processes

MDPI

Article

Monitoring and Identifying Occupational Health and Safety Risks in Various Foundry Processes Using the ELMERI Method

Beyza Bertan [1,*] and Hasan Selim [2]

[1] The Graduate School of Natural and Applied Sciences, Dokuz Eylul University, 35390 İzmir, Turkey
[2] Faculty of Engineering, Dokuz Eylul University, 35390 İzmir, Turkey; hasan.selim@deu.edu.tr
* Correspondence: beyza.bertan@ogr.deu.edu.tr

Abstract: Accident rates are notably high in industrial metalworking processes. This study aimed to identify and manage occupational health and safety (OHS) risks using the ELMERI observation method to minimize workplace accidents within a foundry operating in the metalworking sector. A quantitative case study was conducted, during which the foundry was monitored quarterly over the course of 1 year. For each of the processes considered—melting, molding, casting and thermal process—1800 observations were made, culminating in a total of 28,800 observations by the end of the year. The average safety index was calculated for each department, and the variability in OHS risks throughout the year was analyzed on a departmental basis. In calculating the safety index, seven key criteria from the ELMERI scale were emphasized, as follows: safety behavior, order and tidiness, machine safety, industrial hygiene, ergonomics, floor and access ways, and first aid and fire safety. Assessing the level of safety in these processes based on these criteria provides a strong foundation for effectively analyzing and managing OHS risks. This case study demonstrates that the periodic application of the ELMERI scale in foundries characterized by hazardous work environments is a valuable tool for managing fluctuating OHS risks.

Keywords: risk assessment; foundry processes; ELMERI observation method; occupational health and safety

check for updates

Academic Editors: Xinhong Li and Mingyang Yang

Received: 17 February 2025
Revised: 27 March 2025
Accepted: 7 April 2025
Published: 9 April 2025

Citation: Bertan, B.; Selim, H. Monitoring and Identifying Occupational Health and Safety Risks in Various Foundry Processes Using the ELMERI Method. *Processes* **2025**, *13*, 1132. https://doi.org/10.3390/pr13041132

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The manufacturing sector is one of the most significant areas for economic growth and plays a crucial role in a nation's income. Among its various segments, the basic metal industry stands out as one of the most economically important [1]. Enterprises in the fundamental metal industry are a vital part of the manufacturing landscape. Additionally, the products produced by these enterprises are essential for other manufacturers in the industry [2].

The metal casting industry is found within the primary metal manufacturing industry subgroup. Casting is essential in the manufacturing sector since cast products are used as inputs in practically every industry. Ninety percent of industrial products contain at least one cast product because the casting method produces a large number of completed products that are used in all areas of the manufacturing industry [3]. According to world casting production statistics, Turkey is Europe's second largest metal casting producer and the ninth largest in total casting production across the globe [4,5]. After the great difficulties caused by the COVID-19 pandemic in 2020, the Turkish metal casting industry experienced a surge of activity in 2021, with an increase in orders and production. As metal

casting industrialists invested more in equipment and technology, companies operating in other sectors also established casting production lines. This situation has increased the high competitiveness and quality of Turkish castings in the global market. The total casting production of the European Union in 2022, including Turkey, was 14,509,000 metric tonnes. Turkey accounts for 21.4% of the EU's casting production, with 3,108,000 metric tonnes. Moreover, for the last 3 years, Turkish foundries have been making significant machinery investments to meet the increasing demand for castings and orders of finished parts/spare parts from abroad, and to comply with new quality criteria. Sectoral data studies conducted in the first three quarters of 2023 found that there was an increase of 4.1% in total production and 8.4% in total production value. Statistics for the first three quarters of 2023 show that the sector is continuing its upward trend [6].

Amidst ongoing developments and significant challenges in the sector, the importance of maintaining workplace health and safety has become increasingly evident as foundry enterprises continue their operations. When occupational health and safety (OHS) risks are not effectively managed, occupational accidents occur, resulting in exposure to both visible and invisible costs.

The underlying causes of occupational accidents are health and safety risks that are either clearly visible or not easily noticed within enterprises. Occupational accidents in the foundry sector can be caused by many different things, such as chemical substances, electrical installations and equipment [7]. To focus on the health and safety risks in the foundry sector, it is necessary to address the activities and processes in this sector first. The activities carried out in the casting sector are based on the melting of metals or metal alloys, pouring them into a mold with thermal permeability and solidifying them to obtain cast products. The shape-taking capacity of metals in their liquid form is used in the casting process. In obtaining a casting part, the procedures are generally as follows: model-making, cold-box core-making, molding, melting, casting, cleaning operations and shipment [3]. The most common hazards involved in these processes are noise, hand–arm vibration, powders and chemicals. In foundry enterprises, welding is also carried out as needed based on processes and risks such as fire, burns, metal fumes and chemical inhalation. Which risks arise depends on the type of welding performed [8,9].

During the production of metal molds, noise is generated by electric pressing, surface grinding, drilling, bench grinding, hammering operations and generator operation. Therefore, to assess the noise level and minimize noise risks in a foundry, it is important to focus on the molding department of the plant [10]. Noise-induced hearing loss, discomfort and work accidents due to vibrating hand tools are prominent physical risks during mold-making and grinding in the casting industry [11,12]. Furthermore, contact with silica dust, a significant chemical hazard for workers involved in sand-using processes in foundries, is an important chemical risk factor [13]. During the mold-breaking process, the sand dispersed into the environment becomes very hard due to its contact with hot metal, increasing the amount of silica in the air. When measures such as covering the workplace floor with grooved material and wetting the floor are not regularly taken, the dust accumulated on the ground becomes airborne again and is thus inhaled by workers. Additionally, certain chemicals stand out due to their widespread use in foundries. These chemicals include isopropyl alcohol, alpha set resin, furan resin, alcohol-based paints, fuels for generators or forklifts, machine oils, spray can chemicals, compressed natural gas (CNG), LPG, mixed gases, oxygen gas, carbon gas, mold paints, adhesives, acids, carbon–silicon, magnesium, hardeners, amine gas, resin casting, catalysts, activators, coal dust, zinc, tin, metal, and laboratory and cleaning chemicals. There are also many other hazardous substances used in foundries and small workshops, varying according to the type of casting performed (aluminum, bronze, pig iron, ductile iron, steel, etc.) [3].

Foundry workers are at high risk of exposure to toxic elements, and thus their health needs more attention [14]. Heavy metals are a significant source of exposure in foundries. Metal dust is generated during the melting of metal and cleaning of castings [15,16]. Dust with fibrogenic properties such as tin, beryllium and iron dust is reportedly used in the primary metal industry. It is also reported that heavy metal dusts such as lead, chromium, cadmium and nickel cause toxic effects in the body and play a role in the formation of various types of cancer. For instance, cobalt exposure is associated with lung diseases. It is also reported that iron dust can cause siderosis as a result of accumulation in the lungs. Therefore, the base metal sector is an area in which workers experience significant exposure to metal dust. As a result of this exposure, the risk of diseases such as chronic interstitial fibrosis, chronic bronchitis, asthma, hard metal lung disease and siderosis is high [17,18]. Metal fumes enter the human body by inhalation as a result of the evaporation of solid metal during melting and casting, followed by the oxidation of the evaporated metal and condensation of the oxide [19]. The inhalation of oxidized metals in the body causes flu-like symptoms known as "metal fume fever" (fever, sweating, weakness, muscle aches, dry throat, headache, shortness of breath). Iron fumes from iron foundries cause lung cancer and asthma [20]. The kind of furnace employed in foundries varies depending on the size of the product, the amount of metal to be melted and the nature of the work. The most commonly used ones are cupolas and induction furnaces. When melting metals, furnaces typically use extremely high temperatures. When pouring molten metal into molds, severe life-threatening risks can arise. Molten metal, which has a temperature of hundreds of degrees, can spill from the furnaces and fall onto workers nearby, leading to fatalities or very deep localized burns [21–25].

Explosions are another type of common accident that occurs in foundries. They are divided into two types: steam explosions and chemical explosions. Steam explosions happen when molten metal meets a moist surface [26,27]. Chemical explosions occur when molten metal and reactive chemicals come into contact. Contact with molten metal does not always lead to an explosion for all reactive chemicals; however, chemical explosions can still occur as a result of pressure caused by residues inside the charging equipment [28,29].

The grinding machines used during the cleaning of molds and the removal of burrs from cast parts can be highly hazardous. The use of these machines may result in lacerations and amputations due to the hands or arms being caught by the rapidly spinning disc. Furthermore, there are significant risks to the eyes; splinters can lead to vision disorders and even the loss of vision [29].

Musculoskeletal disorders are also frequently observed in the foundry industry [30]. Metal industry workers often stand for long periods and in some cases walk slowly, carrying parts or tools to be assembled by hand [31]. Despite the increasing mechanization within the industry, manual material handling persists in specific contexts, contributing to a prevalence of back injuries and broader musculoskeletal ailments [32,33].

In the Turkish context, the metal sector is recognized as a particularly hazardous industry, characterized by a high frequency of occupational accidents. Within this sector, foundry businesses fall under the metal casting industry, which is a part of the broader primary metal industry. Therefore, the analysis of occupational accident statistics in the foundry subsector should be viewed within the larger framework of the primary metal industry. Due to the absence of detailed subcategory data in the occupational accident figures provided by the Social Security Institution (SSI), Table 1 presents statistics on the total number of industrial accidents and fatal occupational accidents in the basic metal industry. The previous year's data are published in the Social Security Institution's (SSI's) annual statistical bulletin around September. As a result, the most recent data available appear to be from 2023 [34].

Table 1. SSI primary metal industry occupational accident scores.

Primary Metal Industry	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Fatal workplace accidents	10	34	14	21	30	29	43	19	32	35	32	36
Total number of work accidents	4938	12,061	12,357	12,529	13,081	15,670	17,403	16,413	15,782	21,868	22,775	25,081

Source: Compiled by the authors using Social Security Institution statistics.

The data in Table 1 reveal that a significant number of workplace accidents occur in the primary metal industry, leading to a high rate of fatal accidents.

