buildings

MDPI

Article

An Empirical Study of the Human Error-Related Factors Leading to Site Accidents in the Iranian Urban Construction Industry

Daniel W. M. Chan [1], Alireza Babaie Baghbaderani [2] and Hadi Sarvari [1,2,*]

[1] Department of Building and Real Estate, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China
[2] Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan 81551-39998, Iran
* Correspondence: h.sarvari@khuisf.ac.ir; Tel.: +98-901-727-7879

Abstract: Human errors are one of the major causes of accidents in the construction industry. Human errors can be caused by various factors across diverse types of projects. Hence, this research study seeks to determine the major factors influencing human errors associated with the urban construction industry (UCI). To achieve this, three rounds of Delphi survey were conducted with 17 experts engaged in construction site safety management. The Delphi panel members were determined using a targeted snowball sampling method. According to the results of the Delphi survey, 35 significant factors leading to the incidence of human errors in the UCI were identified and collated. Then, an empirical questionnaire was developed based on a five-point Likert measurement scale and distributed among construction experts to evaluate the impact level of each identified human error in the UCI. The questionnaire included 35 effective factors pertaining to human errors classified into five main groups of environmental factors, information systems/technological factors, individual factors (permanently related), individual factors (temporarily related), and organizational factors. Findings indicate that all evaluated factors are at a higher-than-average level and can be considered as the significant factors leading to the occurrence of site accidents attributed to human errors in the UCI. In addition, the top five most significant factors include improper work and safety culture, low level of technology deployed for equipment and safety protection, violation of safety regulations, rushing to do work, and lack of a proper education system in the organization. The results of this study can be useful for producing better-informed decisions by various major industrial practitioners and site safety managers.

Keywords: human errors; urban construction; construction industry; site accidents; Delphi survey

Citation: Chan, D.W.M.; Baghbaderani, A.B.; Sarvari, H. An Empirical Study of the Human Error-Related Factors Leading to Site Accidents in the Iranian Urban Construction Industry. *Buildings* **2022**, *12*, 1858. https://doi.org/10.3390/buildings12111858

Academic Editors: Ahmed Senouci and Heap-Yih Chong

Received: 8 September 2022
Accepted: 1 November 2022
Published: 2 November 2022

1. Introduction

The construction industry has always been one of the largest industries in the world, requiring the support of a great percentage of each country's annual income. Some developing countries spend more than 70% of their total annual income to expand construction and infrastructure projects [1]. Construction projects are allocated a high percentage of financial resources but they usually are completed beyond the cost estimated and time planned. This issue has caused construction project management to become much more complex and difficult [2]. Likewise, the development of construction infrastructure projects has become much more complex and difficult to manage [3]. One example of this complexity is the interdependencies of stakeholders in various projects (e.g., financing institutions, authorities, architects, engineers, contractors, and suppliers of construction projects) [4,5]. The evidence shows that diverse workforces are employed in the construction industry. Therefore, human resource management is challenging in the construction industry. Human resources are the most significant factor in achieving success in any construction project; however, due to low labor costs compared which other resources, such as materials and machinery, they do not receive much attention. Nowadays, human resources are the most important source of competitive advantage in any company and project. Investigating the interaction between the transformed work environment and variable and adaptable workforces, one must consider different ways to control human behavior depending on knowledge and familiarity with the system and its features [6]. When confronted with a new system, environment, or complex machine, every human shows a series of features and characteristics which are called human factors. Facing new and unfamiliar situations, previous experiences are sometimes not useful, there are no specific rules to follow, and human factors may lead to mistakes [7]. Reason [8] subdivided errors into two further categories: knowledge-based errors and rule-based errors. Primarily, errors pertain to the implementation of a defective plan. Knowledge-based errors are those that arise when a situation is misunderstood or the proper judgment is not made. This is due to the lack of information or experience required to comprehend the issue, resulting in the emergence of ambiguity. Rule-based errors are made confidently, but a different process is selected due to a lack of situational analysis, or the wrong action was selected. These two subcategories of errors are comparable to Rasmussen's [9] "skill, rule, and knowledge" (SRK)-based approach.

Researchers have found that hidden costs can affect the final cost of a project in addition to the main project cost, which has direct impacts. Costs incurred by accidents due to human errors in the work process account for a large part of these hidden expenses, and failure to consider these risks and improper management of human errors threaten a project's long-term success [10].

Workers are often exposed to various hazards and accidents in industrial environments because of different machinery and tools. With the development of technology and the increasing use of machines in production, the probability of hazards and accidents in such environments increases [11]. Construction projects face many risks throughout the project life cycle, especially the construction phase, including non-observance of safety tips by personnel, machinery hazards, geographical location of the area, workload, etc. [12]. Human errors can occur in all human activities throughout an organization, including at the managerial, conceptual, or technical levels [13]. Errors in construction projects can be due to various factors, including errors related to investors, users, suppliers, etc. Other factors that can affect individual decisions, leading to errors, include the quality of education, working experience under pressure, workload, fatigue, workplace ergonomics, working hours, social climate, etc. Errors can be considered as a chain of events, including causes, human errors, defects, consequences, etc. [14]. Some human errors in the project include errors in civil and architectural design, errors by consulting companies and their employees, and errors related to construction plans, building supervision, construction operations, contractor's office, construction materials, construction equipment, and regulations [15,16].

Therefore, manpower can suffer human errors under stressful conditions. Previous studies on human errors have reported their occurrence in more than 80% of accidents [17]. For example, damage from health, safety, and environmental hazards in industries such as construction impose high costs on companies [18]. Hence, identifying human errors in all stages of construction projects is a necessity for project success and the survival of the entire organization [19]. Accidents in any form and degree impose numerous economic, social, and health problems on society. Since the consequences of accidents can go beyond the boundaries of the project and affect more extensive dimensions, measures are required to prevent the occurrence of similar incidents using previous experiences and lessons [20]. According to research, one of the most practical methods available to prevent and reduce the occurrence of human errors is the use of appropriate techniques to predict and identify types of human errors, investigate the root causes of errors, and find appropriate solutions for control [21]. There have been many efforts in recent years to identify the causes of accidents in various industries. It is believed that most accidents are caused by human error due to carelessness or inadequacy in performing tasks. However, researchers investigating accidents have found that it is possible to prevent accidents by identifying their causes [22].

Over the past two decades, the development of urbanization and the consequent increase in demand for welfare and a safe and secure living environment have been accompanied by an increase in demand for housing and the number of construction projects [1]. Successful urban development is tied to the successful development of the necessary projects and infrastructure to a great extent, highlighting the importance of higher reliability in projects that always face crises. The project environment is significantly affected by uncertainty, which is more acute for large projects. On the other hand, establishing and monitoring site safety performance is an important and necessary condition for starting, conducting, terminating, and operating in the life cycle of projects. Despite the special contribution of this factor to the project's success, little attention is paid to this category, especially in developing countries, due to the impact of various cultural, social, economic, and technical factors. Various accidents and numerous human and financial losses can be the result of this lack of attention [23]. Urban projects face many uncertainties due to their special conditions; hence, detecting human errors in the construction of urban projects can significantly reduce the costs incurred by the poor quality of construction [24]. Accordingly, this research aims to identify and evaluate the factors affecting the occurrence of accidents in urban construction projects to contribute to the success of these projects. Hence, a comprehensive literature review was initially conducted to identify the effective factors in the occurrence of accidents. Then, three rounds of the Delphi technique were implemented to screen the identified factors, which were finally evaluated. The results of this study can be used as a decision tool for key stakeholders in urban construction projects.

2. Review of Previous Research Work

Incidents like Bhopal in India have shown that, despite advances in technologies and the use of automation in different industries, as well as the reduction of the human role in the workplace, human error can still lead to unfortunate human and financial disasters [25]. This is because, on the one hand, human duties in the workplace are associated with an increase in the psychological burden and complexity of work, which increases the likelihood of error; and on the other hand, as the burden of responsibility increases, the consequences of human error will increase [26]. Human error is one of the most significant human factors and includes those occurrences when people make a mistake when faced with a system and a machine [27]. It is human decision and behavior that determines in which direction the system moves. Errors occur due to a lack of awareness, limited human function, incorrect attitude, inappropriate methods, tools, and working environment conditions [28].

