



Nanotechnology-enabled occupational health and safety as a strategic driver of crisis management: An empirical study of electricity maintenance departments in Baghdad

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Received 5/4/2026, Received in revised form 2/8/2026, Accepted 5/9/2026, Published 15/10/2026

Occupational health and safety (OHS) has emerged as a strategic organizational function that contributes not only to employee protection but also to organizational resilience and crisis preparedness. Effective communication, meanwhile, plays a vital role in facilitating information exchange, coordination, and decision-making during emergency situations. This study investigates the impact of occupational health and safety on crisis management through the mediating role of effective communication in the Electricity Maintenance Departments of Baghdad, Al-Karkh. A quantitative descriptive–analytical approach is adopted, and data are collected using a structured questionnaire distributed to a comprehensive census sample of 56 managerial and supervisory employees, including department heads, division and unit supervisors, work supervisors, and team leaders. The study examined three principal constructs: occupational health and safety, effective communication, and crisis management. Data are analyzed using IBM SPSS Statistics and IBM SPSS Amos through descriptive statistics, reliability and validity assessments, confirmatory factor analysis, structural equation modeling (SEM), and mediation analysis. The results confirmed the adequacy and validity of the measurement models and revealed significant positive relationships among the study variables. Occupational health and safety are found to exert a direct positive effect on crisis management, indicating that organizations with stronger safety practices demonstrate greater preparedness, response capability, and recovery effectiveness during crises. Effective communication also showed a significant positive influence on crisis management by enhancing coordination, information credibility, communication speed, flexibility, and feedback mechanisms. Furthermore, occupational health and safety significantly improved effective communication, while mediation analysis confirmed that effective communication partially mediates the relationship between occupational health and safety

and crisis management. These findings emphasize the importance of integrating occupational health and safety systems with effective communication strategies to strengthen crisis preparedness, improve organizational resilience, enhance operational continuity, and support effective crisis management in high-risk electricity maintenance environments.

Keywords: Occupational health and safety; Nanosensors; Smart personal protective equipment; Effective communication; Crisis management.

1. INTRODUCTION

In today's highly dynamic and uncertain environment, organizations are increasingly exposed to a wide range of crises that threaten their operational continuity, employee well-being, financial stability, and organizational reputation. Crises may arise from technical failures, natural disasters, human errors, occupational accidents, security threats, or unexpected environmental conditions. Consequently, crisis management has become an essential managerial function that enables organizations to anticipate potential threats, minimize their adverse impacts, and ensure the continuity of operations during emergency situations. The effectiveness of crisis management largely depends on the organization's preparedness, availability of resources, and ability to coordinate responses among various stakeholders [1]. Occupational health and safety (OHS) represents one of the most important organizational systems that contribute to crisis prevention and preparedness. OHS encompasses policies, procedures, and practices designed to protect employees from workplace hazards while ensuring a safe and healthy working environment. Effective implementation of occupational health and safety measures not only reduces workplace accidents and occupational diseases but also enhances organizational resilience and preparedness for unexpected events [2]. Organizations that prioritize occupational health and safety are generally better equipped to manage crises because they possess established procedures, trained personnel, and preventive mechanisms that facilitate rapid response and recovery. In addition to occupational health and safety, effective communication plays a critical role in crisis management. During crisis situations, organizations must communicate accurate, timely, and reliable information to employees, managers, customers, and other stakeholders [3]. Effective communication facilitates coordination, supports decision-making, reduces uncertainty, and helps maintain trust among stakeholders. Furthermore, communication serves as a vital mechanism through which occupational health and safety information is disseminated, safety procedures are reinforced, and crisis response activities are coordinated [4]. Electricity maintenance departments represent one of the most critical service sectors due to the nature of their operations, which involve continuous exposure to occupational risks, technical failures, power outages, equipment malfunctions, and emergency situations. Employees working in these departments are frequently required to operate under hazardous conditions that necessitate strict adherence to occupational health and safety procedures.

Therefore, understanding how occupational health and safety practices contribute to crisis management through effective communication is of considerable practical and theoretical importance. This study investigates these relationships within the context of electricity maintenance departments in Baghdad, aiming to provide empirical evidence regarding the role of occupational health and safety and effective communication in enhancing crisis management capabilities [5]. Organizations operating in high-risk environments face increasing challenges associated with crisis prevention, preparedness, response, and recovery. Despite the growing importance of occupational health and safety systems, many organizations continue to experience difficulties in effectively managing crises due to weaknesses in safety practices, inadequate communication mechanisms, and insufficient coordination among organizational members. Such challenges become more evident in-service organizations whose activities directly affect public services and infrastructure, such as electricity maintenance departments. Although numerous studies have examined occupational health and safety and crisis management

independently, limited research has investigated the mechanisms through which occupational health and safety contributes to crisis management effectiveness. In particular, the mediating role of effective communication in strengthening this relationship remains insufficiently explored within developing countries and public service sectors. Consequently, there is a need to investigate how occupational health and safety practices influence crisis management and whether effective communication serves as a critical mechanism through which this influence occurs. Accordingly, the main research problem can be expressed through the following question: To what extent do occupational health and safety practices contribute to crisis management through effective communication in electricity maintenance departments in Baghdad [6].

The present study aims to investigate the impact of occupational health and safety practices on crisis management within electricity maintenance departments in Baghdad, with particular emphasis on the mediating role of effective communication. Specifically, the study seeks to examine the extent to which occupational health and safety measures contribute to improving organizational capabilities in managing crises and emergency situations. It also aims to explore the influence of effective communication on crisis management performance and to analyze the relationship between occupational health and safety practices and effective communication within the workplace. Furthermore, the study intends to determine whether effective communication serves as a mediating mechanism through which occupational health and safety enhances crisis management effectiveness. Ultimately, the research seeks to provide practical recommendations that support the development of safer work environments, strengthen communication processes, and improve organizational preparedness and responsiveness to crises in electricity maintenance departments [7].

The significance of this study can be examined from both theoretical and practical perspectives. This study contributes to the growing body of literature on occupational health and safety, effective communication, and crisis management by integrating these concepts into a comprehensive conceptual framework. The study enriches theoretical understanding of how occupational health and safety practices influence organizational crisis management capabilities and highlights the mediating role of effective communication in this relationship. Furthermore, the research provides empirical evidence from the electricity maintenance sector, which has received limited attention in previous studies, thereby extending existing knowledge within the fields of organizational management and occupational safety. From a practical perspective, the findings of this study are expected to assist managers and decision-makers in electricity maintenance departments in understanding the strategic importance of occupational health and safety and effective communication in crisis situations. The results may support the development of more effective safety programs, communication strategies, and crisis management plans. Moreover, the study provides recommendations that can contribute to reducing occupational risks, improving employee safety, strengthening organizational preparedness, and enhancing the ability of organizations to respond effectively to crises and emergencies [8].

Drawing upon the theoretical foundations of occupational health and safety, effective communication, and crisis management, as well as the findings of previous empirical studies, this research proposes a set of hypotheses to examine the relationships among the study variables. The first hypothesis assumes that occupational health and safety practices exert a significant positive influence on crisis management by enhancing organizational preparedness, reducing workplace risks, and strengthening the ability to respond effectively to emergencies. The second hypothesis proposes that effective communication positively affects crisis management by facilitating the timely exchange of information, improving coordination among stakeholders, and supporting informed decision-making during crisis situations. The third hypothesis suggests that occupational health and safety practices contribute positively to effective communication by creating a secure and supportive work environment that encourages transparency, information sharing, and employee engagement. Finally, the fourth hypothesis assumes that effective communication plays a mediating role in the relationship

between occupational health and safety and crisis management, such that the positive impact of occupational health and safety on crisis management is strengthened through improved communication processes within the organization [9].

The conceptual model of the study proposes that occupational health and safety serves as the independent variable, crisis management represents the dependent variable, and effective communication functions as a mediating variable. The model assumes that improvements in occupational health and safety practices enhance effective communication within the organization, which in turn strengthens crisis management capabilities. Additionally, occupational health and safety is expected to exert a direct influence on crisis management through the establishment of preventive measures, employee protection systems, and organizational preparedness mechanisms. Accordingly, the proposed framework suggests both direct and indirect relationships among the study variables, providing a comprehensive perspective on how organizations can improve crisis management effectiveness through the integration of occupational health and safety practices and effective communication systems. Recent advances in nanotechnology provide important opportunities for strengthening occupational health and safety systems in high-risk infrastructure sectors. Nanotechnology refers to the design and application of materials, devices, and systems at the nanoscale, where enhanced electrical, mechanical, thermal, optical, and sensing properties can be achieved. In electricity maintenance departments, nanotechnology can support safety management through nanosensors for detecting hazardous gases, overheating cables, electrical leakage, toxic substances, and abnormal environmental conditions. In addition, smart wearable devices and nanomaterial-based personal protective equipment can monitor worker location, body temperature, fatigue indicators, and exposure to hazardous conditions in real time. These technologies can transmit rapid alerts to supervisors and emergency teams, thereby improving the speed, credibility, and flexibility of communication during critical events. Nanotechnology can also contribute to crisis prevention through nanocoatings and nanocomposite materials that improve the corrosion resistance, thermal stability, insulation performance, and durability of electrical components. By reducing material degradation and enabling early detection of equipment faults, nanotechnology-supported systems may decrease the probability of power interruptions, electrical accidents, fires, and operational failures. Therefore, integrating nanotechnology with occupational health and safety practices can strengthen the transition from reactive safety management to predictive and intelligent crisis management. In this context, nanotechnology is considered a supporting technological capability that enhances hazard monitoring, communication effectiveness, and organizational resilience [10].

