Vol.6, Issue 4, pp.1261-1273, 2025
DOI: https://doi.org/10.62754/ais.v6i4.748

https://journals.ap2.pt/index.php/ais/index

Proposed Strategies for Improving Safety Management in Irrigation Projects Based on SWOT–AHP

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Abstract

This research aims to improve safety management in irrigation projects and identify the most suitable strategies for project implementation that enhance their potential to promote safety and development. To achieve this, the SWOT-AHP methodology was used, which enabled us to identify six strategies: (1) Establishing a centralized digital system for documenting, analyzing, and reporting incidents; (2) Implementing comprehensive specialized training programs (HSE, ISO 45001, OSHA) for engineers and technicians in cooperation with recognized international organizations; (3) Upgrading outdated equipment and introducing modern maintenance techniques to enhance reliability and reduce operational risks; (4) Aligning Iraqi safety law with international standards and directly integrating safety requirements into contract documents; (5) Improving monitoring and follow-up mechanisms by activating the role of the occupational safety and health unit and using technology-supported inspection tools; (6) Strengthening cooperation with universities and research centers to develop advanced methodologies in safety engineering and specially designed training modules. CR = 0.093 <10% is accepted,The sensitivity analysis demonstrates that the model is structurally stable Opportunities (O3) and strengths (S1) emerged as the most influential factors, confirming their critical role in enhancing overall safety-management performance . These strategies have been formulated so that they can be implemented by any entity, whether public or private.

Keywords: *safety management; sensitivity analysis; SWOT-AHP; strategy*

Introduction

Safety management has become a critical pillar in the successful implementation of infrastructure projects worldwide. While extensive research has been conducted on safety practices in general infrastructure projects, the specific domain of irrigation projects—particularly in developing countries such as Iraq—has received insufficient scholarly attention. Irrigation projects present distinctive challenges, including environmental variability, specialized equipment requirements, and complex operational procedures that differ significantly from conventional construction contexts.In recent decades, safety management infrastructure sectors have gained significant attention from governments and international organizations such as the International Labour Organization (1), the World Health Organization(WHO), (2) and ISO. For instance, the 1985 ILO conference in Geneva emphasized that work must be performed in a safe and healthy environment, consistent with human dignity, supported by safety policies at both governmental and institutional levels(3) . Accident analysis in irrigation infrastructure projects reveals that most incidents are due to human error or negligence. These include insufficient design for integrated safety, inadequate provision of protective measures, failure of workers to follow safety protocols, managerial shortcomings in staffing and supervision, lack of regular maintenance, and weak enforcement of legal safety requirements. Legal authorities also often fall short in monitoring construction activities (4).The consequences of accidents are far-reaching, affecting workers, employers, and the national economy. Workers may lose income or suffer permanent disability, while employers bear financial losses and productivity setbacks. These, in turn, impact national production and economic growth. Preventing accidents and embedding safety into the operational culture is critical. Research confirms that most workplace accidents are preventable through scientific safety practices. Studies (5)(6) demonstrate that unsafe acts and conditions—rather than natural disasters—account for over 98% of construction-related accidents.Effective safety management includes risk assessment, accident root cause analysis, and behavior-based interventions. Globally accepted guidelines support establishing a comprehensive safety management system. Prior to the

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1970s, formal safety regulations were scarce. However, the establishment of OSHA significantly improved safety standards in construction (1)(7).developed countries have adopted advanced safety systems to strive for zero-accident rates, supported by continuous improvement programs and incentives. In contrast, developing nations still struggle with weak enforcement and low safety awareness(8)(9) .The irrigation projects play a pivotal role in sustainable development and economic progress. Yet, it involves diverse and dynamic hazards—such as varying site conditions, heavy equipment use, and worker behavior—that require strategic safety interventions(9,10).Work accidents often result from poor supervision, non-compliance with PPE use, ineffective site management, difficult work environments, and limited safety knowledge among workers(11)(12)(13). Additionally, frequent equipment movement, inappropriate material handling, and communication breakdowns exacerbate risks.The irrigation projects are frequently criticized for their weak safety performance. Traditional beliefs that risk is intrinsic to construction work have led to lax safety behaviors and resistance to precautionary measures. Yet, integrating a strong safety culture and focusing on proactive risk controls—rather than merely reactive responses—can substantially improve outcomes(14)(15). Safety performance should be assessed using leading indicators such as safe behavior, not just lagging indicators like accident frequency. Safety management should encompass all elements—policies, roles, responsibilities, standards, procedures, tools, and data—necessary to ensure on-site safety (16) .In developing countries, safety implementation often suffers from illiteracy among workers, lack of institutional support, insufficient safety enforcement, and limited access to training and protective equipment(17) . Although the construction sector employs a large workforce, occupational safety activities are often neglected.Several studies have stressed the importance of safety planning during both execution phases to prevent recurring hazards(18)(19). However, despite the introduction of formal safety frameworks, accident rates in infrastructure projects remain high. This study seeks to bridge this gap by developing a comprehensive safety management framework specifically designed for irrigation projects. Methodologically, the study employs SWOT strategy and AHP to suitable strategy to improving safety management during external and internal factors . In terms of practical contribution, the findings provide implementable recommendations aimed at policy makers, engineers, and project managers, ensuring that alternative safety strategies are effectively translated into field-level applications.by addressing a largely neglected area in the literature, this research not only enhances the theoretical understanding of safety management in irrigation projects but also offers actionable recommendations for improving occupational safety and operational efficiency in similar contexts worldwide.

