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ENHANCING HEALTH, SAFETY, AND ENVIRONMENT (HSE) IN BUILDING PROJECTS: A COMPREHENSIVE AND COMPARATIVE STUDY

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Research Paper

Abstract: *Construction project management's Health, Safety, and Environment (HSE) factors greatly impact project results. Executive leadership and project staff are responsible for HSE management, even if organizational strategies may influence it. HSE research is abundant, but more is needed to understand its complex interactions and hierarchical relevance. This research examines HSE dynamics in residential and office building in Iraq and Iran using Structural Equation Modelling (SEM). It contrasts and explains the complex relationship structures in these different places. Our empirical results show significant differences across country models. Most importantly, this study provides a conceptual framework to help project managers prioritize HSE measures based on their operating environment. The analytical procedure was robust because variables were operationalized carefully using SPSS software. The studies confirm the accuracy of data calculation and encoding, proving the study instrument's 5-point Likert scale fidelity. The methodological rigor of this study is supported by rigorous evaluation, including comparison assessments against societal standards and data distribution diagnostics. Validating the factor analysis model and documenting results requires fit indices. Favourable fit indices and Cronbach's alpha values demonstrate the model's accuracy and dependability. Thus, the questionnaire captures the target constructs with 95% confidence. This research emphasizes the need for project managers to carefully negotiate each nation's cultural, legal, and regulatory milieu while implementing HSE management practices. It provides useful insights to improve HSE governance in varied developmental scenarios.*

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1. Introduction

1.1 Background and Motivation

The 1980s brought about the development of the extensive management system known as health, safety, and environment (HSE). Its primary objectives are to support sustainable growth, reduce hazards, prevent accidents, and ensure safe manufacturing (Alianto et al., 2022). In high-risk sectors, such as petroleum companies (Khosravi et al., 2014), paint manufacturing facilities (Yap and Lee, 2020), gas refineries, petrochemical plants, and oil and gas transportation plants (Gumusburun Ayalp, 2022) HSE has been gradually applied. The manufacturing procedures of these sectors include managing hazards to the environment, safety, and occupational health. The suitability of HSE management systems to unusual transport projects including a mix of cross-sea channels, bridges, tunnels, and islands is still little researched. Researchers have worked hard on HSE risk assessment by using a range of well-established techniques and cutting-edge technologies. In the field of health, safety, and environment (HSE), risk assessment methods usually consider the elements of severity and probability to calculate the risk value (Bowen et al. 2014; Li et al., 2022).

The interaction and impact of variables on HSE outcomes are shown by SEM analysis of HSE variable dynamics (Li et al., 2022; Wang et al., 2022). Considering the variety of HSE models across different places, this research also attempts to compare SEM analysis to investigate HSE features in two developing nations, Iran and Iraq. Clarifying the factors impacting and their interplay in the decision-making process in HSE management is the aim of this research. The report concludes with a conceptual framework that builds upon past studies to provide a comprehensive model for assessing HSE components. Among the anticipated outcomes are significant insights for academics and construction project managers that will raise the efficiency and effectiveness of project execution.

A primary driver behind construction project failures lies in the imperative for managers to possess an enhanced comprehension of HSE requirements. The proposed model is poised to offer a lucid and precise viewpoint for project implementation, facilitating the application of project-specific safety regulations and considering other pertinent factors affecting project success. Consequently, this study aims to address the following research inquiries:

RQ1 delves into prioritizing the factors influencing HSE in construction projects. Meanwhile, RQ2 aims to elucidate the relationships among these factors. The structure of this paper encompasses distinct sections, including a comprehensive literature review, a detailed methodology, presentation and discussion of results, and concluding remarks.

2. Literature Review

Numerous scholars have extensively explored the HSE domain within the construction project context, employing diverse perspectives encompassing economic, technical, and qualitative dimensions.

HSE management's major influence on project results and worker well-being has made its significance in the construction sector generally acknowledged. Many researchers have stressed that, especially in high-risk building projects, HSE must be approached holistically. In this regard, Gholami et al. (2024) carried out a landmark research that concentrated on the HSE issues present in non-mechanized tunnel building and emphasised how important proactive risk management techniques are to improving safety results.

To reduce risks and safeguard workers and the environment, effective construction project management calls for strict HSE procedures. Predicted on this premise, Beyer et al. (2024) examined the Anchor project, which illustrates proactive HSE management in offshore energy projects. For worker safety and construction sustainability, SHE management systems are essential in dynamic construction project management. Asah-Kissiedu et al. (2023) realized 20 features in five themes. Strategy (the organization's vision and top management commitment); process (its SHE management procedures and processes); people (its human resources, their competence, roles, responsibilities, and involvement in SHE management); resources (its physical and financial resources); and information Thematic categories and their qualities have varied weights, but strategy-related attributes are most essential, followed by people-related attributes. Construction businesses and other industry stakeholders should use this research to assess their capabilities to establish an integrated SHE management system. Construction businesses should prioritize SHE management efforts and investments.

Zhang et al. (2023) created a methodology to assess employee performance and identified significant determinants. The employee performance and HSE metrics are based on literature study. A questionnaire-based artificial neural network (ANN) model of employee activity efficacy is then created to assess employee performance. To identify employee performance determinants, sensitivity analysis is used. A validation case study is the Hong Kong-Zhuhai-Macau Bridge, a massive cross-sea channel project. The model shows that workers are happy with HSE management, but psychological stress increases. Risk control and employee involvement improve performance, whereas work happiness hurts it. To avoid overwork, operators should pay greater attention to workers' psychological impression of work and create a consistent process management and control plan. This research helps construction systems and managers discover HSE management strengths and limitations. Our study exclusively examines how HSE hazards affect managers' performance in complicated transport building projects. Future engineering projects and personnel performance in composite situations may increase productivity.

Ahmadi and Rafieizonooz (2020) investigated Tehran construction project incidents and proposed solutions. Reviewing literature divides accident causes into distal and proximal elements. According to distal factor analysis, several difficulties and reasons cause accidents in Tehran. Significant causes include ‘Cash flow problems’, ‘inadequate supervision budget’, ‘Lack of suitable experience’, ‘Recruit inexperienced operatives’, and ‘Reduce project budget’. By studying effective safety

program implementation aspects, respondents believe Tehran company general management is not fully devoted to safety and neglects safety. In addition, labor inspectors often overlook inspections. Lack of worker engagement in safety programs may lead to accidents and make the program ineffective. Finally, to reduce and prevent accidents on Tehran construction sites, management should allocate adequate budget for designing sections, have enough and relevant experience and knowledge about projects, and recruit trained operatives with relevant skills.