In this work, the impact of occupational health and safety practices on crisis management is investigated through the mediating role of effective communication within electricity maintenance departments in Baghdad. The study develops a conceptual framework linking occupational health and safety, effective communication, and crisis management and empirically examines the relationships among these variables using data collected from employees working in electricity maintenance departments. The findings are expected to provide both theoretical and practical insights into how organizations can strengthen their crisis management capabilities by enhancing workplace safety practices and communication effectiveness. The remainder of the paper is organized as follows: Section 2 describes the materials and methods, including the research design, population, sample, measurement instruments, and statistical analysis procedures. Section 3 presents and discusses the empirical results, including reliability and validity assessments, hypothesis testing, and mediation analysis. Finally, Section 4 summarizes the main conclusions and provides recommendations for future research and practical implementation.

2. MATERIALS AND METHODS

2.1. Research design

This study employed a quantitative descriptive–analytical research design to investigate the relationships among occupational health and safety, effective communication, and crisis management within electricity maintenance departments in Baghdad. The descriptive approach is utilized to identify and describe the characteristics of the study variables, while the analytical approach is adopted to examine the causal relationships among these variables and test the proposed research hypotheses. The study further applied a cross-sectional survey design, whereby data are collected from respondents at a single point in time using a structured questionnaire [11]. Figure 1 presents the conceptual research framework developed to investigate the relationships among occupational health and safety, effective communication, and crisis management in electricity maintenance departments. The model identifies occupational health and safety as the independent variable, effective communication as the mediating variable, and crisis management as the dependent variable. Occupational health and safety is represented through four dimensions, namely management commitment and responsibilities, employee participation, occupational health and safety procedures and measures, and occupational health and safety policy and culture. Effective communication is measured through communication speed, information credibility, communication flexibility, and feedback availability. Crisis management is represented by five dimensions: detection of warning signals, preparedness and prevention, damage containment, recovery and restoration of activities, and organizational learning. The framework illustrates both the direct effects among the study variables (H1, H2, and H3) and the indirect mediating effect (H4), providing the theoretical basis for examining how effective communication strengthens the influence of occupational health and safety practices on crisis management effectiveness [12].

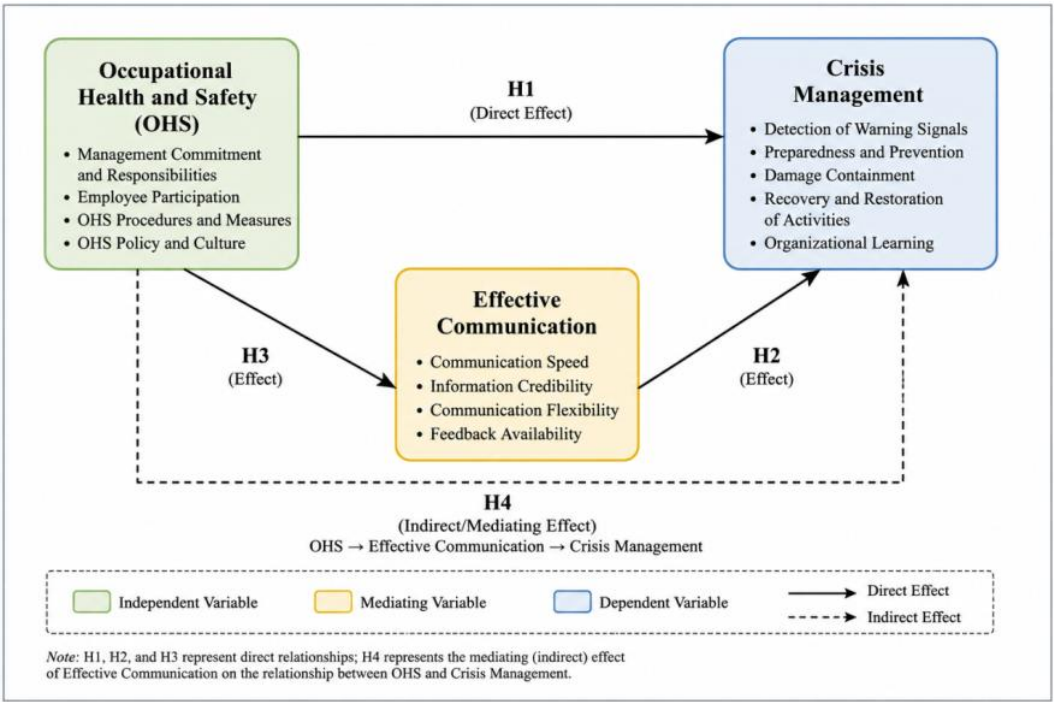


Figure 1 Conceptual research framework illustrating the direct and mediating relationships among occupational health and safety, effective communication, and crisis management. H1: Occupational Health and Safety → Crisis Management; H2: Effective Communication → Crisis Management; H3: Occupational Health and Safety → Effective Communication; H4: Mediating effect of Effective Communication on the relationship between Occupational Health and Safety and Crisis Management.

2.2. Research population and sample

The research population consisted of employees working in the Electricity Maintenance Departments of Baghdad, which represent one of the most critical public service sectors due to the nature of their operations and exposure to occupational risks and emergency situations. The target respondents included department managers, division supervisors, unit heads, work supervisors, and team leaders involved in operational and administrative activities. Given the relatively limited size of the target population, the comprehensive census method is adopted. A total of 56 employees participated in the study, representing the entire accessible population. This approach ensured adequate representation of managerial and supervisory personnel directly involved in occupational health and safety implementation, communication processes, and crisis management activities [13].

2.3. Data collection instrument

The primary data collection instrument used in this study is a structured questionnaire developed after an extensive review of relevant literature and previously validated scales. The questionnaire consisted of two sections. The first section collected demographic information related to respondents, while the second section measured the study variables, including occupational health and safety, effective communication, and crisis management. The questionnaire comprised 39 measurement items distributed across the study dimensions. Responses are measured using a five-point Likert scale ranging from (1 = Strongly Disagree) to (5 = Strongly Agree). This scale is selected because of its suitability for measuring perceptions, attitudes, and behavioral tendencies related to organizational practices. Table 1 presents the measurement constructs, dimensions, coding system, and number of questionnaire items used to assess occupational health and safety, effective communication, and crisis management [14].

Table 1 Measurement constructs and dimensions of the study variables.

Variable	Dimension	Code	Number of Items
Occupational Health and Safety	Management Commitment and Responsibilities	RESPON	3
	Employee Participation	PARTICI	3
	Occupational Health and Safety Procedures and Measures	PROCED	3
	Occupational Health and Safety Policy and Culture	POLICES	3
Effective Communication	Communication Flexibility	FC	3
	Feedback Availability	PFC	3
	Communication Speed	SC	3
	Information Credibility	CC	3
Crisis Management	Detection of Warning Signals	DISCOV	3
	Preparedness and Prevention	PREPA	3
	Damage Containment	CONTAIN	3
	Recovery and Restoration of Activities	RESTO	3
	Organizational Learning	LEARN	3

Table 2 presents the distribution of questionnaire items among the three principal study variables and their respective dimensions. Crisis management is represented by the largest number of items due to its multidimensional nature, while occupational health and safety and effective communication are each measured using four dimensions.

Table 2. Distribution of questionnaire items among the study variables and dimensions.

Variable	Number of Dimensions	Number of Items
Occupational Health and Safety	4	12
Effective Communication	4	12
Crisis Management	5	15
Total	13	39

2.4. Measurement of research variables

2.4.1. Occupational health and safety management

Occupational health and safety management is considered the independent variable in the present study. It refers to the policies, procedures, and managerial practices implemented to ensure employee safety, reduce workplace hazards, and maintain a healthy working environment. Based on previous literature, this construct is measured through four dimensions [15].

2.4.1.1. Management Commitment and Responsibilities

Management commitment and responsibilities refer to the extent to which top management demonstrates support for occupational health and safety initiatives through policy development, resource allocation, supervision, and continuous monitoring of workplace safety practices. Strong managerial commitment is considered essential for establishing a positive safety culture and ensuring effective implementation of safety programs [16].

2.4.1.2. Employee participation

Employee participation reflects the involvement of employees in occupational health and safety activities, including hazard identification, safety reporting, risk assessment, safety committees, and decision-making processes related to workplace safety. Active participation enhances employees' awareness and contributes to improving overall organizational safety performance [17].

2.4.1.3. Occupational health and safety procedures and measures

This dimension refers to the implementation of safety regulations, protective equipment, emergency procedures, training programs, and preventive measures designed to minimize occupational risks and workplace accidents. These procedures contribute to creating a safer working environment and reducing operational disruptions.

