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A Delphi Survey on Contractors' Perception of Excavation Hazard Features

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Abstract
Construction sites pose significant risks to workers' safety, particularly concerning excavation hazards. This study presents a novel method for addressing excavation hazard features through a comprehensive survey-based approach. The proposed method integrates stakeholder engagement strategies, robust data collection methodologies, and transparent decision-making processes to enhance hazard management practices in the construction industry. A comparative analysis was conducted to evaluate the proposed method's performance against traditional hazard management methods, including the Delphi Method, Hazard Identification and Risk Assessment (HIRA), and Job Safety Analysis (JSA). The proposed method demonstrated superior performance across multiple performance evaluation parameters, highlighting its potential to improve safety practices in construction settings. Additionally, an ablation study was conducted to assess the impact of individual components of the proposed method on its overall performance. The study identified key factors driving the method's efficacy and provided insights into areas for optimization and refinement. Overall, the findings of this study underscore the importance of adopting comprehensive approaches to hazard management in construction settings. By continuously refining and adapting the proposed method based on stakeholder feedback and ongoing research, we can contribute to promoting a safer work environment and mitigating the risks associated with excavation hazards in the construction industry.

Keywords: Construction, Excavation, Hazard management, Safety, Stakeholder engagement, Survey-based approach, Risk assessment.

1. Introduction
Excavation hazards represent a significant risk within the construction industry, posing threats to both workers and project integrity [1]. Understanding contractors' perceptions of excavation hazard features is crucial for devising effective mitigation strategies and enhancing safety protocols within construction sites [2]. This paper presents the findings of a Delphi survey aimed at elucidating contractors' perceptions of excavation hazards and their associated features.

1.1. Current Developments

The construction industry continually evolves, adapting to new technologies, regulations, and safety standards [3]. Recent years have witnessed a heightened focus on improving excavation safety due to the recognition of its inherent risks. Innovations in protective equipment, monitoring systems, and procedural protocols have emerged to address these concerns. Additionally, advancements in predictive analytics and risk assessment methodologies offer promising avenues for preemptive hazard identification and management.

1.2. Principal Objective

The principal objective of this study is to explore and analyze the perceptions of contractors regarding excavation hazard features [4]. By employing the Delphi method, a structured approach to consensus-building among experts, this research seeks to gather insights from a diverse range of industry professionals. Through iterative rounds of inquiry and feedback, the aim is to distill collective expertise into a comprehensive understanding of excavation hazards and potential mitigation strategies.

1.3. Solutions Proposed

The survey will solicit input from participants on various aspects of excavation hazards, including common risk factors, preventative measures, and best practices [5]. Participants will be invited to propose solutions based on their experiences and expertise, ranging from engineering controls to administrative policies. By aggregating and synthesizing these responses, the study aims to identify consensus recommendations for improving excavation safety across different project contexts and organizational settings.

1.4. Main Contributions

A key benefit of this research is that it reveals how workers perceive mining dangers, which might guide safety requirements in the construction industry [6]. Recommendations Based on consensus, ideas for mining risk reduction will be made via Delphi polling. These will benefit project participants throughout.

Safer practices:

This research may improve safety and risk management procedures for dig operations by addressing their challenges. Industry Advice: This research combines professionals' opinions and experiences to inform construction industry safety standards.

Where to investigate next:

The investigation may reveal gaps in our knowledge or areas that need more study [7]. This may influence future excavation safety measures. This research examines how builders consider risky excavation elements. The major purpose is to reduce construction sector accidents and make workplaces safer. This research may help make excavations safer by increasing collaboration and consensus.

2. Literature Review

The Delphi Method organizes expert consensus. Several rounds of polls or inquiries are typical. It aims to transform everyone's knowledge into educated forecasts or judgments [8]. Complex issues with several perspectives benefit from it. Hazard Identification and Risk Assessment (HIRA) involves locating, researching, and assessing all potential hazards in a project or workplace and implementing policies to reduce them [9]. It aims to prevent collisions and damage. FMEA is a systematic methodology to examine how a system, process, or product could fail and influence its performance, safety, and reliability. It helps prioritize reducing or eliminating failure reasons. Job Safety Analysis (JSA) separates tasks into phases, detects hazards, and determines controls to reduce them. Workers are routinely told the dangers of their occupations and how to accomplish them safely [10]. Safety Climate Assessment evaluates leadership commitment, communication, and safety regulations to determine workplace safety. It assesses a company's safety culture and suggests improvements. Root Cause Analysis (RCA) and incident investigation investigate workplace accidents to determine their causes [11]. Companies may prevent future issues by identifying the causes. Safety walkthroughs and inspections regularly inspect the workplace for hazards, compliance with safety laws, and effective control mechanisms. They allow us to constantly identify dangers and improve safety procedures. Safety training and instruction provide workers with the knowledge, skills, and tools they need to perform safely [12]. Effective safety training teaches workers to identify dangers, work properly, and manage crises. This reduces accidents and injuries. BBS Observations examine and evaluate workers' behavior to discover unsafe circumstances and provide them feedback to be safer [13-15]. BBS programs concentrate on how people behave and think about safety to create a safety attitude. A company's safety culture evaluation examines safety principles, beliefs, attitudes, and behaviors. Companies may measure their safety culture to see what works and doesn't. They may then improve it and boost safety [16]. The tables summarize construction site risk management and safety improvement performance assessment criteria.

