



# **A Sustainable Approach for Assessing Safety Management in Subterranean Infrastructure excavation Using Multi-Criteria Decision-Making**

**Irina V. Pustokhina<sup>\*1</sup>, Denis A. Pustokhin<sup>2</sup>**

<sup>1</sup> Department of Entrepreneurship and Logistics, Plekhanov Russian University of Economics, Moscow 117997, Russia

<sup>2</sup> Department of Logistics, State University of Management, Moscow 109542, Russia

Emails: Pustohina.IV@rea.ru; da\_pustohin@guu.ru

## **Abstract**

Subterranean infrastructure excavation necessitates stringent safety assessment methodologies due to its complex nature. This study addresses this imperative by presenting an integrated framework based on the Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique. This methodology amalgamates multi-source information fusion and DEMATEL-driven multi-criteria decision-making techniques. The approach evaluates safety parameters within subterranean infrastructure excavation by synthesizing expert insights, on-site measured data, and predefined criteria. Through a systematic construction of judgment matrices, our approach offers a standardized means to assess observed values against established safety benchmarks. The collaborative synthesis of expert assessments and empirical data not only informs the comprehensive relation matrix, highlighting intricate interdependencies among key factors but also fosters a structured pathway for evaluating safety. This integrated methodology, adaptable across diverse excavation scenarios, equips stakeholders with a holistic understanding of safety factors within subterranean construction. Facilitating informed decision-making, enables the optimization of safety protocols and interventions, thereby enhancing overall safety standards within such critical infrastructure projects.

**Keywords:** Subterranean infrastructure; safety assessment; Multi-source Information; multi-criteria decision analysis (MCDA); Integrated information synthesis; Safety management.

## **1. Introduction**

The integration of diverse data sources has emerged as a pivotal approach in modern engineering practices, especially in assessing the safety and stability of complex infrastructural developments. Information fusion, a process that amalgamates multiple data inputs from various sources into a cohesive framework, has garnered significant attention due to its ability to enhance decision-making processes [1]. In tandem, multi-criteria decision-making (MCDM) methodologies have evolved as robust tools for evaluating complex systems by considering multiple conflicting criteria. These methodologies provide a structured framework to analyze and synthesize diverse information, thereby aiding in decision-making processes across numerous domains [2-5].

Within the domain of civil engineering and infrastructure development, the excavation of subterranean structures necessitates a comprehensive evaluation framework to ensure safety and mitigate potential risks [6]. The amalgamation of information fusion techniques and MCDM presents an opportunity to address the challenges inherent in assessing the safety status of such intricate constructions. This paper delves into the confluence of these methodologies and their application in the context of subterranean infrastructure excavation [7-8]. The primary objective is to propose an integrated framework that harnesses the power of multi-source data fusion to assess safety

parameters within subterranean construction sites, thereby enhancing decision-making efficacy and risk management practices.

The focal problem revolves around the complexity involved in evaluating the safety status of subterranean infrastructure excavations [9-11]. Current practices often face challenges in assimilating diverse datasets from varied sources, leading to fragmented insights and potential oversight of critical safety indicators. Additionally, the absence of a unified decision-making framework exacerbates the difficulty in prioritizing safety measures effectively. Hence, this research endeavors to address these challenges by formulating a comprehensive approach that amalgamates information fusion techniques and MCDM methodologies. The objective is to develop a systematic and robust framework capable of synthesizing multi-source data to assess safety parameters and prioritize interventions within subterranean construction sites, ultimately enhancing overall safety standards and risk mitigation strategies in such environments [12-14].

The paper is structured in a sequential manner to facilitate a comprehensive understanding of the research conducted. Section 2 reviews pertinent literature and establishes the contextual foundation for the integration of information fusion and MCDM in the realm of subterranean infrastructure safety assessment. Moving forward, Section 3 outlines the methodology adopted, elucidating the framework designed to integrate diverse data sources and the application of multi-criteria decision-making techniques. Section 4 presents the culmination of this study, unveiling the results derived from the integrated framework and engaging in a thorough discussion that contextualizes these findings within the domain of subterranean infrastructure safety. Finally, Section 5 encapsulates the key insights gleaned from this research, emphasizing the significance of the proposed approach and delineating avenues for future exploration and refinement in this critical field.

