced economies (Takala, 2019).

In European countries, workplace accidents remain a key area of action within the EU's social policy with an emphasis on risk prevention and mitigation of consequences (Ivascu & Cioca, 2019).

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According to the definitions (ESAW, 2026), fatal accidents at work are incidents that result in the death of the victim within one year of the accident. In contrast, non-fatal workplace accidents are incidents that do not result in death but are severe enough to cause at least four full days of absence from work. These definitions enable a clear distinction between the most severe outcomes and less severe, yet still significant, workplace injuries.

Since 2015, in the European countries, the fatal accident rate has declined due to preventive actions at the member state level (Jørgensen, 2016). However, there is a strong call for tracking occupational injuries across countries (Hale, 2019). This is not merely a statistical issue. It is a key tool for understanding risks, formulating policies, and improving working conditions.

This study aims to contribute to the field of work safety. Monitoring this issue by country allows not only the identification of problems but also the creation of targeted interventions, the development of cooperation between stakeholders, and the transfer of knowledge between different economic and institutional contexts.

The main goal of the research is to classify European countries into two homogeneous groups based on workplace injury indicators from 2014 to 2023, to distinguish countries with relatively safer and less safe working environments within the aggregated categories of agriculture, industry and construction, and business economy services.

2. LITERATURE REVIEW

Occupational injuries remain a complex and multidimensional issue, influenced by a wide range of economic, social, demographic, and organisational factors.

The study by Tompa et al. (2021) developed a new methodological framework for estimating the economic burden of work injuries and diseases, applying it in selected European Union countries. The findings suggested that indirect costs make up the largest part of the economic burden, followed by direct and intangible costs. According to the results, Poland, Italy, the Netherlands, Germany, and Finland had the highest overall costs.

In research by Dodoo and Al-Samarraie (2023), a systematic review of the literature included 73 empirical studies from various regions, such as Europe, Africa, the Middle East, Asia, Australia, and America (USA and Canada). The results showed that the highest number of injuries and deaths occurred in the construction industry. It was also found that most of the analysed research was conducted in developing countries, primarily in Africa and Asia.

The study by Zermane et al. (2023) examined fatal workplace accidents caused by falls from height in the Malaysian construction industry. The research aimed to analyse the relationship between key variables associated with fatal falls and to identify areas for prevention. The analysis was based on a dataset of fatal fall accidents recorded between 2010 and 2020. The findings indicated that general workers are the most vulnerable group, accounting for an average of 32% of fatalities annually, while supervisors are the least affected (4%).

The study by Wulz et al. (2023) explored county-level data on age-adjusted fatal injury rates for 2015–2019, combined with the Social Vulnerability Index (SVI), which measures the level of social vulnerability within communities. Linear regression analysis revealed a significant positive relationship between SVI and unintentional fatal injury rates, indicating that counties with higher social vulnerability tend to experience higher levels of fatal injuries. Another study by Kearney et al. (2024) provides a comprehensive analysis of fatal incidents among landscaping and tree care workers, based on 93 investigative reports in the USA covering 1987–2023. The findings indicate that the most common causes of fatalities are electrocution from power lines (18.3%), falls from trees (16.1%), and incidents involving

workers being caught in wood-chipping machines (12.9%). Notably, more than two-thirds of fatal accidents occurred among workers with less than one year of job experience, highlighting the vulnerability of newly employed workers. The authors emphasised the practical implications, stressing the importance of employer responsibility, structured training and mentorship programmes, and targeted risk-reduction strategies.

The study by Park et al. (2024) examined whether workforce ageing is associated with an increase in fatal occupational accidents and explored the underlying reasons for this trend in the Republic of Korea. The findings indicated that fatal workplace accidents are significantly more frequent among older workers, with an incidence rate approximately four times higher than that of younger workers. Most injuries among older workers occur in the construction sector, particularly among those employed in elementary occupations and engaged in daily wage employment.

The study by Walters (2024) analyses key antecedents of contemporary practice, focusing on structural economic factors and regulatory frameworks, drawing on sociological theories of professions. As a result, these professionals have become more prevalent in the safety infrastructures of advanced economies. However, the study also suggests that such developments may have important implications for professional autonomy and practice, especially in environments shaped by organisational demands.