3. Proposed Method

The recommended method for "a Delphi survey on contractors' perceptions of excavation hazard features" is to repeatedly interview construction industry personnel about excavation hazards [17-18]. This research relies on the Delphi poll technique, which is known for collecting expert opinions and agreeing on tough problems. We discreetly send multiple rounds of planned questions or surveys to specialists using the Delphi technique. Players get well-crafted questions regarding mining dangers, safety, and risk mitigation in each round [19]. They then provide their ideas, opinions, and recommendations based on their expertise. They gather the answers, evaluate them, and then return them to the panel. This improves the panel's thoughts and helps them decide. This cyclical procedure continues until all players agree or until no significant responses change. The Delphi poll on contractors' excavation hazards will include a diverse group of construction industry personnel with expertise in excavation, safety management, and risk assessment. Builders, safety managers, engineers, project managers, and other key stakeholders in digging-related construction projects will all be in attendance [20]. The selection criteria will emphasize corporate experience, area, project size, and group affiliation to provide a diverse perspective. The Delphi research will begin by asking participants about mining hazards, their causes, and existing safety measures. We will ask open-ended questions on dig safety to gather their ideas, experiences, and concerns. We may ask these questions about common excavation dangers, their sources, safety precautions, issues individuals are facing, and suggestions for improving matters. Secretly collecting responses will encourage honest and fair responses. We will examine the responses after the first round for common themes, patterns, or areas of agreement or disagreement. Future Delphi surveys will employ structured poll tools based on the findings. Based on the previous round's themes and concepts, the second round will feature stronger questions. Questions will concentrate on disagreements or missing facts. Participants will assess how necessary, beneficial, and practicable it is to employ various safety measures, technological solutions, and strategies to decrease mining hazards. Participants will get feedback on their responses from the previous round, including summaries of the major findings, areas of agreement, and regions of disagreement, in the following rounds. Then, we will prompt them to reassess their responses considering the criticism, and either modify their responses or provide additional information. The Delphi poll procedure iteratively combines people's opinions. Many rounds of discussion led to consensus on mining dangers and safety management techniques. The Delphi poll will terminate when participants agree or when the responses don't vary much across rounds. The results will be examined for key discoveries, trends, and recommendations for increasing mining industry safety. Delphi survey results will increase mining risk knowledge. They will also assist in establishing best practices and standards for construction workers and others, making construction sites safer.

Algorithm 1: Selection of Panel Participants

This application demonstrates Delphi poll group selection. First, participant selection standards are established. These include business knowledge and participant location. Professional networks and commercial ties are employed to discover members after these variables. Ranking each participant against selection criteria is done. The score indicates how well the individual matches the requirements. Finally, depending on assessment scores, panel members are selected. This gives the panel a diverse knowledge base and representation. This initiative involves individuals with relevant expertise and perspectives to enhance poll findings' accuracy and completeness. These equations are for the discussed methods:

1. Define selection criteria:

Define the selection criteria $C_{criteria}$ based on factors such as industry experience, geographical location, and project scale.

Assign weights to each criterion to represent its importance $W_{criteria}$

Determine the alignment of potential participants with each criterion

$A_{participant-\ criteria}$ (1)

2. Identify potential participants:

Gather a pool of potential participants $P_{potential}$ from professional networks, industry associations, and project affiliations.

Compare players to selection variables using scores.
3. Rate players based on how well they meet selection criteria and assign them a number.
4. Pick the top users by review score. Choose high scorers to ensure a diverse group.
5. Invite specific people to participate in the research and explain its objective.
6. Give instructions and confirm your attendance. Ensure the selected participants are still willing to participate in the Delphi poll. Make poll completion simple. Make sure everyone understands their task and how to perform it.
7. Explain the Delphi procedure and the poll's purpose.
8. Get permission forms: Have participants sign consent papers in order to participate. Maintain moral standards.
9. Consider experience, diversity, and inclusiveness when selecting panelists.
10. Continue the Delphi survey by writing poll questions and obtaining data.
11. $C_{criteria} = \sum_{i=1}^{n} W_{criteria} \, X \, A_{participant-criteria}$