An error is an unintentional failure to perform a purposeful action, individually or as part of a planned chain of actions, to achieve the expected result within the permissible limit of the action or its consequence [29]. Errors can be considered as a chain of events, including reasons, human error, defects, consequences, etc. Most corrective actions of these chains involve repeated loops, meaning that there are several human errors and defects that occur before diagnosis [30]. According to Kohn [31], human error is a general term and includes all events during which the planned chain of mental or physical activities does not achieve the expected result and these defects cannot be attributed to chance. According to this definition, an error may occur because of incorrect planning or execution. Crowl [32] also stated that an error is an unauthorized action when the permitted performance limits are defined by the system. Errors are unintentional actions including slips, forgetfulness, and mistake. Violations are classified as a group of intentional acts [33]. Reason [8] distinguished between mistakes and violations, both of which are errors of intent—mistakes are the consequence of unsuitable intents or inaccurate diagnoses of situations, whereas violations are the result of bad actions.

According to Boal and Meckler [34], conditions for mistakes and misbehavior exist in all operational domains and can negatively impact the performance of a person or a group. OSHA also suggests that a good study of occupational safety may avoid a number of accidents and illnesses, and identified the technical and managerial control measures, training needs, personal protective equipment necessary, and executive instructions for each activity. This approach is suggested for use in all industries and at all phases of system life [35].

There have been more accidents in the construction industry with the increase of urbanization in developing countries over the past two decades and the consequent increase in the demand for urban housing and infrastructure. Many researchers have considered this issue and sought to assess such events. For example, as stated by [36], with the expansion of construction projects in Turkey, the mortality rates of workers also increased. They noted that staff and worker awareness significantly reduced risks and accidents in these projects, and workers who received safety training were at lower risk. They also mentioned factors such as experience, equipment, and working conditions as other effective parameters. In another study, Kumar et al. [37] referred to the undeniable role of human factors in causing accidents in construction projects. They introduced factors such as mechanization, technology, machine automation, and increased safety as other effective parameters for the productivity of construction projects. In another study, Hameed et al. [38] presented a method based on the estimation of the risk caused by human factors to determine the time interval between machinery repair and shutdown. Their proposed method included three stages of equipment selection according to the sensitivity of operations, modeling system failure considering human error, and an inspection to estimate the time interval between machinery repair and shutdown to reduce errors caused by human factors.

There have been many different theoretical approaches and conceptual frameworks suggested for investigating accidents. The human factors analysis categorization system (HFACS) is one example of a theoretical framework that contributes to a better understanding of the complex nature of accidents. For instance, Shappell and Wiegmann [39] created HFACS as a tool for evaluating human mistakes based on Reason's [8] model of latent and active failures. This model was used as the foundation for the development of HFACS. Additionally, the cognitive reliability and analysis approach is a categorization system that is founded on a theory that enables the analysis and prediction of mistakes. This method was developed by Hollnagel [40]. On the basis of HFACS, Garrett and Teizer [41] recommended the development of a new error analysis instructional and categorization tool for use in the construction sector to improve worker safety. They discussed numerous different arguments for why their behavior was risky. In addition to this, they found a number of elements that contributed to the problem and separated them into the following four categories: culture, operations, resource management, and executive management (policy). In addition, Xia and colleagues [42] developed a causality framework that makes use of HFACS for the purpose of studying the underlying elements that influence construction safety performance. This framework for determining causes includes 18 risk factors that come from organizational, environmental, and human aspects. These risk factors are organized into five levels, which are as follows: unsafe acts of workers, preconditions for unsafe acts, unsafe supervision and monitoring, adverse organizational influences, and adverse environmental influences. In a separate line of research, a safety preventive and control system that was based on HFACS was created [43]. The prevention and control strategies to prevent the incidence of accidents have also been offered from four different perspectives: the external environment, the organizational variables, the conditions for triggering accidents, and risky leadership behaviors.

Construction research institutes have made extensive efforts to investigate the causes of building and construction defects [44,45]. Bentley [46] examined 27 construction projects and identified the causes of construction defects in seven categories of lack of skill, failure in maintenance, lack of knowledge and awareness in executive workshops, complexity and difficulty of the structure, poor design quality and project information, weakness and ambiguity of project, and some aspects of project/design information. Investigations revealed incomplete and ambiguous project information as the most mentioned cause of the deficiencies. In the meantime, scientific studies indicate that human errors have a dominant and more significant role in the occurrence of various structural defects. These errors can lead to work duplication, higher costs, delays in scheduling, and environmental insecurity, affecting project performance. Design errors also threaten the success of construction projects, the main source of which is human error [47].

Various studies have confirmed the direct relationship between safety performance and a positive safety climate in construction projects [48]. For example, studies have shown that employees reporting workplace insecurity are less motivated to perform tasks safely or follow safety guidelines, which in turn leads to human error and, consequently, a higher level of injury and loss at work [49]. According to Griffin and Neal [50], safety researchers are interested in those studies seeking mediators in safety research. Previous studies have identified personal characteristics, perspectives, and organizational variables as mediators. A review of the literature shows a relatively large number of efforts to identify the causes of accidents in construction projects. In the meantime, many factors have been identified and placed in different categories, one of which represents human-related factors. These factors may be different in a variety of situations and projects and impose various effects. For example, previous studies have widely considered the occurrence of human errors in various projects such as road projects, dam construction, power plant construction, and industrial projects. However, some other types of projects, including urban construction projects, have received less attention. Therefore, this study seeks to identify and evaluate the effective factors for the occurrence of human errors in the UCI to take a step to fill the gap in the literature.

3. Research Methodology

The main objective of this study is to determine the significant contributing factors affecting the occurrence of human errors in UCI based in Iran. Since the effective factors contributing to the occurrence of human errors are multitudinous and various in each country and region, it was essential to develop a new questionnaire focused on the context of the studied country of Iran. To this end, firstly, a comprehensive and detailed review of the previous literature was conducted. Then, 3 rounds of the Delphi survey were implemented to monitor the influential factors identified in the relevant literature. During the 3 rounds of the Delphi survey, 17 experts in the field of study were invited to comment on and rate the level of importance of the identified human error factors based on a 5-point Likert scale. Various previous studies have manifested that the reliability and validity of 2- or 3-point scales are lower compared to higher-point scales, and the level of reliability and validity in scales with points higher than 7 also decreases to some extent. Therefore, in most cases, the designer of the questionnaire will adopt a range of 5 to 7 scaling numbers for delineating the measurement. Furthermore, the 5-point Likert scale has been widely used in other related research studies before, e.g., [1,7,12]. This stage selected only factors that had the importance of $\geq$3. Fink et al. [51] proposed this method to facilitate members reaching a consensus regarding different items and their selection or removal. There is no robust or explicit rule for the selection of Delphi panel experts; however, the quality of experts is more important than their number [52]. Hence, the Delphi panel members are experts and critics with sufficient knowledge and experience in a similar field and effective communication skills, who also have enough time to participate in the study [53]. The number of experts is usually <50 and often from 10 to 20 [54]. The number of experts depends on factors such as sample homogeneity, Delphi goals, the scope of difficulty, quality of decision making, research team abilities, internal and external reliability, data collection time, and available resources. Finally, the empirical questionnaire was developed based on a 5-point Likert scale of measurement and distributed among the experts. This study adopted a purposive sampling method to select the Delphi panel members, which was performed by other researchers for similar research questions [55]. Figure 1 illustrates the entire research process of the study.