Safety leading indicators are an emerging construction industry topic. However, leading indicator definitions, viability, and usefulness are not widely agreed upon. Still, Xu et al. (2021) suggested some construction management metrics. The results are inconsistent, and the links between leading indicators and accident attributors are ambiguous. Safety leading indicators and proactive safety management in construction may be hindered by this information gap. After a systematic literature review, this study aims to develop a common working definition of safety leading indicator to better understand current construction research, identify construction safety leading indicators, and create an integrated framework for proactive safety management in the complex and fragmented construction industry. Sixteen indicators were divided into two categories to assess the safety performance of organizations, projects, groups, and people and identify organizational, operational, cognitive, and behavioural difficulties that might cause accidents and injuries. The results suggest that academics and practitioners should incorporate ecosystem impacts, temporal effects, and qualitative and quantitative assessments in future research and construction safety leading indicators.

The understanding of and improvements in HSE procedures within building projects have been greatly advanced by a number of studies. Of them, the papers by Kukoyi et al. (2021) and Kukoyi and Adebowale (2021) are noteworthy for their concentrated study of raising HSE standards in the building industry, especially in the setting of Nigeria. The importance of safety and health issues in Nigeria's construction industry is clarified by these studies via careful questionnaire distribution and statistical analysis that follows. Their conclusions highlight the ongoing concern of stakeholders for HSE and the need of project management teams paying close attention. Through the clarification of the direct and indirect effects of giving the HSE category priority, these studies provide insightful information that affects many aspects of project management practice outside of the building industry.

Construction project management requires a safety culture to protect workers and reduce accidents. Wang and Cheng (2022) introduced an organizational network concept to improve construction project safety knowledge. The researchers created this model by analysing the social networks of project stakeholders such employers, contractors, supervisors, and others. This organizational network approach helps stakeholders communicate and collaborate on construction safety.

Safety and cost optimization are integral to building project management. These essential concepts define project success and guide project results. Researchers seek to understand the complex relationship between safety procedures and financial efficiency. Ketabi and Heravi (2022) developed a methodology to evaluate building project safety levels and optimize safety factor costs. The research used literature review and questionnaire survey to examine 95 Iranian metal structure building projects. After identifying six major safety parameters for cost allocation, experts

determined expenses. Multiple linear regression (MLR) was used to forecast future situations. This model shows how each aspect affects project safety and predicts the total safety level. The research shows that optimizing safety factor costs improves construction safety. However, the research did not include all HSE criteria, thus its conclusions should be interpreted cautiously. Another study evaluated managers and workers' reactions to a Safety Management System (SMS) in Hong Kong's construction sector. They identified key SMS implementation parameters first. They then reviewed SMS literature and conducted structured interviews to assess the implementation process's pros and cons. This research synthesized and condensed variables improving Hong Kong building project safety management.

Results showed that SMS deployment success was driven by human resources commitment, SMS cost allocation, and construction project safety management ability.

Construction project managers struggle to balance cost, time, quality, and safety. Sharma and Trivedi (2022) stressed the need of using a proper model to balance cost, time, quality, and safety in building projects, with a focus on safety. They combined time, money, and quality in a cost-time-quality-safety trade-off optimisation model for project activities analysis. A construction project demonstrated how the proposed model outperformed earlier models in terms of cost, time, quality, and safety. This study suggests that project managers may utilize the proposed method to enhance management, save expenses, and raise safety. The concept beat earlier models in terms of simplifying management, cutting project costs, and enhancing safety, according to a construction project case study. According to this study, project managers might use the recommended strategy to balance safety and project outcomes optimization.

Initially, factors pertinent to HSE management were identified by conducting keyword searches in Google across 231 journal articles. Notably, 52% of these articles were published between 2017 and 2021. Subsequently, final factors were determined through coding, analysis, and synthesis of the extracted concepts. Table 1 presents the essential elements essential for managing HSE in building projects.

Table 1: Main Factors Involved in HSE Management

Factors / Variables	Description	Reference
HSE-related laws and regulations (F_1)	Regional, national, and international rules make up the HSE legal framework.	(Abbasianjahromi & Etemadi, 2019; Hwang et al., 2018; Jitwasinkul & Hadikusumo, 2011; Kaharuddin et al., 2020)
Resources required for successful implementation of each activity and process considering various aspects of HSE (F_2)	Resources: human, financial, materials, equipment Human resources: appropriate age, skill, culture; encompassing all physical, mental, and professional conditions affecting individual performance Financial resources: necessary costs for HSE allocation Materials and equipment: high-quality resources for project implementation; including provisions for healthy food, drinking water, detergents, and high-standard safety equipment	(Ahmadi & Rafieizonooz, 2020; Boadu et al., 2021; Carter & Smith, 2006; Oswald et al., 2019; Sun et al., 2020)
Integrated project HSE management system (F_3)	The system uses data management and monitoring to assign responsibilities based on individual HSE compliance and track behaviour. It adjusts tasks to comply with regulations, utilizing new technologies for efficient HSE management. Project managers must be aware of risks from non-compliance, while the system aids in stakeholder management and conflict resolution.	(Ju et al., 2022; Soltanzadeh et al., 2019; Xu et al., 2022)
Organizational learning and training in HSE (F_4)	Pre-project training to prevent incidents Ongoing training during project execution to incorporate lessons learned Post-project training during operations	(Abbasianjahromi & Etemadi, 2019; Anaman & Osei-Amponsah, 2007; McCabe et al., 2008; Xu et al., 2023)

The structure and way of organizing the project towards the coherence of HSE management (F_5)	Every project has a unique structure tailored to its goals and vision. It clearly outlines the responsibilities of different roles. It provides a comprehensive understanding of components and implementation strategies.	(Akinlolu et al., 2020; Chatzimichailidou & Ma, 2022; Welege et al., 2021)
Organisational culture to implement HSE (F_6)	Organizational culture represents the typical pattern of interaction among project members. It sets the standard for judging attitudes and behaviours. Effective project leadership and a supportive environment are essential for clarifying and enhancing organizational culture.	(Bowen et al., 2014; Fletcher et al., 2015; Kaharuddin et al., 2020)
Compliance with health at the project level (F_7)	This factor encompasses the mental, physical, and professional well-being of project participants. It addresses issues such as fatigue and exhaustion, as well as the overall health of both individuals and the project environment.	(McCabe et al., 2008; Miller & Tucker, 2014; Roy et al., 2017; Terwel & Jansen, 2015)
Importance to the scope and appropriateness of the environment (F_8)	Project size and location must be accurately determined. Environmental factors such as light and temperature should be continuously monitored based on the activity, its type, and timing to minimize potential risks.	(Bjerkan, 2010; Boadu et al., 2021; Duryan et al., 2020; Mohandes & Zhang, 2021; Tijani et al., 2020)

2.1 Paper Contribution

This study endeavours to utilize influential factors to enhance HSE practices within construction projects. The aim is to meticulously analyse the variables and their interrelationships to offer tailored solutions for effective HSE management in building projects. Consequently, the current research is geared towards investigating multi-story residential and office buildings in Developing Countries, with a specific focus on Iran and Iraq. A comparative analysis will be undertaken to discern any divergences between the identified models for evaluating HSE factors in these two nations. Should discrepancies arise, caution must be exercised in generalizing findings to all developing countries. Moreover, employing descriptive research methods, the study primarily seeks to explore the factors influencing HSE improvement through surveys and correlational analyses.