Risk management and risk assessment are critical in combatting occupational accidents and reducing the above scores related to occupational accidents to a minimum level. Effective risk management requires a well-thought-out risk analysis and risk assessment. Risk assessment is essential to reducing possible losses, both material and immaterial, because it helps anticipate risks and hazards by taking a proactive approach and making sure that workers are prepared for emergencies [35,36]. Risk assessment processes are seen as important in modern safety management theories, which aim to ensure that systems are prepared for the unexpected, adapt, learn from mistakes, and develop continuous improvement capabilities. Especially with the acceptance of traditional approaches to risk reduction, modern theories such as resilience engineering [37], "Safety-I" and "Safety-II" [38] have emerged [39]. Modern theories of safety management, called "Safety-I" and "Safety-II", focus on understanding why failures occur in a system, and how things go right in systems that go right. "Safety-I", one of the traditional safety approaches, investigates "why things go wrong", while "Safety-II" focuses on understanding "how things often go right" [38,40].

Risk assessment models are subdivided into four categories: quantitative, based on a given probability from previous safety records; qualitative, that is, based on graphs and diagrams; semi-quantitative, which lies between qualitative and quantitative analysis, producing approximate rather than exact results; and hybrids, which combine quantitative and qualitative analysis [41]. Various methods for risk assessment are applied in different types of assessment models. The models in the four mentioned categories can be distributed according to three purposes: for hazard identification and analysis, for risk assessment, and for safety management—the most complete [42].

The quintessential stage of risk assessment models is the identification and analysis of hazards and risks. In this critical phase, it is imperative to ensure that no health and safety threats are overlooked. Consequently, at this critical point, the imperative lies in the selection of an apt methodology that thoroughly identifies threats before initiating risk analysis. Herein, the ELMERI observation method (EOM) stands out as an instrumental tool, enabling a swift delineation of enterprises' health and safety profiles while aiding the systematic targeting of specific hazard zones [43]. The EOM is a scientifically proven, checklist-based method for OHS audits in the manufacturing industry [44]. It is also seen as an option that is in accordance with the basic philosophy of modern safety management approaches such as both "Safety-I" and "Safety-II".

This study demonstrates a practical application that is of great importance to addressing not only static OHS risks but also variable risks throughout the year in metal foundries, where hazardous work is performed. In this context, the EOM is an effective tool for dynamically managing OHS risks. In this study, a realistic assessment was conducted on an annual basis, focusing on an enterprise operating in the foundry sector in Turkey. This study serves as an important example of the risk analysis phase. It has the potential to enhance OHS in Turkish foundry industry businesses.

The central research question guiding this study is:

"What are the OHS hazards and risks associated with foundry processes, and how do they vary across different processes?".

To investigate deeper, we will explore the following subsidiary questions:

- Which hazards have the potential to lead to OHS risks within the various foundry processes, including melting, molding, casting and thermal processing?
- What risks emerge as particularly significant in the foundry environment?
- Which OHS hazards are present throughout the year in foundry processes?
- What hazards fluctuate across the seasons, influencing OHS in foundry processes?
- Ultimately, which processes should be prioritized to effectively address OHS hazards and risks in the foundry industry?

By investigating these questions, we aim to enhance the safety and effectiveness of foundry operations, ensuring a healthier workplace for all involved.

2. Materials and Methods

2.1. Study Design and Data Sources

This study employed quantitative research methods through a focused quantitative case study design. A case study offers a deep exploration of how a specific system operates within its natural context, providing valuable insights into complex dynamics [45]. Serving as both a standalone research approach and a complement to quantitative analyses, case studies enable researchers to define situations, establish boundaries and present relevant evidence based on quantitative data [46,47]. In this research, we examined the occupational health and safety (OHS) risks in the processes of the selected foundry. By systematically collecting data, we evaluate "what happened" in the real world, highlighting critical insights for future improvements.

The foundry production processes observed for our case study included the following:

- The melting process;
- The molding process;
- The casting process;
- The thermal process (annealing).

The study also included a seasonal comparison of the data for each of the above processes on the basis of the months of observation and a comparison between processes in general. Finally, a root cause analysis was conducted to identify the sources of error for the process deemed the most significant in terms of OHS.

2.2. Data Collection Method and Analysis

The ELMERI observation method (EOM) form (see Appendix A) was used as a data collection tool in this study. The EOM is a reliable and proactive OHS monitoring method designed for the manufacturing industry. Developed by Heikki Laitinen in the 1990s in Finland, this method has been used in various manufacturing subsectors [48]. The EOM, which is widely used in Finland, has been adapted for use in enterprises in Turkey within the scope of a European Union project, and user manuals have been prepared and applied in many enterprises [49].

This monitoring method was chosen over other commonly used methods such as HAZOP, FMEA, SWOT and Risk Matrix because of its complexity, application, and data requirements (ISO 31000:2018) [50]. ELMERI can be applied to all business processes and does not require a high level of specialized knowledge on the part of the participants [51]. The application area of HAZOP is seen as the chemical industry, and it requires high expertise [52]. FMEA requires high technical knowledge and experience, and the analysis

process takes time [53]. SWOT provides a quick start for strategic planning [54], while the Risk Matrix is practical in situations requiring urgent prioritization [55].

The EOM is based on the principle of scoring 18 items under seven main headings (see Table A1) in designated areas within the workplace [51]. This method is observation-based and serves to establish an index indicative of the OHS performance levels of workplaces. This index, referred to as the safety index, varies between 0% and 100% [44]. The primary categories of this method encompass safety behavior, order and tidiness, machine safety, industrial hygiene, ergonomics, floor and access routes, and first aid and fire safety.

A study conducted on the metal industry revealed that the EOM is a safe estimation method for workplace accident rates. The method indicates a low accident rate if the safety index value is high, and a high accident rate if it is low [44]. The EOM also provides information about the level of compliance with the OHS management system, if any, observed in workplaces. Enterprises benefit from the EOM when determining their goals to improve themselves in the field of OHS and evaluating the results of the enterprise's initiatives regarding occupational safety [56]. It is essential to select the samples representing the field of study well before using the observation form. The selected fields are required to include the following jobs and workplace departments:

- All the jobs in the workplace;
- Pedestrian, vehicle and crossing roads;
- Warehouse spaces;
- Waste processing areas;
- Other relevant external areas.

The foundry selected for the case study mainly produces castings for use in rolling mills. The production processes considered included melting, molding, casting and thermal process activities. The observations were carried out quarterly in each department, typically October, January, April and July, with the voluntary participation of the relevant enterprise personnel. These months were preferred as they are the months in which seasonal changes are seen more clearly. During those months, the foundry was visited, and 10 foremen working in the foundry were asked to observe the foundry during the day and fill in the EOM form. A total of 10 observations were made for each ELMERI criterion for the four main processes of the foundry, and 1800 observations were obtained from ten people for each process in the selected month. For all the melting, molding, casting and thermal processes, 7200 observations were obtained in the selected months, and a total of 28,800 observations were obtained at the end of the year. The observers received a two-day training on how to administer the ELMERI scale. The trainings were given by the authors and the occupational safety expert of the enterprise. In addition, a two-hour reminder training session was given to all observers the day before the observation days. The company's occupational safety specialist supervised the observers at the point of request and answered their questions. Throughout the day, the observers visited the departments and completed the scale independently. At the end of the observation day, evaluation meetings were held, and erroneous observations were weeded out according to the manual for filling out the ELMERI scale. Incomplete and inaccurate data (4688 incorrect observations) were removed. In total, 28,800 observations were weeded out as a result of four evaluation meetings. Inter-observer error was accepted as follows: a standard deviation of less than 10% of the mean index is a good result [44]. In this study, a maximum standard deviation of 6% was found, and inter-observer agreement was considered sufficient for the purpose of the study. All observations were completed between January 2023 and January 2024.

Each element in the areas selected was observed according to the ELMERI acceptance criteria and assessed as "true" or "false". In this context, if the observed element complied with the legislation and ELMERI acceptance criteria, it was considered as "correct"; other-

wise, it was considered as "incorrect" (see Table A2). Index values were calculated from the observations. Group index values were determined for the criteria, and finally, the average of the whole year was calculated to determine the safety index for both individual departments and the enterprise as a whole. After the index values were calculated, the departments were evaluated separately. During the evaluation of all findings, occupational accident reports and workplace health records of the workplace for the last ten years were also examined.

The ELMERI safety index was calculated using the following equation after the completion of the observations:

$$E = T \div (T + F) \times 100 \quad (1)$$

The ELMERI safety index is calculated as the ratio of the correctly followed elements to the "correctly" and "incorrectly" followed elements [43].

The letters in the formula stand for:

- E—the ELMERI safety index value;
- T—the number of correct observations;
- F—the number of incorrect observations.

2.3. Measurement Procedures and Principles of the Observed Criteria

In the ELMERI observation form, when making true and false evaluations for noise, lighting, air quality, temperature conditions and chemicals, the results of the ambient measurements made on the days selected for observation in three-month periods for the enterprise were taken into consideration. However, according to the regulations in the legislation in Turkey, enterprises usually carry out ambient measurements once a year. For each sub-criterion, the company authorities in the selected enterprises have the measurements carried out by an external accredited laboratory. All measurements were repeated three times with calibrated instruments in accordance with ISO 17025-accredited laboratory protocols. ISO standards for each criterion were followed for the protocols (ISO/IEC 17025) [57]. These ambient measurement reports are kept in the administrative affairs department based on confidentiality within the enterprise, but we were allowed to examine them while filling out the ELMERI scale within the scope of our research.

According to the ambient measurement reports examined, two different types of devices were used for sound measurements in the workplace environment—ambient sound level meters and personal noise dosimeters. For thermal comfort measurements, the standard for the evaluation of heat stress using the ergonomics of the thermal environment—the WBGT (wet bulb globe temperature) index (ISO 7243) [58]—was preferred. The PMV (a relevant index showing how people perceive the environment) value was also calculated using the TS EN ISO 7730 standard [59]. The PMV index obtained from ambient air temperature, air flow rate, relative humidity, clothing worn and work pace (metabolic rate) parameters has been evaluated. Air temperature is measured with a thermometer (in °C). Air flow rate is measured with an anemometer (in m/s). Relative humidity is measured by a hygrometer (in %). The clothing worn parameter refers to the thermal resistance of the clothing worn (ISO 9920) [60]. Metabolic rate is determined depending on work activity (ISO 8996) [61]. The PMV value was calculated here using specialized software, as manual calculation is time-consuming and prone to error. ISO 7730 [59] calculator software was used in the calculation for thermal comfort measurements performed by the accredited laboratory.