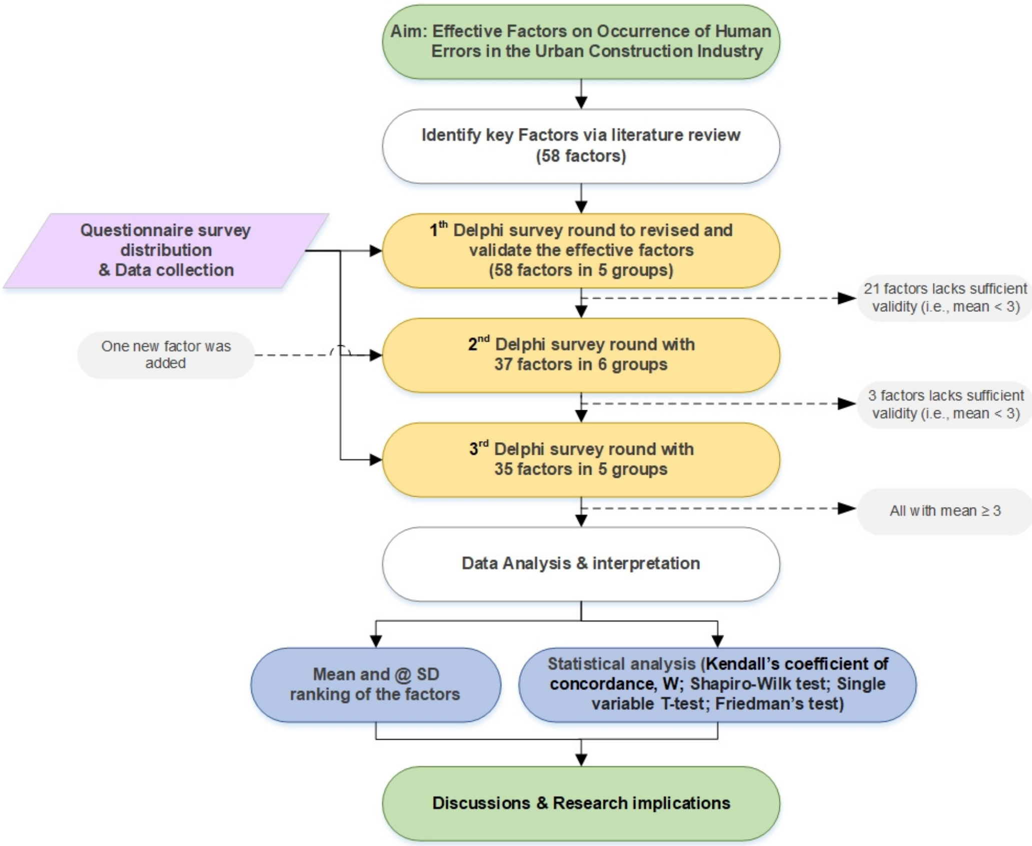

Figure 1. The overall research design for the study.

The Delphi survey method was used to monitor and screen the identified factors from the research literature. Accordingly, the questionnaire of the first Delphi round was developed based on the previous studies and initial surveys of researchers, including 58 effective factors on the occurrence of human errors in five groups of environmental factors, information systems/technological factors and equipment and machinery, individual factors (permanently related), individual factors (temporarily related), and organizational factors. A total of 17 experts were asked to comment to determine whether the identified factors could be regarded as effective factors in the occurrence of accidents caused by human error in the UCI. Table 1 provides the demographic information of the Delphi panel experts participating in the study. The Delphi panel members were determined using a targeted snowball sampling method. The targeted snowball sampling approach is a method extensively used for recruiting experts in research. It is a process in which a qualified participant invites similar experts who fulfil the requirements needed for the study [56]. For this study, experts that were aware and knowledgeable of the UCI and site safety management (faculty members, project managers, construction manager, safety managers, site engineers, and other related professionals in the AECO industry) were invited for participation. According to the results of the first round, out of 58 factors, some factors were integrated, deleted, or corrected, in terms of expression. The experts also suggested dividing the group of information systems/technological factors and equipment and machinery into two separate groups. Therefore, a new questionnaire with 37 factors categorized into 6 groups was dispatched to Delphi panel members in the 2nd round, leading to integrating or eliminating some factors. It is noteworthy that all questions were removed in the new group of equipment and machinery because of a mean of <3. However, before data analysis in this round, it was suggested to transfer the factor of operational barriers caused by construction machinery to the group of environmental factors. Therefore, although this question scored <3, it was transferred to environmental factors (the score may have been obtained because the selected group was not suitable for the item). It was also suggested to add a new factor referred to as low level of technology deployed for equipment and safety protection (traditional repair and maintenance systems, lack of necessary tools and equipment, and lack of knowledge of required resources) to the group of information systems/technological factors. Some factors had to be corrected in terms of grammar or writing in this round. Thus, a new questionnaire with 35 factors classified into 5 different groups was forwarded again to the experts in the 3rd round. In this round, the Delphi panel members concluded that all the 35 identified factors were effective in the occurrence of site accidents caused by human errors in the UCI. The opinions of some respondents were used to evaluate the face validity of the questionnaire.

Table 1. Demographic information of the Delphi study's experts.

Feature	Code	Number (%)
Gender	Men	4 (23.5)
	Women	13 (76.5)
Age	<30 years old	1 (5.95)
	30–50 years old	12 (69.55)
	>50 years old	4 (23.5)
Educational level	Bachelor's degree Master's degree PhD degree	4 (23.5) 11 (64.7) 2 (11.8)
Tenure in the construction sector	<10 years 10–20 years >20 years	4 (23.5) 9 (53.0) 4 (23.5)
Tenure in safety management	<10 years 10–20 years >20 years	9 (53.0) 6 (35.3) 2 (11.7)
Role	Client Consultant Contractor	2 (11.7) 10 (58.8) 5 (29.5)
Job position	Architect Engineer—Civil, Electrical, and Mechanical Safety Manager General Manager—Procurement and Contracts Project Manager Senior Project Manager University Professor	1 (5.95) 3 (17.6) 4 (23.5) 3 (17.6) 2 (11.8) 3 (17.6) 1 (5.95)

Content validity was confirmed using a Delphi panel consisting of 17 experts, based on 3 Delphi rounds, Lawshe content validity, and Kendall's coefficient of concordance [57]. The Kendall coefficient of concordance shows that people sort several categories according to their use of the same criteria to judge the importance of each category and reach consensus in this regard [58]. In addition, Cronbach's alpha coefficient was calculated using the SPSS software program to evaluate the reliability of the questionnaire. Given that the total reliability of the questionnaire was 0.978, the questionnaire had high reliability for performing any further statistical tests.

4. Illustration of Survey Results

During the three rounds of the Delphi survey, 35 different effective factors leading to the occurrence of site accidents attributed by human errors in the UCI were identified. Accordingly, the 35 identified factors were classified into five main groups: (1) environmental, (2) information systems/technological factors, (3) individual factors (permanently related), (4) individual factors (temporarily related), and (5) organizational factors. Table 2 portrays the overall results after the completion of the third round of the Delphi survey.

Table 2. The overall results after completion of the third round of the Delphi survey.

