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# Risk Assessment Framework for BOT Projects in Post-War Reconstruction

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**Abstract:** Driven by an urgent need for systematic risk assessment of Build-Operate-Transfer (BOT) projects in Syria's post-war reconstruction context, this research addresses the critical risk factors specific to BOT projects in post-conflict environments, systematically classifies and prioritizes these risks, and develops a framework for effective risk assessment and management. Using a rigorous mixed-methods approach, we developed a comprehensive risk register that identifies and categorizes 48 distinct risks across five major categories: organization/political, financial/economic, environmental/natural, design/implementation/operation, and humanitarian/materials/equipment. The research methodology consisted of questionnaire responses from 161 industry professionals, including government officials and engineering consultants. The collected data were analyzed using SPSS for validation. Both the impact and the probability of each risk were measured on a five-point Likert scale, and a z-test was used to test the hypothesis. The results indicated that organizational and political risks, specifically the imposition of international sanctions and regional tensions, pose the primary threat to BOT project implementation in Syria, while environmental risks were found to be less critical. The developed risk register provides a structured tool for risk assessment and management, incorporating local contextual factors that are often absent in traditional frameworks. For policymakers, investors, and project managers involved in Syria's post-conflict reconstruction, this research offers practical insights and contributes to a theoretical understanding of BOT projects more generally.

**Keywords**: Risk register, build-operate-transfer (BOT), post-war reconstruction, infrastructure development, project risk management.



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## 1. Introduction

Financing and implementing infrastructure development in post-conflict regions requires new approaches, due to their unique challenges. Infrastructure reconstruction has become an important area for the application of BOT contracts, especially where public resources are limited and private sector investment is needed for the development (Koseoglu et al., 2019). In recent years, they have grown in importance in post-conflict reconstruction efforts worldwide, facilitating private sector involvement in public infrastructure projects. The BOT projects in the post-conflict environment, specifically in Syria's reconstruction context, as investigated in this research, encompass various types of infrastructure developments, including transportation systems (highways, airports), utilities (water treatment plants, power generation facilities), and telecommunications networks. However, BOT projects in post-conflict environments face risks that are greater than those encountered in stable regions, calling for specialized risk management approaches (Ebrahimnejad et al., 2010). Moreover, BOT projects face more solidified challenges than conventional projects, specifically due to their extended timelines, large scale, and the involvement of numerous local and international stakeholders (Al-Azemi et al., 2014). The complexity is exacerbated in post-conflict situations characterized by severely damaged infrastructure, strained economic resources, weak institutional capacity, and the presence of international sanctions and regional tensions. Given these unique risks,

current risk assessment and management approaches have lagged behind the demands of post-conflict reconstruction, a gap highlighted in academic literature.

In addition, traditional risk assessment approaches often fail to consider the specific challenges of post-conflict recovery contexts. The lack of comprehensive risk classification systems tailored to post-conflict BOT projects is a significant hurdle to their effective implementation and management (Al-Kana'neh, 2016).

Current risk assessment frameworks lack comprehensive classification systems for post-conflict environments, failing to address unique challenges such as international sanctions, regional instability, and institutional capacity limitations. This research aims to fill these gaps by developing a framework that organizes these risks by importance and provides practical tools to help investors identify and manage these challenges. The outcome is a comprehensive risk register customized for application in BOT projects in post-conflict environments. Using a mixed-method approach combining quantitative analysis of questionnaire data from 161 industry professionals with qualitative expert validation, a robust risk classification system is developed. This work contributes a structured approach to risk identification and classification in complex project environments, providing a framework for future studies in similar contexts. The systematic methodology is designed to be applied across different post-conflict scenarios while also being sensitive to their particularities.

In addition, this research makes substantial contributions across theoretical, methodological, and practical dimensions of BOT project risk management in post-conflict environments. From a theoretical perspective, this study advances understanding by developing a comprehensive risk classification system that identifies and categorizes 48 distinct risks across five major categories. This represents the first systematic categorization of post-conflict BOT projects. This research contributes to the first systematic categorization developed specifically for post-conflict BOT projects. The novelty lies in this context-specific framework that addresses gaps in traditional risk assessment approaches. This research is enhanced by the creation of a novel risk assessment matrix specifically calibrated for post-conflict environments, providing a more nuanced understanding of risk relationships in complex reconstruction scenarios. The research also illuminates the interconnections between different risk categories, contributing to a more sophisticated understanding of risk interaction patterns and broadening the theoretical foundation of BOT risk management.

The practical contributions provide a comprehensive risk register template, provided by this research, which is immediately available for direct application to project planning and implementation. This tool is complemented by the development of specific risk mitigation strategies for high-priority risks, offering project managers concrete recommendations for addressing these challenges. Furthermore, the research establishes clear guidelines to support risk prioritization in post-conflict BOT projects and subsequently to manage resource allocation and risk response planning in such projects. Finally, the structured approach to risk assessment and management equips practitioners with a systematic approach to recognize, analyze and react to risk at multiple phases of the project lifecycle.