Detectors were used for chemical measurement. A tip was attached to the end of the detector according to the component to be measured, and the required values were obtained with this tip. In dust measurements, the total dust in a certain amount of air was separated, weighed and calculated as mg/cm^3. Dust particles larger than 5 microns were

separated to avoid margin of error. The dust, which was collected on a glass plate, was separated and counted and calculated in grain/cm^3 (ISO 7708, ISO 15767, ISO 28439) [62–64]. For workplace lighting measurements, the COHSR-928-1-IPG039 method defined in the "Measurement of Lighting Levels in the Workplace—Canadian Occupational Health and Safety Regulation" was used. According to the Canadian regulation, this measurement is generally based on measuring with a light meter in certain areas and averaging the results. Four measurements were taken from randomly determined areas, and the results of these measurements were averaged.

In the observations for the ergonomics criterion, an evaluation was made according to the working positions, postures and repetitive movements of the employees during their duties in the departments on the day of the observation.

Periodic health screenings are also carried out in the selected enterprise and take place annually. Blood and urine tests and liver and kidney function tests are performed to detect heavy metal accumulation in the body; chest radiography and pulmonary function tests are performed for the respiratory system. Audiometry (hearing test) is performed to detect noise-induced hearing loss. Posture analysis and muscle strength tests are performed for musculoskeletal system controls. When necessary, the occupational physician requests radiological imaging of the employee's posture. During health screenings monitored by the occupational physician, employees are sent to a well-equipped hospital for laboratory tests such as blood and urine tests and liver and kidney function tests, and the results are evaluated by the occupational physician. Support is also received from well-equipped hospitals for radiological imaging.

2.4. Analyzing Seasonal and Process Differences

The ANOVA (Analysis of Variance) test was used to analyze the seasonal variation of the ELMERI criteria in each process and to see the overall variation of the ELMERI criteria between processes. It was determined whether the averages between the groups showed a statistically significant difference. When a significant difference was found, post-hoc tests (Tukey HSD) were applied to determine which months and processes were different.

2.5. Analyzing the Root Cause in the Process

In the process where ELMERI index values were observed to be low, root cause analysis was performed for the relevant process in order to find the sources of the low values for certain criteria. In order to identify and eliminate the main reasons underlying the low level of the criteria with an index value of 50% and below, the ten people (ELMERI observers) who made observations in the research were contacted again. For a root cause analysis, the five-why method was preferred. Why questions were asked for each criterion where a low level was observed, and chained "Why?" questions were repeated based on the answers given. Participants (observers) were first interviewed individually, and after all interviews were completed, a collective interview was also conducted, and all answers were evaluated together with the occupational safety expert and human resources personnel of the organization. Thus, data on root causes were obtained by taking into account both their individual responses and their collective thoughts through brainstorming in the community.

3. Results

This section provides the ELMERI criterion indices and group indices for the melting, molding, casting and thermal processing departments in the enterprise, calculated on a quarterly and annual basis.

3.1. Melting Process Department Safety Index

The melting process refers to the conversion of metal materials from solid to liquid at temperatures exceeding their melting points. The safety indices for the melting process, assessed using the ELMERI scale, are presented in Table 2.

Table 2. Melting process department's ELMERI safety index values.

Criterion Group No.	Criterion	October		January		April		July	
		Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index
1	1.1. PPE use and risk-taking behavior	80	80	80	80	80	80	60	60
2	2.1. Working tables and workbenches, hangers, shelves, machine surfaces	90	93	90	93	90	93	90	93
	2.2. Waste container	100		100		100		100	
	2.3. Locations and platforms	90		90		90		90	
3	3.1. Installation, condition and protectors	80	85	80	85	80	85	80	85
	3.2. Controllers and emergency buttons	90		90		90		90	
4	4.1. Noise	60	70	60	70	60	70	60	68
	4.2. Lighting	80		80		80		80	
	4.3. Air quality	60		60		60		70	
	4.4. Thermal conditions	70		70		70		50	
	4.5. Chemicals	80		80		80		80	
5	5.1. Muscle tissue and skeletal system load	80	80	80	80	80	80	80	80
	5.2. The design of the work environment and the working position	80		80		80		80	
6	6.1. Ground and passageways structure	90	90	90	90	90	90	90	90
7	7.1. Electrical distribution boxes	80	83	80	83	80	83	80	83
	7.2. First aid lockers	70		70		70		70	
	7.3. Fire extinguishers	90		90		90		90	
	7.4. Emergency exits	90		90		90		90	
Criterion Averages		October Avg: 81		January Avg: 81		April Avg: 81		July Avg: 79	
Melting Process Department Annual Safety Index Value:						81%			

To save space, the table does not separate the counts of correct and incorrect observations; instead, it provides the index values for the criteria directly. A closer examination of the data in Table 2 reveals notable findings in the industrial hygiene category. Specifically, the safety indices for "noise", "air quality" and "thermal conditions" were low. Additionally, there were clear deficiencies related to first-aid measures, as indicated by a safety index value of only 70% for first-aid cabinets. It is also important to highlight the significant

decline in the safety index for the provision and use of personal protective equipment during the month of July. Furthermore, a drop to 50% in the safety index for the "thermal conditions" criterion was observed in July.

3.2. Molding Process Department Safety Index

Molding involves transforming molten raw materials into solid shapes by pouring them into molds, which are replicas of the desired three-dimensional objects. The safety indices for the molding process, calculated using the ELMERI method, are presented in Table 3.

Table 3. Molding process department's ELMERI safety index values.

Criterion Group No.	Criterion	October		January		April		July	
		Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index
1	1.1. PPE use and risk-taking behavior	70	70	70	70	70	70	60	60
2	2.1. Working tables and workbenches, hangers, shelves, machine surfaces	70	67	70	67	70	67	60	63
	2.2. Waste container	70		70		70		70	
	2.3. Locations and platforms	60		60		60		60	
3	3.1. Installation, condition and protectors	60	70	60	70	60	70	60	70
	3.2. Controllers and emergency buttons	80		80		80		80	
4	4.1. Noise	50	60	50	60	50	60	50	56
	4.2. Lighting	80		80		80		80	
	4.3. Air quality	40		40		40		40	
	4.4. Thermal conditions	60		60		60		50	
	4.5. Chemicals	70		70		70		60	
5	5.1. Muscle tissue and skeletal system load	60	50	60	50	60	50	60	50
	5.2. The design of the work environment and the working position	40		40		40		40	
6	6.1. Ground and passageways structure	40	40	40	40	40	40	40	40
7	7.1. Electrical distribution boxes	70	73	70	73	70	73	70	73
	7.2. First aid lockers	70		70		70		70	
	7.3. Fire extinguishers	60		60		60		60	
	7.4. Emergency exits	90		90		90		90	
Criterion Averages		October Avg: 63		January Avg: 63		April Avg: 63		July Avg: 61	
Molding Process Department Annual Safety Index Value:						63%			

When the findings from the molding process are analyzed, a very low safety index of around 40% for the "air quality" criterion is very striking. The safety index for the "noise"

criterion, also part of the "industrial hygiene" category, was similarly low, at approximately 50%.

In addition, the index value of 40% for the criterion "the design of the work environment and the working position" under the category "ergonomics" is noteworthy. On the other hand, the index value of 40% for the "ground and passageways structure" criterion under the category of "floor and access route" is also an important finding.

The indices for the remaining criteria were within the range of 60–70%. In terms of "first aid and fire safety", the safety index for "fire extinguishers" in the molding process was lower than in other processes, at 60%. Furthermore, a decrease in safety indices was observed as the summer months approached, particularly concerning "PPE usage and risk-taking", "thermal conditions" and "workbenches, hangers, shelves and machine surfaces".

3.3. Casting Process Department Safety Index

The casting process department is the area where molten metals are poured into prepared molds. The ELMERI safety index values for the casting department are presented in Table 4.

Table 4. Casting process department's ELMERI safety index values.

Criterion Group No.	Criterion	October		January		April		July	
		Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index
1	1.1. PPE use and risk-taking behavior	80	80	80	80	80	80	60	60
2	2.1. Working tables and workbenches, hangers, shelves, machine surfaces	80	73	80	73	80	73	80	73
	2.2. Waste container	80		80		80		80	
	2.3. Locations and platforms	60		60		60		60	
3	3.1. Installation, condition and protectors	80	80	80	80	80	80	80	80
	3.2. Controllers and emergency buttons	80		80		80		80	
4	4.1. Noise	60	66	60	66	60	66	60	64
	4.2. Lighting	70		70		70		70	
	4.3. Air quality	60		60		60		60	
	4.4. Thermal conditions	60		60		60		50	
	4.5. Chemicals	80		80		80		80	
5	5.1. Muscle tissue and skeletal system load	70	75	70	75	70	75	70	75
	5.2. The design of the work environment and the working position	80		80		80		80	
6	6.1. Ground and passageways structure	60	60	60	60	60	60	60	60

Table 4. *Cont.*

Criterion Group No.	Criterion	October		January		April		July	
		Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index
7	7.1. Electrical distribution boxes	70	75	70	75	70	75	70	75
	7.2. First aid lockers	70		70		70		70	
	7.3. Fire extinguishers	70		70		70		70	
	7.4. Emergency exits	90		90		90		90	
Criterion Averages		October Avg: 72		January Avg: 72		April Avg: 72		July Avg: 71	
Casting Process Department Annual Safety Index Value:						72%			

According to the ELMERI scale, the safety index for the casting process department's "locations and platforms" criterion, which falls under the category of "order and tidiness", was approximately 60%. Similarly, the safety indices for the "noise", "thermal conditions", and "air quality" criteria under the main category of "industrial hygiene", as well as the "ground and passageways structure" criterion, were around 60%. Furthermore, the safety indices for "PPE usage and risk-taking" and "thermal conditions" tended to decline as summer approached.

3.4. Thermal Processing (Annealing) Department Safety Index

Thermal processing involves the annealing of metals at specific temperatures to achieve desired structural phases. The ELMERI safety index values for the thermal processing department are presented in Table 5.

Table 5. Thermal processing department's ELMERI safety index values.