The review by Hilson (2025) analyses occupational health and safety conditions in the artisanal and small-scale mining (ASM) sector, seeking to explain why safety-related challenges have persisted and, in many cases, intensified over time. It argues that most health and safety issues observed at ASM sites globally stem from the sector's strong presence within the informal economy. After examining existing literature that highlights the prevalence of specific safety risks and evaluates previous efforts to mitigate them, the study further supports its argument through case analyses from Brazil, Colombia, Uganda, and Zimbabwe. These examples demonstrate that the sector's poor safety performance is closely linked to its ongoing informality, which is, to a significant extent, shaped and reinforced by existing regulatory and policy frameworks.

The review by Sadeghi et al. (2025) emphasised the importance of tracking injuries in modular integrated construction. The results showed that fall-related hazards are the most commonly researched and mitigated, while health-related hazards are most frequently introduced.

The study by Jamhiri et al. (2026) addresses the increasing importance of gender-specific challenges in the workplace, focusing on risks to women's physical and mental health arising from biological factors, male-dominated organisational structures, and broader socio-cultural inequalities. The analysis highlights that foundational factors such as physiological characteristics and role conflict contribute to more complex structural challenges, including job insecurity and pressure to accept unfavourable working conditions. Overall, the findings emphasise that women face multidimensional and interconnected challenges affecting their health, productivity, and career opportunities.

Based on the reviewed literature, previous studies highlight the significant economic burden of workplace injuries, the dominance of high-risk sectors such as construction, and the vulnerability of specific groups, including older workers, newly employed individuals, and women. Additionally, social vulnerability, informal employment, and structural characteristics of economies have been identified as key determinants of injury rates and workplace safety outcomes.

While existing research provides valuable insights into specific contexts, sectors, and risk factors, there is a lack of comprehensive cross-country analyses that simultaneously consider both fatal and non-fatal injuries over time. This study therefore contributes to the

literature by applying a clustering approach to European countries, enabling the identification of groups with similar safety patterns and offering a more integrated perspective on workplace safety at the macro level.

The main research question of this study is: Which groups of European countries can be identified based on the level of occupational injuries during 2014-2023, and which countries have relatively safer or less safe working environments?

3. METHODS

The analysis uses secondary data from Eurostat. The dataset includes indicators for the total number of fatal and non-fatal workplace accidents, classified according to the NACE Rev. 2 activity classification. The observed category is an aggregated sector comprising agriculture, industry, and construction (excluding mining), as well as business economy services (Eurostat, 2026).

The dataset covers a ten-year period (2014–2023) and contains observations for 30 European countries. Before analysis, the data were structured into a consistent panel format to ensure comparability across countries and years.

The prepared dataset serves as input for K-means cluster analysis, a widely used non-hierarchical clustering technique that partitions observations into a predefined number of homogeneous groups (Likas et al., 2003). The method aims to minimise within-cluster variance and maximise between-cluster differences, enabling identification of countries with similar patterns of occupational injuries.

The main issue in performing K-means cluster analysis is determining the number of clusters (Kodinariya et al., 2013). Given the research objective, the number of clusters (k) was set to two. This specification allows clear differentiation between groups of countries characterised by lower and higher levels of occupational injuries over the observed period.

Before applying the K-means clustering algorithm, all variables were standardised using Z-score normalisation. Standardisation transforms the original values to a common scale with a mean of zero and a standard deviation of one, ensuring that each variable contributes equally to the clustering process (Kathiresan & Sumathi, 2012).

This step was necessary due to differences in scale between the observed indicators, particularly between fatal and non-fatal workplace accidents. Without this transformation, variables with larger numerical ranges, such as non-fatal injuries, could dominate the clustering results and bias cluster formation.

4. RESULTS AND DISCUSSION

This section presents and discusses the results of the K-means cluster analysis applied to European countries. The analysis aims to identify groups of countries with similar workplace safety patterns and to distinguish between relatively safe and less safe working environments.