Collectively, these multi-dimensional contributions advance both the practical implementation and the theoretical understanding of BOT projects in post-conflict environments, providing valuable insights for academics, policymakers, investors, and project managers involved in post-conflict reconstruction. In so doing, this research bridges the gap between theory and practice and provides a foundation for a more successful implementation of BOT projects in such post-conflict environments.

## 2. Evolution of Risk Classification in BOT Projects

Over the past two decades, the development of risk classification systems applied to BOT projects has improved considerably. Early studies identified basic concepts of project risks as potential challenges that may constrain its implementation or even completely halt a project in construction, funding or initiation phases (Jaafari, 2001). This initial conceptualization was later developed by framing risk management as an iterative process of identifying risk and determining appropriate action, and as the laying of foundations for more systematic ways to classify risk (McNamara, 2006). Oyeyoade et al. (2025) conducted a study focused on risk factors in BOT projects by conducting a systematic search of 38 articles relevant to this matter published between 1994 and 2024. The analysis recognized theme areas of risk assessment, critical risk factors, critical success factors, and risk mitigation in different types of BOT projects, with most studies being made in China, Australia, the UK, and the USA. It was found that there has been steady growth in the number of studies based on the risk factors in BOT projects since 2007. The article ended by suggesting further studies of risk factors in specific BOT projects, as much fewer efforts are spent on the risk typologies according to the specifics of the sector.

Empirical research has significantly refined the risk register as a practical project management tool. Research has revealed an increasing trend in the use of BOT schemes for infrastructure works in both developed and developing countries (Chan et al., 2015). Their research also highlighted the need for systematic risk documentation and classification, particularly given limited government funding. Ma and Fu (2020) used qualitative comparative analysis to demonstrate how specific "complexity combinations" impact mega construction project success, finding that "high organizational complexity or a combination of high environmental and goal complexity can lead to serious schedule delays".

Further steps were taken towards the development of risk register methodology by designing a comprehensive framework around BOT projects (Dey and Ogunlana, 2004). Their work is particularly notable for its systematic risk categorization. In addition to traditional organizational and political risks, their framework includes financial/economic, technical/operational, and environmental/social risks. While this categorization system has remained influential in subsequent research, it requires adaptation for post-conflict scenarios. In a case study, Ghadage et al. (2020) utilized the traditional Failure Mode and Effects Analysis (FMEA) methodology, employing Severity (S), Occurrence (O), and Detection (D) parameters to calculate Risk Priority Numbers (RPN). They used survey data from four management-level respondents to systematically identify and prioritize project risks. By calculating and ranking RPNs from highest to lowest

scores, the research demonstrated how manufacturing based FMEA techniques can be effectively adapted to assess and manage risks in innovative project environments.

Research conducted over the last decade has increasingly focused on developing sophisticated methodologies for risk assessment in complex project environments. Pimplikar and Mane (2013) identified that the most significant risks faced by BOT projects and proposed methods for proper risk management. Cheng et al. (2021) developed a conceptual framework of sustainability-oriented Public-Private Partnership (PPPs), outlining three evolutionary phases: PPP1.0, PPP2.0, and PPP3.0. They validated this framework through a case study of the Taizhou commuter-rail Line S1 PPP project, analyzing it across four dimensions: driving force, subject, process, and object. This research supports the need for comprehensive risk classification frameworks in BOT projects that extend beyond traditional economic considerations to encompass sustainability and stakeholder value creation. Their research also highlighted the importance of the information shown in Table 1.

**Table 1.** Evolution of risk assessment approaches in BOT projects

| Period | Focus Area | Key Contributors | Major Findings |
|---|---|---|---|
| 2000-2010 | Basic Risk Classification | Jaafari (2001) | Initial risk categorization |
| 2010-2015 | Systematic Approaches | Ebrahimnejad (2010) | Dual risk classification |
| 2015-2020 | Complex Environments | Chan et al. (2015) | Context-specific factors |
| 2020-present | Post-conflict Contexts | Khudhaire (2021) | Reconstruction challenges |

### 2.1. Post-Conflict Considerations in Risk Classification

Applying risk classification systems to post-conflict environments introduces unique complications (Al-Thibyanni, 2014). Their author identified critical factors specific to post-conflict situations, including limitations on government transparency, inadequacies in the legal framework, and economic information gaps. Akram et al. (2023) examined PPP challenges in Pakistan's construction sector, finding that while BOT models are effective for large-scale infrastructure projects, they remain vulnerable to political instability. The study identified critical issues, including regulatory complexity, changing jurisdiction, coordination issues, financial constraints, and the absence of standardized resources. However, their work lacks a systematic risk classification framework suitable for post-conflict environments, where political volatility and institutional weaknesses are amplified for BOT projects. Alshamleh and Sabri (2018) further explored the major obstacles to BOT implementation in politically volatile regions. They found that specialized risk classification approaches are needed, as indicated in Table 2.