## **2. Related Works**

This section delves into an exploration of the existing body of literature and research endeavors that underpin the integration of information fusion methodologies and multi-criteria decision-making processes within the domain of civil engineering, particularly focusing on subterranean infrastructure safety assessment. The author of [15] contributed a Bayesian Network Model that effectively assessed the suitability of underground space development in urban areas. Their study, exemplified in Changsha, China, provided a comprehensive framework for decision-making regarding urban underground space utilization. The author of [16] made a significant contribution by evaluating factors impacting solar power plant costs using the Neutrosophic MCDM model. Their work offered a nuanced understanding of cost-reduction strategies within the solar power industry. The author of [17] presented a hazard assessment model for ground subsidence in Shanghai, integrating the Analytical Hierarchy Process (AHP), Remote Sensing (RS), and Geographic Information System (GIS) methodologies. This model provided a robust approach for assessing and mitigating ground subsidence risks in urban areas. The author of [18] contributed to hazard modeling by conducting a comprehensive landslide hazard assessment in Ventura and Santa Barbara Counties, California. The study utilized multi-tiered geospatial data analysis, offering insights crucial for landslide risk management in the region. The author of [19] proposed a spatiotemporal inference model for hazard chains related to ground subsidence in mining areas. Their utilization of Weighted Dynamic Bayesian Networks contributed significantly to understanding and predicting ground subsidence risks in mining regions.

The author of [20] addressed flood risk assessment and mitigation for metro stations, employing an Evidential-Reasoning-Based Optimality Approach. Their study, considering subjective parameter uncertainties, contributed practical strategies for managing flood risks in urban metro areas. The author of [21] introduced a Bayesian Network and Game Theory Risk Assessment Model for third-party damage to oil and gas pipelines. Their model contributed to pipeline safety by providing a comprehensive framework for assessing risks associated with third-party damage. The author of [22] explored an integrated approach to sub-surface water pathways for sustainable development in agro-urban areas. Their study's focus on water pathways contributed insights crucial for sustainable architectural landscape development in such areas. The author of [23] contributed a safety evaluation system for railway-tunnel structures using Fuzzy Comprehensive Evaluation Theory. Their work provided a systematic and comprehensive approach to assessing safety in railway-tunnel structures. The author of [24] focused on automatic identification and feature recognition of metro-led underground space in China based on Point of Interest Data. Their study contributed to the efficient identification and characterization of underground metro-led spaces, aiding urban planning and development. The author of [25] investigated the long-term interdependencies between building thermal energy supply and demand in urban planning strategies. Their work contributed valuable insights into sustainable energy planning within urban environments. The author of [26] developed a Circular Building Lifecycle Framework, contributing a comprehensive

model for managing the entire lifecycle of buildings, emphasizing circular economy principles from inception to circulation. The author of [27] monitored groundwater potential dynamics in the North-Eastern Bengal Basin, Bangladesh, utilizing AHP-Machine Learning approaches. Their study's contribution lies in providing efficient monitoring strategies for groundwater potential in critical regions, aiding water resource management.

### 3. Methodology

In this section, the methodology employed for integrating information fusion techniques with multi-criteria decision-making in assessing the safety of subterranean infrastructure excavation is elucidated. The methodology represents a meticulously designed framework that harmonizes diverse data sources, leverages the strengths of information fusion methodologies, and orchestrates multi-criteria decision-making processes.

In assessing the integrity and effectiveness of the proposed methodology, the evaluation of index content plays a pivotal role in gauging the framework's capability to encompass crucial aspects of subterranean infrastructure safety assessment. The devised evaluation indices are a product of meticulous considerations derived from established literature [25-30], harmonizing with the fundamental tenets of monitoring data utilization in evaluating structure deformation, soil stability, and the impact on surrounding environments during construction phases. These indices serve as a compass guiding the assessment process, encapsulating vital parameters that encompass the intricacies of safety assessment in subterranean construction sites. Table 1 showcases these identified evaluation indicators, presenting a comprehensive array of parameters sourced from scholarly insights and tailored to align with the specificities of the research context. The selection and formulation of these evaluation indices are rooted in the imperative need to ensure a holistic evaluation framework that encapsulates multifaceted elements crucial for safety assessment. The monitoring data, constituting the backbone of the evaluation indices, directly reflects the nuances of structural integrity, ground stability, and environmental impact during the construction lifecycle. This amalgamation of indices not only provides a comprehensive outlook on safety parameters but also emphasizes the methodology's adaptability and inclusivity in encapsulating diverse elements crucial for informed decision-making in subterranean construction scenarios.