The clustering results are interpreted using descriptive statistics and observed data dispersion, providing insights into cross-country differences in occupational injury levels. Particular attention is given to the consistency of cluster membership across the two models, as well as to countries that show divergent positions depending on whether fatal or non-fatal injuries are considered.

Figure 1 presents the average value of fatal occupational injuries per country over the observed period from 2014 to 2023.

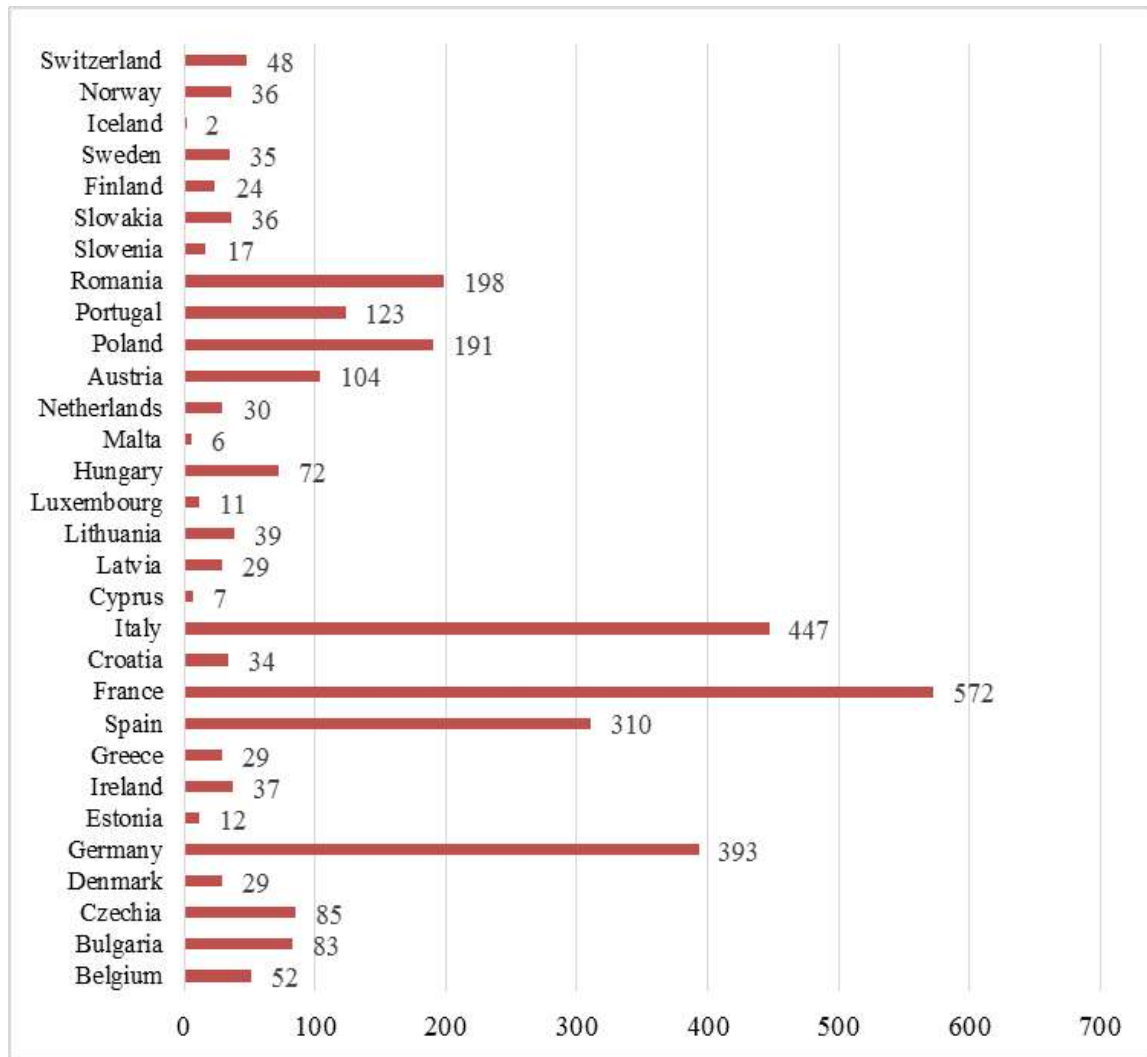


Figure 1. Fatal injuries (average value)

For fatal injuries, the minimum average is 2 injuries (Iceland), while the maximum average is 572 (France). Iceland had the lowest standard deviation during the observed period (Std. Dev. = 1.05), whereas France had the highest standard deviation (Std. Dev. = 83.71).