SWOT Analysis

Since its inception in the early 1980s, SWOT analysis has gradually matured. It studies the internal strengths and weaknesses of an projects and emphasizes the opportunities and threats presented by the environment in which the organization operates (20).This holistic qualitative analysis is a valuable tool for strategic planning. By systematically matching strengths with opportunities (SO), weaknesses with opportunities (WO), strengths with threats (ST), and weaknesses with threats (WT), the analysis yields appropriate and rational development strategies.

. The four parameters involved in SWOT analysis could be defined as:

- Strengths: Internal attributes and resources that support a successful outcome.
- Weaknesses: Internal attributes and resources that work against a successful outcome.
- Opportunities: External factors that the entity can capitalize on or use to its advantage.
- Threats: External factors that could jeopardize the entity's success.

The above four pieces of information can be grouped into two main classes:

- Internal factors: The strengths and weaknesses associated with the internal environment of system.
- External factors: The opportunities and threats associated with the external environment of system.

The SWOT analysis thus allow an project to recognize and plan to utilize the system strengths to exploit available opportunities in the external environment and to identify their weaknesses, and secure against any known threats. The objectives of the SWOT to maximize the strengths and opportunities, and minimize the weaknesses and threat, by turning the recognized weaknesses into strengths, and to get the benefit of opportunities (21).

AHP

The Analytic Hierarchy Process (AHP) is an analytical method used for quantitatively modeling complex problems. This method combines qualitative and quantitative analyses by initially decomposing the problem to be analyzed into multiple criteria and sub-criteria based on logical relationships. By determining the weights of these criteria across different levels and computing pairwise comparison matrices, AHP facilitates the determination of the overall weights for different decision alternatives, ultimately leading to the optimalsolution for the target problem (22). In the construction industry, AHP has been employed to prioritize unresolved challenges(23). It is also utilized in analyses of construction safety management(24) , helping to systematically evaluate various factors that influence safety and decision-making in construction projects. This structured approach allows stakeholders to make more informed and effective decisions by quantifying the relative weights of each factor involved in the project process.

SWOT-AHP

SWOTanalysis provides fundamental and relevant strategies; however, its capability to assess the importance of each factor is limited, and it does not facilitate quantitative analysis for priority ranking. When combined with the Analytic Hierarchy Process (AHP), however, it becomes possible to quantitatively estimate the importance of each factor in decision-making, thereby maximizing the strengths of both analytical methods. SWOT AHPtechnology has been widely applied across various sectors in numerous countries and regions globally, demonstrating its extensive utility as a decision support tool. This methodology has been instrumental in identifying key factors involved in improvment safety management , table 1 shown previous studies .

Table 1. summarized previous studies using the SWOT-AHP method

Authors and Year	Industry	Purpose
(25)	Forestry	achieving sustainable forest management, emphasizing its potential to align stakeholder interests and enhance forest conservation efforts
(26)	Industrial Company	Assessing the current situation
(27)	satellite and space	accelerating the growth of the satellite industry
(28)	Agricultural	appraise the factors for smooth assimilation of Climate Smart Agriculture (CSA)
(29)	Construction	Development of a comprehensive decision-support framework that enhances the sustainability, resilience, and efficiency of material logistics
(30)	private investment	identifying private stakeholder's investment criteria

In this study, SWOT–AHP analytical was employed to develop rigorous and evidence-based strategies aimed at improving safety management within irrigation projects. the present study adopts an expanded capable of capturing the full complexity of safety performance in irrigation environments. strategy allows for a deeper assessment of internal and external factors—including human, equipment-related, managerial, material, and environmental dimensions—and quantitatively evaluates their relative influence through expert judgment . the proposed strategies enables a more precise prioritization of strategic alternatives and provides clearer, actionable recommendations for strengthening safety governance, and reducing accident risks. This holistic analytical approach significantly improves the robustness of strategic planning and supports informed decision-making toward establishing a sustainable and resilient safety management in irrigation projects.

Methodology

The data collection process in this study was conducted through approaches, including field observations, semi-structured interviews with ten subject-matter experts (senior engineers, project managers), and a structured questionnaire survey. The questionnaire was administered in two sequential phases to ensure to detetrmine of the strategy for improving safety management in irrigation projects.in the first phase, a questionnaire containing was distributed to identify and evaluate the internal and external factors affecting safety performance in irrigation projects. The responses were analyzed using the SWOT framework, to generate weighted sub-criteria related to strengths, weaknesses, opportunities, and threats specific to irrigation project environments in Iraq. The second phase of the questionnaire was designed to prioritize strategic alternatives aimed at reducing safety risks and enhancing operational safety management. This phase involved pairwise comparisons of proposed strategies and was analyzed using the Analytical Hierarchy Process (AHP) to derive priority weights for each alternative. Additionally, secondary data were obtained from technical reports, relevant scientific literature. These sources provided contextual understanding of existing safety practices within the General commission for Maintenance Irrigation and Drainage Projects.Although several strategic alternatives emerged from the SWOT analysis, it is not feasible for all strategies to be implemented simultaneously due to administrative, financial, and operational constraints. Therefore, a structured prioritization process was required. The AHP method was applied to determine the most suitable and impactful safety improvement strategies, enabling decision-makers to select actions that address critical weaknesses while leveraging available opportunities. The sensitivity analysis will be used to evaluate the model's stability, identify the most influential indicators, and support decision-making by clarifying the factors that will have the greatest impact on safety-management outcomes.