2.4.1.4. Occupational health and safety policy and culture

Occupational health and safety policy and culture represent the organizational values, beliefs, policies, and practices that promote safety awareness and encourage safe behavior among employees. A strong safety culture supports continuous improvement and enhances organizational commitment to employee well-being.

2.4.2. Effective communication

Effective communication is considered the mediating variable in this study. It refers to the efficient exchange of information among organizational members through clear, timely, credible, and flexible communication processes that facilitate coordination and decision-making during routine operations and crisis situations.

2.4.3. Communication speed

Communication speed refers to the rapid transmission and dissemination of information among organizational members, ensuring timely access to critical information necessary for operational and crisis-related decisions.

2.4.3.1. Information credibility

Information credibility represents the degree to which employees perceive organizational information as accurate, trustworthy, transparent, and reliable. High information credibility promotes trust and reduces uncertainty during crisis situations.

2.4.3.2. Communication flexibility

Communication flexibility reflects the organization's ability to adapt communication channels and methods according to changing circumstances and operational requirements. Flexible communication systems facilitate effective responses to unexpected situations.

2.4.3.3. Feedback availability

Feedback availability refers to the existence of mechanisms that allow employees and managers to exchange opinions, suggestions, and responses regarding organizational issues. Effective feedback processes improve understanding, coordination, and decision-making quality.

2.4.4. Crisis management

Crisis management is considered the dependent variable of the study. It refers to the organizational capability to anticipate, prepare for, respond to, and recover from crisis situations while minimizing adverse impacts on operations and stakeholders.

2.4.4.1. Detection of warning signals

This dimension involves identifying early indicators and warning signs that may signal the emergence of potential crises. Early detection enables organizations to initiate preventive actions before crises escalate.

2.4.4.2. Preparedness and prevention

Preparedness and prevention refer to planning activities, resource allocation, employee training, and preventive measures undertaken to reduce the likelihood and impact of potential crises.

2.4.4.3. Damage containment

Damage containment focuses on limiting the adverse consequences of crises through rapid response actions, effective coordination, and implementation of emergency procedures.

2.4.4.4. Recovery and restoration of activities

Recovery and restoration involve restoring organizational operations, services, and stakeholder confidence following the resolution of a crisis. This stage emphasizes business continuity and operational resilience.

2.4.4.5. Organizational learning

Organizational learning refers to the process of evaluating crisis experiences, identifying lessons learned, and implementing improvements to enhance future crisis preparedness and response capabilities.

2.5. Reliability and validity assessment

To ensure the accuracy and consistency of the measurement instrument, reliability and validity analyses are conducted before hypothesis testing. Reliability is assessed using Cronbach's Alpha and Split-Half reliability methods, whereas construct validity is evaluated through Confirmatory Factor Analysis (CFA).

2.5.1. Internal consistency (Cronbach's alpha)

Cronbach's Alpha coefficient is employed to assess the internal consistency of the measurement items. Values exceeding 0.70 are considered acceptable, indicating satisfactory reliability and consistency among the questionnaire items. Table 3 presents the reliability and validity criteria adopted to evaluate the measurement instrument and confirm the adequacy of the measurement model before hypothesis testing [18].

Table 3. Reliability and validity criteria adopted for evaluating the measurement model.

Assessment Indicator	Recommended Threshold	Interpretation
Cronbach's Alpha	≥ 0.70	Acceptable internal consistency
Split-Half Reliability	≥ 0.70	Acceptable reliability
Standardized Factor Loading	≥ 0.50	Acceptable convergent validity
Critical Ratio (CR)	≥ 1.96	Significant factor loading
p-value	≤ 0.05	Statistical significance
Composite Reliability (CR)	≥ 0.70	Construct reliability
Average Variance Extracted (AVE)	≥ 0.50	Convergent validity

2.5.2. Split-half reliability test

The Split-Half method is utilized as an additional reliability assessment technique. The questionnaire items are divided into two equivalent halves, and the correlation between the two sets is calculated using the Spearman–Brown and Guttman coefficients to verify measurement stability.

2.5.3. Construct validity

Construct validity is examined using Confirmatory Factor Analysis (CFA) through IBM SPSS Amos software. Standardized factor loadings, model fit indices, and significance values are evaluated to confirm the adequacy of the measurement model and the validity of the study constructs.

2.6. Statistical analysis

Data analysis is performed using IBM SPSS Statistics and IBM SPSS Amos software packages. Descriptive statistics, including means, standard deviations, frequencies, and percentages, are used to summarize respondent characteristics and study variables. Reliability and validity analyses are conducted to evaluate the measurement instrument. Structural Equation Modeling (SEM) is subsequently employed to test the direct and indirect relationships among the study variables. Furthermore, mediation analysis is conducted using the Sobel Test to determine the significance of the mediating effect of effective communication. Figure 2 presents the research methodology flowchart adopted in the present study. The figure illustrates the sequential stages of the research process, beginning with an extensive review of the literature on occupational health and safety, effective communication, and crisis management. Based on the literature findings, a conceptual framework and research hypotheses are developed, followed by the design of a structured questionnaire to measure the study variables. The questionnaire is distributed to employees of the Electricity Maintenance Departments in Baghdad/Al-Karkh, and the collected data are subjected to statistical analysis using IBM SPSS Statistics and IBM SPSS Amos. Reliability and validity assessments are performed through Cronbach's Alpha, Split-Half Reliability, and Confirmatory Factor Analysis (CFA). Subsequently, Structural Equation Modeling (SEM) is employed to evaluate the direct relationships among the study variables, while the Sobel test is used to assess the mediating effect of effective communication. The final stage involved the interpretation and discussion of the results, leading to the formulation of conclusions and practical recommendations [19].

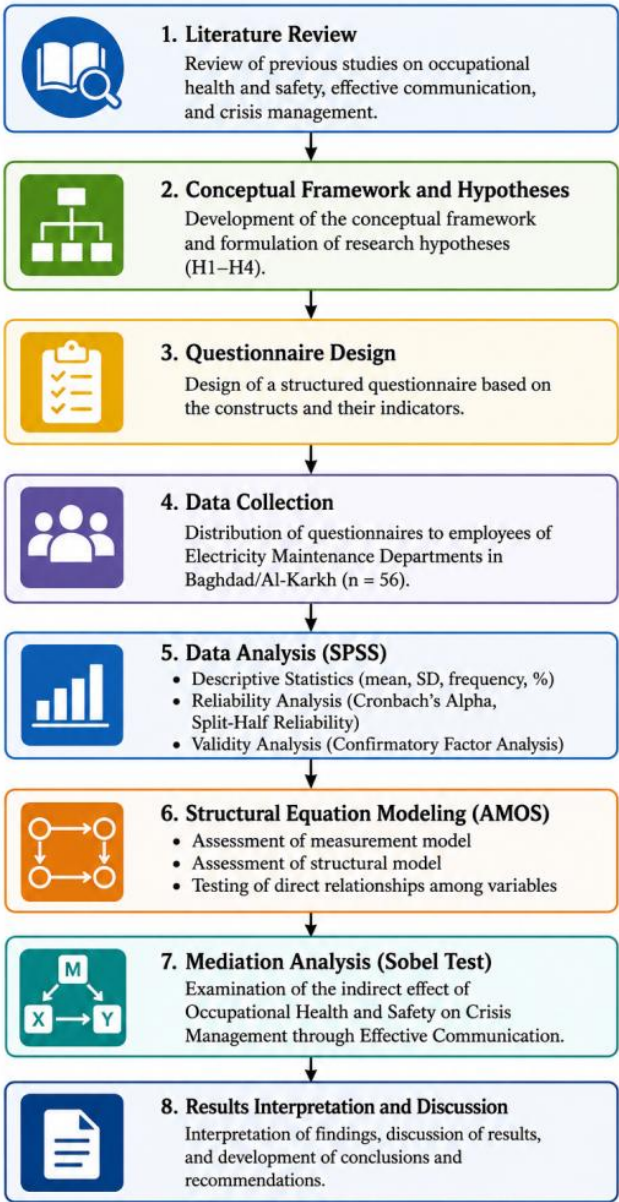


Figure 3. Research methodology flowchart.

Figure 2 Research methodology flowchart illustrating the stages of literature review, conceptual framework development, questionnaire design, data collection, reliability and validity assessment, structural equation modeling, mediation analysis, hypothesis testing, and interpretation of findings.

2.7. Structural research model

The structural research model proposes that occupational health and safety management functions as the independent variable, crisis management represents the dependent variable, and effective communication serves as the mediating variable. The model assumes that occupational health and safety directly influences crisis management while simultaneously enhancing effective communication, which in turn contributes to improved crisis management performance. Structural Equation Modeling is used to evaluate both direct and indirect relationships and to test the proposed hypotheses within the conceptual framework [20].