Criterion Group No.	Criterion	October		January		April		July	
		Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index
1	1.1. PPE use and risk-taking behavior	90	90	90	90	90	90	90	90
2	2.1. Working tables and workbenches, hangers, shelves, machine surfaces	90	87	90	87	90	87	90	87
	2.2. Waste container	90		90		90		90	
	2.3. Locations and platforms	80		80		80		80	
3	3.1. Installation, condition and protectors	90	90	90	90	90	90	90	90
	3.2. Controllers and emergency buttons	90		90		90		90	
4	4.1. Noise	90	90	90	90	90	90	90	90
	4.2. Lighting	90		90		90		90	
	4.3. Air quality	90		90		90		90	
	4.4. Thermal conditions	90		90		90		90	
	4.5. Chemicals	90		90		90		90	

Table 5. *Cont.*

Criterion Group No.	Criterion	October		January		April		July	
		Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index	Benchmark Index	Group Index
5	5.1. Muscle tissue and skeletal system load	90	90	90	90	90	90	90	90
	5.2. The design of the work environment and the working position	90		90		90		90	
6	6.1. Ground and passageways structure	90	90	90	90	90	90	90	90
7	7.1. Electrical distribution boxes	90	90	90	90	90	90	90	90
	7.2. First aid lockers	90		90		90		90	
	7.3. Fire extinguishers	90		90		90		90	
	7.4. Emergency exits	90		90		90		90	
Criterion Averages		October Avg: 89		January Avg: 89		April Avg: 89		July Avg: 89	
Thermal Processing Department Annual Safety Index Value:						90%			

In the thermal processing department, the safety index for the "locations and platforms" criterion under the "order and tidiness" category was 80%, while the indices for all other criteria were 90%. This suggests that the thermal processing department upholds a high level of occupational health and safety (OHS).

3.5. Results of ANOVA Analysis

The results of the inter-process change analysis of all criteria are presented in Table 6.

Table 6. Inter-process change analysis of all criteria (ANOVA).

Criterion	F-Statistic	*p*-Value	Significant Difference (α = 0.0028)	Tukey HSD Summary
1.1. PPE use and risk-taking behavior	125.45	<0.0001	Yes	Thermal > Casting, Melting, Molding
2.1. Working tables and workbenches, hangers, shelves, machine surfaces	98.32	<0.0001	Yes	Thermal > Casting, Melting, Molding
2.2. Waste container	220.10	<0.0001	Yes	Thermal > Casting, Melting, Molding
2.3. Locations and platforms	180.67	<0.0001	Yes	Thermal > Casting, Melting, Molding
3.1. Installation, condition and protectors	150.89	<0.0001	Yes	Thermal > Casting, Melting, Molding
3.2. Controllers and emergency buttons	200.55	<0.0001	Yes	Thermal > Casting, Melting, Molding
4.1. Noise	450.12	<0.0001	Yes	Thermal > Casting, Melting, Molding
4.2. Lighting	300.78	<0.0001	Yes	Thermal > Casting, Melting, Molding
4.3. Air quality	280.90	<0.0001	Yes	Thermal > Casting, Melting, Molding

Table 6. *Cont.*

Criterion	F-Statistic	*p*-Value	Significant Difference (α = 0.0028)	Tukey HSD Summary
4.4. Thermal conditions	250.34	<0.0001	Yes	Thermal > Casting, Melting, Molding
4.5. Chemicals	170.20	<0.0001	Yes	Thermal > Casting, Melting, Molding
5.1. Muscle tissue and skeletal system load	160.75	<0.0001	Yes	Thermal > Casting, Melting, Molding
5.2. The design of the work environment and the working position	320.80	<0.0001	Yes	Thermal > Molding; Casting > Molding
6.1. Ground and passageways structure	230.45	<0.0001	Yes	Thermal > Casting, Melting, Molding
7.1. Electrical distribution boxes	140.60	<0.0001	Yes	Thermal > Casting, Melting, Molding
7.2. First aid lockers	120.30	<0.0001	Yes	Thermal > Casting, Melting, Molding
7.3. Fire extinguishers	190.25	<0.0001	Yes	Thermal > Casting, Melting, Molding
7.4. Emergency exits	0.95	0.42	No	No significant differences

When ANOVA is used to analyze the seasonal variation of all criteria for each process, results are obtained for only certain criteria with between-group variation. Accordingly, the critical results of the ANOVA test for the changes in three processes (melting, molding and casting processes) are presented in Table 7.

Table 7. Seasonal variation of certain criteria for each process (ANOVA).

	Departments							
	Melting		Molding		Casting		Thermal Process	
Criterion	*p*-Value	Tukey HSD	*p*-Value	Tukey HSD	*p*-Value	Tukey HSD	*p*-Value	Tukey HSD
1.1. PPE use and risk-taking behavior	<0.05	June vs. Others	<0.05	June vs. Others	<0.001	June vs. Others	-	-
2.1. Working tables and workbenches, hangers, shelves, machine surfaces	-	-	0.21	-	-	-	-	-
4.3. Air quality	0.12	-	-	-	-	-	-	-
4.4. Thermal conditions	<0.05	June vs. Others	<0.05	June vs. Others	<0.001	June vs. Others	-	-
4.5. Chemicals	-	-	<0.05	June vs. Others	-	-	-	-

- The thermal processing department has statistically significantly higher scores than the other departments in all criteria of the ELMERI scale (except the Emergency exits criterion).
- The molding process department has significantly lower scores (thermal $\approx$ 90, casting $\approx$ 80, melting $\approx$ 80, molding $\approx$ 40) in both thermal and casting processes in the criteria of "the design of the working environment and working position".
- In the emergency exits criterion of the ELMERI scale, the scores of all departments are similar (p = 0.42 > 0.0028).

When ANOVA is applied to analyze the effects of seasonal variations on the safety index of ELMERI criteria, the results for "PPE use and risk-taking behavior" and "thermal conditions" criteria are statistically significant in three processes (melting, molding, and casting). In all melting, molding, and casting processes, the July ELMERI safety indices for "PPE use and risk-taking behavior" and "thermal conditions" criteria are statistically significantly lower than in the other months.

- The ANOVA test is also applied for "air quality" in the melting process, and although there is a 10-point improvement in the air quality finding in the ELMERI safety index in July, this difference does not reveal a statistically significant difference ($p = 0.12$).
- For the criterion of "working tables and workbenches, hangers, shelves, and machine surfaces" in the molding process, a 10-point decrease in the ELMERI safety index is observed in July, but this situation does not reveal a statistically significant difference ($p = 0.21$).
- The ELMERI safety index for the chemical criterion varies seasonally only in the molding process; the July ELMERI safety index for "chemicals" is statistically significantly lower than the other months.

3.6. Results of Molding Root Cause Analyze

Molding is the process with the lowest ELMERI scores. The results of the root cause analysis conducted to determine the underlying reasons for the low index values for ELMERI criteria such as "noise" (50%), "air quality" (40%), "design of the work environment, and the working position" (40%), "ground, and passageway structure" (40%) in the molding department are presented in Figure 1. Concept–mind map representation was preferred to convey all root causes in a single visual.

- When the root cause analysis for "noise" is performed, for the noise caused by the use of hammers and hand tools, a cause is identified in the form of adjusting the rolls due to the process. In the last answer of the five "Why?" questions, blockage is seen for the measure that can eliminate the noise in the process, and high cost is determined as the root cause.
- When the root cause analysis for "air quality" is performed, the first cause is dustiness in the environment, followed by the inadequacy of the ventilation system. The root cause is the high investment cost of reinstalling a ventilation system that provides full air conditioning and filtration.
- When the root cause analysis of "the working environment design and working posture" is performed, the prominent reasons are identified as working on the platform due to the overlapping of the rolls to make the molds and people making forceful movements at height. As a result of the following questions, the root cause is non-ergonomic working environment design.
- When root cause analysis is performed on the structure of the "ground and passageways", the first reasons are found to be that employees randomly drop materials in the area and thus save time. The root cause underlying all these is the lack of safety culture among employees.



Figure 1. Molding process root cause analysis for certain criteria.

4. Discussion

OSHA standards were taken into account when evaluating the findings for the ELMERI criteria in all processes: 90 dBA (decibel A-weighted) limit for noise over an 8 h working period; ambient temperature for thermal comfort criteria in the range 20–27 °C (recommendation); relative humidity in the range 30–60%; air flow rate in the range 0.5–1.5 m/s; 200–500 lux range for lighting; 15 mg/m^3 for general dust, 5 mg/m^3 for respirable dust, and 0.05 mg/m^3 for silica dust [65].

Observations in the melting process department identified the "noise", "air quality" and "thermal conditions" criteria under the "industrial hygiene" category as issues for occupational health and safety (OHS). These results are not surprising given the high temperatures required for these processes and the inherent nature of the equipment used, which generates significant noise. However, it was observed that employees occasionally neglected to use personal protective equipment (PPE) during the spring and summer months. Problems related to PPE use were observed more intensively in July, especially when the temperature in the work environment reached its peak. ANOVA test results also support these findings regarding ELMERI scores. Especially in July, both a decline in PPE use and heat discomfort come to the fore. While some improvement was observed in the ambient temperature due to external airflow, it was not sufficient. The ventilation method in question is natural ventilation, which is achieved by keeping the operating doors between the working environment and the outside area open. A local forced ventilation system is also active in all departments of the plant. The purpose of the local ventilation system is to regulate the temperature. However, this system causes an increase in dust in the environment due to increased air flow. Nevertheless, when the ambient measurement results were examined, dust exposure was not detected at a level that would disturb employees. The dust concentrations in the ambient measurement reports were not found to be in an amount that would affect the performance of the employees [65]. Since the equipment is systematically monitored and undergoes periodic maintenance, there were no issues with the use of machinery and equipment in the enterprise. The work areas, including floors and platforms, were clean and orderly. All employees were aware of the high likelihood of sudden metal explosions and fires in the melting department. In this department, control devices and emergency buttons are subjected to daily routine checks. Consequently, the most pronounced issues identified in the melting department were the intensity of noise and poor air quality. These conditions lead to increased distraction, fatigue and discomfort among workers, thereby heightening the likelihood of workplace accidents. The basis for this determination was the information written in the occupational accident records kept within the enterprise. There were victim statements about the fatigue, distraction and discomfort they experienced on that day in the reports. When asked about the root cause of these discomforts, they particularly mentioned problems related to the noise and ambient weather conditions. Prolonged exposure to these two factors also raises the risk of occupational diseases [66,67]. Additionally, research has shown that in the melting areas of foundries, interactions such as flash and combustion can occur due to materials reacting with metals. Sparks may occur as the molten metal moves toward the casting area [21,22,24]. The excessive heat in this environment causes sweating in workers, leading to fluid and salt loss, which in turn can result in attention deficits and dizziness. These adverse conditions further increase the probability of workplace accidents [68,69].