SWOT-AHP Analysis Method

SWOT-AHP Analysis Method Step 1. Based on table 2,

Table 2 .Score Factors (22)

	Rating	**Meaning**		**Rating**	**Meaning**
(S)	4	Very strong strength	(W)	1	Severe weakness
	3	Strong strength		2	Moderate weakness
	2	Weak strength		3	Minor weakness
	1	Strength virtually nonexistent		4	Negligible / insignificant weakness
(O)	**Rating**	**Meaning**	(T)	**Rating**	**Meaning**
	4	Very high, highly exploitable opportunity		1	Very severe threat
	3	Significant opportunity		2	Major threat
	2	Limited opportunity		3	Moderate threat
	1	Weak opportunity		4	Minor / low-level threat

$$\text{Rating} = \frac{\sum \text{Expert assessments}}{N} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots..[1]$$

N = Number of Experts

$$GM_i = (P_i)^{\frac{1}{n}} \dots\dots\dots\dots\dots\dots\dots\dots\dots.\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.[5]$$

GMi = Geometric Mean

Pi = Expert assessments

n = Number of Experts

λ= AS $_{row(1,\dots,6)*}$ Table ( ) *X average Table ( )………...[2]

The eigenvalue (λ_i) = which is primarily used to evaluate the consistency of the pairwise comparison matrix in the Analytic Hierarchy Process (AHP).

AS = Number of Rows

$$Aij = \begin{pmatrix} a11 & \cdots & a1j \\ \vdots & \ddots & \vdots \\ ai1 & \cdots & aij \end{pmatrix} \qquad i = 1,2, \dots\dots..n \dots\dots\dots\dots\dots\dots\dots..[3]$$

The values calculated for RI are those provided by(22). The consistency indices for the randomly generated matrix are presented in table 3, n being the number of elements that are compared. To continue the AHP analysis the value obtained from the calculation for CR must be less or equal to 0.1

Table 3. Consistency indices for the randomly generated matrix(22)

n	3	4	5	**6**	7	8
RI	0.58	0.9	1.12	**1.24**	1.32	1.41

$$CI = \frac{\lambda\_\max \quad - n}{n - 1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ [3]$$

CI = Consistency Index

λmax = Maximum eigenvalue calculated from the matrix

n = Number of comparison elements

$$CR = \frac{CI}{RI} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ [4]$$

CR= Consistency Ratio (Saaty (0.10))

RI = Random Consistency Index (Empirical Simulation) as conducted by(22)

Results and Discussion

The identification of factors influencing strategic for improving safety management in irrigation projects was carried out through an integrated approach that included an extensive review of relevant literature, and direct engagement with experts through interviews and structured questionnaires. The selected informants—comprising senior engineers and techinical within the irrigation sector—were chosen based on their expertise and familiarity with the operational conditions and safety challenges addressed in this study.following the identification of key internal and external indicators, a SWOT-based questionnaire was developed to obtain expert assessments regarding the weights and ratings of each factor. The responses were analyzed to quantify the influence of the identified strengths, weaknesses, opportunities, and threats on safety performance. Based on expert evaluations, the study generated both an Internal Factor Analysis Summary (IFAS) and an External Factor Analysis Summary (EFAS), which are presented in the corresponding tables (tables 4,5,6,7). These matrices form the analytical foundation for determining the most appropriate strategic direction for enhancing safety management in irrigation project environments.

Table 4. Internal Strategy Factor Analysis (IFA)

Code	**Strength**	**Weight**	**Rating**	**(W × R)**
S1	Iraqi Safety Code	**0.22**	2	0.44
S2	Skilled Engineering and Technical Staff	**0.31**	3	0.93
S3	Occupational Safety & Health Unit	0.16	2	0.32
S4	Owned Specialized Equipment & Machinery	0.21	2	0.42
	Total Strength			**2.11**

Table 5. Internal Strategy Factor Analysis (IFA)

Code	**Weakness**	**Weight**	**Rating**	**(W × R)**
W1	Weak implementation of the Iraqi code	**0.24**	**3**	0.78
W2	Lack of specialized HSE training	0.18	**3**	0.45
W3	Lack of documentation system	0.21	**3**	0.60
W4	Outdated equipment & machinery	**0.22**	**3**	0.66
W5	Lack of monitoring and follow-up	0.17	**2**	0.41
	Total Weakness			**2.84**

Table 6. External Strategy Factor Analysis (EFA)

Code	Opportunities	Weight	Rating	(W × R)
O1	Align Iraqi code with ISO/OSHA	0.14	1	0.14
O2	Advanced training with OSHA/NEBOSH/FAO	0.2	2	0.39
O3	Modern maintenance techniques	**0.32**	3	0.97
O4	Cooperation with universities/research centers	**0.34**	4	1.37
	Total Opportunities			**2.87**

Table 7. External Strategy Factor Analysis (EFA)

Code	Threat	Weight	Rating	(W × R)
T1	Resistance to change	0.18	**2**	**0.35**
T2	Environmental risks	**0.19**	**2**	**0.38**
T3	Lack of legislation / penalties	0.15	**1**	**0.15**
T4	Funding	0.12	**1**	**0.12**
T5	Sudden breakdowns	**0.21**	**2**	**0.42**
T6	Weak safety culture	0.15	**1**	**0.15**
	Total Threats			**1.58**

With a combined score of 5.71, the WO strategy is the strongest option, indicating that significant external opportunities can be strategically utilized to address and overcome existing internal weaknesses.Table X provides an organized presentation of the strategies formulated from the SWOT analytical framework.