No.	Group	Human Error Factors Leading to the Occurrence of Site Accidents in the UCI	Mean	Result	Source
1	Environmental factors	Poor ergonomics and geometry of the project workplace	3.47	Confirmed	[59]
2		Adverse environmental conditions (dust, horizontal visibility, noise, odor, ambient temperature, altitude, weather, snow)	3.58	Confirmed	[60]
3		Social pressures	3.23	Confirmed	[61]
4		Accessibility problems (improper workplace arrangement, etc.)	3.41	Confirmed	[62]
5		Improper work and safety culture (related to the workers' attitudes and perceptions including safety understanding and perceptions of personnel, nationality and culture, religion, fatalism, and optimism)	4.05	Confirmed	[48]
6		Operational barriers because of construction machinery	3.47	Confirmed	[28]
7	Information systems/technological factors	The complexity of work activities due to new technologies (for example, performance diversity, high information volume, etc.)	3.17	Confirmed	[63]
8		Defects in details and information and lack of design dynamics	3.41	Confirmed	[64]
9		Errors in instructions (incorrect information, incomplete information, insufficient requirements, etc.)	3.58	Confirmed	[47]
10		Software defects	3.35	Confirmed	[60]
11		Excessive trust in technology	3.17	Confirmed	[60]
12		Unfamiliarity with new technologies (difference between the operator and designer mindset)	3.29	Confirmed	[27]
13		Poor information management (information collection, identification, and evaluation).	3.35	Confirmed	[65]
14		Low level of technology deployed for equipment and safety protection (traditional repair and maintenance systems, lack of necessary tools and equipment, and lack of knowledge of required resources)	3.76	Confirmed	Interview
15	Individual factors (permanently related)	Individual–job physical and mental incompatibility	3.52	Confirmed	[66]
16		Violation of safety regulations (drug use, etc.)	4.17	Confirmed	[37]
17		Job dissatisfaction	3.52	Confirmed	[67]
18		Job habits and dailiness	3.41	Confirmed	[67]
19	Individual factors (temporarily related)	Physical conditions (fatigue, illness, weight)	3.64	Confirmed	[67]
20		Poor psychological conditions (stress, repetitive jobs, poor memory, personal life problems, allergies, constant alertness, etc.)	3.94	Confirmed	[67]
21		Poor awareness and understanding of the situation in error detection	3.94	Confirmed	[28]
22		Inadequate understanding of information and plan recognition in error detection	3.64	Confirmed	[47]
23		Unintentional unsafe acts (omission of an act or unfinished activities in the project, etc.)	3.82	Confirmed	[37]
24		False beliefs and attitudes towards the effects of error	3.76	Confirmed	[28]
25		Misunderstanding due to simultaneous working with several software systems and different areas (misunderstanding of some general aspects of system performance)	3.58	Confirmed	[28]
26		Haste in doing work (due to lack of time or irregular working hours)	4.05	Confirmed	[65]
27	Organizational factors	Failure to address the error-causing problem	3.64	Confirmed	[61]
28		Failure to manage changes during project implementation	3.41	Confirmed	[28]
29		Lack of proper communication among project stakeholders	3.29	Confirmed	[61]
30		Unavailability of a proper educational system in the organization	4	Confirmed	[67]
31		Failure to accurately predict work risks by the project management department	3.76	Confirmed	[46]
32		Poor project planning	3.47	Confirmed	[61]
33		Lack of organization and improper task assignment	3.58	Confirmed	[61]
34		Poor supervisory inspection	3.88	Confirmed	[65]
35		Improper quality control	3.58	Confirmed	[65]

This study's descriptive and inferential statistical analyses were conducted using the SPSS software package. In the descriptive statistics section, statistical parameters such as frequency, percentage, mean, and standard deviation were calculated. The Shapiro–Wilk test, one-sample *t*-test, and Friedman test were used in the inferential statistics section. The normal distribution of variables is the prerequisite for parametric tests. In general, parametric tests are based on mean and standard deviation, but the correct interpretation of the results is not possible if the population distribution is not normal. Therefore, this test shows a normal distribution if the significance level (Sig.) is zero. The Shapiro–Wilk test was performed in this research to verify the normality of the main research variable. Table 3 shows the hypothesis testing, the results of which indicated a significance level of >0.05 in the overall questionnaire and the groups of environmental factors, information systems/technological factors, individual factors (permanently related), individual factors (temporarily related), and organizational factors. Therefore, the null hypothesis was confirmed and accepted at a 95% confidence level, and the data distribution followed a normal distribution in the research variable. Hence, parametric tests were used to examine the survey data collected from the Delphi panel.

Table 3. Normality evaluation of research data using the Shapiro–Wilk test.

Main Variable	Sig.	Statistics	Error	Hypothesis Confirmation	Normal Distribution
Environmental factors	0.237	0.932	0.05	H_0 [1]	Yes
Information systems/technological factors	0.141	0.919	0.05	H_0	Yes
Individual factors (permanently related)	0.282	0.937	0.05	H_0	Yes
Individual factors (temporarily related)	0.328	0.941	0.05	H_0	Yes
Organizational factors	0.400	0.946	0.05	H_0	Yes
All constituent factors	0.610	0.959	0.05	H_0	Yes

H_0 [1]: The data of the research questionnaire have a normal distribution. H_0: The data of the research questionnaire do not have a normal distribution.

4.1. What Factors Are Effective in Contributing to Site Accidents Caused by Human Errors in the UCI?

According to Table 4, the groups of environmental factors, information systems/technological factors, individual factors (permanently related), individual factors (temporarily related), and organizational factors in the main research variable (human errors in the UCI) were 3.539, 3.389, 3.661, 3.801, and 3.627, respectively, and the mean of the overall questionnaire was 3.601. Since the *p*-value in the above groups and the overall questionnaire were <0.05, the difference with the test value (i.e., 3) was significant and above average. On the other hand, considering the positive values of the upper and lower limits of the confidence interval, all factors and groups under study could be considered "strong" human error factors leading to site accidents in the UCI. On the other hand, the *p*-value in the group of information systems/technological factors was >0.05; thus, it was not significantly different from the test value (i.e., three). In addition, the upper and lower limits of the confidence interval were positive and negative, respectively, indicating the average state of the group of information systems/technological factors.

Table 4. Results of one-sample *t*-test for human error factors in the UCI.

Variable	No.	Mean	SD	Test Value = 3			Lower Limit	Upper Limit
				t	df	*p*-Value		
Environmental factors	17	3.539	0.936	2.374	16	0.030	0.057	1.020
Information systems/Technological factors	17	3.389	0.916	1.754	16	0.099	−0.081	0.860
Individual factors (permanently related)	17	3.661	0.896	3.043	16	0.008	0.200	1.122
Individual factors (temporarily related)	17	3.801	0.837	3.946	16	0.001	0.370	1.232
Organizational factors	17	3.627	0.872	2.966	16	0.009	0.179	1.075

4.2. What Is the Importance of Effective Factors in Contributing to Site Accidents Caused by Human Errors in the UCI?

The Friedman test was used to prioritize the groups of environmental factors, information systems/technological factors, individual factors (permanently related), individual factors (temporarily related), and organizational factors for the variable of human errors in the UCI. This test is used for two-way analysis of variance by the ranking method. In addition, the above test can be used to compare the mean ranking of different groups. According to the results of Table 5, the significance level of groups and factors of human errors in the UCI was less than the threshold (0.05) (p <0.05). Therefore, there was a significant difference between the groups of environmental factors, information systems/technological factors), individual factors (permanently related), individual factors (temporarily related), and organizational factors and human error factors in the UCI.

Table 5. Results of Friedman test (Significance of groups and factors affecting human errors in UCI).

	Chi-square	Df	Sig.	Result
Groups	12.072	4	0.017	Rejection of H_0[1]
Factors	77.577	34	0.000	Rejection of H_0

H_0[1]: The groups/factors have equal mean ranks. H_0: The groups/factors do not have equal mean ranks.

Based on the results of Table 6, concerning the Friedman test ranking, individual factors (temporarily related), individual factors (permanently related), environmental factors, organizational factors, and information systems/technological factors ranked from first to fifth, respectively, in terms of contributing to human errors in the UCI, with mean scores of 3.76, 3.24, 3.03, 2.58, and 2.12, respectively.

Table 6. Results of Friedman test (mean ranking of groups/factors affecting human errors in the UCI).

No.	Group	Mean Rank	Rank	Human Error Factors Leading to the Occurrence of Site Accidents in the UCI	Mean Rank	Rank
1	Environmental factors	3.03	3	Poor ergonomics and geometry of the project workplace	16.24	23
2				Adverse environmental conditions (dust, horizontal visibility, noise, odor, ambient temperature, altitude, weather, snow)	17.68	18
3				Social pressures	13.15	33
4				Accessibility problems (improper workplace arrangement, etc.)	16.03	25
5				Improper work and safety culture (related to the workers' attitudes and perceptions including safety understanding and perceptions of personnel, nationality and culture, religion, fatalism, and optimism)	24.00	2
6				Operational barriers because of construction machinery	16.26	22
7	Information systems/technological factors	2.12	5	The complexity of work activities due to new technologies (for example, performance diversity, high information volume, etc.)	13.32	32
8				Defects in details and information and lack of design dynamics	16.50	20
9				Errors in instructions (incorrect information, incomplete information, insufficient requirements, etc.)	17.88	17
10				Software defects	15.15	29
11				Excessive trust in technology	12.88	34
12				Unfamiliarity with new technologies (difference between the operator and designer mindset)	14.47	30
13				Poor information management (information collection, identification, and evaluation).	15.59	28
14				Low level of technology deployed for equipment and safety protection (traditional repair and maintenance systems, lack of necessary tools and equipment, and lack of knowledge of required resources)	20.68	8