**Table 2.** Risk classification approaches in BOT projects

| Risk Category | Traditional Context | Post-Conflict Context |
|---|---|---|
| Political Risks | Policy changes | Regime instability |
| Economic Risks | Market fluctuation | Currency collapse |
| Operational Risks | Technical issues | Resource scarcity |
| Social Risks | Public resistance | Security concerns |

A growing body of literature addresses risk classification systems that incorporate regional factors. The need for regional instability studies on construction projects has again been brought to context-specific risk assessment tools, flexible classification systems, and adaptable mitigation strategies (Alwaly and Alawi, 2020; Mhetre et al., 2016; Kaleel and Kareem, 2019; Khudhaire and Naji, 2021). However, this body of work also reveals a gap: while it shows the importance of creating risk registers that account for regional variations, it is not systematic.

### 2.2. Contemporary Approaches to Risk Register Development

Recent developments in risk register methodology have emphasized the need for dynamic and adaptable systems. This points toward a comprehensive approach to risk identification and management, shown in Table 3.

**Table 3.** Risk identification and management in BOT projects

| Component | Traditional Approach | Enhanced Approach |
|---|---|---|
| Risk Identification | Static listings | Dynamic updating |
| Risk Assessment | Single perspective | Multi-stakeholder |
| Mitigation Strategies | Generic solutions | Context-specific |
| Monitoring Systems | Periodic review | Continuous adaptation |

## 3. Research Methodology

In general, a research process is divided into several layers, each layer represents a range of data collecting approaches, methods, tactics, and techniques, as shown in Fig. 1 (Saunders, Lewis and Thornhill, 2011).

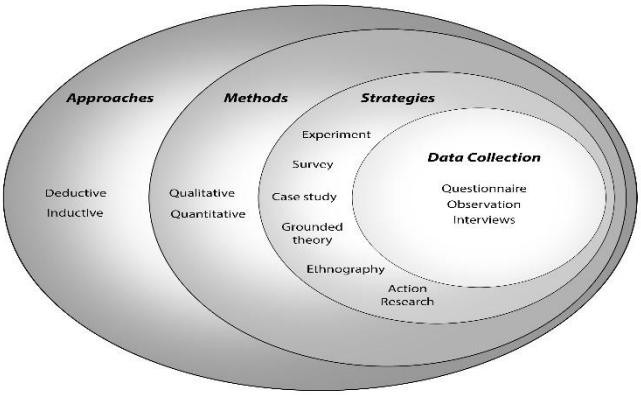


**Fig. 1**. Onion tree of methodology (Saunders, Lewis and Thornhill, 2011)

This research implemented a five-stage systematic approach to investigate risk management in Build-Operate-Transfer (BOT) contract execution:

Stage 1: Literature Review. A comprehensive literature review was conducted to establish the theoretical foundation by examining existing research on risk management in BOT contract execution. This stage involved systematic identification, analysis, and synthesis of relevant academic publications, industry reports, and case studies to establish the theoretical foundation for the case studies.

Stage 2: Risk Classification and Categorization. Based on the literature review, risks associated with BOT contract execution were identified, analyzed, and systematically classified into distinct categories. This taxonomic approach facilitated the development of a comprehensive risk framework that encompasses the multifaceted nature of BOT project risks.

Stage 3: Data Collection Instrument Development and Distribution. A structured questionnaire was designed and validated to gather expert perspectives on BOT risk management practices. The questionnaire was distributed to a targeted sample of engineering professionals and industry experts within Syria and internationally, to ensure diverse geographical and expert representation.

Stage 4: Statistical Analysis and Hypothesis Testing. The survey data was analyzed using SPSS software. This stage involved descriptive statistics, reliability testing, and inferential analysis to validate the research hypotheses and identify significant relationships between variables.

Stage 5: Framework Development and Recommendations. Based on the analytical results from Stage 4, a comprehensive BOT risk management was developed. This final stage culminated in the formulation of evidence-based recommendations that address the identified risk factors and propose practical solutions for effective BOT risk management. The overall methodology framework applied in this research is illustrated in Figure 2.