Table 8. SWOT Matrix

Internal Factors / External Factors	**Strength**	**Weaknesses**
	Iraqi Safety Code	Weak implementation of the Iraqi code
	Skilled Engineering and Technical Staff	Lack of specialized HSE training
	Occupational Safety & Health Unit	Lack of documentation system
	Specialized Equipment & Machinery	Outdated equipment & machinery
		Lack of monitoring and follow-up
	Total Weight S = 2.11	**Total Weight W = 2.84**
Opportunities	**S/O Strategies [S + O =4.98]**	**W/O Strategies[W + O =5.71]**
Align Iraqi code with ISO/OSHA	Strengthen compliance by integrating the Iraqi Safety Code with international standards (S1, O1)	Strengthen compliance with the Iraqi Safety Code through alignment with international standards (W1, O1)
Advanced training with OSHA/NEBOSH/FAO	Enhance professional capacity through advanced international training programs (S2, O2)	Establish specialized HSE training programs in collaboration with international organizations (W2, O2)
Modern maintenance techniques	Improve equipment reliability through modern maintenance technologies (S4, O3)	Develop a centralized digital documentation system for accidents and safety records (W3, O4)
Cooperation with universities/research centers	Promote innovation in safety practices through partnerships with academic and research institutions (S3, O4)	Upgrade outdated equipment and machinery using modern maintenance technologies (W4, O3)
Total Weight O= 2.87		Improve monitoring and follow-up systems through academic collaboration and modern inspection tools (W5, O4)
Threats	**ST/ Strategies[S + T =3.69]**	**WT/ Strategies [W + T =4.42]**
Resistance to change	Enforce the Iraqi Safety Code to counter weak safety culture and resistance to change (S1, T1, T6)	Strengthen enforcement mechanisms to compensate for weak implementation of the Iraqi safety code (W1, T3, T6)
Environmental risks	Leverage skilled engineering and technical staff to mitigate environmental and operational risks (S2, T2, T5)	Provide targeted HSE capacity-building programs to reduce vulnerability to operational and environmental risks (W2, T2, T6)
Lack of legislation / penalties	Activate and empower the Occupational Safety & Health Unit to address legislative gaps and safety enforcement challenges (S3, T3, T6)	Establish a unified accident documentation and reporting system to address resistance to change and limited oversight (W3, T1, T3)
Funding	Utilize specialized equipment and machinery to reduce exposure to environmental risks and minimize breakdown-related hazards (S4, T2, T5)	Replace or rehabilitate outdated equipment to prevent sudden breakdowns and reduce environmental exposure risks (W4, T2, T5)
Sudden breakdowns		Enhance monitoring and follow-up procedures to compensate for funding limitations and weak safety culture (W5, T4, T6)
Weak safety culture		
Total Weight T = 1.58		

The Weakness-Opportunity (WO) approach is the alternate strategy with the highest weight, as shown in Table 7.the quadrant position of the safety management system can be determined by plotting the internal and external strategic dimensions along the X and Y axes.

Calculation of the X-Axis (Internal Factors)

The X-axis represents the balance between strengths and weaknesses:

$$X = \sum(S) - \sum(W) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots [6]$$

From the study's quantitative weighting results:

- Total Strength Weight = 2.11
- Total Weakness Weight = 2.84

Thus:

$$X = 2.11 - 2.84 = -0.73$$

A negative X-value indicates that weaknesses outweigh strengths in the internal environment of the safety management system irrigation projects

Calculation of the Y-Axis (External Factors)

The Y-axis represents the balance between opportunities and threats:

$$Y = \sum(O) - \sum(T) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. [7]$$

From the results:

- Total Opportunity Weight = 2.87
- Total Threat Weight = 1.58

Thus:

$$Y = 2.87 - 1.58 = +1.29$$

A positive Y-value indicates the presence of promising opportunities in the external environment.

Quadrant Position Interpretation

When the calculated values are plotted:

- X = −0.73 (internal weaknesses dominant)
- Y = +1.29 (external opportunities dominant)

This places the safety management system of irrigation projects in Quadrant III of the SWOT strategic matrix.

Figure 1 provides information that the results of the irrigation projects SWOT analysis are in Quadrant III. This projects faces opportunities in managing large work safety. However, on the internal side, there are several obstacles. This condition shows an effort to minimize weaknesses to get opportunities. Or in other words, how to strive for development with conditions that favor the weakest conditions but can be used to capture opportunities

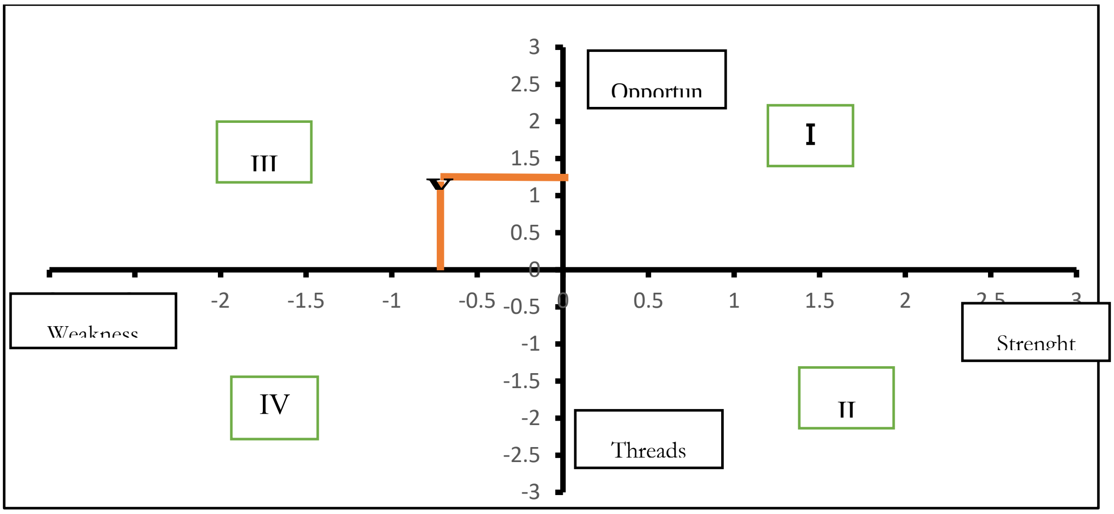

Figure 1. SWOT Analysis Diagram

Strategic Interpretation (Quadrant III – WO Strategy)