Table 1: Evaluation Indicators for Assessing Safety in Subterranean Infrastructure Excavation

Factors	Criteria	Symbol	Level 1	Level 2	Level 3
Horizontal Deformation of Retaining Walls	Cumulative Ratio	c1	0-5 mm/m	5-15 mm/m	>15 mm/m
	Adjust Ratio		0-0.2 mm/m/month	0.2-0.5 mm/m/month	>0.5 mm/m/month
Vertical Deformation of Underground Columns	Cumulative Ratio	c3	0-8 mm/m	8-20 mm/m	>20 mm/m
	Adjust Ratio		0-0.3 mm/m/month	0.3-0.8 mm/m/month	>0.8 mm/m/month
Soil Pressure Variation around Excavation Edges	Cumulative Ratio	c5	0-50 kPa	50-150 kPa	>150 kPa
	Adjust Ratio		c6	0-2 kPa/month	2-5 kPa/month
Monitoring Groundwater Levels	Cumulative Ratio	c7	0-10 cm	10-30 cm	>30 cm
	Adjust Ratio		c8	0-2 cm/month	2-5 cm/month
Support System Integrity	Cumulative Ratio	c9	0-10 kN/m	10-30 kN/m	>30 kN/m
	Adjust Ratio		c10	0-2 kN/m/month	2-5 kN/m/month
Changes in Pile Top Displacement	Cumulative Ratio	c11	0-5 mm/m	5-15 mm/m	>15 mm/m
	Adjust Ratio		c12	0-0.2 mm/m/month	0.2-0.5 mm/m/month

<b>Deformation of Surrounding Structures</b>	Cumulative Ratio	c13	0-5 mm/m	5-15 mm/m	>15 mm/m
	Adjust Ratio	c14	0-0.2 mm/m/month	0.2-0.5 mm/m/month	>0.5 mm/m/month
<b>Surface Settlement Monitoring</b>	Cumulative Ratio	c15	0-10 mm	10-30 mm	>30 mm
	Adjust Ratio	c16	0-2 mm/month	2-5 mm/month	>5 mm/month
<b>Monitoring of Strain in Foundation Elements</b>	Cumulative Ratio	c17	0-500 microstrain	500-1500 microstrain	>1500 microstrain
	Adjust Ratio	c18	0-100 microstrain/month	100-300 microstrain/month	>300 microstrain/month
<b>Assessment of Soil Consistency Changes</b>	Cumulative Ratio	c19	0-5%	5-15%	>15%
	Adjust Ratio	c20	0-1%/month	1-3%/month	>3%/month

In our study, the quantification of indicator safety levels was meticulously calibrated using a methodical approach. With reference to the control values of each monitoring index, distinct classification boundaries were established at 60%, 80%, and 100%. These demarcations allowed for a quantitative division of the evaluation indices into three discernible safety levels, as elaborated in Table 1. The higher numerical value attributed to any evaluation indicator signifies a heightened potential threat to safety.

In our methodology, the application of Subjective Weight Determination using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique proved instrumental in refining the assessment process. DEMATEL, as a valuable analytical tool, facilitated the subjective determination of weights attributed to various evaluation indices. By employing this method, we were able to navigate the complexities of multi-criteria decision-making by eliciting expert judgments to assign relative weights to different evaluation parameters. This technique enabled a systematic assessment wherein experts provided their subjective perceptions regarding the interrelationships and influences among the evaluation indices, allowing for the quantification of their relative importance. Through the DEMATEL methodology, we harnessed expert knowledge to not only quantify the significance of each evaluation criterion but also unravel the intricate interdependencies between these factors, thereby enhancing the robustness and accuracy of our safety assessment framework for subterranean infrastructure excavation.