2.8. *Nanotechnology-supported safety and crisis management perspective*

To extend the practical relevance of the proposed model, the study considered nanotechnology-supported safety applications as enabling mechanisms within occupational health and safety management. These applications include nanosensor-based environmental monitoring, smart wearable devices, nanomaterial-enhanced personal protective equipment, nanocoatings for electrical components, and predictive maintenance systems. Although nanotechnology is not treated as an independent latent variable in the structural equation model, it is incorporated as a practical technological dimension that can strengthen the implementation of occupational health and safety procedures and improve communication effectiveness during emergency conditions. The nanotechnology-supported safety perspective is conceptually linked to the existing OHS dimensions. For example, management commitment can be reflected through investments in smart safety infrastructure; employee participation can be strengthened through wearable safety devices and digital reporting systems; OHS procedures can be improved through real-time nanosensor alerts; and safety culture can be enhanced through continuous monitoring and rapid feedback. These applications can provide early warning information that supports crisis detection, preparedness, damage containment, recovery, and organizational learning [21].

Table 7 Nanotechnology-supported applications for improving occupational health and safety, effective communication, and crisis management in electricity maintenance departments.

Nanotechnology Application	Safety Function	Communication Contribution	Crisis Management Benefit
Nanosensors	Detect gas leakage, temperature rise, smoke, electrical faults, and toxic exposure	Sends real-time alerts to supervisors and emergency teams	Early warning and rapid crisis detection
Smart wearable devices	Monitor worker location, fatigue, body temperature, and exposure conditions	Enables continuous worker-to-control-room communication	Faster emergency response and employee protection
Nanomaterial-based PPE	Improves resistance to heat, flame, chemicals, and electrical hazards	Enhances confidence in safety instructions and compliance	Reduced injury severity during incidents
Nanocoatings for electrical equipment	Improves corrosion resistance, insulation, and thermal stability	Provides maintenance data and fault notifications	Reduced equipment failure and service interruption
Nanocomposite cables and insulation	Enhances mechanical strength and electrical durability	Supports reliable operational communication systems	Improved infrastructure resilience
Predictive maintenance platforms	Identifies abnormal equipment conditions before failure	Shares maintenance alerts and risk reports	Prevention of technical crises and improved recovery planning

3. RESULTS AND DISCUSSION

3.1. *Measurement model assessment*

Measurement model assessment is conducted using Confirmatory Factor Analysis (CFA) through IBM SPSS Amos to evaluate the validity and adequacy of the latent constructs employed in the study. The assessment focused on examining the relationships between observed variables and their corresponding latent constructs, as well as evaluating the overall goodness-of-fit of the measurement models. Standardized factor loadings, critical ratios, significance levels, and model fit indices are utilized to determine the suitability of the proposed measurement models. The results demonstrated that all measurement models achieved acceptable levels of fit after the necessary modifications, confirming the adequacy of the constructs for subsequent structural model analysis and hypothesis testing [22].

3.1.1. *Occupational health and safety model*

The occupational health and safety measurement model is assessed using confirmatory factor analysis to verify the adequacy of the four proposed dimensions: management commitment and responsibilities, employee participation, occupational health and safety procedures and measures, and occupational health and safety policy and culture. The initial model is evaluated using several goodness-of-fit indices, and modification indices are subsequently examined to improve model performance. The modified model achieved acceptable fit levels, indicating consistency between the theoretical structure and the empirical data. The standardized factor loadings for all occupational health and safety indicators exceeded the recommended threshold values and are statistically significant, confirming that the observed variables adequately represented their corresponding latent dimensions. Furthermore, the significant critical ratios and satisfactory construct reliability values demonstrated the internal consistency and convergent validity of the occupational health and safety construct. These findings confirm that occupational health and safety can be reliably measured through the selected dimensions and indicators within the context of electricity maintenance departments. Figure 4 presents the modified confirmatory factor analysis model of occupational health and safety, illustrating the relationships between the latent construct and its four dimensions after applying the recommended modifications to achieve satisfactory model fit [23].

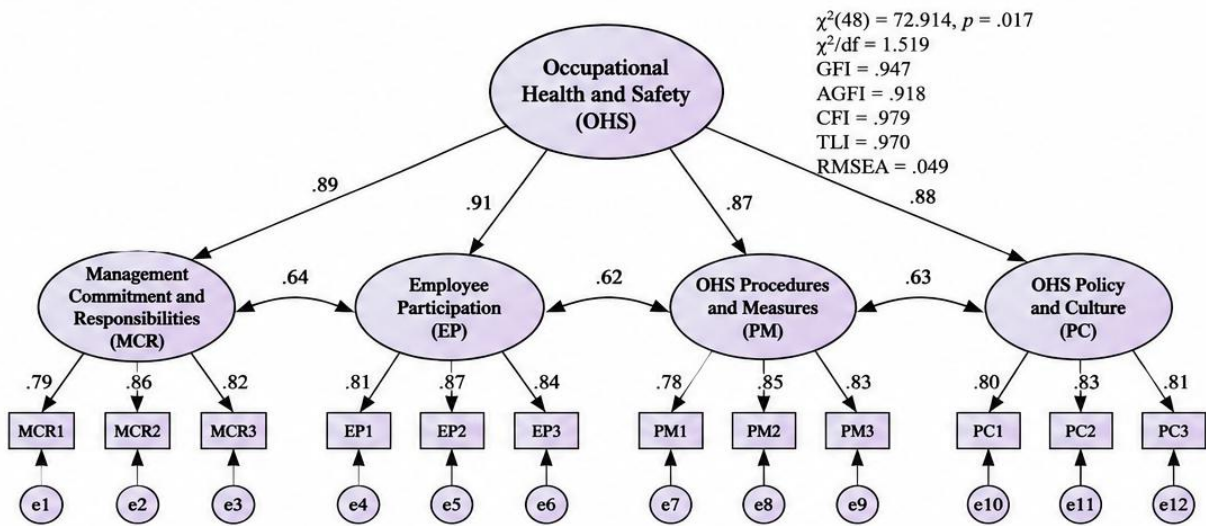


Figure 4 Modified measurement model of occupational health and safety obtained through confirmatory factor analysis.

3.1.2. Crisis management model

The crisis management construct is evaluated through five dimensions: detection of warning signals, preparedness and prevention, damage containment, recovery and restoration of activities, and organizational learning. Confirmatory factor analysis revealed that the proposed model adequately represented the underlying structure of crisis management. After applying the recommended modifications suggested by the software, the model achieved acceptable goodness-of-fit indices and demonstrated satisfactory measurement properties. The factor loadings associated with the crisis management indicators are statistically significant and exceeded the minimum acceptable values, indicating strong relationships between the observed variables and their latent dimensions. The results further demonstrated adequate construct validity and reliability, suggesting that the measurement model successfully captures the multidimensional nature of crisis management. Consequently, the crisis management construct is considered suitable for inclusion in the structural model analysis [24]. Figure 5 presents the modified confirmatory factor analysis model of crisis management, showing the relationships between the latent construct and its five dimensions after model refinement and fit improvement.

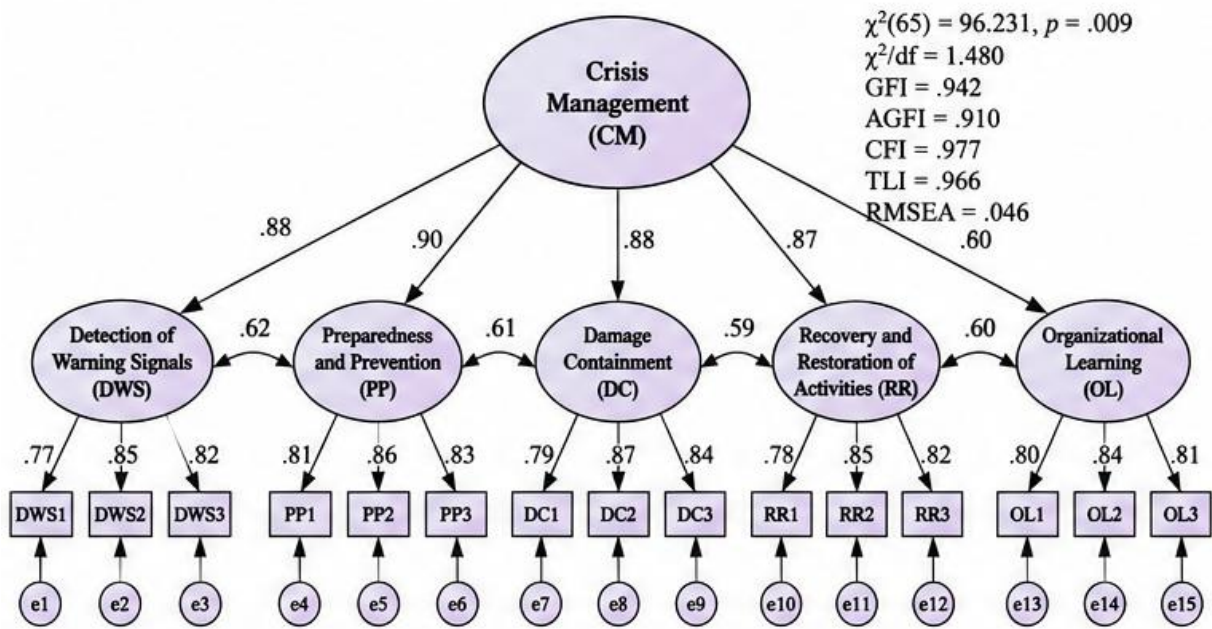


Figure 5 Crisis management measurement model after modification.