Quadrant III indicates:

- The internal environment suffers from critical weaknesses, such as outdated equipment, weak documentation, limited HSE training, and insufficient monitoring.
- The external environment offers strong opportunities, such as advanced training programs, alignment with international safety standards, modern maintenance technologies, and collaboration with academic institutions.

This combination confirms that the most appropriate strategy is:

Weakness–Opportunity (WO) Strategy

"Overcoming internal weaknesses by leveraging external opportunities."

Implications for Iraqi Irrigation Projects

The position in Quadrant III means:

- The organization must first reduce internal deficiencies in safety management.
- At the same time, it should take advantage of available opportunities such as training programs, international standards (ISO 45001, OSHA), and technical cooperation.
- This supports a development-oriented approach where weak internal systems can be strengthened through external institutional and technological support.

Thus, the strategic direction is towards capacity building, modernization, training enhancement, and integration of advanced safety practices.

Based on the SWOT analysis conducted for safety management in irrigation projects, the results indicate that the Weakness–Opportunity (WO) strategy is the most suitable approach. Therefore, several alternative strategic actions were formulated, derived from relevant literature and adapted to the actual operational conditions of irrigation projects under the Ministry of Water Resources. These recommended strategies aim to reduce the likelihood of safety incidents and enhance overall safety performance across irrigation project activities.Several alternative strategies are shown in table 9below.

Table 9. Proposed Alternative Strategies for Irrigation Project Safety Management (WO Strategy)

Code	Alternative Strategy
AS1	Establishing a centralized digital system for documenting, analyzing, and reporting accidents .
AS2	Implementing comprehensive specialized training programs (HSE, ISO 45001, OSHA) for engineers and technicians in collaboration with recognized international organizations.

Code	Alternative Strategy
AS3	Upgrading outdated equipment and introducing modern maintenance techniques to enhance reliability and reduce operational hazards.
AS4	Aligning the Iraqi safety code with international standards and integrating safety requirements directly into contract documents.
AS5	Enhancing monitoring and follow-up mechanisms by activating the role of the Occupational Safety and Health Unit and deploying technology-assisted inspection tools.
AS6	Strengthening collaboration with universities and research centers to develop advanced safety engineering methodologies and tailored training modules.

Based on in Table 9, the subsequent stage involves applying the AHP method to determine the most appropriate strategy. Accordingly, the hierarchical structure of the selection strategies to enhance safety management in irrigation projects is illustrated in figure 2.

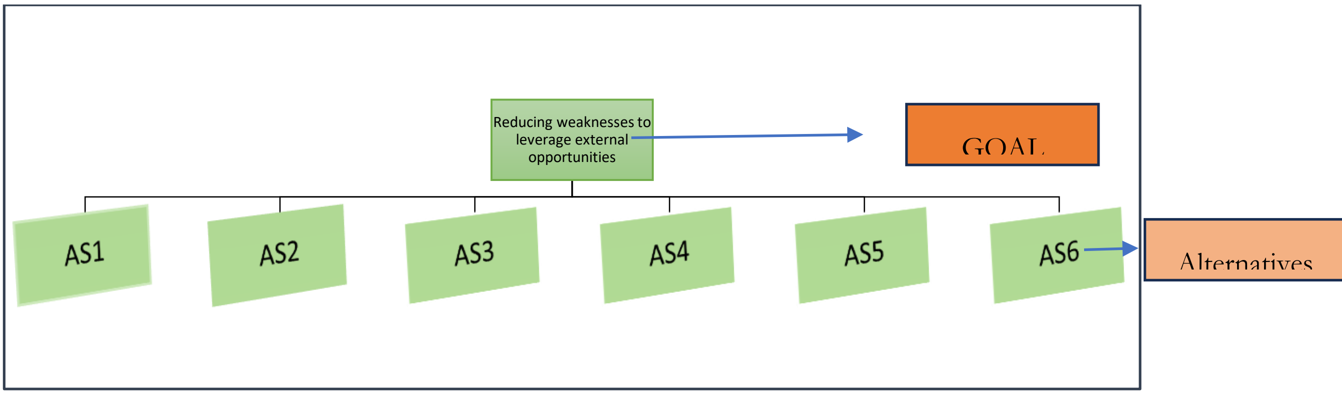

Figure 2. Hierarchical Structure of Alternatives (Researcher)

To determine the priority ranking of the proposed strategic alternatives derived from the SWOT–AHP integration, a second-stage questionnaire was administered to a panel of ten experts specializing in irrigation projects. Experts were asked to perform pairwise comparisons among the proposed WO strategies, using Saaty's fundamental scale.The individual pairwise comparison matrices were aggregated using the geometric mean method, which is the recommended approach for combining expert judgments in multi-criteria decision-making models. The resulting aggregated comparison matrix for the six proposed strategies in this study is presented in table 10.