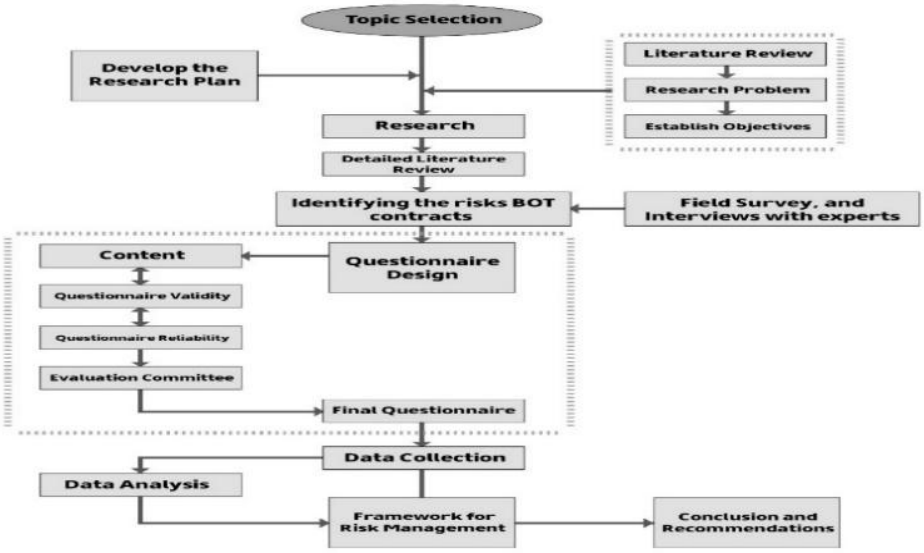


**Fig. 2.** Methodology implementation model

The study population comprised professionals with expertise in BOT contracts from three key sectors: government organizations (the Ministry of Tourism and the Ministry of Transport), engineering consulting companies, and first and second-class contractors. The sample size was determined using Stephen Thompson's equation, Eq. (1) (Thompson, 2012).

$$\boldsymbol{n} = [N \times p \times (1 - p)] / [(N - 1) \times (d^2/Z^2) + p \times (1 - p)] \quad (1)$$

Where:
n: Sample size
N: Population size (225)
Z: Standard score (1.96 for 95% confidence level)
d: Standard error (0.05)
p: Population proportion (0.5)

The calculated minimum sample size was 142. However, the study achieved a response rate of 71.6%, with 161 valid responses from 167 total submissions.

## 4. Questionnaire Design

The questionnaire was designed and consists of three main parts:

- Personal Information:
  - Academic qualifications
  - Professional experience
  - BOT project knowledge
- Risk Impact Assessment:
  - Five-point Likert scale (1: Very Low to 5: Very High)
  - 48 identified risks across five categories
- Risk Probability Assessment**:**
  - Five-point Likert scale (1: Almost Uncertain to 5: Almost Certain)
  - Same 48 risks evaluated for likelihood of occurrence

### 4.1. Content Validity

According to Scheaffer et al. (2011), the validity was assessed as indicated in Table 4.

**Table 4.** Validity of the research

| Correlation Range | Relationship Level | Number of Questions |
|---|---|---|
| 0.0 - 0.3 | Low | 3 |
| 0.3 - 0.5 | Medium | 20 |
| 0.5 - 1.0 | High | 25 |

### 4.2. Data Analysis Methods

Comprehensive statistical analysis was done using SPSS software that incorporated:

- Descriptive Statistics (Mean values, Standard deviations, Frequency distributions)
- Analytical Statistics
  - Z-test Analysis as shown in equation (2)

$$\boldsymbol{Z} = (\bar{X} - \mu) / (\sigma / \sqrt{N}) \quad (2)$$

Where: $\bar{X}$ is sample mean, μ represents population mean, σ represents standard deviation, and N is the sample size

- Risk Value: which can be calculated using equation (3) below

$$\boldsymbol{Risk\ Value} = \text{Impact} \times \text{Probability} \quad (3)$$

The risk value classification matrix is shown in Table 5.

**Table 5.** Risk value classification matrix

| Risk Value Range | Risk Level | Action Required |
|---|---|---|
| 20 – 25 | Very High | Immediate action |
| 15 – 19 | High | Priority attention |
| 10 – 14 | Medium | Regular monitoring |
| 5 – 9 | Low | Periodic review |
| 1 – 4 | Very Low | Awareness |

## 5. Risk Assessment Matrix

The study utilized a (5 × 5) risk assessment matrix to evaluate the combination of impact and probability scores, as indicated in Table 6.

**Table 6.** Risk assessment matrix

| Impact/Probability | Very Low | Low | Medium | High | Very High |
|---|---|---|---|---|---|
| Very High (5) | M | H | H | VH | VH |
| High (4) | L | M | H | H | VH |
| Medium (3) | VL | L | M | H | H |
| Low (2) | VL | L | L | M | H |
| Very Low (1) | VL | VL | L | L | M |

### 5.1. Data Collection Process

Data was collected using an online questionnaire distributed via Google Forms. Follow-up communications were also carried out for data validation and cleaning procedures. Subsequently, the responses were categorized and coded.

## 6. Results and Analysis

This mixed method study aims to develop a comprehensive risk register framework for BOT projects in a post-conflict environment. The analytical framework incorporated quantitative analysis of risk factors, statistical validation of findings, risk categorization and prioritization, and framework development and refinement.

A total of 161 industry professionals responded to this survey, providing a response rate of 71.6%. As shown in Table 7, the respondents were fairly well distributed across key sectors. However, Table 8 demonstrates a potential limitation: the high level of respondent's experience may limit the generalizability of the findings. Notably, 47.2 of respondents had over 16 years of professional experience.