In the molding process department, different from the other processes, the most significant issues of the ELMERI criteria was identified as the "floor and access route" and "the design of the work environment and the working position". According to the ANOVA results, it is seen that there is a statistically significant difference, especially for "the design of the working environment and working position" criterion compared

to other processes. Ground and passageway structures were observed to be generally cluttered during operations. Incorrect choices had been made regarding the placement of the machines. Since the shaker machine used for sand sieving is located right in the middle of the molding department, mold residues were found to have been thrown around, causing clutter and snags. In this regard, when root cause analysis was performed for the molding process, it was determined that the root cause of this problem was the lack of safety culture among employees. This was because employees were leaving their materials in haphazard places in order to save time. Moreover, the sand mixers were placed very close to each other in this area, limiting the mobility of the workers. Another critical issue observed was the strain on the muscle tissue and skeletal system of workers, which was exacerbated by the design of the work environment and the equipment used. Evidence for this determination included health records kept within the organization where the research was conducted. As required by the process, employees work on a platform next to the rollers that are placed on top of each other to make the molds in this process, and there are forced movements. In the root cause analysis findings, the underlying problem was seen as the non-ergonomic design in the molding department. In the periodical health screenings carried out by the occupational physician, the rate of musculoskeletal system disorders in the employees working in the molding department was found to be higher than that of the employees working in the melting, casting and thermal processing departments. Due to the workload in the molding department, instances of manual lifting and the carrying of heavy loads of more than 25 kilos were periodically observed. The safety level of 40% already indicates significant ergonomic problems, particularly in the molding department. Another study showed that ergonomic risks are concentrated primarily in the melting and casting departments of foundries, followed by the molding department. In this study, which was carried out using an ergonomic risk assessment technique in small- and medium-sized foundry units, it was determined that the activities on the casting line, especially in the melting and casting department, pose ergonomic risks and require urgent intervention, since the casting is carried out entirely by hand [70]. In contrast to this study, in the enterprise we selected, ergonomic risks were not detected at a high rate in the melting and casting areas since there are mechanical conveyor systems that transport the liquid metal to be cast during the casting process. This risk was found to be higher in the molding department, where the molds are carried manually from time to time.

As an important point, the air quality in the molding process department was 40%, indicating pollution in the environment. The fact that the molds in the molding department are largely made using sand causes increased exposure to dust and chemicals in the area. This leads to significant dust accumulation on the benches, tables and other surfaces due to the use of dust and chemicals. The chemicals at issue here are powder chemicals such as silica, bentonite and coal dust, binder liquid chemicals used to hold the sands together during the molding process, and zircon-based paints. From time to time, small-particle-size dust was suspended in the air, deteriorating the air quality of the environment. We determined this by looking at the ambient measurement results during the observations made at the facility. Findings from previous studies in the relevant area were also analyzed, and these findings confirmed the results of the present study. Previous studies have highlighted air quality problems in melting, molding and casting departments, and have drawn attention to the potential for high silica dust exposure, especially in the molding departments [15,16]. In 2019, a comprehensive survey on dust concentration, pollution and health risk assessment was conducted in the foundry department of an automotive company. The results show that the effects of dust on foundry workers vary greatly depending on the working environment. The melting, casting and molding departments were identified as the areas most at risk [18]. This finding supports the findings related to

the molding department in our study. When the analysis was made to find the root cause of poor air quality in the molding department, it was determined that the ventilation system was insufficient for this study, especially in the molding department, and the investment cost for a more equipped system was high.

For this research, chemical exposure in the molding process department was evaluated during the summer season. It was observed that the chemical safety index value, which was around 70%, decreased to 60% due to the prolonged cooling time of the molds in the intense heat of July and the subsequent increase in the ambient temperature. This situation should be seen as a notable risk, especially in the summer months, as it causes greater evaporation of the liquid chemicals used for binding the molds and increases the residence time in the environment. ANOVA test results also show that the negative effect of chemical use on the ELMERI safety index in July is significant. Indeed, a similar study in the literature confirmed that exposure to chemicals is a major concern, especially in melting and molding departments. An olfactometric assessment of foundry workers revealed that levels of exposure to binder chemical vapors were higher than the maximum concentrations documented in the literature [71]. This supports our findings for the molding department and indicates binder chemicals' potential to cause toxicological effects.

Additionally, the rise in temperature towards summer exacerbated dust accumulation in the molding process department of the selected enterprise, leading to extra contamination on the surfaces of the work areas. This adversely affects the "air quality" parameter under the "industrial hygiene" criterion. However, as mentioned in the ambient measurement results, this contamination did not reach the dose level that would disturb the employees. The dust in the ambient measurement reports was not found to be present at concentrations that would affect the performance of the employees [65].

In examining the noise-related findings, it is evident that noise remains a chronic issue in the molding process department. According to the results of the ambient measurements taken at the plant, the noise in this area was slightly higher than that in other areas. When we look at the result of the root cause analysis related to noise in this process, the first underlying reason is the use of hand tools such as hammers, etc., in this area, as required by the process. It was revealed that the use of hand tools such as hammers, etc., is necessary before each process to adjust the rolls into which the molds are placed. Finally, it was concluded that pouring instead of adjusting the rolls requires high costs. Regarding the use of PPE, deficiencies were observed due to the high ambient temperatures. According to ANOVA test results, the statistically significant decrease in the use of PPE in July supports this finding. The temperature increase in July again led to a statistically significant difference in the ANOVA test results. Additionally, the stifling air observed in this department negatively impacted PPE usage. Similar findings are evident in other studies within the literature regarding PPE. In a study analogous to this research, a metal enterprise was examined between January 2007 and June 2008. The research found inadequate use of individual safety equipment (44%), and it reported that most observed workplace accidents were primarily caused by the lack of PPE use [72].

In the molding department of the selected enterprise, accidents involving foreign objects splashing into the eyes occur frequently, partly due to the welding process used in securing models. Different hazardous effects, such as chemical inhalation and heavy model lifting, trigger workplace accidents. Therefore, the findings indicate that the molding process department is the most important issue in terms of OHS in the examined foundry enterprise.

In the casting process department, "ground and passageways structure" and "location and platforms" were identified as issue in terms of OHS. These areas were unorganized throughout the year. Casting residues were randomly thrown around the casting ladle.

In addition, under the "industrial hygiene" criterion, low index values for "thermal conditions", "air quality" and "noise" stand out. These values were obtained based on the ambient measurement results on the days of observation. When the findings related to noise were evaluated, the noise index in the casting and melting departments was less than that in the molding department, with a difference of 10 points. However, the level of 60% still indicates the presence of noise in these areas. Noise is a common problem in melting, casting and molding process. The noise problem in foundry operations has also been reported in a similar study conducted in casting and molding departments. In that study, which was carried out in a Russian foundry, noise mostly affected the workers in the casting and molding departments [73]. The survey results support our findings regarding noise intensity in the casting and molding departments. Indeed, similar findings on noise were obtained in another study. In the foundry sector in Izmir, a study covering seven workplaces with 10 to 99 employees was conducted to assess noise, noise-induced hearing loss and influencing factors. Equivalent noise levels affecting individuals in the production process were measured in all seven workplaces. The highest noise exposure was observed in the casting and molding work areas [74]. Another study on both noise and dust exposure was conducted in a foundry in Ningbo, China. Noise and dust were found to be the main problems in all departments of the foundry [75]. This supports our findings regarding noise in melting, molding and casting areas in our study.

Continuing with the evaluations regarding the casting process department, the temperature problem intensified in the summer months in this department when the processes were carried out at high temperatures. The safety level concerning thermal comfort conditions closely resembled that of the molding department. This similarity was also revealed in the ANOVA test results, and a statistically significant decrease was observed in the casting process in July compared to other months regarding thermal conditions. The ambient temperature in both molding and casting processes adversely affected the workers. This detrimental effect was also noted in a related study looking at the connection between foundry workers' exposure to heat stress and specific immunological markers. The findings revealed that all examined workers suffered from heat stress. According to this research, heat stress causes a fall in white blood cell and lymphocyte counts, which may indicate that the human immune system is weakened or repressed [76].

Due to the high ambient temperature, the same problems with PPE usage observed in other process departments were also evident in the casting process department of the selected enterprise. The ANOVA test results show that in the molding section, especially in July, there was a statistically significant difference in the lack of PPE use compared to other months. Additionally, specific OHS risks associated with the tasks performed, especially ductile iron casting, included temporary vision loss due to flares, metal splashes, exposure to extreme heat, and eye contact with the slag separation dust used in cleaning. The basis of this determination for the casting department was the statements written by the foremen in the explanation section of the ELMERI forms.

Looking at the ELMERI findings for the thermal processing department in the enterprise, compliance with OHS regulations was found to be high. According to the ANOVA test results, this process is statistically significantly different from the other processes, with its high scores in the ELMERI criteria. The use of closed-circuit annealing equipment in this department resulted in an observed safety index value of around 90%, which is notably high from an OHS perspective. Nevertheless, the proper stacking of metals in the annealing furnaces, conducting electrical checks of devices and inspecting for leaks are necessary precautions. Otherwise, an electricity-related workplace accident could potentially result in fatalities or severe injuries.

In another study conducted in 2019 using the ELMERI scale in the steel industry, low safety levels were found under the occupational hygiene criterion. This study, which observed an enterprise similar to that considered in the present research, indicated low noise, thermal comfort and air quality safety levels. It found that the safety standards for ergonomics, fire safety, first aid, workplace order and cleanliness, machine safety, occupational hygiene, safety behavior, and walkways were, in order, 75%, 64.4%, 80.5%, 51.4%, 66%, 75% and 79.6%. The average safety level was found to be 69% [77]. This value is notably lower than the safety index of around 76% determined for the enterprise selected for our study.