2.2 Paper Structure

The structure of this paper unfolds as follows: Section 2 elucidates the Methods and Materials employed in the study. Section 3 delineates the Results and Discussion derived from the research findings. Finally, Section 4 encapsulates the Conclusion drawn from the culmination of the study's efforts.

3. Methods and Materials

Following a comprehensive literature review to identify factors influencing the evaluation of HSE aspects in construction projects, drawn from (Aromataris & Pearson, 2014), a field study was conducted to prioritize and categorize these factors. The study period spanned from 2021 to 2022, with Iran and Iraq serving as the research locations. A comparative investigation into the differences in SEM between these two countries was undertaken, given the prevalence of multi-story residential and office building projects therein. Expert opinions from the realm of HSE management were solicited in each country, with the selection criteria based on the number of variables under scrutiny. For exploratory factor analysis, a minimum of five experts per variable is requisite, while confirmatory factor analysis necessitates at least 20 experts per variable. Moreover, for SEM development, the cohort size should not fall below 200 experts. The participants involved in data collection boasted over five years of experience in HSE management within construction and office projects, alongside possessing a minimum bachelor's degree in civil engineering, health and environment, HSE, or project management. Selection of subject matter experts was predicated on their pertinent executive and academic background (Sourani & Sohail, 2015). To this end, project managers or members of the project management team with a minimum of five years of executive experience and proficiency in HSE management in residential and office construction projects were identified and categorized based on education and gender. Given the prevailing circumstances of the COVID-19 pandemic, data collection methodologies encompassed online dissemination of questionnaires and interviews, alongside traditional face-to-face interactions, telephone, video conferencing, and email correspondence. The primary methods employed are expounded below. Qualitative validation and reliability of the questionnaire were conducted with the input of 15 experts through brainstorming sessions. Initially, the questionnaire was distributed among panel members, and

subsequent iterations ensued through expert negotiations until a consensus was reached on the final questionnaire. Furthermore, owing to each country's unique regulatory framework, the panel scrutinized the interplay between variables before embarking on the quantitative analysis phase. The present study delineates six distinct steps, as elucidated in the accompanying flowchart depicted in Figure 1.

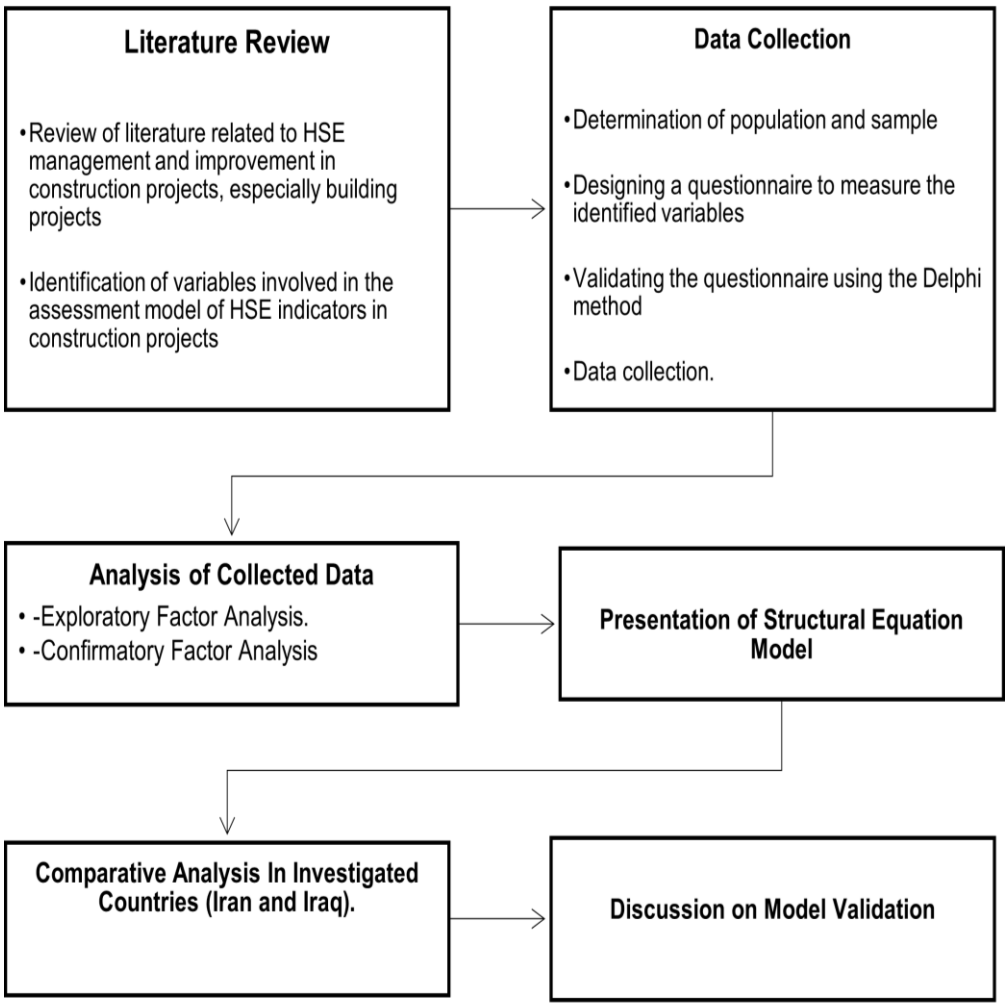

Figure 1: Research Flowchart

3.1 Structural Equation Modelling Method

Factor and route analysis were used in the processing and analysis of data by the SEM framework. Variable interactions were investigated and a new structural framework for the phenomena under investigation was developed using a multivariate method known as factor analysis. Analysis finds factor analysis helpful because it makes complex situations with numerous variables easier to understand (Malang-Indonesia, 2014). Robust statistical technique path analysis is useful for modelling social events as it may provide more intricate and realistic models than