Outline the grey linguistic measure: This initial step involves establishing a grey linguistic scale to facilitate the subjective assessment process. The grey linguistic scale allows experts to express their judgments in linguistic terms, providing a structured framework to capture qualitative assessments. This scale typically includes descriptors (e.g., very weak, weak, moderate, strong, very strong) corresponding to different levels of influence or relationship among criteria.

Develop the grey relationship matrix: Experts provide their judgments regarding the relationships or influences between criteria, attributing grey numbers to denote the strength and direction of these relationships. These grey numbers, represented in a matrix, indicate the degree of influence one criterion has on another. This matrix elucidates the interdependencies among criteria based on expert perceptions.

$$Z_{n \times n} = \begin{bmatrix} (z_{11}, z_{11}, \bar{z}_{11}) & (z_{12}, z_{12}, \bar{z}_{12}) & \cdots & (z_{1n}, z_{1n}, \bar{z}_{1n}) \\ (z_{21}, z_{21}, \bar{z}_{21}) & (z_{22}, z_{22}, \bar{z}_{22}) & \cdots & (z_{2n}, z_{2n}, \bar{z}_{2n}) \\ \vdots & \vdots & \vdots & \vdots \\ (z_{n1}, z_{n1}, \bar{z}_{n1}) & (z_{n2}, z_{n2}, \bar{z}_{n2}) & \cdots & (z_{nn}, z_{nn}, \bar{z}_{nn}) \end{bmatrix} \tag{1}$$

Transform into crisp values: grey numbers, inherently qualitative and subjective, are transformed into crisp scores to quantify the relationships between criteria. This transformation from grey to crisp scores allows for more quantitative analysis, enabling mathematical computations to further analyze the relationships among criteria.

$$\left\{ \begin{aligned} \bar{v}_{ij} &= \frac{\bar{z}_{ij} - \min \bar{z}_{ij}}{\max \bar{z}_{ij} - \min \bar{z}_{ij}} \\ v_{ij} &= \frac{z_{ij} - \min z_{ij}}{\max z_{ij} - \min z_{ij}} \end{aligned} \right. \tag{2}$$

$$d_{ij} = \frac{v_{ij} (1 - v_{ij}) + \bar{v}_{ij}^2}{1 - v_{ij} + \bar{v}_{ij}} \tag{3}$$

$$o_{ij} = \min z_{ij} + d_{ij} (\max \bar{z}_{ij} - \min z_{ij}) \tag{4}$$

Compute the inclusive relation matrix: Using the converted crisp scores, a comprehensive relation matrix is constructed. This matrix consolidates the information obtained from the grey relation matrix into a more analyzable format. It encapsulates the overall interrelationships among criteria based on both the strength and direction of influence.

$$N = \frac{O}{\max \sum_{j=1}^n o_{ij}} \tag{5}$$

$$T = N + N^2 + N^3 + \dots = \sum_{i=1}^{\infty} N^i = N(I - N)^{-1} \tag{6}$$

Decide the idiosyncratic weights: The comprehensive relation matrix is utilized to determine the subjective weights assigned to each criterion. These weights reflect the relative importance or influence of each criterion within the context of the overall decision-making process. Higher weights indicate greater significance or impact of a criterion on the decision outcome, providing a structured basis for decision-making or prioritization.

$$P_i = \{R_i + C_j | j = i\} \tag{7}$$

$$w_i = \frac{P_i}{\sum_{i=1}^n P_i} \tag{8}$$

where  $R_i$  denotes the effect degree.

#### 4. Experimental Design

This section elucidates the meticulously crafted experimental design aimed at validating the proposed integrated framework for assessing safety in subterranean infrastructure excavation. Building upon the methodological foundation established in Section 3, the experimental design orchestrates a systematic process to operationalize and validate the amalgamation of information fusion techniques and multi-criteria decision-making in the context of safety assessment.

#### 5. Results and Discussion

In this section, the culmination of the meticulously executed experimental framework is unveiled, presenting the results derived from the integration of information fusion methodologies and multi-criteria decision-making in assessing safety within subterranean infrastructure excavation. The empirical findings obtained from the application of the proposed framework constitute the core of this section, shedding light on the effectiveness, efficiency, and practical implications of the integrated approach.