Table 6. *Cont.*

No.	Group	Mean Rank	Rank	Human Error Factors Leading to the Occurrence of Site Accidents in the UCI	Mean Rank	Rank
15	Individual factors (permanently related)	3.24	2	Individual–job physical and mental incompatibility	15.76	27
16				Violation of safety regulations (drug use, etc.)	24.26	1
17				Job dissatisfaction	18.00	16
18				Job habits and dailiness	15.82	26
19	Individual factors (temporarily related)	3.76	1	Physical conditions (fatigue, illness, weight)	18.32	14
20				Poor psychological conditions (stress, repetitive jobs, poor memory, personal life problems, allergies, constant alertness, etc.)	22.06	5
21				Poor awareness and understanding of the situation in error detection	21.56	6
22				Inadequate understanding of information and plan recognition in error detection	18.68	13
23				Unintentional unsafe acts (omission of an act or unfinished activities in the project, etc.)	20.38	9
24				False beliefs and attitudes towards the effects of error	19.71	10
25				Misunderstanding due to simultaneous working with several software systems and different areas (misunderstanding of some general aspects of system performance)	18.06	15
26				Haste in doing work (due to lack of time or irregular working hours)	22.91	4
27	Organizational factors	2.85	4	Failure to address the error-causing problem	18.74	12
28				Failure to manage changes during project implementation	16.44	21
29				Lack of proper communication among project stakeholders	14.38	31
30				Unavailability of a proper education system in the organization	23.26	3
31				Failure to accurately predict work risks by the project management department	19.62	11
32				Poor project planning	16.12	24
33				Lack of organization and improper task assignment	16.85	19
34				Poor supervisory inspection	21.35	7
35				Improper quality control	17.88	17

In addition, violation of safety regulations (drug use, etc.) (mean rank = 24.26), improper work and safety culture (related to the workers' attitudes and perceptions including safety understanding and perceptions of personnel, nationality and culture, religion, fatalism, and optimism) (mean rank = 24.00), unavailability of proper educational system in the organization (mean rank = 23.26), haste in doing work (due to lack of time or irregular working hours) (mean rank = 22.91), poor psychological conditions (stress, repetitive jobs, poor memory, personal life problems, allergies, constant alertness, etc.) (mean rank = 22.06), poor awareness and understanding of the situation in error detection (mean rank = 21.26), poor supervisory inspection (mean rank = 21.35), low level of technology deployed for equipment and safety protection (traditional repair and maintenance systems, lack of necessary tools and equipment, and lack of knowledge of required resources) (mean rank = 20.68), unintentional unsafe acts (omission of act or unfinished activities in the project, etc.) (mean rank = 20.38), false beliefs and attitudes towards the effects of error (mean rank = 19.71), failure to accurately predict work risks by the project management department (mean rank = 19.62), failure to address the error-causing problem (mean rank = 18.74), inadequate understanding of information and plan recognition in error detection (mean rank = 18.68), physical conditions (fatigue, illness, weight) (mean rank = 18.32), misunderstanding due to simultaneous working with several software systems and different areas (misunderstanding of some general aspects of system performance) (mean rank = 18.06), job dissatisfaction (mean rank = 18.00), errors in instructions (incorrect information, incomplete information, insufficient requirements, etc.) and poor quality control (mean rank = 17.88), adverse environmental conditions (dust, horizontal visibility, noise, odor, ambient temperature, altitude, weather, snow) (mean rank = 17.68), lack of organization and improper task assignment (mean rank = 16.85), defects in details and information and lack of design dynamics (mean rank = 16.50), failure to manage changes during project implementation (mean rank = 16.44), operational barriers because of construction machinery (mean rank = 16.26), poor ergonomics and geometry of the project workplace (mean rank = 16.24), poor project planning (mean rank = 16.12), accessibility problems (improper workplace arrangement, etc.) (mean rank = 16.03), job habit and dailiness (mean rank = 15.82), individual–job physical and mental incompatibility (mean rank = 15.76), poor information management (information collection, identification, and evaluation) (mean rank = 15.59), software defects (15.15), unfamiliarity with new technologies (difference between the operator and designer mindset) (mean rank = 14.47), lack of proper communication among project stakeholders (mean rank = 14.38), the complexity of work activities due to new technologies (for example, performance diversity, high information volume, etc.) (mean rank = 13.32), social pressure (mean rank = 13.15), and excessive trust in technology (mean rank = 12.88), were ranked first to thirty-fifth, respectively, in the ranking of human error factors in the UCI.

5. Discussion of Analytical Results

The overall findings of this study (portrayed in Figure 2) align with those of earlier research. For example, Kumar et al. [37] referred to the undeniable contribution of human factors to accidents in construction projects. They also introduced factors such as mechanization, technology, machine automation, and increased safety as key parameters that increase the productivity of construction projects. In another study, Gürcanlı et al. [36] examined civil project risks in Turkey and introduced safety training, experience, equipment, working conditions, and other project-related parameters as the influencing factors in the reduction of human error. The results of this study showed the importance of parameters such as safety training and working with a guide, indicating that workers who received safety training were at lower risk. Barbaranelli et al. [48] and Zou and Sunindijo [49] observed that employees who reported workplace insecurity were less motivated to perform tasks safely and less willing to follow safety instructions, leading to a higher level of work-related injuries and losses. As mentioned, project safety status is measured by a parameter called safety performance. Many studies have confirmed the direct relationship between the safe performance of construction projects and a positive safety climate in projects. He et al. [68] highlighted the impact of a lack of operational prognosis based on operational risks for the system in construction projects.

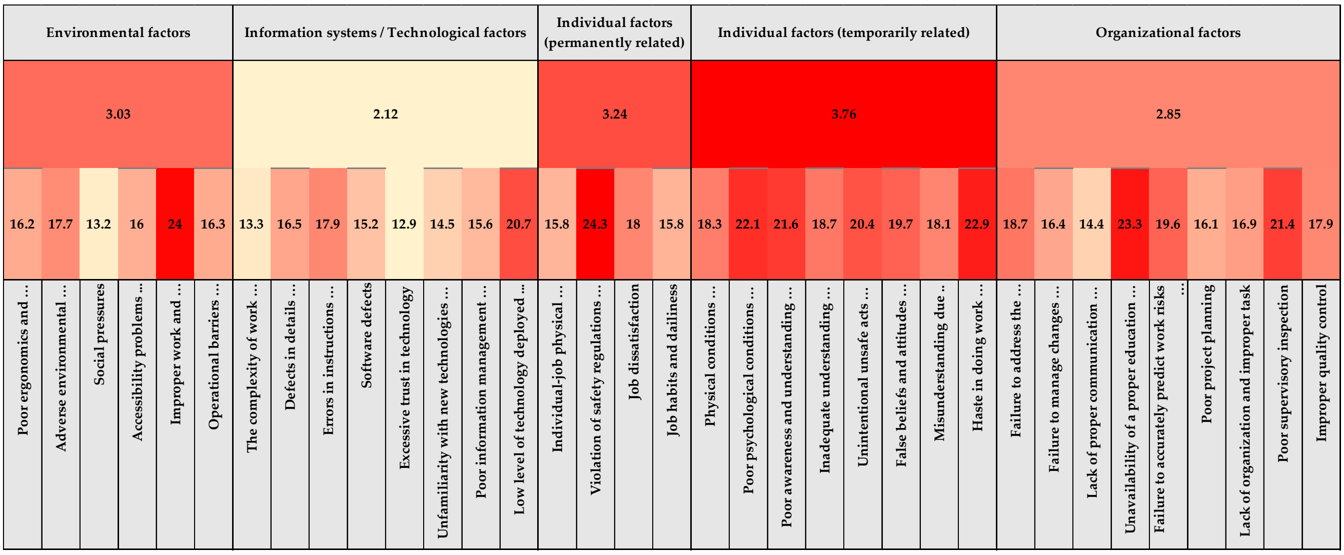

Figure 2. Heatmap delineating the levels of impact of various human error factors leading to the occurrence of site accidents in the UCI of Iran measured by mean ranks (the significance of the factors decline from red to yellow).