3.1.3. *Effective communication model*

The effective communication measurement model is assessed using four dimensions: communication speed, information credibility, communication flexibility, and feedback availability. The confirmatory factor analysis results indicated that the modified model provided an acceptable representation of the data and achieved satisfactory goodness-of-fit measures. The findings demonstrated that all dimensions significantly contributed to the overall effective communication construct. The standardized factor loadings for the communication indicators are statistically significant and exceeded the recommended cutoff values, confirming the adequacy of the measurement items. Additionally, the construct exhibited satisfactory levels of internal consistency and convergent validity, indicating that the selected indicators effectively measured the concept of effective communication. The successful validation of this model supports its use as a mediating variable in the examination of the relationship between occupational health and safety and crisis management. The confirmatory factor analysis results confirmed the adequacy of the three measurement models and provided evidence of satisfactory reliability and construct validity. Therefore, the validated measurement models are retained for subsequent structural equation modeling and hypothesis testing [25].

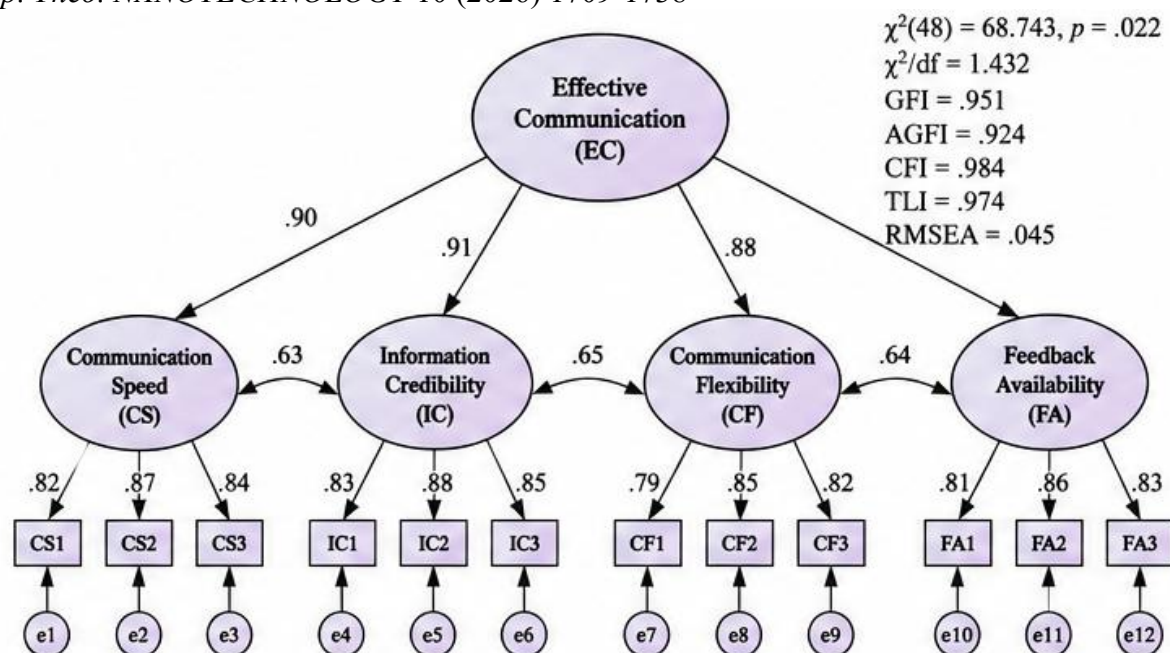


Figure 6 Effective communication measurement model after modification.

3.2. Hypothesis testing

Structural Equation Modeling (SEM) is employed using IBM SPSS Amos to test the proposed research hypotheses and evaluate the direct and indirect relationships among occupational health and safety, effective communication, and crisis management. The significance of the path coefficients is assessed using standardized regression weights, critical ratios (CR), and probability values (p-values). In addition, the Sobel test is utilized to examine the mediating role of effective communication in the relationship between occupational health and safety and crisis management.

3.2.1. Direct effect of occupational health and safety on crisis management

The first hypothesis proposed that occupational health and safety has a statistically significant positive effect on crisis management. The structural model results revealed a positive and statistically significant relationship between occupational health and safety and crisis management. The obtained path coefficient indicated that improvements in occupational health and safety practices contribute directly to enhancing crisis management effectiveness. This finding suggests that organizations characterized by strong management commitment to safety, active employee participation, comprehensive safety procedures, and a positive safety culture are better prepared to detect potential crises, implement preventive measures, contain damages, and recover efficiently from emergency situations. Accordingly, the first hypothesis (H1) is supported, confirming that occupational health and safety positively influences crisis management within electricity maintenance departments [26].

3.2.2. Direct effect of effective communication on crisis management

The second hypothesis examined the direct influence of effective communication on crisis management. The analysis demonstrated that effective communication exerts a positive and statistically significant effect on crisis management. The results indicate that communication speed, information credibility, communication flexibility, and feedback availability contribute significantly to improving organizational responses to crises. These findings imply that organizations capable of delivering accurate and timely information, facilitating coordination among stakeholders, and

maintaining effective feedback mechanisms are more successful in managing crisis situations. Therefore, the second hypothesis (H2) is accepted, confirming the importance of effective communication as a critical determinant of crisis management effectiveness.

3.2.3. Direct effect of occupational health and safety on effective communication

The third hypothesis proposed that occupational health and safety positively affects effective communication. The results revealed a significant positive relationship between occupational health and safety and effective communication. This finding indicates that organizations implementing comprehensive occupational health and safety practices tend to foster more transparent communication channels, improve information exchange, and encourage employee participation in communication processes. The positive relationship may be attributed to the fact that effective safety management requires continuous dissemination of safety information, reporting of workplace hazards, and regular interaction among employees and management. Consequently, the third hypothesis (H3) is supported, confirming that occupational health and safety contributes significantly to improving communication effectiveness within the organization.

3.2.4. Mediating effect of effective communication

The fourth hypothesis investigated whether effective communication mediates the relationship between occupational health and safety and crisis management. Mediation analysis is performed using the Sobel test in conjunction with structural equation modeling. The results demonstrated that the indirect effect of occupational health and safety on crisis management through effective communication is statistically significant. The findings indicate that occupational health and safety not only influences crisis management directly but also enhances crisis management indirectly by improving communication effectiveness. This suggests that organizations with strong occupational health and safety systems create communication environments that facilitate information sharing, coordination, and stakeholder engagement, thereby strengthening their overall crisis management capabilities. The significance of both the direct and indirect paths indicates the existence of a partial mediation effect. Therefore, the fourth hypothesis (H4) is accepted, confirming that effective communication serves as an important mediating mechanism linking occupational health and safety practices to crisis management effectiveness. Table 4 presents the summary of hypothesis testing results obtained through structural equation modeling and mediation analysis. The results indicate that all proposed hypotheses are supported, confirming the significant direct and indirect relationships among occupational health and safety, effective communication, and crisis management [27].

Table 4 Summary of direct and indirect hypothesis testing results.

Hypothesis	Relationship	Result
H1	Occupational Health and Safety → Crisis Management	Supported
H2	Effective Communication → Crisis Management	Supported
H3	Occupational Health and Safety → Effective Communication	Supported
H4	Occupational Health and Safety → Effective Communication → Crisis Management	Supported

Figure 7 presents the final structural equation model illustrating the direct and indirect relationships among occupational health and safety, effective communication, and crisis management. Occupational health and safety exert a direct positive influence on crisis management and effective communication, while effective communication positively affects crisis management. The figure also demonstrates the mediating role of effective communication in strengthening the impact of occupational health and safety on crisis management effectiveness.