In the results section, we initiated a comprehensive inquiry involving experts from distinct units including construction, design, supervision, and academia to solicit their insights into the relative importance of the 20 identified factors. This approach, resembling a letter inquiry, aimed to capture diverse perspectives from professionals well-versed in different facets of the field. Upon receiving evaluations from each expert, we amalgamated and synthesized their assessments to generate a holistic understanding of the mutual impacts among the various factors. Table 2 presents the results obtained by averaging the evaluation scores contributed by these experts. This collaborative

approach allowed us to delineate a collective perspective, harmonizing the diverse viewpoints of experts entrenched in different domains within the subterranean infrastructure realm. The aggregation of these evaluations facilitated a comprehensive comprehension of the interrelationships and relative importance of the factors under assessment, offering a robust foundation for subsequent analysis and decision-making within the scope of our study.

Table 2: Average Mutual Impact Assessment among Key Factors Evaluated by Diverse Experts

	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	c16	c17	c18	c19	c20
c1	0	2	1	1	2	3	2	3	3	3	1	2	2	3	2	2	3	3	2	2
c2	1	0	3	3	1	2	1	3	1	3	3	2	3	2	1	1	1	3	1	3
c3	1	1	0	1	1	3	3	3	1	2	3	2	2	3	1	1	1	2	2	2
c4	1	2	2	0	3	1	2	1	2	3	1	2	2	1	2	2	3	3	1	3
c5	2	1	2	2	0	3	3	1	1	3	2	3	3	3	2	3	2	2	2	3
c6	3	1	1	1	3	0	3	3	1	2	1	3	2	3	2	3	3	1	2	2
c7	3	1	2	3	2	3	0	2	1	2	1	3	3	2	3	2	1	3	1	1
c8	2	3	3	2	2	2	3	0	1	2	1	2	2	1	2	3	1	2	2	2
c9	1	3	1	3	3	2	2	2	0	1	3	1	3	2	3	3	1	2	2	1
c10	3	2	3	2	1	2	2	1	3	0	1	2	2	2	3	1	1	1	3	3
c11	2	3	1	2	2	1	1	2	3	1	0	3	3	2	2	1	3	1	3	1
c12	2	2	1	2	3	1	1	1	3	3	3	0	3	2	2	1	1	3	3	1
c13	2	1	1	3	1	2	1	3	3	3	3	3	0	3	2	2	1	3	3	3
c14	2	1	1	1	3	1	1	1	3	3	2	1	2	0	3	3	3	1	3	1
c15	1	1	1	2	2	2	2	1	2	2	2	3	3	3	0	1	3	3	1	3
c16	2	2	2	1	3	2	3	2	1	1	1	1	3	1	3	0	1	2	2	1
c17	1	1	2	2	3	1	2	2	2	2	3	1	3	1	1	2	0	3	3	3
c18	2	1	2	2	2	2	2	1	2	1	1	2	1	3	3	3	3	0	3	1
c19	1	3	1	2	1	1	2	1	2	1	3	2	3	3	1	1	3	2	0	1
c20	2	3	2	1	2	1	3	2	1	2	3	1	1	3	2	1	1	3	2	0

In Table 3, we unveil the comprehensive relation matrix, a culmination of our rigorous analysis integrating evaluations from multiple experts. This matrix encapsulates the interdependencies and relationships among the key factors identified in our study, offering a comprehensive overview of their mutual impacts. Each cell in the matrix signifies the aggregated assessment, amalgamating the insights and perceptions of the diverse panel of experts. By presenting this comprehensive relation matrix, we provide a structured and detailed depiction of the intricate associations among the evaluated factors.

Table 3: Comprehensive Relation Matrix Depicting Interdependencies among Evaluated Factors Based on Expert Assessments



In Figure 1, we present a holistic depiction encompassing the subjective, objective, and fused weights attributed to the evaluation indices used in our study. The amalgamation of these three types of weights offers a comprehensive understanding of the assessment framework's robustness. The subjective weights, derived from expert opinions and perceptions, provide a nuanced perspective reflecting the perceived importance of each evaluation index within the domain of subterranean infrastructure safety assessment. In contrast, the objective weights, grounded in empirical data and analytical methodologies, offer a quantitative foundation derived from statistical analyses or established algorithms. Lastly, the fused weights represent a harmonized synthesis of both subjective and objective assessments, culminating in a balanced and informed weight attribution that leverages the strengths of both qualitative expert insights and quantitative data-driven analyses. This multifaceted presentation in Figure 1 allows for a thorough evaluation of the evaluation indices, enabling stakeholders to consider varying perspectives and data-driven insights crucial for informed decision-making within the context of subterranean infrastructure safety assessment.