multiple regression analyses (Barbeau et al., 2019). A number of HSE studies have used these techniques. While (Seo et al., 2015) looked at the temporary safety behaviors of construction workers, (Soltanzadeh et al., 2019) employed SEM to research HSE concerns associated to occupational injuries. In Malaysia, SEM was used to study quantitative safety measures by Ramli et al. (2014)and accident factors influencing construction safety performance by (Sukamani & Wang, 2020; Alaloul et al., 2015). Content validity of the questionnaires was verified using a five-point Likert scale and the Delphi method. Expert consensus on quantitative or qualitative issues is sought for in the Delphi method, a well-known group decision-making procedure. This methodical data collection and analysis approach is typical in many scientific disciplines. Experts in Iraq and Iran have several commonalities. In Iran (96%) and Iraq (93%) the majority of responses were men; the remaining respondents were women. While some were from the health and environment sectors, the majority of experts in both countries have degrees in civil engineering (92% in Iran and 86% in Iraq).

4. Results and Discussion

Based on the existing literature and expert insights, it was found that the factors influencing HSE management in Iran and Iraq were largely similar, although subtle variations existed in their interrelationships. Through thorough examination, all conceivable connections among variables impacting HSE management enhancement were delineated, and experts in each country adjudicated the direction of their influence. These potential relationships, encapsulated as hypotheses, are comprehensively enumerated in Table 2.

Following the implementation of factor analysis, the findings for the nations of Iran and Iraq are as delineated below:

4.1 Statistical Description of Research Variables

The description of variables is integral as the research hypotheses' outcomes hinge upon the data and indicators of these variables. The research data are measured on an interval scale. Centrality and dispersion indices elucidate the variables discussed in Tables 3 and 4. The questionnaire employed a five-point Likert scale (ranging from 1 to 5), encompassing several questions for each variable. In SPSS software, these variables were constructed by aggregating related inquiries. The results presented in the aforementioned table confirm the accurate calculation of scores for all variables, indicating that the collected data have been appropriately coded, entered, and processed within the software environment.

Table 2: The Relationship between Variables (Hypotheses) Based on the Opinion of Experts in Iran and Iraq

Relationship number	Relationship Between Variables
R_1	The variable "laws and regulations related to HSE" significantly affects the "resources required for successfully implementing each activity and process."
R_2	The "laws and regulations related to HSE" variable significantly affects the "integrated project HSE management system" variable.
R_3	The variable "laws and regulations related to HSE" significantly affects the variable "organizational learning and training in the field of HSE."
R_4	The variable "Structure and way of organizing the project towards the coherence of HSE management" significantly affects the variable "Laws and regulations related to HSE."
R_5	The variable "laws and regulations related to HSE" significantly affects the inconsistent "organizational culture for implementing HSE."
R_6	The variable "laws and regulations related to HSE" significantly affects the variable "health compliance at the project level."
R_7	The variable "laws and regulations related to HSE" significantly affects the variable "importance to the scope and appropriateness of the environment."
R_8	The "Resources required for successfully implementing each activity and process" variable significantly affects the "Integrated Project HSE Management System" variable.
R_9	The variable "resources required for the successful implementation of each activity and process" significantly affects the variable "organizational learning and training in the field of HSE."
R_{10}	The variable "Structure and way of organizing the project towards the coherence of HSE management" significantly affects the variable "Resources required for the successful implementation of each activity and process."
R_{11}	The variable "organizational culture for the implementation of HSE" significantly affects the variable "resources required for the successful implementation of each activity and process."
R_{12}	The variable "resources required for the successful implementation of each activity and process" significantly affects "health compliance at the project level."
R_{13}	The variable "resources required for the successful implementation of each activity and process" significantly affects the variable "importance to the scope and appropriateness of the environment."
R_{14}	The variable "integrated project HSE management system" significantly affects the variable "organizational learning and training in the field of HSE."
R_{15}	The variable "integrated project HSE management system" significantly affects the variable "health compliance at the project level."

R_{16}	The variable "integrated project HSE management system" significantly affects the variable "importance to the scope and appropriateness of the environment."
R_{17}	The variable "Structure and way of organizing the project in the direction of HSE management coherence" significantly affects the "Integrated Project HSE Management System" variable.
R_{18}	The "organizational culture for the implementation of HSE" variable significantly affects the "integrated project HSE management system" variable.
R_{19}	The variable "Organisational learning and training in the field of HSE" significantly affects the variable "Health compliance at the project level."
R_{20}	The variable "organizational learning and training in the field of HSE" significantly affects the variable "importance to the scope and appropriateness of the environment."
R_{21}	The variable "Structure and way of organizing the project towards the coherence of HSE management" significantly affects the variable "Organizational learning and training in the field of HSE."
R_{22}	The variable "organizational culture for the implementation of HSE" significantly affects the variable "organizational learning and training in the field of HSE."
R_{23}	The variable "Structure and way of organizing the project for the coherence of HSE management" significantly affects the variable "Organizational culture for the implementation of HSE."
R_{24}	The variable "Structure and way of organizing the project towards the coherence of HSE management" significantly affects "Health compliance at the project level."
R_{25}	The variable "structure and way of organizing the project in the direction of HSE management coherence" significantly affects the variable "importance to the scope and appropriateness of the environment."
R_{26}	The variable "organizational culture for the implementation of HSE" significantly affects the inconsistent "health compliance at the project level."
R_{27}	The variable "organizational culture for the implementation of HSE" significantly affects the variable "importance to the scope and appropriateness of the environment."
R_{28}	The variable "importance to the scope and appropriateness of the environment" significantly affects "health compliance at the project level."