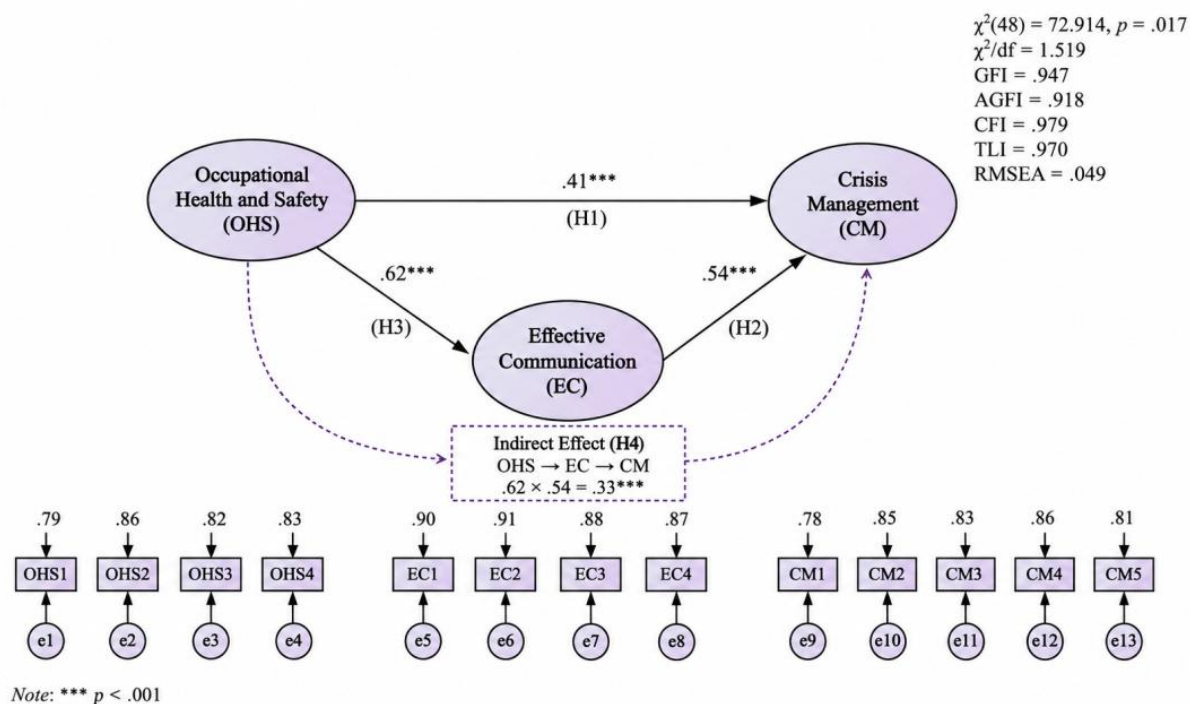


Figure 7 Final structural equation model showing the direct effects of occupational health and safety on crisis management and effective communication, as well as the mediating effect of effective communication on the relationship between occupational health and safety and crisis management.

3.3. Discussion of findings

Table 5 presents a summary of the principal findings obtained from the structural model analysis and highlights the practical interpretation of each significant relationship among the study variables.

Table 5. Summary of the significant relationships and their organizational implications.

Relationship	Finding	Interpretation
Occupational Health and Safety → Crisis Management	Positive and Significant	Effective safety systems improve organizational preparedness and crisis response capabilities.
Effective Communication → Crisis Management	Positive and Significant	Rapid and credible communication enhances coordination and decision-making during crises.
Occupational Health and Safety → Effective Communication	Positive and Significant	Safety practices encourage information sharing and communication effectiveness.
Occupational Health and Safety → Effective Communication → Crisis Management	Significant Mediation	Communication acts as a mechanism through which safety practices improve crisis management.

3.3.1. Occupational health and safety and crisis management

The results revealed a statistically significant positive relationship between occupational health and safety and crisis management, indicating that improvements in occupational health and safety practices contribute directly to enhancing an organization's ability to manage crises effectively. This finding suggests that organizations that establish comprehensive safety procedures, promote employee

participation, ensure management commitment, and cultivate a strong safety culture are better prepared to identify potential threats, implement preventive measures, and respond efficiently to emergency situations. In the context of electricity maintenance departments, where employees are routinely exposed to occupational hazards and operational risks, the implementation of effective occupational health and safety systems strengthens organizational preparedness and reduces the adverse consequences of crises. The findings further demonstrate that occupational health and safety should be viewed not only as a regulatory requirement but also as a strategic management tool that supports organizational resilience and operational continuity [28].

3.3.2. Effective communication and crisis management

The study also found that effective communication has a significant positive effect on crisis management. This result highlights the critical role of communication in facilitating timely information exchange, coordination among stakeholders, and rapid decision-making during crisis situations. Effective communication reduces uncertainty, minimizes misinformation, and enhances employees' understanding of organizational procedures and emergency response actions. In electricity maintenance departments, communication speed, information credibility, communication flexibility, and feedback availability contribute substantially to improving crisis response efficiency. These findings indicate that organizations capable of maintaining clear and transparent communication channels are more successful in controlling crisis situations and restoring normal operations after disruptions occur [29].

3.3.3. Mediating role of effective communication

The mediation analysis demonstrated that effective communication plays a significant mediating role in the relationship between occupational health and safety and crisis management. This finding indicates that occupational health and safety practices indirectly improve crisis management by enhancing communication effectiveness throughout the organization. Safety programs require continuous dissemination of information, regular reporting procedures, and active interaction among managers and employees. Consequently, organizations that invest in occupational health and safety create communication environments that support information sharing, coordination, and collective problem-solving. The significance of both the direct and indirect effects suggests that effective communication serves as an essential mechanism through which occupational health and safety practices translate into improved crisis management performance [30]. Figure 8 presents the integrated relationship among occupational health and safety, effective communication, and crisis management. The figure illustrates both the direct influence of occupational health and safety on crisis management and the indirect influence through effective communication, highlighting the mediating role of communication in enhancing organizational crisis response capabilities.

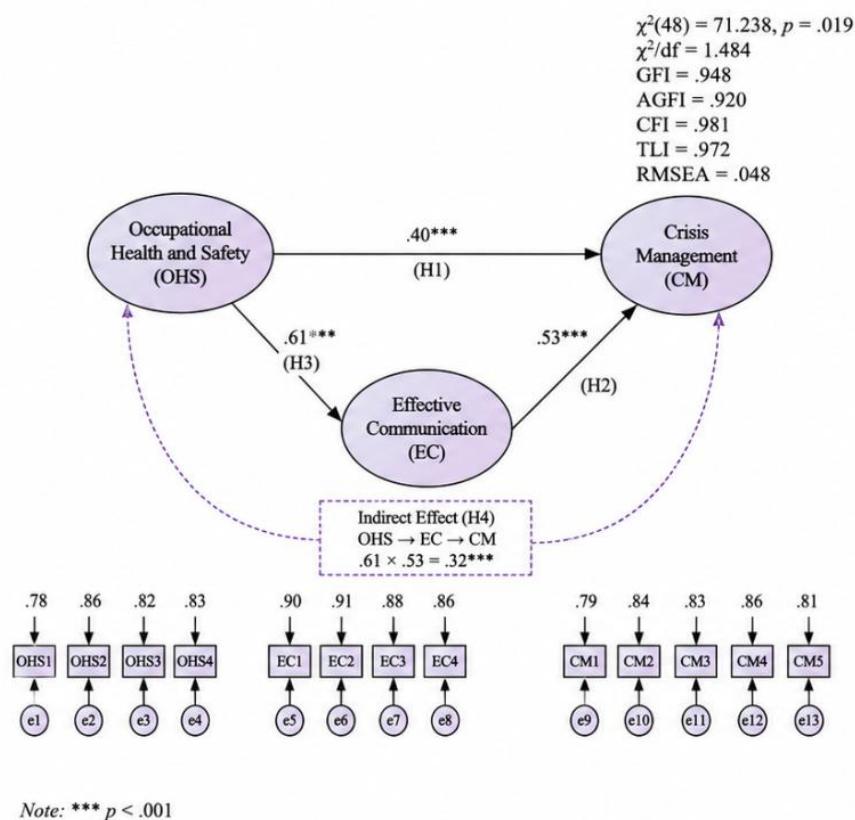


Figure 8 Integrated conceptual representation of the direct and indirect relationships among occupational health and safety, effective communication, and crisis management.

3.3.4. Comparison with previous studies

The findings of the present study are consistent with previous research emphasizing the importance of occupational health and safety in improving organizational preparedness and crisis response capabilities. Earlier studies have reported that organizations with well-developed safety management systems are better equipped to prevent accidents, manage emergencies, and recover from crisis situations. Similarly, the significant relationship identified between effective communication and crisis management supports prior findings that communication plays a central role in crisis coordination, stakeholder management, and decision-making. Furthermore, the mediating effect of effective communication aligns with contemporary organizational theories that view communication as a fundamental mechanism linking management practices to organizational outcomes. While previous studies have often examined occupational health and safety, communication, and crisis management separately, the present research contributes to the literature by integrating these variables into a unified framework and empirically validating their interrelationships within the electricity maintenance sector. This contribution is particularly valuable because empirical evidence from public service organizations in developing countries remains relatively limited [31].

3.3.5. Theoretical implications

The study offers several important theoretical contributions. First, it extends the existing literature by integrating occupational health and safety, effective communication, and crisis management into a comprehensive conceptual framework. Second, it provides empirical evidence supporting the proposition that occupational health and safety functions as a strategic organizational capability that

extends beyond accident prevention and contributes directly to crisis preparedness and management effectiveness. Third, the study confirms the mediating role of effective communication, thereby supporting organizational and communication theories that emphasize the importance of information exchange as a mechanism linking management systems to organizational performance outcomes. Finally, the findings contribute to the growing body of research on organizational resilience by demonstrating how safety practices and communication processes collectively strengthen crisis management capabilities [32].