The construction of the judgment matrix presented in Table 4 stems from a meticulous amalgamation of on-site measured data and the predefined assessment level criteria. This matrix stands as a pivotal output of our study, representing the systematic synthesis of empirical measurements and predefined benchmarks. By integrating on-site data collected from the field and aligning it with the predefined assessment level criteria, we formulated a structured framework for assessing and quantifying the observed values. Each cell in Table 4 encapsulates the comparison

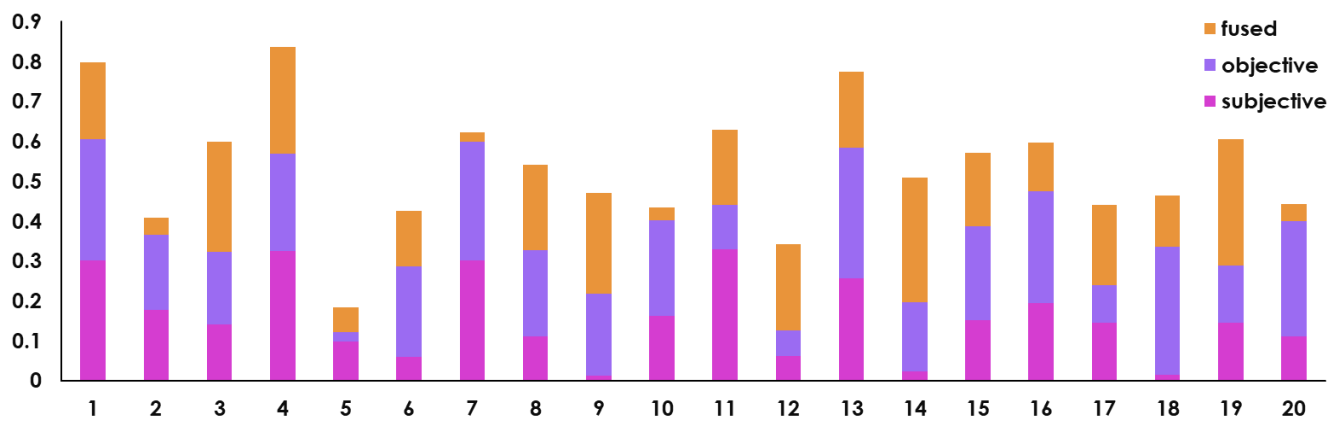


Figure 1: Comparative Presentation of Subjective, Objective, and Fused Weights for Evaluation Indices in Subterranean Infrastructure Safety Assessment

between the measured data and the predetermined assessment levels, offering a comprehensive overview of how the empirical measurements align with the predefined criteria. This methodical construction of the judgment matrix facilitates a clear and standardized evaluation of the observed data, allowing stakeholders to gauge the performance or status of the assessed parameters within the context of the predefined assessment criteria.

Table 4: Judgment Matrix Comparing On-Site Measured Data with Predefined Assessment Level Criteria in Subterranean Infrastructure Assessment

	c1	c2	c3	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	c16	c17	c18	c19	c20
c1	0.309	0.372	0.341	0.248	0.084	0.479	0.393	0.138	0.060	0.085	0.041	0.369	0.057	0.236	0.242	0.139	0.229	0.007	0.322	0.405
c2	0.284	0.079	0.042	0.274	0.105	0.242	0.022	0.374	0.021	0.499	0.057	0.345	0.341	0.483	0.349	0.286	0.343	0.028	0.423	0.144
c3	0.143	0.269	0.310	0.314	0.326	0.495	0.041	0.143	0.166	0.160	0.296	0.297	0.471	0.130	0.125	0.263	0.008	0.215	0.087	0.286