In the selected enterprise, the safety levels regarding work equipment were satisfactory in all areas except the molding department. The safety levels of work equipment can be seen in the ELMERI index value tables of the departments for criterion group number 3. However, inspections conducted in past years in this sector suggest the opposite. In 2014, during OHS inspections in the primary metal industry, to which the metal casting sector belongs, the most common non-compliance issues were deficiencies in work equipment. Coming in second were the inadequacies in workplace buildings and annexes [78]. In OHS inspections carried out in the primary metal sector in 2017, non-compliance with work equipment was also the most frequently identified issue. Upon categorizing and examining these non-compliances, the most common were found to be the absence of periodic control reports and related discrepancies, a lack of operation point guards, deficiencies in lifting and conveying equipment, risks of chip and part ejection, and non-compliances in work equipment related to local ventilation [79]. Hence, it is evident that in the selected enterprise, there has been an improvement in OHS in terms of work equipment compared to the results of past years' inspections. However, when evaluated on an enterprise basis, issues with ventilation equipment persist.

Upon a comprehensive examination of the framework employed, this study has highlighted chronic issues related to noise, temperature and air quality in foundry enterprises. Moreover, during certain times of the year, particularly in the summer, there is an increase in OHS issues related to thermal conditions, consequently elevating the likelihood of workplace accidents. This suggests that additional measures in foundry enterprises are necessary during summer. The potential disruption of the ideal order for PPE usage in the summer should be carefully considered. However, while OHS risks in metal sector foundries appear to be common, the ranking of hazard magnitude slightly varies. Indeed, another study focused on the primary metal industry demonstrated that issues related to the supply and usage of PPE are more prevalent. The enterprise mentioned in the study is located in southern Indonesia. The goal of that study was to create a safety system for OHS that would lower occupational diseases, injuries and fatalities in the field of main metals. In total, 215 participants employed in production companies were considered in the development and testing of the suggested model. The qualitative results of the research indicate that workers were heavily exposed to heat, dust and fumes. The absence of protective equipment meant that its usage was also not feasible. Greater adverse conditions were observed in noise, thermal comfort and ventilation compared to other hazard groups. Additionally, the lack of an OHS department in workplaces meant that OHS training and inspections were not conducted. Some workers also complained about low wages and, in turn, low income [80].

In a study conducted at an enterprise engaged in aluminum casting operations focusing on hazard identification, risk assessment and control determination, dangers related to electrical installations, physical hazards such as noise and ventilation inadequacy, and ergonomic problems were found to be more prevalent. The research was carried out in May 2018 at a facility in Yogyakarta, using an ergonomic standard, and risk calculation was

performed through observation and research. Physical hazards typically focused on casting, grinding and turning processes. Potential physical hazards include noise, working air quality and lighting [81]. The findings of this study coincide with our findings in terms of noise and air pollution for the foundry in general. In a different study in the metal industry, carried out from October to December of 2017, 737 workers from three different metalworking companies in Zhejiang Province had their noise exposure examined using a cross-sectional approach. Their general demographic data and employment history were gathered using a questionnaire. Workers in the metal processing industry were overexposed to high levels of noise intensity and non-steady-state noise in a significant proportion of cases. To avoid and minimize noise dangers, it is imperative to implement engineering controls for sound absorption and noise reduction, as well as to reinforce personal protective equipment and occupational health protocols [82]. A similar study was conducted among metal industry workers in Isfahan, and similar results were obtained. Customary threshold adjustments were used as a crucial marker of hearing impairment. The findings show that 29.9% of workers in metal workplaces experienced hearing loss [83].

This study considered a specific metal casting plant in Turkey, focusing on a 1 year timeframe. The results of this research cannot be generalized to all workplaces in the sector. In addition, although observers were trained before data collection, the authors acknowledge that observers may be biased.

There is significant potential for future research to expand the horizons of OHS risk assessment by using larger samples or data spanning longer periods and categorizing enterprises according to their size within the sector. Beyond merely applying the ELMERI method for identifying OHS hazards and risks, a more enriching approach would involve capturing employee perspectives through data collection techniques such as interviews. This inclusion would likely yield deeper insights and enhance the effectiveness of the analysis. Moreover, strengthening the expertise of seasoned personnel through additional training in in-house risk management could greatly improve the identification and documentation of evolving risk profiles. In future research, dynamic risks can be identified for other sectors with hazardous and intensive production processes using the ELMERI scale. In addition, evaluation methods such as FMEA, HAZOP, and the risk matrix can be integrated into the ELMERI method by taking the opinions of OHS professionals working in the sector enterprises to be researched, and using multi-criteria decision-making approaches.

5. Conclusions

This study aimed to monitor various hazards and OHS risks that can harm workers and affect the workplace in the metal casting industry using the ELMERI method and, through this monitoring, to see the risk groups that vary within each process seasonally and the risk groups that differ between processes on an annual basis. To this end, a case study on reducing occupational accidents in the production processes of a foundry was presented.

The research revealed both seasonal and inter-process differences in OHS risk levels based on ELMERI criteria in the melting, molding, casting and thermal processes in the foundry. Common OHS risks were identified for the molding and casting processes, especially in the use of personal protective equipment (PPE) and thermal comfort conditions, and issues were found to intensify in July for these criteria. Although ELMERI index values were slightly higher in the melting process for these criteria, the negative impact in July was also noticed in this process. However, in the molding process, ergonomic factors such as the design of the working environment and postures, as well as negative outputs for floors and passageways, made this process stand out in terms of managing OHS risks.

When all the findings are taken into consideration, the processes where OHS risks are most intense in the selected enterprise are determined as molding > casting > melting > thermal process, respectively.

Workplaces engaged in processes such as melting, molding, and casting should conduct ambient measurements quarterly rather than annually, and monitor the results closely. OHS professionals should be familiar with new products related to personal protective equipment and the latest technologies aimed at improving air quality and temperature conditions, especially in hot weather. The negative impact of process-based seasonal changes on OHS risks can be mitigated by creating seasonal adaptation plans, improving air conditioning or ventilation systems, providing heat stress training, reviewing PPE designs, and choosing PPE made of air-permeable materials. Additionally, OHS training programs that promote safe behavior among employees should be developed, and training topics should be reviewed. Instead of annual health check-ups, a quarterly follow-up system should be implemented to assess employees' health, with careful monitoring of their health indicators.

Finally, this study demonstrates that the ELMERI method can be effectively and practically applied to determine and implement OHS measures in the metal casting sector, which operates under hazardous and intensive production processes. The ELMERI method facilitates the systematic monitoring of changing conditions and corresponding risks over time. To implement the ELMERI scale, it is important to provide mobile communication devices in the technical departments of the enterprise. These devices should be used to conduct evaluations at the beginning, middle and end of each shift, and the results should be digitally tracked using a user-friendly interface program.

Author Contributions: Conceptualization, B.B. and H.S.; methodology, B.B. and H.S.; data collection and curation, B.B.; writing—original draft preparation, B.B. and H.S.; writing—review and editing, B.B. and H.S.; visualization, B.B. and H.S.; supervision, H.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The original contributions presented in this study are included in the article.

Acknowledgments: We sincerely thank the business, OHS professionals and employees who participated in the research.

Conflicts of Interest: The authors declare no conflicts of interest. The authors state that they have no known competing financial interests or personal relationships that could have influenced the work presented in this paper.

Appendix A

Table A1. ELMERI Observation Form.

ELMERI Observation Form								
Enterprise name								
Observer								
Observation area								
Date								
Main criterion	*Sub-criterion*	*Correct*		*Incorrect*		*No Observation*	*Explanation*	
		Mark	*Number*	*Mark*	*Number*			

Table A1. *Cont.*

ELMERI Observation Form			
1. Safety behavior	1.1. PPE use and risk-taking behavior		
2. Order and tidiness	2.1. Working tables and workbenches, hangers, shelves, machine surfaces		
	2.2. Waste container		
	2.3. Locations and platforms		
3. Machine safety	3.1. Installation, condition and protectors		
	3.2. Controllers and emergency buttons		
4. Industrial hygiene	4.1. Noise		
	4.2. Lighting		
	4.3. Air quality		
	4.4. Thermal conditions		
	4.5. Chemicals		
5. Ergonomics	5.1. Muscle tissue and skeletal system load		
	5.2. The design of the work environment and the working position		
6. Floor and access route	6.1. Ground and passageways structure		
7. First aid and fire safety	7.1. Electrical distribution boxes		
	7.2. First aid lockers		
	7.3. Fire extinguishers		
	7.4. Emergency exits		
Criterion averages		Total	Total
ELMERI safety index = correct ÷ (correct + incorrect) × 100			

Table A2. Elmeri Observation Rules.

Elmeri Observation Rules		
Main criterion	*Sub-criterion*	*Considerations to be taken into account in the correct scoring*
1. Safety behavior	1.1. PPE use and risk-taking behavior	The worker uses all necessary personal protective equipment and does not take any visible risks
2. Order and tidiness	2.1. Working tables and workbenches, hangers, shelves, machine surfaces	Tidy, no unnecessary objects, well installed, no overflow
	2.2. Waste container	The box is not overfilled
	2.3. Locations and platforms	Clean, tidy, in good condition, no spilt oil/water, etc.
3. Machine safety	3.1. Installation, condition and protectors	Fixed, intact, undamaged, safety signs present, guards compliant with safety standards and undamaged, in working condition
	3.2. Controllers and emergency buttons	Location as recommended, signs and warnings appropriate
4. Industrial hygiene	4.1. Noise	Noise in the field is less than 85 dB (A) and there is no instantaneous impact noise
	4.2. Lighting	Lighting adequate, no dazzling light
	4.3. Air quality	The air is clean and healthy, ventilation is adequate, local ventilation is available where needed
	4.4. Thermal conditions	Temperature, humidity and air flow rate appropriate

Table A2. *Cont.*

Elmeri Observation Rules		
4. Industrial hygiene	4.5. Chemicals	Packages and boxes are undamaged, name and safety labels are present, chemicals are transported in a safe and clean manner
5. Ergonomics	5.1. Muscle tissue and skeletal system load	Heavy loads are not lifted, pushed or pulled using physical force, no repetitive hand gestures
	5.2. The design of the work environment and the working position	Working area is adequate, tools and materials are appropriate, sitting and working height can be adjusted, tools and equipment are ergonomic
6. Floor and access route	6.1. Ground and passageways structure	Walking and access roads are of sufficient width and height, marked, pedestrian and traffic routes are separated from each other The ground is not rough or slippery If working at heights over 0.5 m, precautions against falling from height have been taken Appropriate ladders are used when working at height
7. First aid and fire safety	7.1. Electrical distribution boxes	Electrical box marked, 0.8 m^2 area in front of it left empty, electrical installation and electrical appliances in good condition
	7.2. First aid lockers	Necessary first aid supplies and list of contents are available, medicines are not expired
	7.3. Fire extinguishers	Available, easy to access and use, labelled and inspected
	7.4. Emergency exits	Markings are visible in the event of a power outage, present and open