**Table 7.** Industry professionals

| Organization Type | Number | Percentage |
|---|---|---|
| Governmental Organization | 62 | 38.5% |
| Engineering Company | 48 | 29.8% |
| Contracting Firm | 51 | 31.7% |
| Total | 161 | 100% |

**Table 8.** Respondent experience levels

| Experience Range | Number | Percentage |
|---|---|---|
| 0-5 years | 19 | 11.8% |
| 6-10 years | 27 | 16.8% |
| 11-15 years | 39 | 24.2% |
| More than 16 years | 76 | 47.2% |
| Total | 161 | 100% |

The results for the studied risks categories, Organizational and Political Risks, Financial and Economic Risks, Environmental and Natural Risks, Design, Implementation, operation and development risks, and Humanitarian, Materials and Equipment risks" are indicated in Tables 9, 10, 11, 12, and 13, respectively. Each table contains the relevant survey questions and an analysis of responses, including the following metrics: Risk Statements, Mean, St. D, Rank, Z, Effect/ Reject, and Level of Importance.

A sample of results related to the questionnaire / personal information / academic qualifications, is illustrated in Fig. 3.

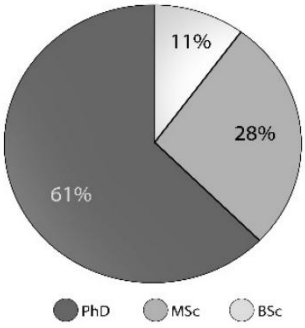


**Fig. 3.** A Sample of Distribution by Educational Level

### 6.1. Questionnaire Survey Analysis

### 6.2. Overall Risk Category Rankings

Table 14 shows distinct patterns in risk perception across the five major categories that were statistically analyzed.

**Table 9.** Results of responses "Organizational and Political Risks"

| No | Risk Description | Mean | St. D | Rank | Z | Effect/ Reject | Level of Importance |
|---|---|---|---|---|---|---|---|
| 4 | Potential International sanctions (stoppage risk) | 4.11 | 0.76 | 1 | 18.61 | Effect | High |
| 3 | International and regional tension (delay risk) | 4.11 | 0.88 | 2 | 15.99 | Effect | High |
| 5 | Collapse of political system, security, economy | 3.63 | 1.21 | 3 | 6.56 | Effect | High |
| 1 | Political licenses cancelation or ratifications risk | 3.53 | 1.11 | 4 | 6.02 | Effect | High |
| 9 | lack of compliance to concession deadline | 3.33 | 0.95 | 5 | 4.79 | Effect | Medium |
| 6 | Inaccurate B.O.T regulations. | 3.32 | 1.03 | 6 | 4.38 | Effect | Medium |
| 2 | Government change project revocation | 3.31 | 1.26 | 7 | 3.96 | Effect | Medium |
| 8 | Competing project development | 3.27 | 0.72 | 8 | 3.14 | Effect | Medium |
| 7 | Failure to comply any level of regulations | 3.12 | 0.90 | 9 | 1.75 | Reject | Medium |
| | Total | 3.53 | 0.98 | -- | 7.24 | Effect | High |

**Table 10.** Results of responses "Financial and Economic Risks"

| No | Risk Statement | Mean | St. D | Rank | Z | Effect/ Reject | Level of Importance |
|---|---|---|---|---|---|---|---|
| 11 | Sudden changes to currency exchange rates | 4.29 | 0.79 | 1 | 20.55 | Effect | Very High |
| 10 | Imposing on foreign currency transfers restrictions. | 3.90 | 1.00 | 2 | 11.48 | Effect | High |
| 13 | Imposed new conditions for different reasons. | 3.62 | 0.89 | 3 | 8.88 | Effect | High |
| 14 | Failure to pay payments on time. | 3.58 | 1.10 | 4 | 6.71 | Effect | High |
| 12 | Changes in taxes regulations. | 3.43 | 0.94 | 5 | 5.86 | Effect | High |
| 15 | Contract opacity issues or disclosure deficits | 3.33 | 1.04 | 6 | 4.01 | Effect | Medium |
| 16 | End-of-term neglect | 3.27 | 0.83 | 8 | 4.18 | Effect | Medium |
| 20 | Dishonesty in contract implementation | 3.25 | 1.05 | 7 | 2.99 | Effect | Medium |
| 17 | Long-term pricing gaps | 3.19 | 0.95 | 9 | 2.57 | Effect | Medium |
| 18 | Changes in work permits regulations | 3.17 | 0.93 | 10 | 2.24 | Effect | Medium |
| 19 | Changes to project outcomes during concession | 3.12 | 0.70 | 11 | 2.36 | Effect | Medium |
| | Total | 3.47 | 0.93 | -- | 6.53 | Effect | High |