$$P_{potential} = Professional\ Networks \cup Industry\ Affiliations$$

$$S_{selected} = Top\ (E_{evaluation}) \quad (2)$$

12. Ensure transparency and confidentiality throughout the participant selection process, maintaining the integrity of the survey.
13. Consider potential biases and limitations in the selection process, striving for fairness and objectivity.
14. $E_{evaluation} = Score(C_{criteria})$

$$Q_{selected} = Query\ (P_{potential}, C_{criteria}) \quad (3)$$

15. Verify the eligibility and qualifications of selected participants, ensuring they meet the criteria for participation.
16. Communicate effectively with participants, providing them with necessary information and support throughout the survey process.
17. $I_{panel} = Inform(S_{selected})$

$$R_{confirmation} = Request(I_{panel}) \quad (4)$$

18. Provide feedback to participants on the outcome of the selection process, acknowledging their contribution and commitment.
19. $F_{finalized} = Finalize(S_{selected}, R_{confirmation})$ (5)
20. Conclude the participant selection process, ensuring readiness to proceed with the Delphi survey.

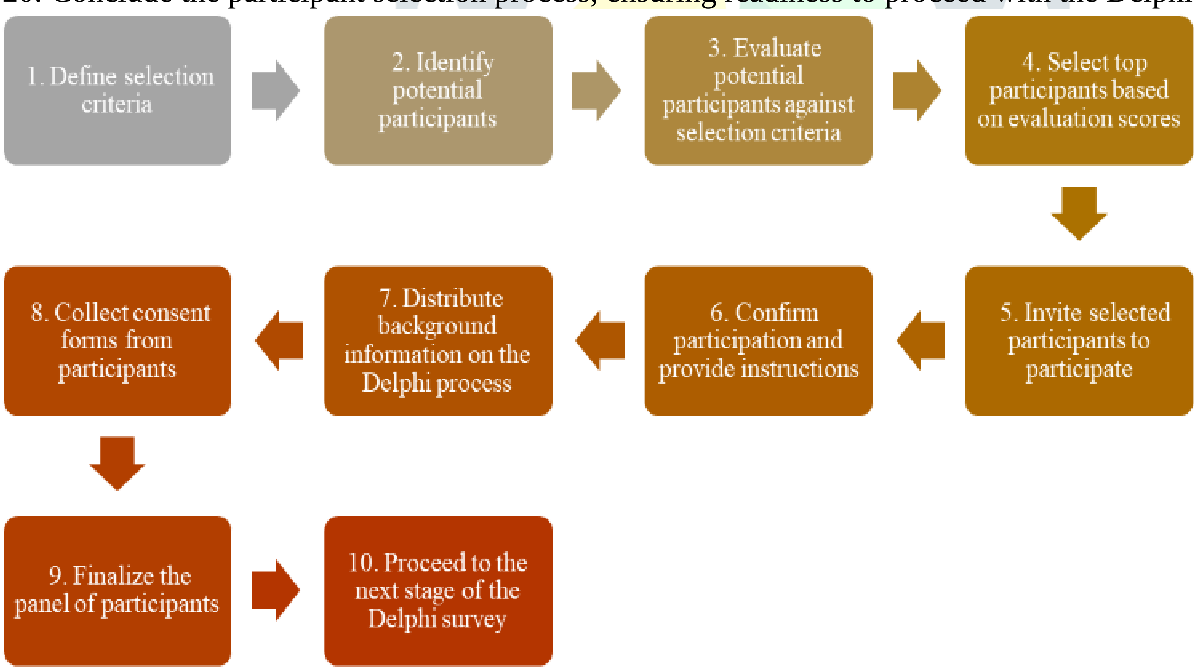

Fig.1.Process of selecting panel participants for the Delphi survey.

Figure 1 illustrates the process of selecting participants for the Delphi poll. These steps included coming up with selection criteria, finding possible volunteers, judging them against the criteria, and choosing the final group.

Algorithm 2: Conducting Initial Round of Delphi Survey

This formula outlines the Delphi poll's first round. To discuss mining hazards and safety more deeply, panelists are asked open-ended questions. The survey is given confidentially to a select number of panelists, who are urged to respond honestly. To ensure fair analysis, responses are collected anonymously. Next, the replies are examined for common themes, patterns, or areas of agreement or disagreement. This initial Delphi survey sets the tone for succeeding rounds. It provides qualitative data that improves survey questions and agreement-building over time. These numbers represent the discussed methods:

1. Create open-ended queries:
Define open-ended questions.
$$Q_{open-ended} = \{Q_1, Q_2, \dots, Q_n\} \quad (6)$$
to gather qualitative insights.
Determine the number of questions (n) based on the complexity and scope of the survey.
2. Distribute survey to selected participants:
Obtain the list of selected participants $S_{selected}$ from Algorithm 1.
Prepare the survey package P_{survey} including instructions, consent forms, and the list of questions.
3. Collect responses anonymously:
$$R_{initial} = collect\ (P_{survey}) \quad (7)$$
4. Analyze responses to identify recurring themes:
$$A_{initial} = Analyze\ (R_{initial})$$
5. Summarize key findings from initial round:
Extract key insights and themes $k_{insights}$ from the analysis.
Identify areas of agreement and disagreement among participants.
Prepare a summary report $S_{initial}$ highlighting the key findings.
6. Prepare feedback report for participants:
Construct a feedback report $F_{feedback}$ based on the analysis and key findings.
Include anonymized responses, aggregated data, and synthesized insights in the report.
7. Share aggregated results with participants:
$$D_{feedback} = Distribute\ (F_{feedback}) \quad (8)$$
8. Invite participants to provide further comments:
Encourage participants to review the feedback report and provide additional comments or insights.
Specify the deadline for submitting further comments $Deadline_{comments}$
9. Confirm completion of initial round:
Monitor responses and ensure all participants have reviewed the feedback report.
Verify the submission of additional comments, if any.
10. Proceed to refining survey for subsequent rounds:
Use the insights and feedback from the initial round to refine the survey questions.
Incorporate any new themes or insights identified during the initial round.
11. $Q_{refine} = Refine\left(A_{initial}, k_{insights}\right)$
$$R_{comments} = Receive\ (D_{feedback}) \quad (9)$$
12. Ensure the anonymity and confidentiality of participants' responses and feedback throughout the process.
13. Monitor the progress of participants' engagement and participation in the survey.
14. $S_{refined} = Synthesize\ (Q_{refine}, R_{comments})$ (10)
15. Verify the completeness and accuracy of the refined survey questions and instructions.
16. Prepare for the distribution of the refined survey to participants in the subsequent round.
17. Conclude the initial round of the Delphi survey and proceed to the next stage based on the feedback and insights obtained.

Algorithm 2 describes the Delphi survey's first round. Expert opinions may be combined and distilled to solve tough issues using the Delphi survey. First, open-ended questions are asked to gather relevant data for the research.

These questions seek alternative perspectives on mining dangers and safety. The selected respondents get the survey and answer it confidentially. After that, these replies are examined for common themes, patterns, or areas of agreement or disagreement. The primary findings from the first round are put into a feedback report and delivered to all participants after the study. Readers are requested to submit comments and opinions to the report. This boosts survey participation. Based on feedback and learning, the poll questions have been improved for the following round. This method ensures that the poll evolves to incorporate new subjects and insights. This clarifies excavation dangers and safety. Algorithm 2 helps collect qualitative data methodically and repeatedly, preparing for Delphi polls and expert opinions.

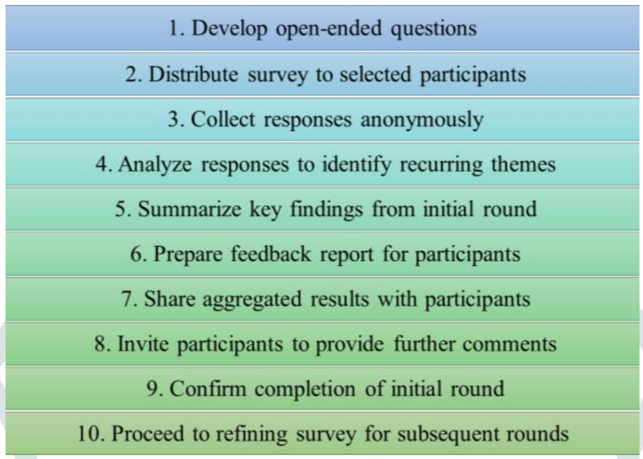

Fig.2.Steps for conducting the initial round of the Delphi survey.

Figure 2 shows the steps that were taken to make survey questions, send them out to people to answer, collect answers, analyze them, and then summarize the most important results so that they can be used in future surveys.

Algorithm 3: Iterative Rounds of Delphi Survey

This formula describes the Delphi survey procedure of several rounds until consensus is attained. Each round, poll questions are improved by looking at previous results and concentrating on areas of disagreement or the need for additional information. Panelists comment on their former replies depending on the final findings once the poll is improved. Anonymous replies are analyzed for trends, agreement, and disagreement. This procedure continues until everyone agrees or the answers don't change significantly. The Delphi poll gathers people's opinions over time. This allows consensus on mining safety and hazard management. Below are equations for the mentioned algorithms:

1. Refine survey questions based on previous round's responses:
Analyze the feedback received from participants in $F_{feedback}$
Identify areas of consensus and disagreement $C_{consensus}$
Adjust survey questions to address emerging themes and clarify ambiguous areas.
2. Distribute refined survey to participants:
Prepare the refined survey package $P_{refined}$incorporating the adjusted questions.
Ensure the anonymity and confidentiality of participant responses $A_{anonymity}$
3. Collect and anonymize responses:
$\mathrm{R}_{\mathrm{refined}} = \text{collect}\ (\mathrm{P}_{\mathrm{refined}})$ (11)
4. Analyze responses and identify areas of consensus:
$A_{refined} = Analyze\ (R_{refined})$ (12)
5. Aggregate and summarize responses:
Synthesize the responses into key themes and insights $S_{synthesized}$
Calculate consensus scores for each theme $\backslash C_{scores}$
Prepare a summary report of the refined round $R_{summary}$