Overall, Figure 1 highlights a strong imbalance in the distribution of fatal occupational injuries, with a small number of countries accounting for a disproportionately large share of total fatalities. These differences may be influenced by factors such as country size, workforce structure, industrial composition, and the effectiveness of occupational safety regulations.

Figure 2 presents the average number of non-fatal occupational injuries per country over the observed period from 2014 to 2023.

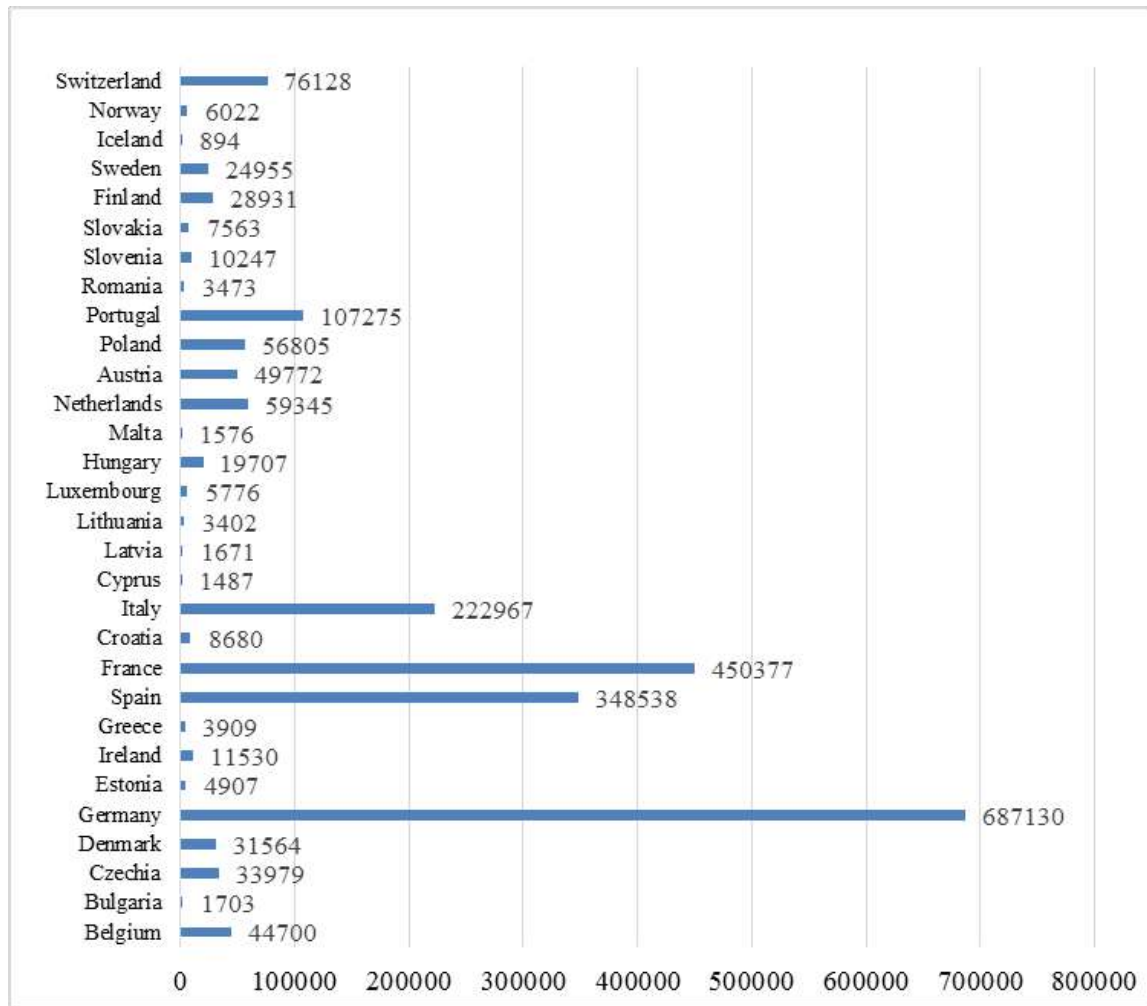


Figure 2. Non-fatal injuries (average value)

Regarding fatal injuries, the minimum average value is 894 injuries (Iceland) while the maximum average value is 687130 (Germany). Iceland showed the minimum standard deviation for observed time period (Std. Dev. =8 3.94), and Spain showed the maximum standard deviation (Std. Dev. = 37357.47).