Table 10. Results of Pairwise Comparison Matrix Using Geometric Mean

Alternatives	AS1	AS2	AS3	AS4	AS5	AS6
AS1	1	2.4	2.1	2.2	1.9	2.4
AS2	0.42	1	2.1	2.6	1.8	1.7
AS3	0.48	0.48	1	2.5	2.9	2
AS4	0.45	0.38	0.4	1	2.2	3.4
AS5	0.53	0.56	0.34	0.45	1	2.6
AS6	0.42	0.59	0.5	0.29	0.38	1
Total	3.29	5.40	6.44	9.05	10.18	13.1

The matrix was then normalized by dividing each cell value by the sum of its corresponding column. Based on this normalized matrix, the priority weights were obtained by calculating the mean (Ẋ) of each row. The normalized results are presented in table 10 below.

Table 11. Normalized Weight Pairwise Comparison Ratings

Alternatives	AS1	AS2	AS3	AS4	AS5	AS6	∑	X
AS1	0.30	0.44	0.33	0.24	0.19	0.18	1.69	0.28123721
AS2	0.13	0.19	0.33	0.29	0.18	0.13	1.23	0.20529994
AS3	0.14	0.09	0.16	0.28	0.28	0.15	1.10	0.18366480
AS4	0.14	0.07	0.06	0.11	0.22	0.26	0.86	0.14294097
AS5	0.16	0.10	0.05	0.05	0.10	0.20	0.66	0.11055514
AS6	0.13	0.11	0.08	0.03	0.04	0.08	0.46	0.07663919
Total	1.00	1.00	1.00	1.00	1.00	1.00	6.00	1.00

Based on Table 10, the Consistency Ratio (CR) is calculated. If the Consistency Ratio (CR) is smaller or equal to 10%, the matrix meets the requirements of consistency(31). Based on the calculation results, the CR value is around 0.093. The consistency value is ≤ 10%, the consistency value is acceptable.Based on the results of data processing that the hierarchical structure in Figure 2 has been consistent. This is proven by the consistency ratio that is smaller than 10%. table 12 shown Key indicators

Table 12. Results of Key indicators

n		*RI*	*CI*	*Total λ_max*	*CR*	
6		1.24	0.116	6.58	0.093	*Accepted*

The analysis further shows that among the six WO-focused alternative strategies designed for improving safety management in irrigation projects, the highest priority weight was assigned to AS1: Establishing a centralized digital system for documenting, analyzing, and reporting accidents . This strategy achieved the largest normalized weight (0.28 depending on your final table), indicating that experts view systematic documentation Analysis as the most critical requirement for reducing safety risks. Ranked second was AS2: Implementing specialized HSE/ISO/OSHA training programs, followed by AS3 (equipment modernization) Strategies AS4 and AS5 followed with slightly weights.AS6 (university collaboration to develop advanced safety-engineering methodologies with slightly lower weights).Regarding the strategic position derived from the SWOT analysis, the plotted values on the X and Y axes demonstrate that the safety management environment in Iraq's irrigation projects falls within Quadrant III (WO – Weakness–Opportunity strategy). This quadrant is characterized by internal weaknesses—such as insufficient training, outdated equipment, and gaps in accident documentation—combined with significant external opportunities, including international safety standards (ISO 45001, OSHA), modern maintenance technologies, and expanding partnerships with training institutions.This strategic position implies that the organization must prioritize minimizing internal weaknesses to capture available opportunities, which aligns with a "turnaround strategy." Similar to the findings of(32) , the WO strategy often emphasizes strengthening Occupational Health and Safety (OHS) evaluation systems to compensate for internal limitations.

To operationalize the selected WO strategy within irrigation project safety management, several stakeholders must contribute. These include project managers and supervisors responsible for oversight, the Occupational Safety and Health Unit tasked with monitoring and evaluation, and engineers and technicians whose compliance is essential for effective implementation. The first practical step involves establishing a dedicated OHS monitoring team to systematically supervise field activities and ensure alignment with established safety protocols.

Regular monitoring of equipment use, field operations, and adherence to safety procedures—supported by digital documentation—helps maintain compliance with updated safety instructions. The use of centralized digital records enables early detection of hazards, ensures accurate reporting.

Routine inspections, preventive maintenance actions, and immediate reporting of unsafe conditions are also incorporated into this improvement cycle.Furthermore, when deviations from safety procedures are detected, corrective measures are introduced progressively, starting with verbal notifications and escalating to formal written warnings when necessary. This structured enforcement mechanism aims to minimize non-compliance, thereby reducing the likelihood of accidents across irrigation project sites.Overall, the integration of SWOT and AHP results confirms that focusing on WO strategies, particularly the implementation of a digital safety documentation and monitoring system (AS1), represents the most effective pathway for enhancing occupational safety performance in Iraq's irrigation infrastructure projects as .