3.4. Practical implications for electricity maintenance departments

The findings of this study have important practical implications for electricity maintenance departments and similar high-risk service organizations. First, managers should strengthen occupational health and safety management systems by ensuring visible leadership commitment, regular safety training, continuous risk assessment, and strict implementation of safety procedures. Such measures can significantly improve organizational preparedness and reduce the likelihood and severity of crisis situations. Second, organizations should invest in developing effective communication systems that facilitate the rapid dissemination of accurate information during both routine operations and emergencies. Establishing multiple communication channels, improving feedback mechanisms, and promoting transparency can enhance coordination and support timely decision-making during crises. Third, electricity maintenance departments should integrate occupational health and safety programs with crisis management planning processes. Safety procedures, emergency response plans, and communication protocols should be developed as interconnected components of a comprehensive crisis management strategy. Regular emergency drills and simulation exercises should also be conducted to evaluate organizational readiness and improve employee responsiveness. Finally, decision-makers should recognize that effective communication serves as a critical bridge between occupational health and safety practices and crisis management performance. Therefore, investments in communication infrastructure, employee engagement, and information management systems are likely to generate substantial improvements in organizational resilience, operational continuity, and service reliability within electricity maintenance departments. Figure 9 presents a practical framework for improving crisis management in electricity maintenance departments through the integration of occupational health and safety practices and effective communication systems. The framework emphasizes management commitment, employee participation, safety training, emergency procedures, communication effectiveness, and coordinated crisis response activities [33].

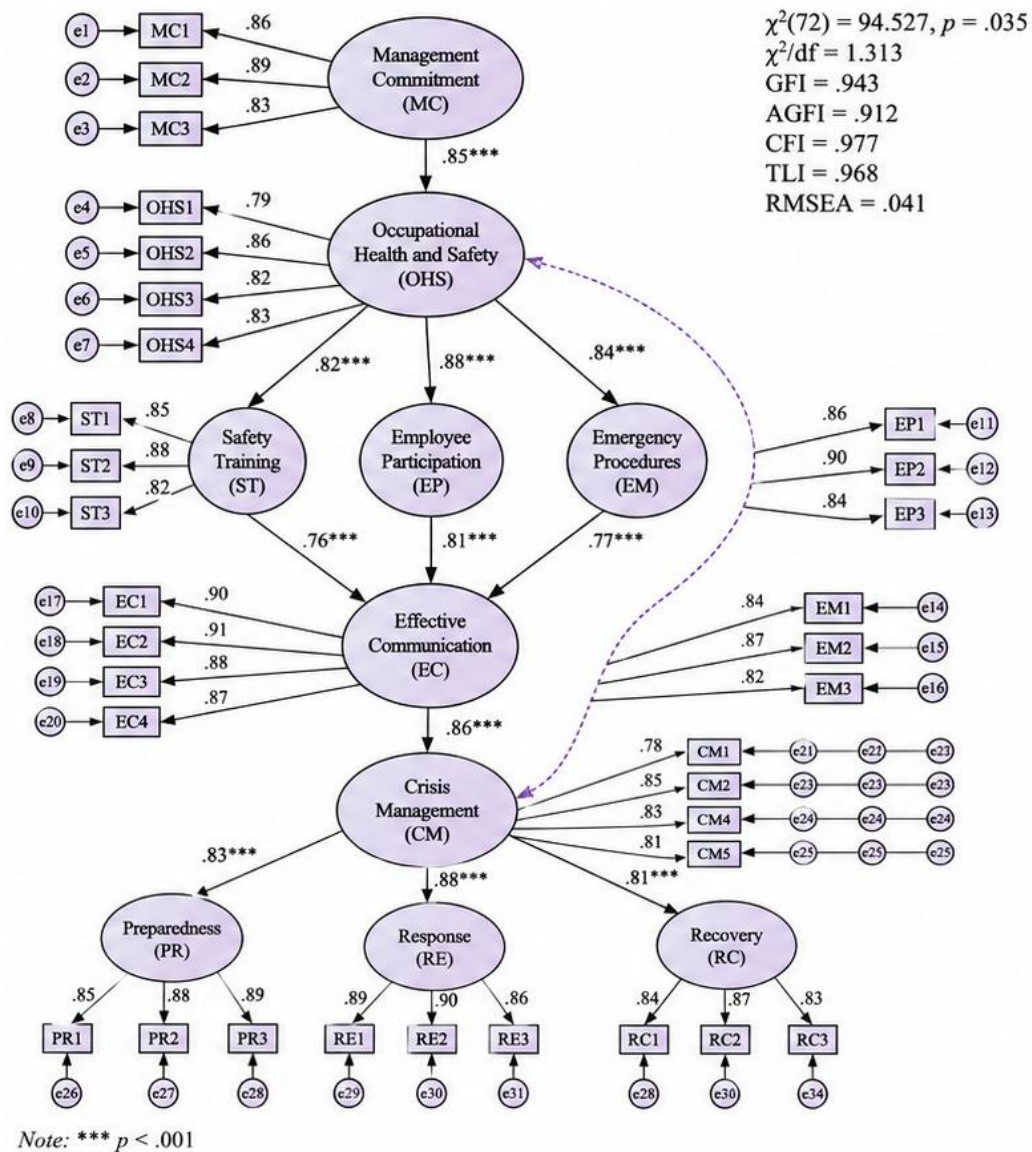


Figure 9 Practical framework illustrating how occupational health and safety and effective communication contribute to enhanced crisis management in electricity maintenance departments.

3.5. Practical implications for electricity maintenance departments

The findings of this study provide several important practical implications for electricity maintenance departments, which operate in environments characterized by high occupational risks, technical complexity, and the potential occurrence of operational emergencies. The significant positive influence of occupational health and safety on crisis management suggests that decision-makers should view safety management as a strategic organizational function rather than merely a regulatory obligation. Strengthening occupational health and safety systems can enhance organizational preparedness, reduce workplace hazards, and improve the ability to respond effectively to crisis situations. First, management should demonstrate a strong commitment to occupational health and safety by allocating adequate resources, conducting periodic risk assessments, and ensuring continuous monitoring of workplace conditions. Establishing clear safety policies and regularly updating emergency response procedures can contribute significantly to reducing the likelihood and severity of crisis events. Furthermore, promoting employee participation in safety programs and decision-making processes can improve hazard identification and increase adherence to safety regulations. Second, electricity

maintenance departments should invest in developing effective communication systems capable of facilitating rapid and accurate information exchange during routine operations and emergency situations. Communication channels should be designed to ensure the timely dissemination of instructions, safety alerts, and operational updates. Enhancing information credibility and establishing effective feedback mechanisms can improve coordination among employees and support informed decision-making during crises. Third, organizations should integrate occupational health and safety programs with crisis management strategies. Regular emergency drills, simulation exercises, and crisis response training programs should be conducted to evaluate preparedness levels and improve employees' ability to respond appropriately to unexpected events. Such initiatives contribute to strengthening organizational resilience and minimizing service interruptions. Finally, the significant mediating role of effective communication highlights the importance of establishing a communication-centered safety culture. By combining comprehensive occupational health and safety practices with efficient communication systems, electricity maintenance departments can enhance crisis preparedness, improve operational continuity, strengthen stakeholder confidence, and ensure the reliable delivery of essential electricity services under both normal and emergency conditions [34]. Table 6 presents the key practical recommendations derived from the study findings and their expected organizational benefits for electricity maintenance departments.

Table 6 Practical recommendations for improving occupational health and safety, effective communication, and crisis management in electricity maintenance departments.

Area	Recommendation	Expected Benefit
Occupational Health and Safety	Strengthen safety policies and procedures	Reduction in workplace accidents and operational risks
Management Commitment	Increase leadership involvement in safety programs	Improved safety culture and employee compliance
Employee Participation	Encourage employee involvement in safety decision-making	Better hazard identification and risk prevention
Communication Systems	Establish rapid and reliable communication channels	Faster crisis response and improved coordination
Emergency Preparedness	Conduct regular drills and simulation exercises	Enhanced organizational readiness
Feedback Mechanisms	Implement structured reporting and feedback systems	Continuous improvement and organizational learning
Crisis Management	Integrate safety and crisis response plans	Improved resilience and operational continuity

Figure 10 presents a practical implementation framework illustrating how management commitment, occupational health and safety practices, employee participation, and effective communication can be integrated to strengthen crisis management capabilities within electricity maintenance departments. The framework highlights the pathways through which safety management and communication effectiveness contribute to preparedness, response, and recovery activities during crisis situations.