Figure 2 highlights extreme skewness and dispersion in the distribution of non-fatal injuries, with a small number of large economies accounting for a disproportionately high number of cases. Similarly to fatal injuries, these differences are likely influenced by variations in population size, labor market scale, sectoral structure, and reporting systems.

Table 1 shows that both fatal and non-fatal injuries vary considerably across countries.

Overall, the results show substantial variability between countries, particularly for non-fatal injuries. For fatal injuries, minimum values range from 1 to 4 cases annually, while maximum values vary between 491 and 698, indicating notable cross-country differences in extreme cases.

The mean number of fatal injuries remains relatively stable throughout the observed period, fluctuating around 100 cases per year. However, the relatively high standard deviation (ranging from 134 to 156) and variance indicate pronounced data dispersion, highlighting significant heterogeneity among countries.

Table 1. Descriptive Statistics regarding observed year

Year	Fatal injuries					Non-fatal injuries				
	Min	Max	Mean	Std. Deviation	Variance	Min	Max	Mean	Std. Deviation	Variance
Y 2014	2	517	109.83	144.333	20831.937	835	706980	77529.43	157422.74	835
Y 2015	2	528	112.07	147.827	21852.961	877	707138	77817.87	158062.66	877
Y 2016	4	528	102.20	134.158	17998.372	896	714114	79116.9	159667.83	896
Y 2017	1	496	99.50	134.145	17994.879	950	715195	80575.43	161117.31	950
Y 2018	3	530	101.20	135.608	18389.476	1034	723704	81533.13	164984.69	1034
Y 2019	1	689	103.00	155.208	24089.379	931	718391	82012	166252.36	931
Y 2020	3	491	96.77	135.841	18452.668	762	633894	67947.97	138828.55	762
Y 2021	1	593	102.80	153.320	23507.062	745	667104	75357.13	152399.34	745
Y 2022	1	669	100.37	154.769	23953.344	903	647973	74976.80	149500.29	903
Y 2023	1	698	101.73	156.333	24440.133	1002	636807	74803.23	148255.88	1002

A similar pattern is observed for non-fatal injuries, but with considerably higher absolute values and variability. Minimum values range from 745 to 1,034, while maximum values exceed 700,000 in several years. The average number of non-fatal injuries shows an increasing trend from 2014 to 2019, peaking in 2019 (82,012), followed by a noticeable decline in 2020 (67,947.97).

To further distinguish between countries with relatively safer and less safe working environments, K-means cluster analysis was applied. Table 2 presents the cluster membership of European countries based on K-means clustering applied separately to fatal and non-fatal occupational injuries, along with an indication of whether the results are consistent across the two models.

The results show that 18 out of 30 countries display consistent cluster membership, meaning they are classified in the same cluster regardless of whether fatal or non-fatal injuries are considered. This indicates a relatively stable pattern of workplace safety in most countries.

A large group of countries, including Belgium, Bulgaria, Czechia, Germany, Estonia, Ireland, Luxembourg, the Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, and Iceland, are consistently assigned to Cluster 1, indicating relatively lower levels of occupational injuries and therefore safer working environments.

In contrast, countries such as Denmark and Spain are consistently classified in Cluster 2, suggesting higher levels of occupational injuries and comparatively less safe working conditions. Similar findings were reported by Tompa et al. (2021).