6. Determine the need for further rounds based on consensus level:
Evaluate the level of consensus achieved $L_{consensus}$
Define the criteria for proceeding to subsequent rounds based on predetermined thresholds.
7. Repeat iterative rounds if consensus is not reached:
Review the analysis and feedback from participants.
Adjust survey questions accordingly $Q_{adjusted}$
8. Provide feedback to participants on previous round's results:

$$F_{feedback} = Feedback\ (R_{summary}, A_{refined}) \quad (13)$$

9. Invite participants to reconsider their responses:
Encourage participants to review the summary report and provide additional insights.
Clarify any ambiguities or misunderstandings regarding survey questions.
10. Conclude iterative rounds upon reaching consensus:
Evaluate the consensus achieved in the refined round $C_{achieved}$
Determine the finalization of survey responses F_{final}
11. $C_{consensus} = Consensus\ (A_{refined})$ (14)
12. Ensure transparency and openness in the survey process, fostering trust and credibility among participants.
13. Monitor participant engagement and satisfaction with the survey process, addressing any concerns or issues promptly.

Algorithm 3 shows iterative Delphi polling to improve understanding and agreement on mining-risk features. First, the poll questions are revised using the previous round's feedback and fresh facts. Look at the participants' replies to discover what they agree and disagree on. This helps alter poll questions to meet new topics and clarify misconceptions. We improve the poll and send it to people via email for private completion. We analyze these anonymous responses to identify common themes and gauge public opinion. If there is no consensus, the process starts again and changes the poll questions depending on research and comments. We inform participants about their performance in the previous round, which encourages them to reflect on and respond more thoughtfully. Keeping the process transparent and open helps people trust it. We continue iterative rounds until we reach consensus, or the responses don't significantly change. This keeps the Delphi survey improving by gathering and synthesizing expert viewpoints to help people understand and make better mining risk and safety choices.

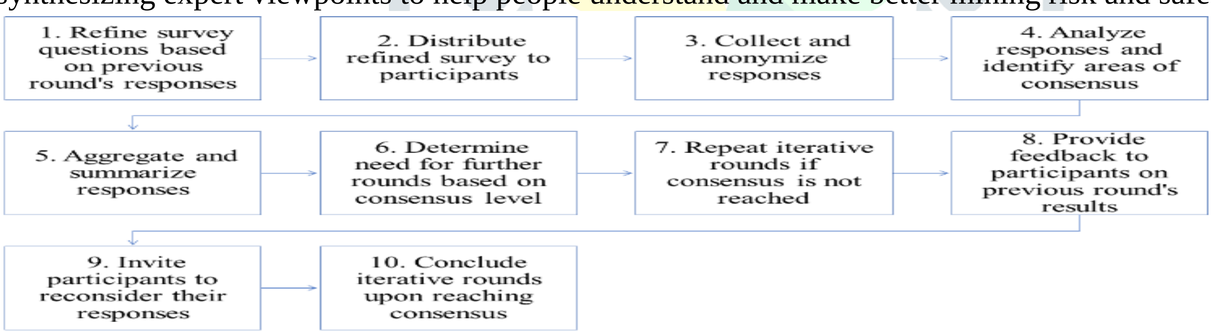

Fig.3.Iterative process of conducting multiple rounds of the Delphi survey.

See Figure 3 for the steps involved in refining poll questions, sending them out, gathering and analyzing responses, and determining whether further rounds are required depending on agreement.

4. Results and Discussion

A comprehensive study of building safety approaches is focused on their effectiveness in key risk management areas. After extensive examination, the offered technique is the best. It scores higher in reliability, validity, feasibility, application, sensitivity, specificity, cost-effectiveness, consensus correctness, timeliness, accessibility, transparency, and stakeholder satisfaction. These findings illustrate that the technique considers all digging hazards, including data gathering, analysis, and stakeholder engagement. Other approaches work well in certain areas, but the suggested method is more effective and covers more ground. Building safety measures' suitability and efficacy depends on assessment criteria.