Soualhi et al. [63] also pointed to the impact of lack of intelligence in complex situations in construction industry projects. Dong et al. [65] referred to the effects of poor real-time monitoring and accurate prediction of machine failure in maintenance decisions. Zhang et al. [69] highlighted the lack of a centralized method for finding acceptable solutions in construction industry projects. Adamson et al. [70] indicated the impact of cognitive processes, judgment, selection, segregation, and traditional maintenance methods and repairs on construction industry projects. Kumar et al. [37] also highlighted the effects of unintentional unsafe practices, violation of safety regulations, sensory and memory impairment, inaccuracy of manpower, and non-compliance with workplace safety rules and regulations in construction projects. In a study, Morais et al. [67] referred to the impact of lack of pre-work prediction in construction industry projects.

Considering the findings of previous studies as well as those obtained in the current study, researchers have put in a lot of work over the past few years to increase awareness and introduce effective factors for the occurrence of human errors in the construction industry. For example, we can refer to the model provided by Shappell and Wiegmann [39], which was developed for investigating human errors, or the cognitive reliability and analysis method of Hollnagel [40]. In addition, Garrett and Teizer [41] proposed a new error analysis educational and classification tool that categorizes the contributing factors into four groups: culture, operations, resource management, and executive management (policy). The suggested HFACS by Xia et al. [42] includes five levels: unsafe acts of workers, preconditions for unsafe acts, unsafe supervision and monitoring, adverse organizational influences, and adverse environmental influences. The prevention and control of accidents may be broken down into four categories: external environment, organizational factors, prerequisites for triggering accidents, and unsafe leadership [43] However, employers, contractors, and other major stakeholders in construction projects still confront a great deal of ambiguity and difficulties in the construction sector when it comes to the detection, prediction, and management of human mistakes. At the same time, the detection, prediction, and management of human mistakes in the construction industry is a crucial problem in the growth of the construction industry. This is because human error is the most common cause of accidents in the construction industry. As a result, it is very necessary to conduct a comprehensive research of human mistakes and the variables that contribute to them, particularly in emerging nations. As a result, putting more emphasis on environmental factors, information systems and technological factors, individual factors (permanently related), individual factors (temporarily related), and organizational factors can be an effective way to reduce the number of human errors and the factors that effectively contribute to those errors in the construction industry.

As the results of the present study show, improper work and safety culture (related to the workers' attitudes and perceptions, including safety understanding and perceptions of personnel, nationality and culture, religion, fatalism, and optimism) had the highest rank in the group of environmental factors. Low level of technology deployed for equipment and safety protection (traditional repair and maintenance systems, lack of necessary tools and equipment, and lack of knowledge of required resources) had the highest rank in the group of information systems/technological factors. Violation of safety regulations (drug use, etc.) had the highest rank in the group of individual factors (permanently related). Haste in doing work (due to lack of time or irregular working hours) had the highest rank in the group of individual factors (temporarily related). Finally, the unavailability of a proper educational system in the organization had the highest rank in the group of organizational factors. Therefore, managers and experts active in the construction industry of developing countries, including Iran, should try to combat the effective factors leading to the occurrence of site accidents caused by human errors with the help of systemic thinking and coherent management.

The survey results advocate that improper work and safety culture (related to the workers' attitudes and perceptions including safety understanding and perceptions of personnel, nationality and culture, religion, fatalism, and optimism) is one of the critical factors in the occurrence of site accidents caused by construction human errors. In this connection, previous studies opine that management has a greater influence on safety culture in the organization compared to workers [66]. Weak safety culture has generated an increase in stress and anxiety, which in turn hinders the performance of employees and causes employees not to have the necessary ability to respond effectively to the potential risks at the job site. On the other hand, employees who report on the insecurity of their work environment have less motivation to perform tasks safely and have less desire to follow the promulgated safety instructions, which in turn leads to a higher level of work injuries and fatalities [71]. This issue can be attributed to factors such as the unavailability of a proper educational system in the organization, and/or haste in doing work on site. Numerous extant studies have confirmed the existence of a direct relationship between the safe operation of construction projects and the existence of a proper safety training system in the organization [48]. Accident reports in the construction industry also confirm the importance of these cases [7]. The construction industry safety reports advocate that the incidents have resulted in significant financial losses, and at the same time, there have been fatal consequences, including death and serious injuries. Investigating all these serious accidents and their underlying major reasons can be an effective measure in determining the causes of an accident, the consequences of the accident, the evaluation of existing control measures, and, ultimately, in mitigating or avoiding their occurrence in the future construction industry for achieving excellence in site safety performance.

6. Conclusions and Practical Implications of the Study

This study aimed to identify and investigate the effective factors conducive to the occurrence of site accidents caused by human errors in the Iranian urban construction industry. Accordingly, the effective factors for the occurrence of human errors in the UCI were extracted from the research literature and then monitored through three rounds of the Delphi survey. Finally, 35 important factors were identified, based on which a researcher-produced questionnaire was developed under five main groups, including environmental factors, information systems/technological factors, individual factors (permanently related), individual factors (temporarily related), and organizational factors, on a five-point Likert scale of measurement. Then, the questionnaire was distributed among 17 construction experts based in Iran. SPSS software program was used to analyze the gleaned data after collecting the returned questionnaires. The findings of the study indicated that the effective factors on the occurrence of human errors in the Iranian construction industry were assessed as above average, and all the identified effective factors could be considered "strong", in terms of influencing on occurrence of human errors in Iranian UCI.. In addition to the group ranking, individual factors (temporarily related), individual factors (permanently related), environmental factors, organizational factors, and information systems/technological factors held the first rank to the fifth rank, with mean ranks of 3.76, 3.24, 3.03, 2.85, and 2.12, respectively.

Concerning the practical implications of the study, organizations are recommended to determine the relevant influencing factors well in advance and to set industry standards and protocols for organizations first to diminish human errors in the construction industry. A structured definition of safety management significantly increases the chance of reducing and controlling human errors in the construction industry.

In terms of the study's theoretical implications, the identification of the effective key factors leading to the occurrence of site accidents due to human errors in the UCI aids in the improvement of site safety management in construction, whereas no previous quantitative research studies have been conducted in this area. Particularly, the supervision of the activities of persons and equipment, as well as the correct planning of processes, enables construction organizations to increase their safety management effectiveness and productivity. To succeed in site safety management, construction enterprises require effective organization, regulation of individual operations, improvement of environmental conditions, organization modernization in terms of technology deployment, and expansion of rescue facilities and equipment. Consequently, the followings are some prospective future research study paths for expanding and using the derived findings in practice: What management and environmental competencies will help construction businesses to improve their site safety performance? How might technological advancement help construction businesses to improve site safety? What are the suggested measures for construction businesses to implement in order to reduce human-induced errors and thus uplift construction site safety performance?

This study focuses heavily on the personal opinions and practical experiences of the 17 managers and academics involved in the Delphi survey to analyze the identified human error elements in Iran's urban building construction sector. Given this primary restriction, future research can augment the generalizability of the analytical survey results produced from a comparable study by analyzing the quality of UCI accident reports and covering a larger spectrum of construction specialists. However, Sarvari et al. [55] recommended evaluating the variables effective in the incidence of human mistakes based on the level and rate of development of the nations under investigation (developed vs. developing) in order to detect any parallels and differences. In conclusion, the findings of this study can aid different senior industrial stakeholders and site safety managers in their roles as decision facilitators in controlling, preventing, and minimizing human mistakes inherent with building projects that may result in site accidents.