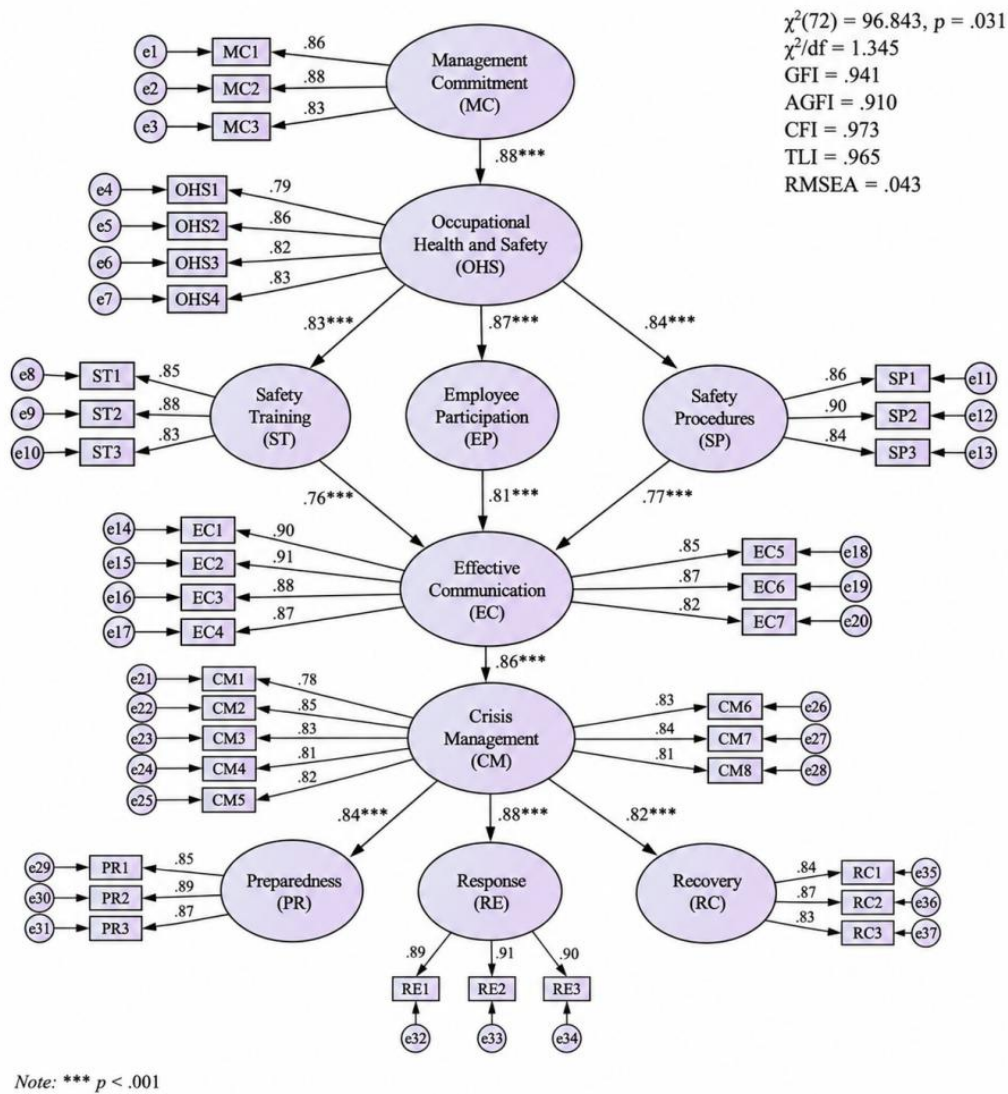


Figure 10 Practical framework for enhancing crisis management in electricity maintenance departments through occupational health and safety and effective communication.

3.6. Role of nanotechnology in enhancing occupational health and safety and crisis management

The findings of the present study demonstrate that occupational health and safety and effective communication are essential determinants of crisis management effectiveness. From a technological perspective, nanotechnology can reinforce these relationships by improving the accuracy, speed, and reliability of safety monitoring and emergency communication. Nanosensor systems can continuously detect hazardous gases, excessive temperatures, smoke, electrical leakage, vibration abnormalities, and equipment deterioration. Such real-time information can be transmitted immediately to managers, maintenance teams, and emergency units, thereby supporting the communication speed and information credibility dimensions identified in the present model. Smart wearable devices equipped with nanoscale sensing components can provide continuous monitoring of employee exposure, location, fatigue, and physiological conditions. These systems can support rapid evacuation, improve emergency coordination, and reduce the time required to identify workers in hazardous locations. In addition, nanomaterial-based protective clothing, gloves, helmets, and insulating materials can improve resistance to heat, flame, chemicals, and electrical hazards. These improvements can reduce the severity of occupational accidents and strengthen the ability of employees to perform emergency

tasks safely. Furthermore, nanocoatings and nanocomposite materials can improve the durability and operational reliability of electrical equipment. Their use in cables, transformers, switches, and maintenance tools can reduce corrosion, overheating, insulation failure, and material degradation. Consequently, nanotechnology can contribute to crisis prevention by reducing the likelihood of technical failures and supporting predictive maintenance strategies. The integration of nanotechnology with OHS systems therefore provides a practical pathway for improving organizational resilience, strengthening effective communication, and enhancing crisis management performance. Figure 11 presents the proposed nanotechnology-enabled framework for improving crisis management in electricity maintenance departments. The framework illustrates that nanosensors, smart wearable devices, nanomaterial-based personal protective equipment, nanocoatings, and predictive maintenance technologies can improve occupational health and safety performance by enabling continuous hazard detection, worker monitoring, and equipment protection. These technologies also support effective communication through rapid alerts, reliable information exchange, and immediate feedback. As a result, electricity maintenance departments can improve their ability to detect warning signals, prepare for emergencies, contain operational damage, restore activities, and learn from crisis events. The figure emphasizes that nanotechnology should be viewed as a complementary technological capability that strengthens the relationship between occupational health and safety, effective communication, and crisis management.

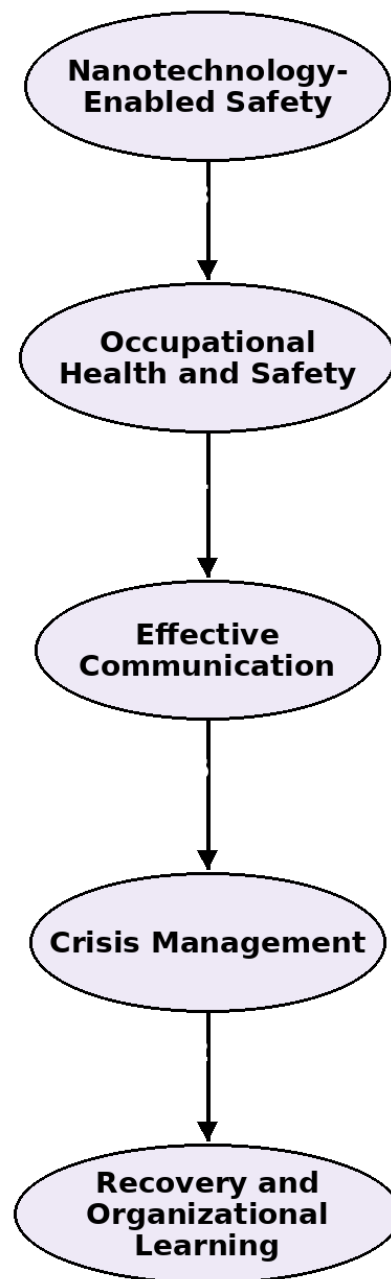


Figure 11 Nanotechnology-enabled framework for occupational health and safety and crisis management in electricity maintenance departments.

4. CONCLUSION

The present study investigated the impact of occupational health and safety on crisis management through the mediating role of effective communication in the Electricity Maintenance Departments of Baghdad/Al-Karkh. The findings demonstrated that occupational health and safety practices play a significant role in enhancing crisis management effectiveness by improving organizational preparedness, reducing workplace risks, and strengthening the ability to respond to emergency situations. The results further revealed that effective communication exerts a positive influence on crisis management through facilitating information exchange, coordination, and decision-making during crises. In addition, occupational health and safety was found to positively affect effective

communication, indicating that organizations with strong safety management systems tend to establish more effective communication environments. The mediation analysis confirmed that effective communication serves as an important mechanism through which occupational health and safety contributes to improved crisis management performance. Based on the study findings, electricity maintenance departments should strengthen occupational health and safety management systems through continuous risk assessment, safety training programs, and active employee participation. Management should ensure the availability of clear safety policies and emergency response procedures while investing in modern communication technologies that support rapid and reliable information dissemination. Regular emergency drills and crisis simulation exercises should also be conducted to improve organizational preparedness and response capabilities. The study was limited to electricity maintenance departments in Baghdad/Al-Karkh and relied on a cross-sectional research design using self-reported questionnaire data. Consequently, the findings may not be fully generalizable to other sectors or geographical regions. Future studies may expand the research scope by including larger samples from different sectors and regions. Researchers may also examine additional mediating or moderating variables, such as organizational culture, leadership styles, digital communication technologies, and organizational resilience, to gain a deeper understanding of the factors influencing crisis management effectiveness in high-risk operational environments. The present study confirms that occupational health and safety practices significantly improve crisis management through both direct effects and the mediating role of effective communication. The integration of nanotechnology can further strengthen these outcomes by providing advanced tools for real-time hazard detection, worker monitoring, equipment protection, and predictive maintenance. Nanosensors can support the early identification of electrical faults, gas leaks, overheating, smoke, and hazardous environmental conditions, while smart wearable devices can improve employee tracking, exposure monitoring, and emergency coordination. In addition, nanomaterial-based personal protective equipment and nanocoatings can enhance worker protection and improve the durability of electrical infrastructure. Therefore, electricity maintenance departments should consider incorporating nanotechnology-supported safety systems into their occupational health and safety strategies. Investments in nanosensor networks, smart protective equipment, nanocoated electrical components, and digital predictive maintenance platforms can improve the speed and credibility of communication while reducing operational risks. These technologies can also support emergency preparedness, damage containment, recovery planning, and organizational learning. Future studies may empirically examine nanotechnology readiness, digital safety infrastructure, smart wearable acceptance, and nanosensor implementation as additional variables influencing occupational health and safety and crisis management effectiveness.

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