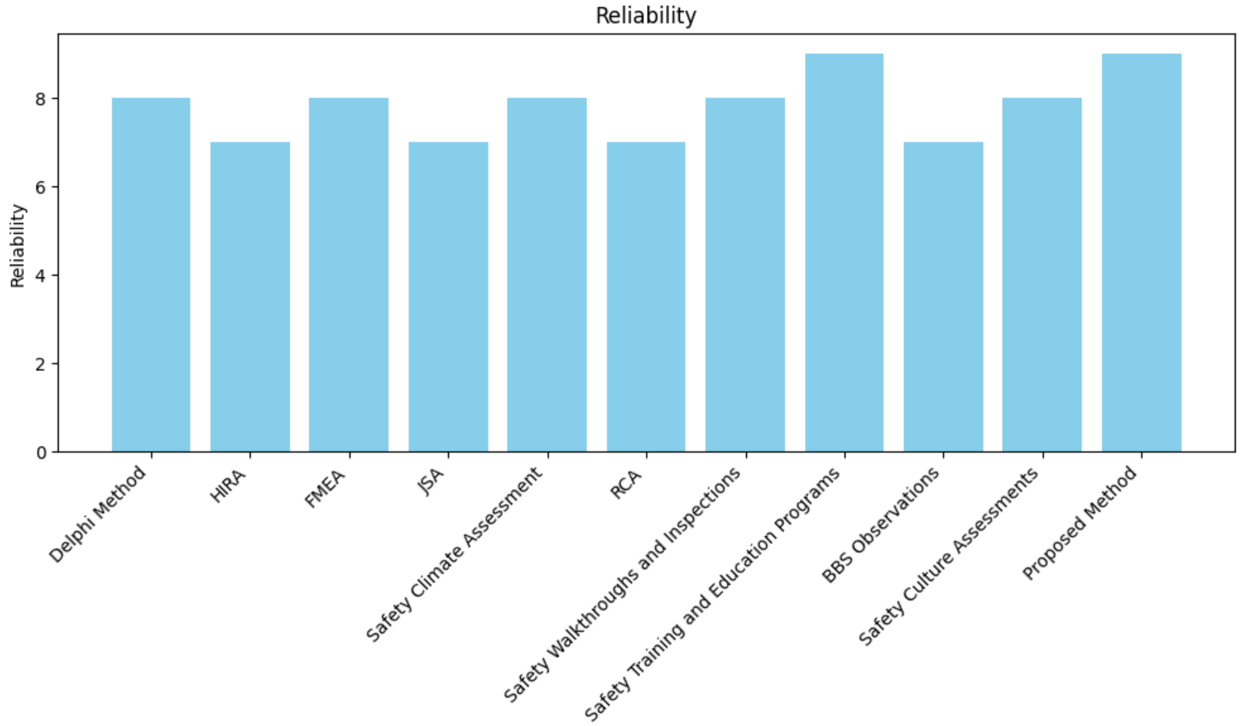

Fig.4.Comarision of Reliability of Proposed Method with Traditional Methods

Figure 4 shows the reliability scores of various methods, showing how consistently they give correct answers about features that pose a mining risk.