Table12 displays the process and results of the sensitivitya nalysis. The primary purpose of sensitivity analysisis to assess the stability of the model under different scenarios by adjusting the weights of key indicator supanddown.This analysis helps identify which factors have asignificant impact on safety improvement in irrigation projects ,there by verifyingt he robustness oft he model results and Providing data support for future strategic recommendations.Based on the results of the SWOT analysis,the weights of key indicators are adjusted by±10% to assess their impact on the overall SWOT score , as shown in figure3

Table13.Sensitivity Analysis Process and Results

SWOTCategory	Adjusted Indicator	Original Weight	AdjustedWeight Range(±10%)	Score Range	Rangeof Variation
Strengths	S1	0.22	[0.198,0.242]	[0.477,0.583]	0.106
	S2	0.31	[0.279,0.341]		
Weakness	W1	0.24	[0.216,0.264]	[0.414,0.488]	0.074
	W4	0.22	[0.198,0.242]		
Opportunties	O3	0.32	[0.288,0.352]	[0.594,0.726]	0.132
	O4	0.34	[0.306,0.374]		
Threads	T2	0.19	[0.171,0.209]	[0.36,0.44]	0.08
	T5	0.21	[0.189,0.231]		

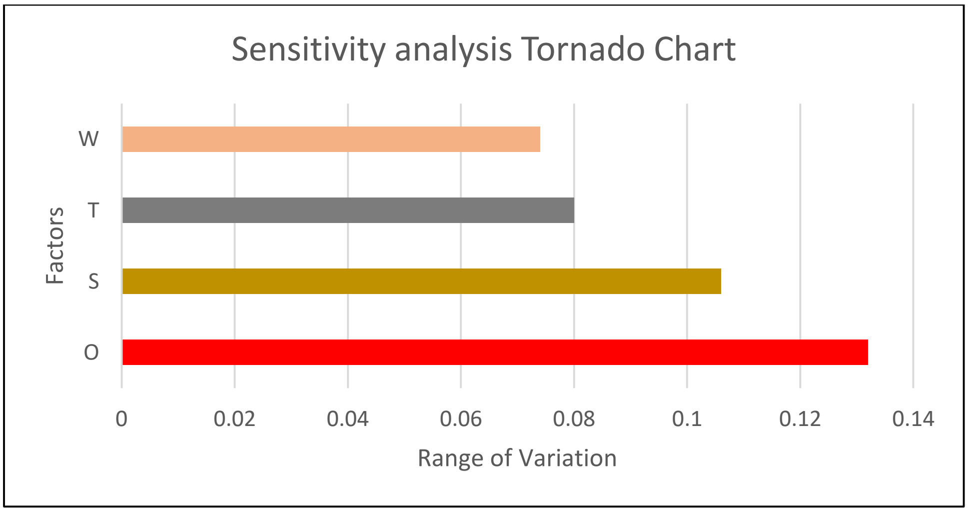

Figure 3. Sensitivity analysis Tornado Chart

The sensitivity analysis of the SWOT indicators, after adjusting their weights within a ±10% range, revealed notable variations in their influence on the model's outcomes. The O3 (Opportunities) indicator exhibited the highest sensitivity, with a range of variation of 0.132, highlighting the critical role of opportunities associated with the integration of artificial intelligence technologies in enhancing the performance of safety management systems. The S1 (Strengths) indicator also demonstrated a relatively high level of sensitivity, with a variation of 0.106**,** reflecting its significance in strengthening internal system capabilities and improving risk-management efficiency. Meanwhile, the T2 (Threats) indicator showed a moderate sensitivity level of 0.08**,** whereas the W1 **(**Weaknesses) indicator recorded the lowest variation of 0.074, indicating its relative stability compared to other indicators. Collectively, these results suggest that the model maintains a strong degree of structural stability, with opportunities and strengths emerging as the most influential components in improving overall safety-management outcomes.

Conclusion

Based on the strategic processes conducted in this study—integrating SWOT analysis with the Analytic Hierarchy Process (AHP)—it can be concluded that the primary contributors to safety risks in irrigation projects are internal weaknesses, particularly the lack of specialized safety training, outdated equipment, insufficient accident documentation, and weaknesses in monitoring and emergency preparedness. After evaluating all internal and external factors, the most suitable strategic orientation for improving safety performance was identified as the Weakness–Opportunity (WO) strategy, which focuses on minimizing internal limitations by leveraging available external opportunities such as international safety standards, modern maintenance technologies.Using the AHP method to prioritize alternative strategies within the WO approach, the analysis showed that the highest-ranked option was AS1: Establishing a centralized digital system for documenting, analyzing, and reporting accidents , with a priority weight close to 0.28 and a consistency ratio (CR) of 0.093, indicating an acceptable level of expert judgment consistency. This result highlights the critical importance of developing a unified and data-driven safety documentation system as a foundation for preventing recurrent incidents in irrigation projects . The sensitivity analysis demonstrates that the model is structurally stable, with only limited variation resulting from ±10% changes in indicator weights. Opportunities (O3) and strengths (S1) emerged as the most influential factors, confirming their critical role in enhancing overall safety-management performance.

Recommendations

strengthening monitoring and evaluation mechanisms within project sites, conducting routine inspections and preventive maintenance for field equipment, and updating operational procedures in alignment with Iraqi and international safety standards. Additionally, future research is recommended to explore advanced digital tools and predictive safety models to further enhance risk management capabilities and support long-term improvements in occupational safety within Iraq's irrigation infrastructure sector.