Table 3: Descriptive indices of the studied variables related to the country of Iran

Variable	Number of items	Average	Standard deviation	Minimum	Maximum
HSE	52	3.247	0.657	1.31	4.73
F_1	3	3.350	0.867	1.00	5.00
F_2	21	3.204	0.955	1.00	5.00
F_3	5	3.323	0.869	1.00	5.00
F_4	4	3.331	0.839	1.00	5.00
F_5	2	3.273	0.898	1.00	5.00
F_6	3	3.392	0.958	1.00	5.00
F_7	12	3.224	0.885	1.25	4.83
F_8	2	3.190	0.869	1.00	5.00

Table 4: Descriptive indices of the studied variables related to the country of Iraq

Variable	Number of items	Average	Standard deviation	Minimum	Maximum
HSE	52	3.388	0.570	1.85	4.71
F_1	3	3.517	0.890	1.00	5.00
F_2	21	3.335	0.787	1.43	5.00
F_3	5	3.393	0.763	1.20	5.00
F_4	4	3.518	0.814	1.50	5.00
F_5	2	3.388	0.893	1.00	5.00
F_6	3	3.380	0.858	1.00	5.00
F_7	12	3.422	0.775	1.50	5.00
F_8	2	3.280	0.925	1.00	5.00

The one-sample t-test served as the statistical tool to assess the status of research variables in alignment with the analysis and testing of the aforementioned hypothesis, recognized as a quantitative univariate hypothesis. This pertains to the questionnaire design of the research, which utilizes a 5-point Likert scale, and involves the comparison of the sample's obtained average with the societal standard norm, alongside considering the values derived from the skewness and kurtosis tests, which depict the expected distribution of the data. Corresponding values are presented in Table 5 and Table 6.

Table 5: Identifying the status of the research variables using a sample t-tech test related to the country of Iran

Variable	Average	The amount of T	level of Significance	Mean Difference	95% Confidence Interval Mean Difference	
					Low limit	Upper Line
HSE	3.247	5.321	0.000	0.247	0.156	0.339
F_1	3.350	5.711	0.000	0.350	0.229	0.471
F_2	3.204	3.015	0.003	0.204	0.070	0.337
F_3	3.323	5.256	0.000	0.323	0.202	0.444
F_4	3.331	5.585	0.000	0.331	0.214	0.448
F_5	3.273	4.292	0.000	0.273	0.147	0.398
F_6	3.392	5.783	0.000	0.392	0.258	0.525
F_7	3.224	3.584	0.000	0.224	0.101	0.348
F_8	3.190	2.464	0.025	0.190	0.031	0.211

Validity assessment of the questionnaire items related to health, safety, and environment variables was conducted through first-order confirmatory factor analysis, as depicted in Figure 2 and Figure 3. Standardized factor loading values for all questions in both Iran and Iraq exceeded 0.4. Additionally, all critical ratios (CR)

between the items and their respective variables surpassed 1.96, with significance levels below the error level of 0.05. Consequently, the validity of the measurement structures for the pertinent variables was affirmed at a significance level of 0.05, obviating the necessity for altering or excluding questions from the research model and questionnaire. Furthermore, Cronbach's alpha coefficient results are provided for all research variables, with values exceeding 0.7. Moreover, second-order confirmatory factor analysis for Iran and Iraq is depicted in Figure 4 and Figure 5, respectively.

Table 6: Identifying the status of the research variables using a sample t-tech test related to the country of Iraq

Variable	Average	The amount of T	level of Significance	95% Confidence Interval Mean Difference	95% Confidence Interval Mean Difference	
					Upper Line	Upper Line
HSE	3.388	9.623	0.000	0.388	0.308	0.467
F_1	3.517	8.207	0.000	0.517	0.393	0.641
F_2	3.335	6.026	0.000	0.335	0.226	0.445
F_3	3.393	7.284	0.000	0.393	0.287	0.499
F_4	3.518	8.992	0.000	0.518	0.404	0.631
F_5	3.388	6.136	0.000	0.388	0.263	0.512
F_6	3.380	6.264	0.000	0.380	0.260	0.500
F_7	3.422	7.701	0.000	0.422	0.314	0.530
F_8	3.280	4.280	0.000	0.280	0.151	0.409