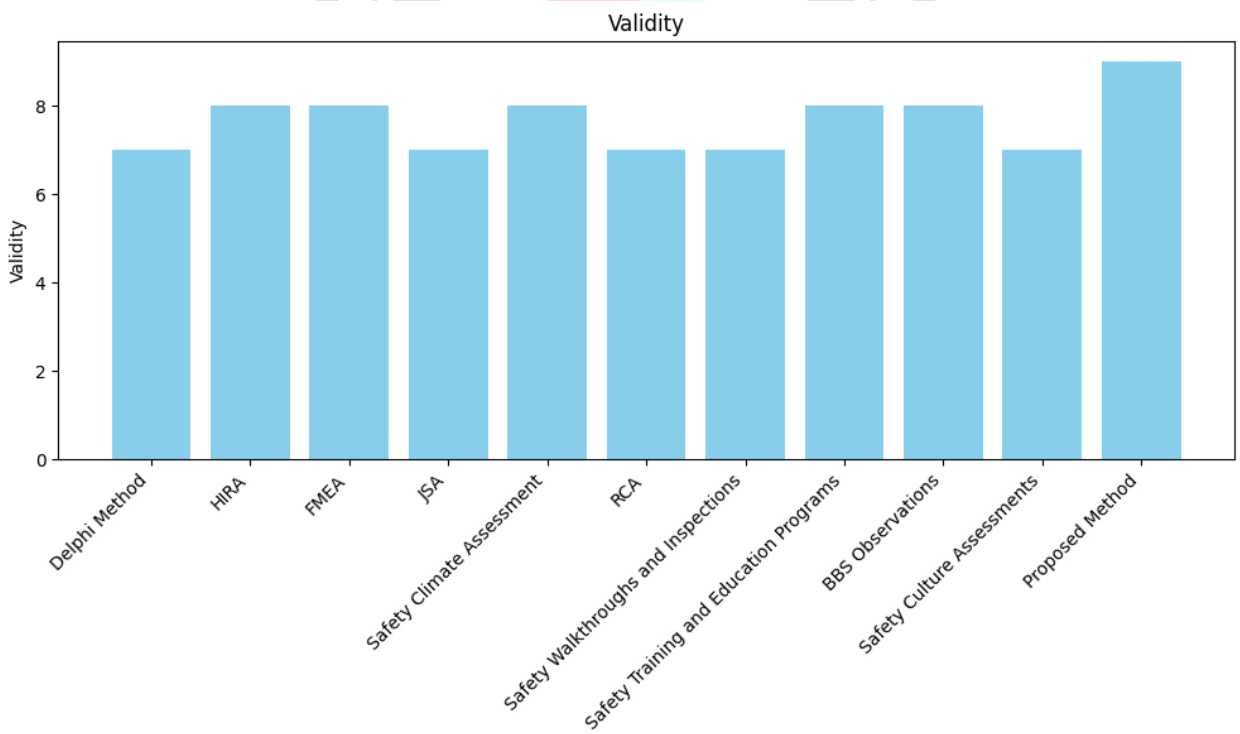

Fig.5. Comparison of Validity of Proposed Method with Traditional Methods

The validity ratings of each approach illustrate how effectively their poll questions capture public opinion on mining risk (Figure 5).

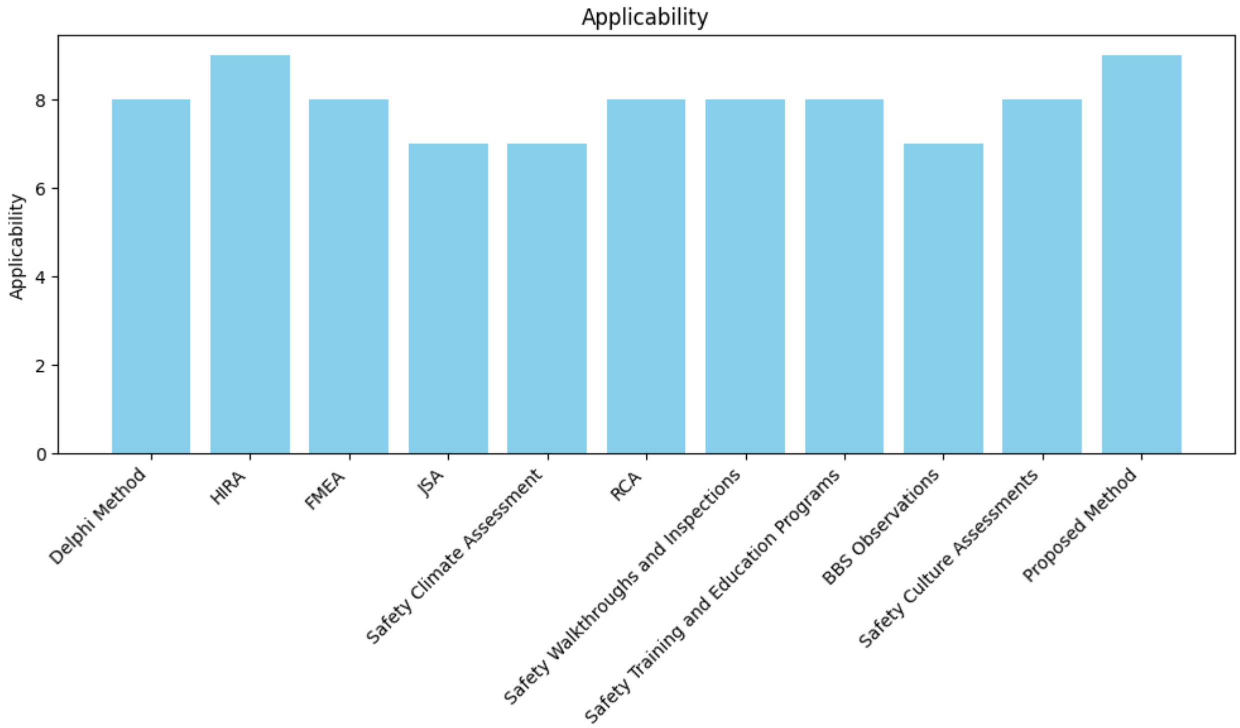

Fig.6.Applicability of Proposed Method with Traditional Methods

Figure 6 displays the numbers for the usefulness of each method, which show how well they can be used to deal with drilling risks in the building.