Author Contributions: Conceptualization, H.S. and D.W.M.C.; methodology, H.S. and A.B.B.; formal analysis, H.S. and A.B.B.; investigation, D.W.M.C. and H.S.; data curation, H.S. and D.W.M.C.; writing—original draft preparation, H.S. and A.B.B.; writing—review and editing, D.W.M.C.; visualization, H.S.; supervision, H.S.; project administration, D.W.M.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Sarvari, H.; Mehrabi, A.; Chan, D.W.M.; Cristofaro, M. Evaluating urban housing development patterns in developing countries: Case study of worn-out urban fabrics in Iran. *Sustain. Cities Soc.* **2021**, *70*, 102941. [CrossRef]
2. Bryde, D.; Broquetas, M.; Volm, J.M. The project benefits of building information modelling (BIM). *Int. J. Proj. Manag.* **2013**, *31*, 971–980. [CrossRef]
3. Alshawi, M.; Ingirige, B. Web-enabled project management: An emerging paradigm in construction. *Autom. Constr.* **2003**, *12*, 349–364. [CrossRef]
4. Clough, R.H.; Sears, G.A.; Sears, S.K.; Segner, R.O.; Rounds, J.L. *Construction Contracting: A Practical Guide to Company Management*; John Wiley & Sons: New Jersey, NJ, USA, 2015.
5. Guo, X.; Chen, Y. Perceived trust of contractors in building information modeling assisted projects. In *Construction Research Congress 2020: Project Management and Controls, Materials, and Contracts*; American Society of Civil Engineers: Reston, VA, USA, 2020; pp. 11–20.
6. Lowe, C. A human factors perspective on safety management systems. In *Improvements in System Safety*; Springer: London, UK, 2008; pp. 139–153.
7. Rafieyan, A.; Sarvari, H.; Chan, D.W.M. Identifying and evaluating the essential factors affecting the incidence of site accidents caused by human errors in industrial parks construction projects. *Projects. Int. J. Environ. Res. Public Health* **2022**, *19*, 10209. [CrossRef]
8. Reason, J. *Human Error*; Cambridge University Press: New York, NY, USA, 1990; ISBN 9780521314190.
9. Rasmussen, J. Skills, Rules, and Knowledge: Signals, Signs and Symbols and Other Distinctions in Human Performance Models. *IEEE Trans. Syst. Man Cybern.* **1983**, *SMC-13*, 257–267. [CrossRef]
10. Kyriakidis, M.; Simanjuntak, S.; Singh, S.; Majumdar, A. The indirect costs assessment of railway incidents and their relationship to human error-the case of signals passed at danger. *J. Rail Transp. Plan. Manag.* **2019**, *9*, 34–45. [CrossRef]
11. Zhang, J.; Xu, K.; You, G.; Wang, B.; Zhao, L. Causation analysis of risk coupling of gas explosion accident in Chinese underground coal mines. *Risk Anal.* **2019**, *39*, 1634–1646. [CrossRef]

12. Chan, D.W.M.; Cristofaro, M.; Nassereddine, H.; Yiu, N.S.N.; Sarvari, H. Perceptions of safety climate in construction projects between workers and managers/supervisors in the developing country of Iran. *Sustainability* **2021**, *13*, 10398. [CrossRef]
13. Porathe, T.; Hoem, Å.S.; Rødseth, Ø.J.; Fjørtoft, K.E.; Johnsen, S.O. At least as safe as manned shipping? Autonomous shipping, safety and "human error". In *Safety and Reliability–Safe Societies in a Changing World, Proceedings of the ESREL, Trondheim, Norway, 17–21 June*; Routledge Taylor & Francis Group: London, UK, 2018.
14. Aydin, M.; Camliyurt, G.; Akyuz, E.; Arslan, O. Analyzing human error contributions to maritime environmental risk in oil/chemical tanker ship. *Hum. Ecol. Risk Assess. Int. J.* **2021**, *27*, 1838–1859. [CrossRef]
15. Atkinson, A. Human error in the management of building projects. *Constr. Manag. Econ.* **1998**, *16*, 339–349. [CrossRef]
16. Yates, J.K.; Lockley, E.E. Documenting and analyzing construction failures. *J. Constr. Eng. Manag.* **2002**, *128*, 8–17. [CrossRef]
17. Khaleghi, P.; Akbari, H.; Alavi, N.M.; Kashani, M.M.; Batooli, Z. Identification and analysis of human errors in emergency department nurses using SHERPA method. *Int. Emerg. Nurs.* **2022**, *62*, 101159. [CrossRef] [PubMed]
18. Marín, L.S.; Lipscomb, H.; Cifuentes, M.; Punnett, L. Perceptions of safety climate across construction personnel: Associations with injury rates. *Saf. Sci.* **2019**, *118*, 487–496. [CrossRef]
19. Tripathi, K.K.; Jha, K.N. Determining success factors for a construction organization: A structural equation modeling approach. *J. Manag. Eng.* **2018**, *34*, 04017050. [CrossRef]
20. Holen, S.M.; Yang, X.; Utne, I.B.; Haugen, S. Major accidents in Norwegian fish farming. *Saf. Sci.* **2019**, *120*, 32–43. [CrossRef]
21. Akyuz, E.; Celik, M.; Cebi, S. A phase of comprehensive research to determine marine-specific EPC values in human error assessment and reduction technique. *Saf. Sci.* **2016**, *87*, 63–75. [CrossRef]
22. Rolison, J.J.; Regev, S.; Moutari, S.; Feeney, A. What are the factors that contribute to road accidents? An assessment of law enforcement views, ordinary drivers' opinions, and road accident records. *Accid. Anal. Prev.* **2018**, *115*, 11–24. [CrossRef]
23. Boussabaine, A.; Kirkham, R. *Whole Life-Cycle Costing: Risk and Risk Responses*; John Wiley & Sons, Ltd.: New Jersey, NJ, USA, 2008.
24. Rauws, W. Embracing uncertainty without abandoning planning: Exploring an adaptive planning approach for guiding urban transformations. *DisP-Plan. Rev.* **2017**, *53*, 32–45. [CrossRef]
25. Meshkati, N. Human factors in large-scale technological systems' accidents: Three Mile Island, Bhopal, Chernobyl. *Ind. Crisis Q.* **1991**, *5*, 133–154. [CrossRef]
26. Liu, H.; Hwang, S.L.; Liu, T.H.; Chen, G.H. Implementation of human error diagnosis (HED) system. *J. Chin. Inst. Ind. Eng.* **2004**, *21*, 82–91. [CrossRef]
27. Ramiro, J.S.; Aisa, P.B. *Risk Analysis and Reduction in the Chemical Process Industry*; Springer Science & Business Media: New York, NY, USA, 2012.
28. Volk, R.; Stengel, J.; Schultmann, F. Building Information Modeling (BIM) for existing buildings—Literature review and future needs. *Autom. Constr.* **2014**, *38*, 109–127. [CrossRef]
29. Whittingham, R. *The Blame Machine: Why Human Error Causes Accidents*; Routledge: London, UK, 2004.
30. Latorella, K.A.; Prabhu, P.V. A review of human error in aviation maintenance and inspection. *Int. J. Ind. Ergon.* **2000**, *26*, 133–161. [CrossRef]
31. Kohn, L.T.; Corrigan, J.M.; Donaldson, M.S.; McKay, T.; Pike, K.C. (Eds.) Institute of Medicine (US) Committee on Quality of Health Care in America. In *To Err is Human: Building a Safer Health System*; National Academies Press (US): Washington, DC, USA, 2000; Volume 600.
32. Crowl, D.A. (Ed.) *Human Factors Methods for Improving Performance in the Process Industries*; John Wiley & Sons, Ltd.: New Jersey, NJ, USA, 2007.
33. Shanmugam, A.; Robert, T.P. Ranking of aircraft maintenance organization based on human factor performance. *Comput. Ind. Eng.* **2015**, *88*, 410–416. [CrossRef]
34. Boal, K.; Meckler, M. Decision errors of the 4th, 5th, and 6th kind. In *Handbook of Decision Making*; John Wiley & Sons, Ltd.: New Jersey, NJ, USA, 2010; pp. 327–348.
35. Bentley, T.; Tappin, D.; Moore, D.; Legg, S.; Ashby, L.; Parker, R. Investigating slips, trips and falls in the New Zealand dairy farming sector. *Ergonomics* **2005**, *48*, 1008–1019. [CrossRef] [PubMed]
36. Gürcanlı, G.E.; Baradan, S.; Uzun, M. Risk perception of construction equipment operators on construction sites of Turkey. *Int. J. Ind. Ergon.* **2015**, *46*, 59–68. [CrossRef]
37. Kumar, P.; Gupta, S.; Agarwal, M.; Singh, U. Categorization and standardization of accidental risk-criticality levels of human error to develop risk and safety management policy. *Saf. Sci.* **2016**, *85*, 88–98. [CrossRef]
38. Hameed, A.; Khan, F.; Ahmed, S. A risk-based shutdown inspection and maintenance interval estimation considering human error. *Process Saf. Environ. Prot.* **2016**, *100*, 9–21. [CrossRef]
39. Shappell, S.A.; Wiegmann, D.A. Applying reason: The human factor analysis and classification system (HFACS). *Hum. Factors Aerosp. Saf.* **2001**, *1*, 59–86.
40. Hollnagel, E. *Cognitive Reliability and Error Analysis Method (CREAM)*; Elsevier: Amsterdam, The Netherlands, 1998.
41. Garrett, J.W.; Teizer, J. Human Factors Analysis Classification System relating to human error awareness taxonomy in construction Safety. *J. Constr. Eng. Manag.* **2009**, *135*, 754–763. [CrossRef]
42. Xia, N.; Zou, P.X.; Liu, X.; Wang, X.; Zhu, R. A hybrid BN-HFACS model for predicting safety performance in construction projects. *Saf. Sci.* **2018**, *101*, 332–343. [CrossRef]