However, 12 countries show inconsistencies between the two models, indicating that their classification depends on whether fatal or non-fatal injuries are considered. For example, France, Italy, Croatia, and Cyprus are grouped in the higher-risk cluster based on fatal injuries but fall into the lower-risk cluster when non-fatal injuries are analysed. Conversely, countries such as Sweden, Norway, Switzerland, Lithuania, Latvia, and Hungary shift from the lower-risk cluster (fatal injuries) to the higher-risk cluster (non-fatal injuries). This indicates considerable diversity among countries regarding the number of fatal and non-fatal workplace accidents, as also found by Radenović (2023).

These discrepancies suggest that fatal and non-fatal injuries capture different aspects of workplace safety. While some countries may have relatively low fatality rates, they may still experience a high number of non-fatal incidents, and vice versa. This highlights the importance of considering both indicators when assessing occupational safety performance.

The shift from traditional occupational hazards towards more complex and long-term health risks may help explain the differences identified between fatal and non-fatal injury patterns across European countries. Technological advancements, automation, and improved

safety practices have contributed to a reduction in fatal injuries, while non-fatal injuries remain relatively high in many countries (Takala, 2019).

Table 2. Cluster memberships (N = 30)

Country	Cluster membership		Match
	Fatal injuries	Non-fatal injuries	
Belgium	Cluster 1	Cluster 1	✓
Bulgaria	Cluster 1	Cluster 1	✓
Czechia	Cluster 1	Cluster 1	✓
Denmark	Cluster 2	Cluster 2	✓
Germany	Cluster 1	Cluster 1	✓
Estonia	Cluster 1	Cluster 1	✓
Ireland	Cluster 1	Cluster 1	✓
Greece	Cluster 1	Cluster 2	X
Spain	Cluster 2	Cluster 2	✓
France	Cluster 2	Cluster 1	X
Croatia	Cluster 2	Cluster 1	X
Italy	Cluster 2	Cluster 1	X
Cyprus	Cluster 2	Cluster 1	X
Latvia	Cluster 1	Cluster 2	X
Lithuania	Cluster 1	Cluster 2	X
Luxembourg	Cluster 1	Cluster 1	✓
Hungary	Cluster 1	Cluster 2	X
Malta	Cluster 2	Cluster 1	X
Netherlands	Cluster 1	Cluster 1	✓
Austria	Cluster 1	Cluster 1	✓
Poland	Cluster 1	Cluster 1	✓
Portugal	Cluster 1	Cluster 1	✓
Romania	Cluster 1	Cluster 1	✓
Slovenia	Cluster 1	Cluster 1	✓
Slovakia	Cluster 1	Cluster 1	✓
Finland	Cluster 1	Cluster 1	✓
Sweden	Cluster 1	Cluster 2	X
Iceland	Cluster 1	Cluster 1	✓
Norway	Cluster 1	Cluster 2	X
Switzerland	Cluster 1	Cluster 2	X
Matched results:			18

The clustering results further support this interpretation. Countries classified as lower-risk based on fatal injuries but higher-risk in terms of non-fatal injuries may reflect this structural transition. In these cases, improved safety standards successfully reduce fatal outcomes, while the prevalence of non-fatal incidents remains influenced by factors such as work intensity, ergonomic conditions, and psychosocial risks.

5. CONCLUSION

This study advances the understanding of workplace safety in European countries by applying K-means cluster analysis to classify countries based on fatal and non-fatal occupational injuries from 2014 to 2023. The results reveal significant heterogeneity among countries, with a clear distinction between those with relatively safer and less safe working environments. Most countries are consistently grouped in the lower-risk cluster, indicating

stable safety conditions. However, a notable proportion of countries are classified differently depending on whether fatal or non-fatal injuries are considered, highlighting the multidimensional nature of occupational safety. These findings suggest that relying on a single indicator may result in incomplete assessments of workplace risk.

The results also reflect broader structural changes in modern work environments, where improvements in safety standards and technological advancements contribute to the reduction of fatal injuries, while non-fatal injuries remain influenced by factors such as work intensity, ergonomic conditions, and psychosocial risks.

Despite its contributions, the study has certain limitations, including the use of aggregated data and the exclusion of sector-specific or firm-level analysis due to secondary data do not offer such information. Future research could expand the model by incorporating additional variables or applying alternative clustering techniques to gain deeper insights into occupational safety dynamics.

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