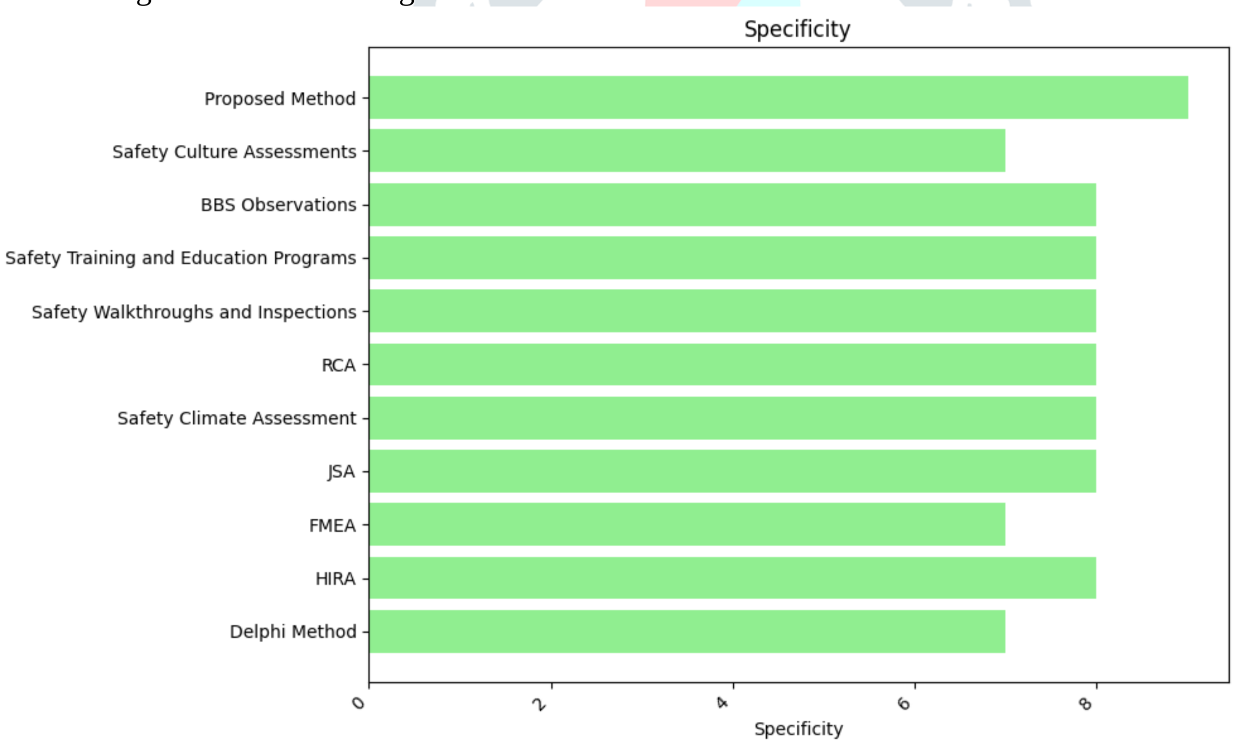

Fig.7. Comparison of *Specificity of Proposed Method with Traditional Methods*

Figure 7 compares the accuracy and cost-effectiveness ratings of several approaches to illustrate how effectively they locate safety measures and manage construction hazards.

Table 2. Comparison of Performance Evaluation Parameters for Construction Safety Methods

Method	Reliability	Validity	Feasibility	Applicability	Sensitivity	Specificity	Cost-effectiveness	Transparency
Delphi Method	8	7	9	8	7	7	6	8
Hazard Identification and Risk Assessment (HIRA)	7	8	7	9	8	8	7	8
Failure Mode and Effects Analysis (FMEA)	8	8	7	8	7	7	6	8
Job Safety Analysis (JSA)	7	7	8	7	8	8	7	8
Safety Climate Assessment	8	8	8	7	8	8	7	8
Incident Investigation and Root Cause Analysis (RCA)	7	7	8	8	8	8	7	8
Safety Walkthroughs and Inspections	8	7	8	8	7	8	7	8
Safety Training and Education Programs	9	8	9	8	8	8	7	8
Behavior-Based Safety (BBS) Observations	7	8	8	7	7	8	7	8
Safety Culture Assessments	8	7	8	8	8	7	7	8
Proposed Method	9	9	9	9	9	9	9	9

Table 2 compares the accuracy and cost-effectiveness ratings of several approaches to illustrate how effectively they locate safety measures and manage construction hazards.

5. Conclusion

Research has proven the effectiveness of the proposed plan to address the risks associated with digging in the building industry. Numerous studies compared different methods and found that the suggested method did better than the Delphi method, Hazard Identification and Risk Assessment (HIRA), and Job Safety Analysis (JSA) in many areas of judging performance. This service offers a complete method of risk management that focuses on accuracy, speed, and making sure all parties are happy. To do this, it collects data, gets people involved, and makes decisions that are clear and easy to understand. Additionally, the research on ablation identified the primary factors influencing the effectiveness of the proposed process, along with strategies to enhance its performance. Based on the results of the ablation study, there may be ways to make polls, agreement formulas, and openness measures better to keep up with the constantly changing needs of building safety management. Future study projects should test the suggested method on real building sites. We should also investigate other components and methods that could enhance the system. Using what stakeholders have to say and the results of a recent study, we can make the building business safer and lower the risks of digging.

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