References

1. Thomas H, Turnbull P. From horizontal to vertical labour governance: The International Labour Organization (ILO) and decent work in global supply chains. Hum Relations. 2018;71(4):536–59.
2. Dobson A. Section 37 of the Health and Safety at Work Act 1974 - re-invigorated. Int J Law Manag. 2013;55(2):141–55.
3. Neupane P, Hamzeh F. SAFETY CULTURE IN CONSTRUCTION. In: Conference of the International Group for Lean Construction (IGLC31). 2023. p. 365–76.
4. Choudhry RM, Fang D, Lingard H. Measuring safety climate of a construction company. J Constr Eng Manag. 2009;135(9):890–9.
5. Sunindijo RY, Zou PXW. How project manager's skills may influence the development of safety climate in construction projects. Int J Proj Organ Manag. 2012;4(3):286–301.
6. Issa Y, Aisheh A, Tayeh BA, Alaloul WS, Almalki A. Health and safety improvement in construction projects : a lean construction approach. Int J Occup Saf Ergon [Internet]. 2021;0(0):1–13. Available from: https://doi.org/10803548.2021.1942648
7. Nowobilski T. Methodology based on causes of accidents for forcasting the effects of falls from scaffoldings using the construction industry in poland as an example ˙ ena Ho ł a. Saf Sci. 2023;157(June 2022).
8. Raheem AA, Issa RRA. Safety implementation framework for Pakistani construction industry. Saf Sci. 2016;82:301–14.
9. Segbenya M, Yeboah E. Effect of occupational health and safety on employee performance in the Ghanaian construction sector. Environ Health Insights. 2022;16:11786302221137222.
10. Zhou Z, Goh YM, Li Q. Overview and analysis of safety management studies in the construction industry. Saf Sci. 2015 Feb 1;72:337–50.
11. Ayob A, Shaari AA, Zaki MFM, Munaaim MAC. Fatal occupational injuries in the Malaysian construction sector–causes and accidental agents. In: IOP Conference Series: Earth and Environmental Science. IOP Publishing; 2018. p. 12095.
12. Mohammadi A, Tavakolan M, Khosravi Y. Factors influencing safety performance on construction projects: A review. Saf Sci. 2018;109:382–97.
13. Samanta S, Gochhayat J. Critique on occupational safety and health in construction sector: An Indian perspective. Mater Today Proc. 2023;80:3016–21.

14. M.N.U. J et al. GLOBAL RESEARCH TREND EVOLUTION IN OCCUPATIONAL HEALTH AND SAFETY OVER THE PAST DECADE. In: e International Conference on Facilities Management Futures 2025. 2025. p. 199–209.
15. Berglund L, Johansson J, Johansson M, Nygren M, Stenberg M. Exploring safety culture research in the construction industry. Work. 2023;76(2):549–60.
16. Amjad U, Wajahat M, Khawaja A. Influence of National Culture on Construction Safety Climate in Peshawar. Univ Wah J Sci Technol. 2024;8:13–24.
17. Elsebaei M, Elnawawy O, Othman AAE, Badawy M. Causes and impacts of site accidents in the Egyptian construction industry. Int J Constr Manag. 2022;22(14):2659–70.
18. Abid SK, Al- AM, Goniewicz K. Factors Affecting Safety Performance of Construction Projects : A Literature Review Factors Affecting Safety Performance of Construction Projects : A Literature Review. In.
19. Li Y, Guldenmund FW. Safety management systems: A broad overview of the literature. Saf Sci. 2018;103:94–123.
20. Rauch P. O RI G I NAL PAPE R SWOT analyses and SWOT strategy formulation for forest owner cooperations in Austria. Eur J For Res. 2006;
21. Nasiri A, Mehdi K. Comparative applicability of MCDM - SWOT based techniques for developing integrated watershed management framework. Nat Resour Model. 2023;(January):1–27.
22. Saaty TL. Decision making with the analytic hierarchy process. Int J Serv Sci. 2008;1(1):83–98.
23. Diar Q, Estate R, Company I. Prioritisation of lean construction barriers in Qatari context : a fuzzy AHP approach Abdulla Yaqoub Al Sayed * Dinesh Seth and Abdel Magid S . Hamouda. Int J Bus Excell. 2019;19(4).
24. Daoutis C, Kantartzis A, Tampekis S, Stergiadou A, Arabatzis G. The Application of SWOT-AHP Analysis in the Design and Construction of Forest Road Network. In: HAICTA. 2022. p. 0–2.
25. Limaei SM, Mozaffari Sahneh Saraei ST, Bonyad A, Mirzaei M. Integrated SWOT and AHP Analysis for Participatory Forest Management–a case study in Qazvin Province, Iran. Austrian J For Sci für das Gesamte Forstwes. 2024;141(4).
26. Popescu G, Gasparotti C. SWOT-AHP hybrid method for ranking the relaunching strategies of an industrial company *. 2022;27(4):709–30.
27. Lee J, Kim I, Kim H, Kang J. Technological Forecasting & Social Change SWOT-AHP analysis of the Korean satellite and space industry : Strategy recommendations for development. Technol Forecast Soc Chang [Internet]. 2021;164(November 2020):120515. Available from: https://doi.org/10.1016/j.techfore.2020.120515
28. Victoria M, Josmee R. Assessment of Factors on Assimilation of Climate Smart Agricultural Practices in the North Eastern Hill Region of India : A SWOT-AHP Analysis. 2022;12(11):3291–9.
29. Xiong P, Lee YS, Ezanee F, Ghazali M. AHP-SWOT-Based Factors for Optimising Material Handling in. 2025;1–31.
30. Gottfried O, Clercq D De, Blair E, Weng X, Wang C, Gottfried O, et al. SWOT-AHP-TOWS analysis of private investment behavior in the Chinese biogas sector. J Clean Prod. 2018;
31. Saaty TL, Vargas LG. Models, Methods, Concepts & Applications of the Analytic Hierarchy Process. Second Edi. Boston, MA: Springer US: Imprint: Springer,; 2012.
32. Andryaldo W. Evaluation Of The Application Of Occupational Safety And Health (K3) Procedures At PT. IPC During A Pandemic Using The analysis Method SWOT. In: Global Research on Sustainable Transport & LogisticS. 2021. p. 692–702.