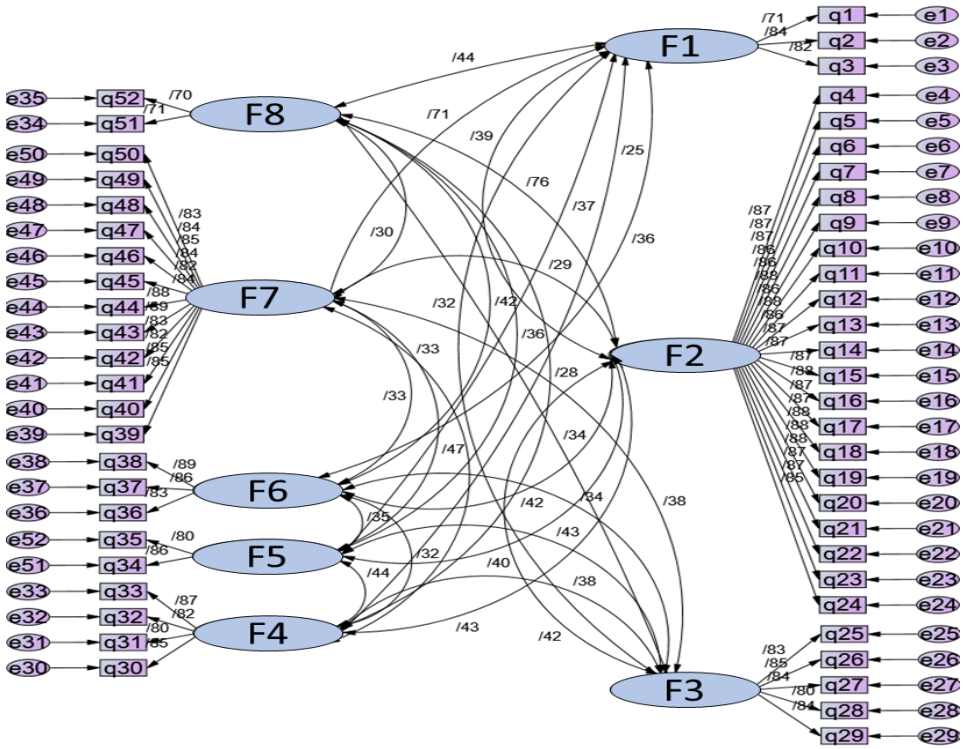

Figure 2: The First-Order Confirmatory Factor Analysis for Iran

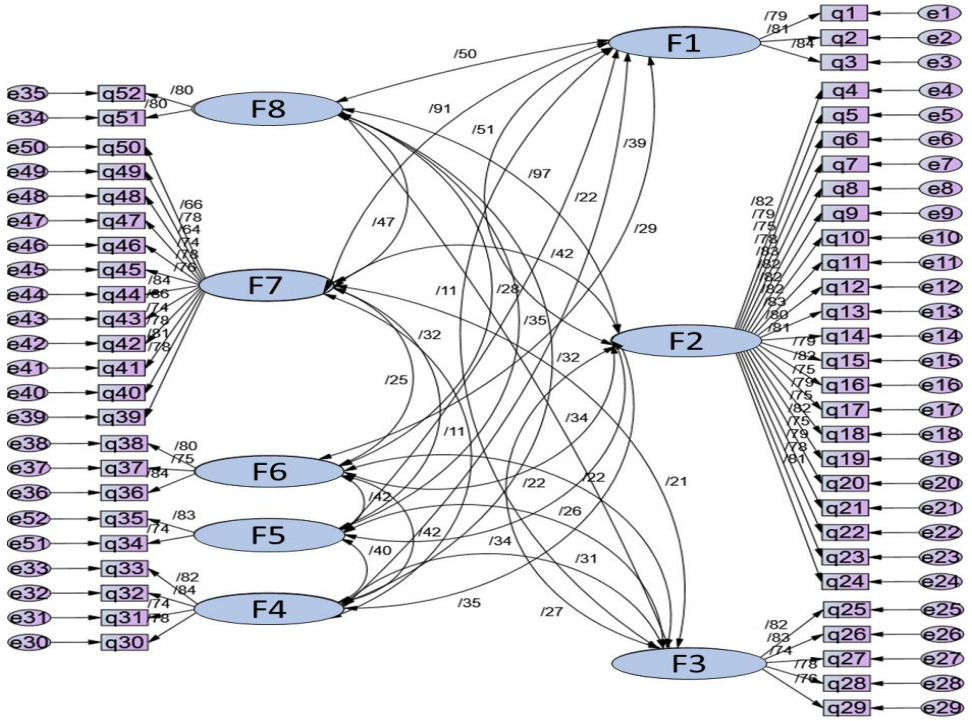

Figure 3: The First-Order Confirmatory Factor Analysis for Iraq

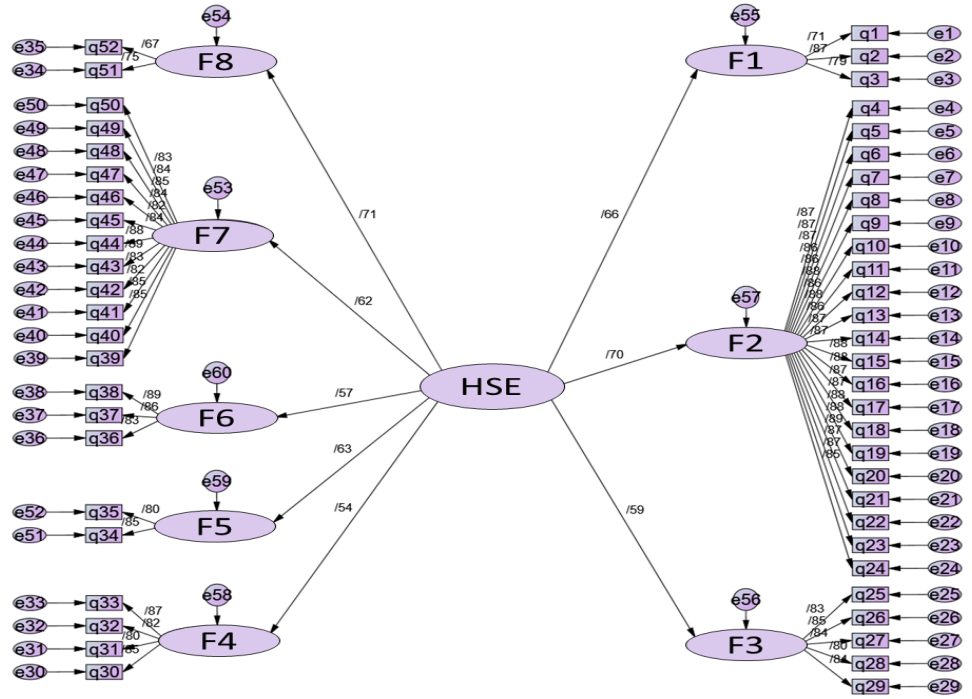

Figure 4: The Second-Order Confirmatory Factor Analysis for Iran

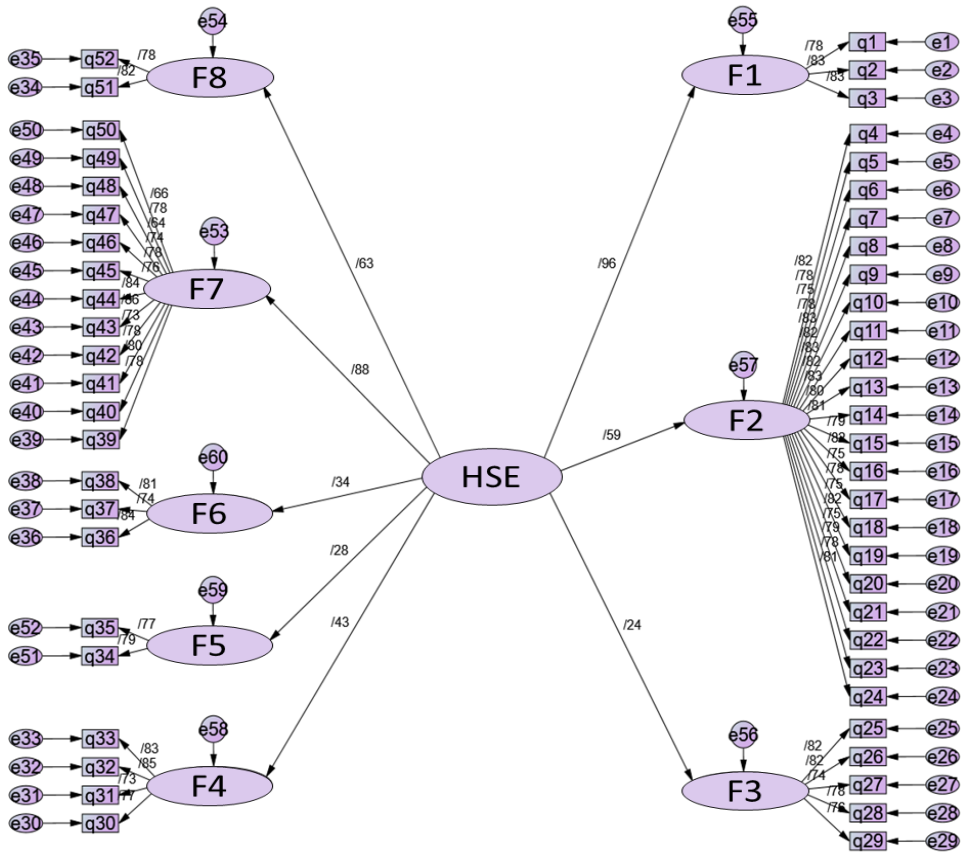

Figure 5: The Second-Order Confirmatory Factor Analysis for Iraq

4.2 Model Fit Indices

To verify the factor analysis model and document the resultant outcomes, it is imperative to assess the model's fit indices for acceptability. The ensuing tables present the pertinent indices alongside their respective values. Tables 7 and 8 present the appropriate indices of the factor analysis model corresponding to the countries of Iran and Iraq, respectively.