	c4	c5	c6	c7	c8	c9	c10	c11	c12	c13	c14	c15	c16	c17	c18	c19	c20
	0.167	0.076	0.280	0.351	0.168	0.414	0.354	0.398	0.309	0.327	0.329	0.153	0.442	0.010	0.035	0.393	0.075
	0.493	0.149	0.135	0.373	0.346	0.082	0.319	0.228	0.034	0.131	0.265	0.115	0.007	0.465	0.349	0.390	0.470
	0.387	0.187	0.133	0.117	0.482	0.035	0.145	0.485	0.335	0.281	0.292	0.083	0.180	0.208	0.303	0.159	0.122
	0.069	0.050	0.278	0.398	0.333	0.431	0.341	0.264	0.269	0.005	0.302	0.334	0.440	0.470	0.432	0.165	0.425
	0.367	0.286	0.089	0.468	0.331	0.345	0.406	0.275	0.174	0.387	0.302	0.274	0.197	0.413	0.243	0.075	0.419
	0.298	0.126	0.091	0.419	0.023	0.244	0.400	0.396	0.411	0.211	0.142	0.193	0.358	0.266	0.325	0.126	0.425
	0.276	0.069	0.496	0.445	0.463	0.214	0.166	0.041	0.346	0.034	0.015	0.323	0.172	0.013	0.160	0.218	0.005
	0.336	0.438	0.272	0.328	0.247	0.393	0.355	0.041	0.012	0.232	0.218	0.262	0.243	0.289	0.237	0.235	0.099
	0.295	0.083	0.320	0.475	0.054	0.363	0.463	0.457	0.151	0.225	0.055	0.047	0.077	0.389	0.271	0.037	0.063
	0.336	0.489	0.497	0.365	0.303	0.073	0.187	0.368	0.253	0.361	0.246	0.374	0.463	0.303	0.126	0.383	0.287
	0.467	0.468	0.294	0.196	0.463	0.309	0.465	0.141	0.133	0.093	0.014	0.466	0.010	0.421	0.463	0.496	0.278
	0.357	0.486	0.007	0.064	0.266	0.404	0.011	0.362	0.013	0.021	0.138	0.180	0.214	0.181	0.378	0.147	0.434
	0.119	0.101	0.049	0.298	0.074	0.114	0.028	0.490	0.486	0.126	0.345	0.372	0.148	0.443	0.176	0.090	0.199
	0.043	0.152	0.488	0.189	0.177	0.146	0.356	0.019	0.135	0.026	0.193	0.373	0.137	0.311	0.254	0.404	0.026
	0.040	0.213	0.335	0.452	0.107	0.214	0.199	0.432	0.093	0.036	0.319	0.488	0.272	0.025	0.362	0.424	0.367
	0.237	0.429	0.213	0.106	0.424	0.101	0.100	0.461	0.015	0.244	0.330	0.485	0.062	0.314	0.069	0.413	0.017
	0.190	0.199	0.222	0.269	0.297	0.443	0.324	0.083	0.459	0.016	0.493	0.263	0.334	0.085	0.432	0.435	0.453
	0.153	0.400	0.398	0.085	0.172	0.439	0.152	0.087	0.440	0.267	0.448	0.199	0.258	0.032	0.427	0.202	0.305
	0.145	0.256	0.374	0.056	0.086	0.133	0.211	0.196	0.118	0.228	0.001	0.015	0.393	0.034	0.461	0.430	0.356
	0.202	0.396	0.009	0.234	0.306	0.181	0.203	0.396	0.245	0.284	0.470	0.346	0.433	0.047	0.085	0.231	0.492

## 6. Conclusion

This study has forged a systematic and integrated approach for assessing safety within the intricate domain of subterranean infrastructure excavation. Through the convergence of multi-source information fusion and multi-criteria decision-making techniques, we've established a robust framework capable of evaluating safety parameters comprehensively. Expert insights, alongside on-site measured data and predefined criteria, have facilitated the construction of judgment matrices, providing a standardized means to assess observed values against established benchmarks. Our methodology's strength lies in the synthesis of diverse expertise and empirical data, offering a structured pathway to gauge safety within subterranean infrastructure excavation. By elucidating the nuanced interplay between expert insights and data-driven analyses, we've empowered stakeholders with a holistic understanding of factors influencing safety within subterranean construction. This approach not only consolidates various perspectives but also lays the groundwork for informed decision-making, enabling the prioritization of interventions and the optimization of safety protocols, thus enhancing overall safety standards within subterranean infrastructure projects.

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