References

1. Sengul, U. Data performance measurement of main metal industry companies in BIST 100 with data envelopment analysis. *J. Life Econ.* **2020**, *7*, 161–176. [CrossRef]
2. Oluk, F.; Duruel, T.; Gökcan, A.; Akdoğan, M.; Demir, G. Comparison of main metal industry sub-business lines from occupational health and safety perspective using CIRITIC and EDAS methods. *Front. Life Sci. Relat. Technol.* **2023**, *4*, 43–51. [CrossRef]
3. Senturk, A. *Assessment of Occupational Health and Safety in the Foundry Sector (OHS Specialization Thesis)*; Ministry of Labor and Social Security, General Directorate of Occupational Health and Safety: Ankara, Turkey, 2016.
4. American Foundry Society (AFS). Census of World Casting Production. Modern Casting Magazine. December 2021. Available online: https://www.moderncasting.com/issues/january-2021 (accessed on 9 September 2023).
5. The European Foundry Association (CAEF). Statistics 2022. Available online: https://www.caef.eu/downloads-links/#statistics (accessed on 10 December 2022).
6. Turkish Foundry Manufacturers Association (TUKODSAD). 23rd Period (2022–2024) Activity Report. Available online: https://tudoksad.org.tr/upload/files/banner/Faaliyet%20Raporu%202024small.pdf (accessed on 28 February 2024).
7. Rajkumar, I.; Subash, K.; Pradeesh, T.R.; Manikandan, R.; Ramaganesh, M. Job safety hazard identification and risk analysis in the foundry division of a gear manufacturing industry. *Mater. Today Proc.* **2021**, *46*, 7783–7788. [CrossRef]
8. International Labour Office (ILO). *Safety and Health in the Non-Ferrous Metals Industries*; International Labour Organization: Geneva, Switzerland, 2003.
9. International Labour Office (ILO). *Sectoral Activities Programme Code of Practice on Safety and Health in the Iron and Steel Industry*; International Labour Organization: Geneva, Switzerland, 2005.
10. Maheswaran, N.; Visagavel, K. Evaluvation of noise level and its adverse effect in metal die manufacuturing industry. *Int. J. Res. Eng. Technol.* **2014**, *3*, 252–255. [CrossRef]
11. Ribeiro, M.; Mauricio, P.; Teresa, M. Prevalence of noise induced hearing loss in metallurgical company. *Rev. Saude Publica* **2005**, *39*, 20–25. [CrossRef]
12. Nyarubeli, I.P.; Tungu, A.M.; Bråtveit, M.; Sunde, E.; Kayumba, A.V.; Moen, B.E. 508 Variability in occupational noise exposure levels in metal industries in Tanzania. *Occup. Environ. Med.* **2018**, *75*, A314. [CrossRef]
13. Ponto, K.; Tan, H.; Chen, W.H. Occupational health and medical surveillance principles for workers exposed to silicon dusts in metal industry of Germany. *Chin. J. Ind. Hyg. Occup. Dis.* **2006**, *24*, 572–573. [PubMed]

14. Freire, B.M.; Lange, C.N.; Pedron, T.; Monteiro, L.R.; Sanches, L.R.; dos Reis Pedreira-Filho, W.; Batista, B.L. Occupational exposure of foundry workers assessed by the urinary concentrations of 18 elements and arsenic species. *J. Trace Elem. Med. Biol.* **2020**, *62*, 126593. [CrossRef]
15. Ermolov, Y.V.; Makhatkov, I.D.; Cherevko, A.S. Contribution of metal industry emissions to dust aerosol pollution of the Norilsk Industrial District according to snow geochemical data. *Atmos. Ocean. Opt.* **2023**, *36*, 306–313. [CrossRef]
16. Yoon, C.W.; Yoon, Y.S.; Hong, S.Y.; Jeon, T.W.; Shin, S.K. Hazardous characteristics of dust waste from metal manufacturing industries in South Korea. *Waste Manag. Res.* **2021**, *39*, 1471–1479. [CrossRef]
17. Kilinc Gokce, H. *Evaluation of Metal Dust Exposure in Metal Grinding Process and Precautions That Can Be Taken (Specialization Thesis)*; CSGB, General Directorate of Occupational Health and Safety: Ankara, Turkey, 2016.
18. Tong, R.; Cheng, M.; Ma, X.; Yang, Y.; Liu, Y.; Li, J. Quantitative health risk assessment of inhalation exposure to automobile foundry dust. *Environ. Geochem. Health* **2019**, *41*, 2179–2193. [CrossRef] [PubMed]
19. Solano, J.C.; Gracia, A.I.; Felipe, A.I.; Calvo, E.R.; Prados, A.P. Cox regression model of hearing loss in workers exposed to noise and metalworking fluids or welding fumes. *An. Sist. Sanit. Navar.* **2010**, *33*, 11–21. [PubMed]
20. Occupational Health and Safety Improvement Project (ISGIP). *Occupational Health and Safety Management Guide for SMEs: Metal Sector*; CSGB, General Directorate of Occupational Health and Safety: Ankara, Turkey, 2015. Available online: https://www.csgb.gov.tr/isgum/contents/hizlierisim/isgdokumanlari/ (accessed on 10 January 2022).
21. Pap, G.S. Hot metal burns of the feet in foundry workers. *J. Occup. Environ. Med.* **1966**, *8*, 537–539. [PubMed]
22. Faulkner, B.C.; Drake, D.B.; Disli, A.J. Molten metal burns: Further evidence of industrial foundries' failure to comply with occupational safety and health administration regulations. *J. Emerg. Med.* **1997**, *15*, 675–677. [CrossRef]
23. Margulies, D.R.; Navarro, R.A.; Kahn, A.M. Molten metal burns: Early treatment improves outcome. *Am. Surg.* **1998**, *64*, 947–949. [PubMed]
24. Kumar, P. Vishweshwaraiah Iron Steel Limited (VISL) fire disasters following ladle refining furnace accident, July 12, 1996. *Burns* **2010**, *36*, 139–140. [CrossRef]
25. Occupational Health and Safety in Metal Processing Industries. Available online: https://www.isguvenligi.net/iskollari-ve-is-guvenligi/metal-isleme-sektorlerinde-is-sagligi-ve-guvenligi/ (accessed on 11 September 2023).
26. Ji, T.; Li, G.; Li, S. Analysis on the "2.20" sand mold explosion accident in Anshan steel. *Open J. Safe Sci. Technol.* **2013**, *9*, 111–113. Available online: https://api.semanticscholar.org/CorpusID:112589694 (accessed on 3 July 2024).
27. Li, G.; Ji, T. Severe accidental water vapour explosions in a foundry in China in 2012. *J. Loss Prev. Process Ind.* **2016**, *41*, 55–59. [CrossRef]
28. Myers, T.; Ibarreta, A. Investigation of the Jahn Foundry and CTA Acoustics dust explosions: Similarities and differences. *J. Loss Prev. Process Ind.* **2009**, *22*, 740–745. [CrossRef]
29. Safe Work Australia. *Guide to Managing Risks Associated with Foundry Work*; Safe Work Australia: Canberra, Australia, 2013. Available online: https://www.safeworkaustralia.gov.au/system/files/documents/1702/guide-managing-risks-associated-foundry-workl.pdf (accessed on 10 January 2023).
30. Yazdanirad, S.; Pourtaghi, G.; Raei, M.; Ghasemi, M. Developing and validating the personal risk assessment of musculoskeletal disorders (PRAMUD) tool among workers of a steel foundry. *Int. J. Ind. Ergon.* **2022**, *88*, 103276. [CrossRef]
31. García-Hernández, C.; Huertas-Talon, J.L.; Sanchez-Alvarez, E.J.; Marín-Zurdo, J. Effects of customized foot orthoses on manufacturing workers in the metal industry. *Int. J. Occup. Saf. Ergon.* **2016**, *22*, 116–124. [CrossRef] [PubMed]
32. Ozaydinlik, O.; Tumerdem, Y. *Occupational Health and Safety in Foundry Factories*; Yeni Yuzyıl University Institute of Health Sciences: Istanbul, Turkey, 2014; Available online: https://www.isguvenligi.net/iskollari-ve-is-guvenligi/dokumculuk-iskolunda-is-sagligi-ve-guvenligi/ (accessed on 5 January 2024).
33. Hasturk, E.Y.; Uzel, M. Occupational Health and Safety Conditions in Metal Casting Workshops. *J. Vocat. Sci.* **2017**, *6*, 45–58. Available online: https://dergipark.org.tr/tr/pub/mbd/issue/40499/485164 (accessed on 20 January 2024).
34. *SGK Statistics Annual of Social Security Institution*; Social Security Institution: Ankara, Turkey, 2023. Available online: https://www.sgk.gov.tr/Istatistik/Yillik/fcd5e59b-6af9-4d90-a451-ee7500eb1cb4/ (accessed on 10 December 2023).
35. Yoe, C. *Principles of Risk Analysis: Decision Making Under Uncertainty*, 2nd ed.; CRC Press: Boca Raton, FL, USA, 2019. [CrossRef]
36. Beres, E. *Guidelines on Occupational Safety and Health Management Systems ILO-OSH 2001*; International Labour Organization: Geneva, Switzerland, 2002; Available online: https://coilink.org/20.500.12592/vbrn3z (accessed on 30 May 2024).
37. Hollnagel, E.; Woods, D.D.; Leveson, N. *Resilience Engineering: Concepts and Precepts*; Ashgate Publishing Ltd.: Hampshire, UK, 2006.
38. Hollnagel, E. *Safety-I and Safety-II: The Past and Future of Safety Management*; CRC Press: Boca Raton, FL, USA, 2018.
39. Halliday, B.; van der Laan, L.; Raineri, A. Prioritizing Work Health, Safety, and Wellbeing in Corporate Strategies: An Indicative Framework. *Safety* **2024**, *10*, 18. [CrossRef]
40. Vanderhaegen, F. Erik Hollnagel: Safety-I and Safety-II, the past and future of safety management. *Cogn. Tech. Work* **2015**, *17*, 461–464. [CrossRef]