**Table 11.** Results of responses "Environmental and Natural Risks"

| No | Risk Statement | Mean | St. D | Rank | Z | Effect/ Reject | Level of Importance |
|---|---|---|---|---|---|---|---|
| 22 | Pandemic related implementation risks | 3.14 | 1.15 | 1 | 1.58 | Reject | Medium |
| 26 | Safety implementation shortfalls | 3.09 | 0.97 | 2 | 1.21 | Reject | Medium |
| 27 | Poor site selection | 2.95 | 0.92 | 3 | -0.68 | Reject | Medium |
| 25 | Project-induced environmental community damage | 2.70 | 1.04 | 4 | -3.70 | Reject | Medium |
| 23 | Geological site invalidation due to seismic hazards | 2.48 | 1.06 | 5 | -6.24 | Reject | Low |
| 24 | Unexpected structural collapse risks | 2.35 | 0.99 | 6 | -8.37 | Reject | Low |
| 21 | Natural disaster site vulnerability | 2.02 | 0.93 | 7 | -13.46 | Reject | Low |
| | Total | 2.68 | 1.01 | - | -4.24 | Reject | Medium |

### 6.3. High-Impact Risk Identification

The analysis identified several risks with significantly high impact scores (mean > 4.0):

- International sanctions impact (Mean: 4.11, SD: 0.76)
- Regional political tensions (Mean: 4.11, SD: 0.88)
- Currency exchange fluctuations (Mean: 4.29, SD: 0.79)

### 6.4. Reliability Analysis

The internal consistency of the risk assessment instrument was confirmed through Cronbach's Alpha (Mohesen, 2011), as shown in Table 15.

### 6.5. Z-Test Results

Z-test analysis for this research confirmed the statistical significance of identified risks, as indicated in Table 16.

### 6.6. Risk Classification Matrix

Based on the survey results, a comprehensive risk classification matrix was developed, as shown in Table 17.

**Table 12.** Results of responses "Design, Implementation, Operation and Development Risks"

| No | Risk Statement | Mean | St. D | Rank | Z | Effect / Reject | Level of Importance |
|---|---|---|---|---|---|---|---|
| 35 | Government interference in project management | 3.82 | 0.81 | 1 | 12.92 | Effect | High |
| 34 | Repetitive utility service disruptions | 3.81 | 1.07 | 2 | 9.67 | Effect | High |
| 33 | Exceeding project building deadlines | 3.61 | 0.79 | 3 | 9.75 | Effect | High |
| 37 | Post-concession maintenance cost burdens | 3.35 | 0.86 | 4 | 5.13 | Effect | Medium |
| 36 | Demand-supply capacity mismatch risks | 3.32 | 0.78 | 6 | 5.26 | Effect | Medium |
| 28 | Design approval delays | 3.32 | 1.02 | 5 | 3.96 | Effect | Medium |
| 31 | Inter-party negotiation complexities | 3.22 | 0.91 | 7 | 3.02 | Effect | Medium |
| 29 | Design modification risks during construction | 3.20 | 0.83 | 8 | 3.13 | Effect | Medium |
| 32 | Project cost estimation errors | 3.20 | 0.95 | 9 | 2.64 | Effect | Medium |
| 30 | Substandard project quality and metrology | 3.06 | 0.92 | 10 | 0.77 | Reject | Medium |
| | Total | 3.39 | 0.89 | -- | 5.63 | Effect | Medium |

**Table 13.** Results of responses "Humanitarian, Materials and Equipment Risks"

| No | Statements | Mean | St. D | Rank | Z | Effect/ Reject | Level of Importance |
|---|---|---|---|---|---|---|---|
| 45 | Essential raw material cost escalation | 3.94 | 0.78 | 1 | 15.27 | Effect | High |
| 43 | Raw material shortage | 3.67 | 0.95 | 2 | 8.92 | Effect | High |
| 44 | Essential equipment and spare parts shortages | 3.61 | 0.76 | 3 | 10.17 | Effect | High |
| 46 | International raw material supply disruptions | 3.47 | 0.97 | 4 | 6.18 | Effect | High |
| 47 | Critical machinery acquisition difficulties | 3.37 | 1.01 | 5 | 4.70 | Effect | Medium |
| 40 | International labor recruitment restrictions | 3.34 | 1.04 | 7 | 4.08 | Effect | Medium |
| 48 | Technology identification and assessment failures | 3.31 | 0.86 | 6 | 4.58 | Effect | Medium |
| 42 | Visa and equipment importation regulatory restrictions | 3.27 | 1.01 | 8 | 3.35 | Effect | Medium |
| 41 | Inadequate staff permit periods for project completion | 3.18 | 0.91 | 9 | 2.50 | Effect | Medium |
| 39 | Specialist expertise acquisition difficulties | 3.06 | 1.20 | 10 | 0.59 | Reject | Medium |
| 38 | Local skilled labor shortage | 2.91 | 1.15 | 11 | -1.03 | Reject | Medium |
| | Total | 3.3 | 0.97 | - - | 5.39 | Effect | Medium |