43. Song, Y.; Wang, J.; Liu, D.; Guo, F. Study of occupational safety risks in prefabricated building hoisting construction based on HFACS-PH and SEM. *Int. J. Environ. Res. Public Health* **2022**, *19*, 1550. [CrossRef] [PubMed]
44. Kletz, T. *An Engineer's View of Human Error*; Routledge Taylor & Francis Group: London, UK, 2018.
45. Chen, G.X.; Shan, M.; Chan, A.P.C.; Liu, X.; Zhao, Y.Q. Investigating the causes of delay in grain bin construction projects: The case of China. *Int. J. Constr. Manag.* **2019**, *19*, 1–14. [CrossRef]
46. Bentley, M.J.C. *Quality Control on Building Sites*; Building Research Station: Acton, London, 1981; 10p.
47. Love, P.E.; Sohal, A.S. Capturing rework costs in projects. *Manag. Audit. J.* **2003**, *18*, 329–339. [CrossRef]
48. Barbaranelli, C.; Petitta, L.; Probst, T.M. Does safety climate predict safety performance in Italy and the USA? Cross-cultural validation of a theoretical model of safety climate. *Accid. Anal. Prev.* **2015**, *77*, 35–44. [CrossRef] [PubMed]
49. Zou, P.X.; Sunindijo, R.Y. Skills for managing safety risk, implementing safety task, and developing positive safety climate in construction project. *Autom. Constr.* **2013**, *34*, 92–100. [CrossRef]
50. Griffin, M.A.; Neal, A. Perceptions of safety at work: A framework for linking safety climate to safety performance, knowledge, and motivation. *J. Occup. Health Psychol.* **2000**, *5*, 347–358. [CrossRef]
51. Fink, A.; Kosecoff, J.; Chassin, M.; Brook, R.H. Consensus methods: Characteristics and guidelines for use. *Am. J. Public Health* **1984**, *74*, 979–983. [CrossRef]
52. Khosravi, M.; Sarvari, H.; Chan, D.W.M.; Cristofaro, M.; Chen, Z. Determining and assessing the risks of commercial and recreational complex building projects in developing countries: A survey of experts in Iran. *J. Facil. Manag.* **2020**, *18*, 259–282. [CrossRef]
53. Lee, C.H.; Wu, K.J.; Tseng, M.L. Resource management practice through eco-innovation toward sustainable development using qualitative information and quantitative data. *J. Clean. Prod.* **2018**, *202*, 120–129. [CrossRef]
54. Sarvari, H.; Chan, D.W.M.; Alaeos, A.K.F.; Olawumi, T.O.; Aldaud, A.A.A. Critical success factors for managing construction small and medium-sized enterprises in developing countries of Middle East: Evidence from Iranian construction enterprises. *J. Build. Eng.* **2021**, *43*, 103152. [CrossRef]
55. Sarvari, H.; Cristofaro, M.; Chan, D.W.M.; Noor, N.M.; Amini, M. Completing abandoned public facility projects by the private sector: Results of a Delphi survey in the Iranian Water and Wastewater Company. *J. Facil. Manag.* **2020**, *18*, 547–566. [CrossRef]
56. Dusek, G.A.; Yurova, Y.V.; Ruppel, C.P. Using social media and targeted snowball sampling to survey a hard-to-reach population: A case study. *Int. J. Dr. Stud.* **2015**, *10*, 279–299. [CrossRef]
57. Onwuegbuzie, A.J.; Combs, J.P. Emergent data analysis techniques in mixed methods research: A synthesis. *Handb. Mix. Methods Soc. Behav. Res.* **2010**, *2*, 398.
58. Schmidt, R.C. Managing Delphi surveys using nonparametric statistical techniques. *Decis. Sci.* **1997**, *28*, 763–774. [CrossRef]
59. Falck, A.C.; Rosenqvist, M. What are the obstacles and needs of proactive ergonomics measures at early product development stages?–An interview study in five Swedish companies. *Int. J. Ind. Ergon.* **2012**, *42*, 406–415. [CrossRef]
60. Needham, D.L.; Slaughter, D.C.; Giles, D.K.; Downey, D. Roadside Spray Control: On-board Monitoring and Recording of Environmental Conditions for the Prevention of Application in Adverse Conditions. *Am. Soc. Agric. Biol. Eng.* **2006**, 061107. [CrossRef]
61. Klein, S.B. *Learning: Principles and Applications*; Sage Publications: California, CA, USA, 2018.
62. Knight, M.; Oswal, S.K. Disability and accessibility in the workplace: Some exemplars and a research agenda for business and professional communication. *Bus. Prof. Commun. Q.* **2018**, *81*, 395–398. [CrossRef]
63. Soualhi, M.; Nguyen, K.T.; Medjaher, K. Pattern recognition method of fault diagnostics based on a new health indicator for smart manufacturing. *Mech. Syst. Signal Processing* **2020**, *142*, 106680. [CrossRef]
64. Deacon, T.W. Shannon-Boltzmann—Darwin: Redefining information (Part II). *Cogn. Semiot.* **2008**, *2*, 169–196. [CrossRef]
65. Dong, Y.; Xia, T.; Fang, X.; Zhang, Z.; Xi, L. Prognostic and health management for adaptive manufacturing systems with online sensors and flexible structures. *Comput. Ind. Eng.* **2019**, *133*, 57–68. [CrossRef]
66. Storey, H. Chapter: Human factors in the development of automotive safety critical software. In *Contemporary Ergonomics*; Taylor & Francis: London, UK, 1994; pp. 205–211. ISBN 9780429180545. [CrossRef]
67. Morais, C.; Estrada-Lugo, H.D.; Tolo, S.; Jacques, T.; Moura, R.; Beer, M.; Patelli, E. Robust data-driven human reliability analysis using credal networks. *Reliab. Eng. Syst. Saf.* **2022**, *218*, 107990. [CrossRef]
68. He, Y.; Zhao, Y.; Han, X.; Zhou, D.; Wang, W. Functional risk-oriented health prognosis approach for intelligent manufacturing systems. *Reliab. Eng. Syst. Saf.* **2020**, *203*, 107090. [CrossRef]
69. Zhang, Y.; Wang, J.; Liu, S.; Qian, C. Game theory based real-time shop floor scheduling strategy and method for cloud manufacturing. *Int. J. Intell. Syst.* **2017**, *32*, 437–463. [CrossRef]
70. Adamson, G.; Wang, L.; Holm, M.; Moore, P. Cloud manufacturing–A critical review of recent development and future trends. *Int. J. Comput. Integr. Manuf.* **2017**, *30*, 347–380. [CrossRef]
71. Guastello, S.J.; Gershon, R.R.; Murphy, L.R. Catastrophe model for the exposure to blood-borne pathogens and other accidents in health care settings. *Accid. Anal. Prev.* **1999**, *31*, 739–749. [CrossRef]