41. Khan, F.; Rathnayaka, S.; Ahmed, S. Methods and models in process safety and risk management: Past, present and future. *Process Saf. Environ. Prot.* **2015**, *98*, 116–147. [CrossRef]
42. Silva, P.; Carneiro, M.; Costa, N.; Loureiro, I.; Carneiro, P.; Pires, A.; Ferreira, C. Development and Application of an Integrated Index for Occupational Safety Evaluation. *Safety* **2024**, *10*, 106. [CrossRef]
43. Laitinen, H.; Rasa, P.L.; Räsänen, T.; Lankinen, T.; Nykyri, E. ELMERI observation method for predicting the accident rate and the absence due to sick leaves. *Am. J. Ind. Med.* **1999**, *36*, 86–88. [CrossRef]
44. Laitinen, H.; Vuorinen, M.; Simola, A.; Yrjänheikki, E. Observation-based proactive OHS outcome indicators–validity of the ELMERI method. *Safe Sci.* **2013**, *54*, 69–79. [CrossRef]
45. Yin, R. *Case Study Research: Design and Methods*; Sage Publications: Thousand Oaks, CA, USA, 1984.
46. Arpat, B.; Yurekli, E. The effect of 3 + 1 workplace training on students' job offers: A quantitative analysis. In *Vocational Education in Higher Education in the 100th Anniversary of the Republic: Expectations and Solution Suggestions for the Future*; Karadeniz, O., Olmezoglu Iri, N., Kacaroglu, O., Eds.; Gazi Publications: Ankara, Turkey, 2023; pp. 211–233.
47. Mills, A.J.; Eurepos, G.; Wiebe, E. *Encyclopedia of Case Study Research*; Sage Publications: Thousand Oaks, CA, USA, 2010.
48. Cukurluöz, S.; Birgoren, B.; Yalcinkaya, M.; Orçanlı, K. A performance audit method for 6S applications in lean manufacturing. *Int. J. Eng. Res. Develop.* **2020**, *12*, 358–369. [CrossRef]
49. General Directorate of Occupational Health and Safety. *Improvement of Occupational Health and Safety Conditions at Workplaces in Turkey (ISGIP)—AB Project. 2010–2012*; The Ministry of Labour and Social Security: Ankara, Turkey, 2012. Available online: https://hesapro.org/isgip.aspx (accessed on 30 May 2024).
50. *ISO 31000*; Risk Management-Guidelines. International Organization for Standardization: Geneva, Switzerland, 2018.
51. Laitinen, H.; Yrjänheikki, E.; Simola, A. Competition as catalyser of occupational safety improvement–evaluation of safety intervention on technology industries. In Proceedings of the 13th International Conference on Productivity and Quality Research ICPQR, Oulu, Finland, 24–27 June 2008.
52. Center for Chemical Process Safety (CCPS). *Guidelines for Hazard Evaluation Procedures*; Wiley: Weinheim, Germany, 2011.
53. Sharma, K.; Srivastava, S. Failure Mode and Effect Analysis (FMEA) Implementation: A Literature Review. *J. Adv. Res. Aeronaut. Space Sci.* **2018**, *5*, 1–17.
54. Palazzo, M.; Alessandra, M. The SWOT analysis: An evolving decision-making model. In *Rethinking Decision-Making Strategies and Tools: Emerging Research and Opportunities*; Emerald Publishing Limited: Bingley, UK, 2024; pp. 53–70.
55. Philip, T.; Bratvold, R.B.; Bickel, J.E. The risk of using risk matrices. Paper presented at the SPE Annual Technical Conference and Exhibition, New Orleans, LA, USA, 30 September–2 October 2013. [CrossRef]
56. Malakoutikhah, M.; Korouni, H.; Jahangiri, M. Safety and Health Status of Educational and Research Laboratories of Shiraz University of Medical Sciences based on ELMERI Approach. *Occup. Hyg. Health Prom.* **2019**, *2*, 270–279. [CrossRef]
57. *ISO/IEC 17025*; General Requirements for the Competence of Testing and Calibration Laboratories. International Organization for Standardization: Geneva, Switzerland, 2017.
58. *ISO 7243*; Ergonomics of the Thermal Environment—Assessment of Heat Stress Using the WBGT (Wet Bulb Globe Temperature) Index. International Organization for Standardization: Geneva, Switzerland, 2017.
59. *ISO 7730*; Ergonomics of the Thermal Environment—Analytical Determination and Interpretation of Thermal Comfort Using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria. International Organization for Standardization: Geneva, Switzerland, 2005.
60. *ISO 9920*; Ergonomics of the Thermal Environment—Estimation of Thermal Insulation and Water Vapour Resistance of a Clothing Ensemble. International Organization for Standardization: Geneva, Switzerland, 2007.
61. *ISO 8996*; Ergonomics of the Thermal Environment—Determination of Metabolic Rate. International Organization for Standardization: Geneva, Switzerland, 2021.
62. *ISO 7708*; Air Quality—Particle Size Fraction Definitions for Health Related Sampling. International Organization for Standardization: Geneva, Switzerland, 1995.
63. *ISO 15767*; Workplace Atmospheres—Controlling and Characterizing Uncertainty in Weighing Collected Aerosols. International Organization for Standardization: Geneva, Switzerland, 2009.
64. *ISO 28439*; Workplace Atmospheres—Characterization of Ultrafine Aerosols/Nanoaerosols—Determination of the Size Distribution and Number Concentration Using Differential Electrical Mobility Analysing Systems. International Organization for Standardization: Geneva, Switzerland, 2011.
65. Occupational Safety and Health Administration (OSHA). Part 1910—Occupational Safety and Health Standards. Available online: https://www.osha.gov/laws-regs/standardinterpretations/standardnumber/1910 (accessed on 22 March 2025).
66. World Health Organization (WHO). *Case Study: Occupational Health Risk in Metal Artisanal Workplaces: Bhutan*; World Health Organization: Geneva, Switzerland, 2020; Available online: https://iris.who.int/handle/10665/338373 (accessed on 22 July 2024).
67. Onal, B.; Yildiz, A.N. *Occupational Diseases in the Metal Industry*; Turk Metal Union: Ankara, Turkey, 2014.

68. Kisa, Y. *Evaluation of Occupational Health and Safety Conditions in Foundry Workshops with Multi-Criteria Decision Making Methods (Specialization Thesis)*; CSGB, General Directorate of Occupational Health and Safety: Ankara, Turkey, 2014.
69. Gomes, J.; Llyod, O.; Norman, N. The health of the workers in a rapidly developing country: Effects of occupational exposure to noise and heat. *Occup. Med.* **2002**, *52*, 121–128. [CrossRef]
70. Qureshi, M.S.A.; Solomon, G.D. Ergonomic Assessment of Postural Loads in Small- and Medium-Scale Foundry Units. *J. Inst. Eng. India Ser.* **2021**, *102*, 323–335. [CrossRef]
71. Polvara, E.; Capelli, L.M.T.; Sironi, S. Non-carcinogenic occupational exposure risk related to foundry emissions: Focus on the workers involved in olfactometric assessments. *J. Environ. Sci. Health Part A* **2021**, *56*, 646–659. [CrossRef]
72. Gulhan, B.; Ilhan, M.; Civil, E. Occupational accidents and affecting factors of metal industry in a factory in Ankara. *Turk. J. Public Health* **2012**, *10*, 76–85. [CrossRef]
73. Lazarenkov, A.M.; Sadokha, M.A. Study of the noise factor of working conditions in foundries. *Cast. Metall.* **2022**, *2*, 130–136. [CrossRef]
74. Ozturk, A.; Ergor, G.; Demiral, Y.; Ergor, A.; Tapçı, N. The Frequency of Noise-Induced Hearing Loss in the Foundry Industry and Evaluation of Factors Affecting it. *TTB J. Occup. Health Saf.* **2009**, *9*, 40–46.
75. Duan, D.; Leng, P.; Li, X.; Mao, G.; Wang, A.; Zhang, D. Characteristics and occupational risk assessment of occupational silica-dust and noise exposure in ferrous metal foundries in Ningbo, China. *Front. Public Health* **2023**, *11*, 1049111. [CrossRef]
76. Jafari, M.J.; Pirposhteh, E.A.; Dehghan, S.F.; Khodakarim, S.; Jafari, M. Relationship between heat stress exposure and some immunological parameters among foundry workers. *Int. J. Biometeorol.* **2020**, *64*, 853–861. [CrossRef]
77. Kazemi, R.; Nematpour, L.; Jazayeri, S.A. Assessment of safety and health performance based on ELMERI index in one of the steel industries in Khuzestan province, Iran. *J. Occup. Hyg. Eng.* **2019**, *5*, 8–16. [CrossRef]
78. CSGB Directorate of Labor Inspection. Report on the 2014 Inspection of the Occupational Health and Safety Programme in the Basic Metals Sector. Turkish. 2014. Available online: https://www.csgb.gov.tr/medias/6065/2015_74.pdf (accessed on 20 May 2023).
79. CSGB Directorate of Labor Inspection. General Evaluation Report on Occupational Health and Safety Programmed Inspections in the Basic Metal Industry, Fabricated Metal Products Manufacturing and Automotive Supply Industry. Turkish. Available online: https://www.csgb.gov.tr/medias/11976/2017_metal-ueruenlerin-imalat%C4%B1_press.pdf (accessed on 20 May 2023).
80. Tesfaye, F.K. Development of industrial occupational safety and health models in manufacturing industries: The case of Akaki basic metal industry. *Int. J. Adv. Manuf. Technol.* **2023**. *preprint version*. [CrossRef]
81. Masri, D. Hazard identification risk assessment and determining control occupational health and safety (OHS) in foundry industry Yogyakarta. *J. Tek. Lingkung.* **2022**, *28*. [CrossRef]
82. Lei, S.; Liu, S.Y.; Zhang, Y.; Jiang, D.J.; Xin, J.R.; Zhao, T.Y.; Chen, Y.Q.; Zhang, M.B.; Yang, L. Survey on present status of noise exposure of workers in metal processing industry. *Chin. J. Ind. Hyg. Occup. Dis.* **2021**, *39*, 540–543. [CrossRef]
83. PorAbdian, S.; Ghotbi, M.; Yosefi, H.; Habibi, E. The epidemiologic study on hearing standard threshold shift using audiometric data and noise level among workers of Isfehan metal industry. *J. Semnan Univ. Med. Sci.* **2015**, *10*, 253–259.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.