**Table 14.** Risk perception

| Risk Category | Impact Mean | Probability Mean | Combined Risk Score |
|---|---|---|---|
| Organizational and Political Risks | 3.53 | 3.41 | 12.04 |
| Financial and Economic Risks | 3.47 | 3.39 | 11.76 |
| Design/Implementation Risks | 3.39 | 3.36 | 11.39 |
| Humanitarian/Materials Risks | 3.37 | 3.42 | 11.52 |
| Environmental and Natural Risks | 2.68 | 2.71 | 7.26 |

**Table 15.** Cronbach's alpha for the risk assessment instrument

| Risk Category | Cronbach's Alpha |
|---|---|
| Organizational/Political Risks | 0.955 |
| Financial/Economic Risks | 0.946 |
| Environmental/Natural Risks | 0.935 |
| Design/Implementation Risks | 0.944 |
| Humanitarian/Materials Risks | 0.953 |

**Table 16.** Z-Test analysis for the risk factors

| Risk Factor | Z-Score | p-value | Significance |
|---|---|---|---|
| International Sanctions | 18.61 | <0.001 | Significant |
| Regional Tensions | 15.99 | <0.001 | Significant |
| Currency Exchange | 20.55 | <0.001 | Significant |

**Table 17.** Risk classification matrix

| Impact Level | Probability Range | Risk Value | Classification |
|---|---|---|---|
| Very High | 4.23 - 5.00 | 20-25 | Critical |
| High | 3.43 - 4.22 | 15-19 | Significant |
| Medium | 2.62 - 3.42 | 10-14 | Moderate |
| Low | 1.81 - 2.61 | 5-9 | Minor |
| Very Low | 1.00 - 1.80 | 1-4 | Negligible |

**Table 18.** Distribution of identified risks across severity levels

| Severity Level | Number of Risks | Percentage |
|---|---|---|
| Critical | 5 | 10.4% |
| Significant | 12 | 25.0% |
| Moderate | 18 | 37.5% |
| Minor | 9 | 18.8% |
| Negligible | 4 | 8.3% |

### 6.7. Risk Distribution Analysis

The distribution of identified risks across severity levels is indicated in Table 18.

### 6.8. Key Findings Synthesis

The survey analysis revealed several critical insights for BOT risk register development. Political and organizational risks dominated the high-impact category. Financial risks showed high probability but moderate impact, while environmental risks consistently ranked lowest in both impact and probability. International factors significantly affected risk perception, where local operational risks showed moderate but consistent impact. Resource-related risks did not represent high concerns which demonstrate high variability. From a temporal point of view, short-term risks focused on political and financial factors, whereas Long-term risks emphasized operational and maintenance aspects, and medium-term risks are mostly centered on implementation challenges.

## 7. Discussion

### 7.1. Risk Category Significance

The analysis of this research reveals significant patterns in risk perception and categorization that extend beyond traditional BOT risk frameworks. The dominance of organizational and political risks (mean impact: 3.53, probability: 3.41) aligns with the findings from Jaafari (2001) but demonstrates higher severity in post-conflict contexts. Notably, five key patterns emerge from the data and summarized in Table 19.

**Table 19.** Key patterns

| Risk Category | Traditional Context[1] | Post-Conflict Context[2] | Variation |
|---|---|---|---|
| Political/Organizational | Medium | Very High | +2 levels |
| Financial/Economic | High | High | No change |
| Technical/Operational | High | Medium | -1 level |
| Environmental | Medium | Low | -1 level |
| Social/Cultural | Low | High | +2 levels |

*Note [1]Based on literature review findings [2]Based on current study results

### 7.2. Risk Register Framework Application

The developed risk register framework, shown in Table 20, demonstrates several key strengths and limitations in practical application.

### 7.4. Implementation Challenges

Several implementation challenges emerged from the analysis:

- Resource Requirements:
  - Initial implementation requires significant resource allocation

- Ongoing monitoring demands sustained organizational commitment
- Training needs for effective framework utilization

- Organizational Integration: The framework's integration into existing project management systems presents specific challenges as shown in Table 22:

**Table 20.** Risk register template and results

| Axis | Risk No. (as listed in tables 9-13) | Risk Impact | Risk Probability | Risk Value | Risk Assessment |
|---|---|---|---|---|---|
| Organizational and Political Risks | 4 | 4.11 | 3.88 | 16 | H |
| | 3 | 4.11 | 3.84 | 16 | H |
| | 5 | 3.63 | 3.47 | 13 | M |
| | 1 | 3.53 | 3.42 | 12 | M |
| | 9 | 3.33 | 3.22 | 11 | M |
| | 6 | 3.32 | 3.17 | 11 | M |
| | 2 | 3.31 | 3.1 | 10 | M |
| | 8 | 3.27 | 3.4 | 11 | M |
| | 7 | 3.12 | 3.19 | 10 | M |
| Financial and Economic Risks | 11 | 4.29 | 3.19 | 14 | M |
| | 10 | 3.9 | 4.06 | 16 | H |
| | 13 | 3.62 | 3.37 | 12 | M |
| | 14 | 3.58 | 3.26 | 12 | M |
| | 12 | 3.43 | 3.48 | 12 | M |
| | 15 | 3.33 | 3.19 | 11 | M |
| | 16 | 3.27 | 3.48 | 11 | M |
| | 20 | 3.25 | 3.09 | 10 | M |
| | 17 | 3.19 | 3.14 | 10 | M |
| | 18 | 3.17 | 3.17 | 10 | M |
| | 19 | 3.12 | 2.81 | 9 | L |
| Environmental and Natural Risks | 22 | 3.14 | 3.16 | 10 | M |
| | 26 | 3.09 | 3.14 | 10 | M |
| | 27 | 2.95 | 2.89 | 9 | L |
| | 25 | 2.7 | 2.73 | 7 | L |
| | 23 | 2.48 | 2.46 | 6 | L |
| | 24 | 2.35 | 2.54 | 6 | L |
| | 21 | 2.02 | 2.04 | 4 | VL |
| Design, Implementation, operation and development risks | 35 | 3.82 | 3.48 | 13 | M |
| | 34 | 3.81 | 3.81 | 15 | H |
| | 33 | 3.61 | 3.45 | 12 | M |
| | 37 | 3.35 | 3.42 | 11 | M |
| | 36 | 3.32 | 3.39 | 11 | M |
| | 28 | 3.32 | 3.32 | 11 | M |
| | 31 | 3.22 | 3.02 | 10 | M |
| | 29 | 3.2 | 3.16 | 10 | M |
| | 32 | 3.2 | 3.52 | 11 | M |
| | 30 | 3.06 | 3.03 | 9 | L |
| Humanitarian, Materials and Equipment risks | 45 | 3.94 | 3.79 | 15 | H |
| | 43 | 3.67 | 3.58 | 13 | M |
| | 44 | 3.61 | 3.64 | 13 | M |
| | 46 | 3.47 | 3.34 | 12 | M |
| | 47 | 3.37 | 3.51 | 12 | M |
| | 40 | 3.34 | 3.55 | 12 | M |
| | 48 | 3.31 | 3.27 | 11 | M |
| | 42 | 3.27 | 3.52 | 12 | M |
| | 41 | 3.18 | 3.2 | 10 | M |
| | 39 | 3.06 | 3.24 | 10 | M |
| | 38 | 2.91 | 3.03 | 9 | L |

### 7.3. Risk Mitigation Strategies

The research findings suggest specific mitigation approaches for high-priority risks as indicated in Table 21.

**Table 21.** Specific mitigation approaches

| Challenge Type | Severity | Mitigation Potential | Resource Impact |
|---|---|---|---|
| Technical Integration | Medium | High | Moderate |
| Staff Training | High | Medium | Significant |
| Process Alignment | Medium | High | Moderate |
| Data Management | High | Medium | Significant |

**Table 22.** Specific challenges

| Challenge Type | Severity | Mitigation Potential | Resource Impact |
|---|---|---|---|
| Technical Integration | Medium | High | Moderate |
| Staff Training | High | Medium | Significant |
| Process Alignment | Medium | High | Moderate |
| Data Management | High | Medium | Significant |

## 8. Research Summary

A risk register framework for BOT projects in post-conflict environments has been developed in this research, which confronts a significant unexplored field in the existing project management literature. The study achieves several significant results through systematic analysis of 161 expert responses, coupled with rigorous statistical validation. It develops a framework which categorizes and identifies 48 distinctive risks into five major categories, providing a structured method for risk assessment and management in the unique and systematically challenging contexts of post-conflict settings.

## 9. Conclusion

The success of BOT projects in post-conflict reconstruction will increasingly depend on sophisticated risk management approaches, and as the field evolves, the integration of new technologies and methodologies will further enhance our ability to manage risks effectively in challenging environments. The research demonstrated that traditional risk classification systems require substantial modification for post-conflict environments. However, the key findings provided insight across multiple research dimensions, including risk categorization, priority ranking, implementation strategy, and validation of results. Five integrated risk categories were used in the risk assessment process. The political risks were identified as the highest priority among professional respondents. It also showed the need for specific localized approaches. The validation results of the developed framework showed high reliability with a Cronbach's alpha of 0.95, confirming its robustness for practical application. The developed integrated risk classification system successfully established an understanding of risk interaction patterns and can advance the dynamic assessment methodology for BOT projects in post-conflict environments. Based on the findings of this study, it is recommended that academics focus on the extension of the developed framework and theoretical model development, for practitioners to adopt systematic risk assessment approaches with context-specific modifications, and policymakers to develop supporting legislative frameworks when they promote international collaboration in a post-conflict environment.

## Author Contributions

Ahmad Labach: methodology, data collection, data analysis, original manuscript draft. Orabi Al Rawi: conceptualization, methodology, validation, project administration, supervision, writing, review and editing. Aya Hamdan: visualization, formal data analysis, draft preparation. Nidal M. Hussein: conceptualization, methodology, validation, supervision, writing, review and editing.

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## Declaration of Artificial Intelligence (AI) Tools

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