Table 7: Fit indices of the factor analysis model related to the country of Iran

Checked Indicators	Latin Symbol	Standard Rate		Estimated Value
Chi-Square/Degree of Freedom	(x2/ df)	Less than 3	Carmines and McIlver (1981)	1.081
Root Mean Square Error of Approximation	(RMSEA)	less than 0.08	Haier et al. (1998)	0.020
Comparative Fit Index	(CFI)	More than 0.9	Bentler and Bonnet (1980)	0.99
Incremental Fit Index	(IF)	More than 0.9		0.99
Goodness-of-Fit	(GFI)	More than 0.8		0.88

Furthermore, the significance coefficients of T and standardized path coefficients between Health, Safety management, and the environment and their constituents are

delineated in the subsequent table. As depicted, the t-statistic of HSE management with its components is deemed significant, surpassing 1.96. Hence, it is inferred that health, safety, and environment management can be subdivided into eight subsets or sub-components. Moreover, the Cronbach's alpha coefficient of the entire questionnaire exceeds 0.7, indicating favourable reliability of the constructs. Tables 9 and 10 exhibit the standardized factor loading value and t-statistics between variables pertaining to Iran and Iraq, respectively.

Table 8: Fit indices of the factor analysis model related to the country of Iraq

Checked Indicators	Latin Symbol	Standard Rate		Estimated Value
Chi-Square/Degree of Freedom	(x2/ df)	Less than 3	Carmines and McIlver (1981)	1.515
Root Mean Square Error of Approximation	(RMSEA)	less than 0.08	Haier et al. (1998)	0.051
Comparative Fit Index	(CFI)	More than 0.9	Bentler and Bonnet (1980)	0.91
Incremental Fit Index	(IFI)	More than 0.9		0.91
Goodness-of-Fit	(GFI)	More than 0.8		0.88

The results of the confirmatory factor analysis ascertain that the factor loading between questionnaire items and related variables holds statistical significance, obviating the need for alterations or amendments to the questionnaire items. Additionally, the model fit indices and Cronbach's alpha value outcomes demonstrate desirability and reliability. Consequently, based on the collected data and with a 95% probability, it can be affirmed that the questionnaire items adequately measure the intended constructs.

Table 9: Standardized factor loading value and T-statistics between variables related to Iran

Variable	Components	Standardized Load Factor	The Amount of T	Level of Significance	Cronbach's Alpha	Rank	Result
HSE	F_1	/958	-	-	0/962	1	Optimal
	F_2	/593	7/339	***		4	Optimal
	F_3	/235	2/931	***		8	Optimal
	F_4	/433	5/178	***		5	Optimal
	F_5	/276	2/907	***		7	Optimal
	F_6	/342	4/126	***		6	Optimal
	F_7	/884	9/391	***		2	Optimal
	F_8	/625	6/841	***		3	Optimal

NOTE: Dark lines in T values indicates fixing that parameter in the model.

The crux of the statistical analysis in the fourth chapter lies in scrutinizing the assumptions and addressing the research hypotheses at the core of the study. Following the description of demographic and main variables, and the evaluation of questionnaires through confirmatory factor analysis, this segment of the research employs path analysis technique to probe the research hypotheses. The determination regarding the acceptance or rejection of these hypotheses hinges upon statistical values. Specifically, the T-VALUE is pivotal in this regard: if the t-value surpasses 1.96,

the corresponding hypothesis is affirmed; conversely, if it falls below 1.96, the hypothesis is deemed non-significant.

Table 10: Standardized factor loading value and T-statistics between the variables related to the country of Iraq

Variable	Components	Standardized Load Factor	The Amount of T	Level of Significance	Cronbach's Alpha	Rank	Result
HSE	F_1	/660	-	-	0/970	3	Optimal
	F_2	/704	6/253	***		2	Optimal
	F_3	/586	5/526	***		6	Optimal
	F_4	/544	5/293	***		8	Optimal
	F_5	/630	5/542	***		4	Optimal
	F_6	/573	5/423	***		7	Optimal
	F_7	/623	5/836	***		5	Optimal
	F_8	/708	5/482	***		1	Optimal

Subsequent to the significance testing, it is imperative to scrutinize the magnitude and direction of relationships between variables, which is facilitated through examination of standardized factor loading coefficients. Positive path coefficients signify direct relationships between endogenous and exogenous latent variables, whereas negative path coefficients (negative beta) indicate inverse relationships between these variables.

Table 11: The Results of Examining the Effect of Variables on Each Other in Iran

Hypotheses	Critical Ration (CR)	Level of Significance	Beta	Result
R1	4.625	0	0.41	Confirmed
R2	3.001	0.009	0.33	Confirmed
R3	2.88	0.012	0.25	Confirmed
R4	3.354	0	0.37	Confirmed
R5	3.125	0	0.36	Confirmed
R6	8.054	0	0.71	Confirmed
R7	6.021	0	0.44	Confirmed
R8	4.852	0	0.42	Confirmed
R9	5.935	0	0.43	Confirmed
R10	4.71	0	0.4	Confirmed
R11	5.688	0	0.42	Confirmed
R12	4.097	0	0.29	Confirmed
R13	8.123	0	0.76	Confirmed
R14	5.052	0	0.39	Confirmed
R15	5.081	0	0.38	Confirmed
R16	3.411	0	0.34	Confirmed
R17	5.046	0	0.44	Confirmed
R18	1.062	0.122	0.14	Rejected
R19	4.378	0	0.33	Confirmed
R20	2.936	0.01	0.28	Confirmed
R21	4.775	0	0.44	Confirmed
R22	4.077	0	0.32	Confirmed
R23	4.086	0	0.35	Confirmed
R24	5.392	0	0.47	Confirmed
R25	2.314	0.002	0.33	Confirmed
R26	5.392	0	0.33	Confirmed
R27	5.001	0	0.41	Confirmed
R28	2.525	0.003	0.3	Confirmed

The outcomes pertaining to the examination of relationships between variables for Iran and Iraq are delineated in Table 11 and 12, respectively.

The SEM results are outlined as follows: Despite the similarities observed in SEM variables related to HSE management improvement across multi-level and administrative construction projects, discernible differences emerged due to distinct parameters such as national laws and cultural contexts. Notably, organizational culture's impact on HSE implementation significantly influences the integrated HSE management system in Iraq, whereas no such correlation is evident in Iran. Conversely, the corporate culture variable's influence on HSE implementation significantly affects the resources necessary for successful task execution and process completion in Iran but not in Iraq. Similarly, while organizational culture significantly affects the importance and adequacy of the environment in Iran, this relationship is not mirrored in Iraq. Furthermore, the capacity and suitability of the environment significantly impact health compliance at the project level in Iran, a relationship not observed in Iraq. A pivotal inference drawn from this model underscores the divergence in variable relationships between different countries, attributable to myriad factors including cultural norms and national legislation.

Table 12: The Results of Examining the Effect of Variables on Each Other in Iraq

Hypotheses	Critical Ration (CR)	Level of Significance	Beta	Result
R1	6.59	0	0.52	Confirmed
R2	2.434	0.014	0.22	Confirmed
R3	4.61	0	0.38	Confirmed
R4	2.368	0.021	0.21	Confirmed
R5	3.58	0	0.3	Confirmed
R6	10.85	0	0.91	Confirmed
R7	5.524	0	0.5	Confirmed
R8	3.504	0	0.27	Confirmed
R9	4.538	0	0.35	Confirmed
R10	3.672	0	0.35	Confirmed
R11	1.849	0.115	0.13	Rejected
R12	5.697	0	0.42	Confirmed
R13	9.646	0	0.87	Confirmed
R14	3.921	0	0.32	Confirmed
R15	2.66	0.009	0.21	Confirmed
R16	4.748	0	0.32	Confirmed
R17	2.825	0.006	0.27	Confirmed
R18	2.658	0.009	0.22	Confirmed
R19	4.088	0	0.32	Confirmed
R20	3.489	0.01	0.32	Confirmed
R21	4.249	0	0.4	Confirmed
R22	5.027	0	0.42	Confirmed
R23	4.435	0	0.42	Confirmed
R24	2.152	0.032	0.19	Confirmed
R25	3.729	0	0.36	Confirmed
R26	3.145	0	0.25	Confirmed
R27	1.85	0.119	0.16	Rejected
R28	1.732	0.15	0.13	Rejected

Both the SEM and the data were closely examined in order to confirm and corroborate the study conclusions. To guarantee data integrity, first the number and calibre of the items representing the variables were carefully assessed. The study was

further given legitimacy by the knowledge and experience of the many specialists engaged in it, especially in the field of HSE management in building projects. First-order confirmatory factor analysis (CFA) was then used, using the AMOS24 and SPSS24 software platforms, to examine the validity and dependability of the questionnaires and the results. This extensive validation procedure helped to strengthen the reliability and solidity of the study results.

Cronbach's alpha was used to evaluate the instrument used for data collecting. The Delphi technique was also used to evaluate the validity and reliability of the data, which indicate the suitability and adequacy of the items in characterizing the variables. This required speaking with 10 specialists—a quantity usually considered sufficient for Delphi-based evaluations—who had the greatest degree of experience and the necessary credentials.

Experts from a few carefully chosen projects in each nation participated in intensive review sessions to verify the final model. This cooperative endeavor was to find any disparities or places that needed improvement. Where revisions were judged required, the data used, the review procedure, and the conclusions were all thoroughly reevaluated. Importantly, (Kang & Ahn, 2021) checklist was used to qualitatively validate and finalize the variables throughout the investigation.

5. Conclusion

In two developing countries, Iran and Iraq, this research attempted to investigate the factors affecting the improvement of HSE management within residential and office building projects. In both cases, similar factors were found via a thorough synthesis of the body of research and practical investigation. Furthermore, a research on the relational dynamics among these variables in the different countries was carried out using SEM. Though there are significant differences in a few instances, overall the results point to a mostly similar pattern in the interactions between factors. Remarkable among the contributing causes of these differences are the legal systems and cultural quirks that each nation has. As such, one important lesson emphasizes the need of carefully taking into account research that is particular to the area in HSE management implementation projects. Even although research in poor countries is growing, in-depth studies are necessary because of the intricacy of HSE dynamics. The pursuit of thorough questions becomes essential in ensuring correct results given the multitude of known and hidden elements that may cause changes in relationship dynamics.

5.1 Contribution to the Field

With an emphasis on Iran and Iraq, this research advances knowledge of the elements affecting the improvement of HSE management in building projects for homes and offices in developing countries. This work clarifies, by the use of SEM and a thorough investigation, that while the factors found showed similarities in both nations, differences in the correlations between these variables sometimes surfaced. This awareness emphasizes the influence of cultural differences and the consequences of different legal systems and norms that each country follows. An important conclusion of this study is the need of thorough research customized to the particular circumstances of every nation as such efforts may reveal important elements causing

differences in the correlations between variables. The need of managers carefully considering the unique cultural, legal, and regulatory environments of each nation when implementing HSE management practices is highlighted by this study, which also provides priceless advice for the efficient application of HSE procedures in a variety of developmental environments. Thus, the originality of this work is found in its thorough examination of the literature, which tries to answer two basic questions about HSE management in building projects. It emphasizes first and foremost the need of identifying the complex elements influencing HSE in this field in order to improve the effectiveness of decision-making procedures. Second, it carefully explains how these elements interact to reveal the complex dynamics that are part of HSE governance in building projects. This work makes a groundbreaking addition to the academic conversation on HSE management in construction settings by means of a systematically organized investigation including a literature review, methodological explanation, empirical observations, and scholarly debates.

5.2 Study Limitations

Though the research concentrated on office and residential building projects in Iraq and Iran, other areas or construction settings may not easily be able to apply the results. The sample size and breadth of the research could restrict the conclusions' wider application. Despite best attempts to take into consideration the cultural variations between Iran and Iraq, there could be subtleties unique to each nation that were not adequately accounted for. SEM has drawbacks even if it is a powerful analytical technique, like sample size constraints and assumptions about data distribution. Problems like respondent bias or missing data might have impacted the validity of the findings even with careful data collecting and analysis.

6. Future Research Directions

Longitudinal research may reveal HSE management strategies' temporal dynamics and efficacy. Comparative investigations across several nations or areas may reveal cultural and contextual aspects affecting construction HSE management. Qualitative studies like interviews and focus groups may enhance quantitative evaluations of stakeholders' HSE management viewpoints. Integrating developing technologies like BIM or IoT into HSE management might improve construction project safety. Government agencies, industry groups, and community leaders may work together to solve HSE issues and promote construction industry best practises.

7. Conflict of interest

The authors reported no conflicts of interest.

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