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# Contextualizing Hybrid Model for Assessing Investment Risks in PPP-Driven BOT Student Housing: A Systematic Literature Review

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**Abstract**
This study investigates how risk assessment techniques are applied in Build-Operate-Transfer (BOT) student housing projects and responds to the growing need for risk assessment frameworks tailored to concessionary educational infrastructure. This is against the background of the knowledge gap in risk assessment techniques in BOT student housing development. A systematic literature review was conducted using the PRISMA protocol. This review contributes to the discourse on PPP infrastructure risk management, showcasing limitations in applying risk assessment techniques to student housing. The review considered 543 peer-reviewed articles published between 2004 and 2024, sourced from Scopus, Web of Science, Google Scholar, and Dimensions. Following screening for relevance and methodological rigour, 45 studies were selected for qualitative synthesis. The analysis shows that while quantitative methods, such as Monte Carlo Simulation, Analytic Hierarchy Process (AHP), and Fuzzy Logic, are widely adopted in BOT risk assessment, contextual variables relevant to student housing projects, such as interruption of academic calendars, student tenant behaviour, student unrest, and shifting policy environments, were overlooked. A significant gap was identified in integrating stakeholder-driven qualitative insights with quantitative modelling approaches. By excluding non-English language sources and incongruous literature, the study may not fully capture region-specific practices, particularly from non-English-speaking developing economies. Future research should consider broader inclusion criteria to strengthen the generalizability of findings.
**Keywords:** public-private partnership (PPP), build-operate-transfer (BOT), student housing, hybrid-model risk assessment, education sector

## 1. **Introduction**

Increased demand for student housing in higher education in countries like Nigeria requires new funding options. The Public-Private Partnership (PPP) through the Build-Operate-Transfer (BOT) model provides an opportunity to bridge the infrastructure deficit (Batra, 2020). Batra (2021) opines that BOT arrangements involve a private party that bears the sole responsibility for financing, designing, constructing, and operating the facility during the concession period before handing it over to the public sector. BOT employs private efficiency and private capital to develop public infrastructure, such as student hostels. Many barriers hinder the feasibility of student housing projects on the paradigm of PPP-BOT, especially in developing economies (Oyeyoade et. al, 2024). Investment risks emanate from uncertainties related to finance, politics, law, and operations (Fu et al., 2023). Issues of outright interference with government policies, high costs of financing, corruption, and poor risk allocation pose serious hurdles (Opawole et al., 2019; Babatunde et al., 2019). The incidences of risk deter private investors and jeopardize the sustainability of BOT projects in the education sector. Given this scenario, carrying out necessary risk assessment before procurement of contracts becomes important as it may mar or make the success of BOT student housing (Opawole et al., 2019). However, it appears that the knowledge of risk assessment techniques for students housing, especially in developing countries, is still very scanty. This is because stakeholders are still using conventional risk assessment methods (Oyeyoade et al., 2024; Ameyaw & Chan, 2015).

Risk assessment is the systematic analysis of identified risks in terms of the probability of their occurrence and the maximum severity of consequence on the project objectives (Nambiar et al., 2006). It is the next stage after risk identification, before planning a risk response. The assessment process identifies risks, assesses their degree of probability and consequence, and ranks the critical ones that require proactive treatment and others to be kept under observation for any changes in the project lifecycle (Abednego & Ogunlana, 2006).

Past studies have concentrated on improving risk assessment techniques for various BOT projects, while few have focused on risk assessment for BOT student housing. The limited research on risk assessment in BOT student accommodation primarily investigated the identification and classification of various risks (Oyeyoade et al., 2024; Opawole et al., 2019) without paying much attention to the assessment methods. Studies, such as Ameyaw & Chan (2015) have shown that the stakeholders are using conventional risk assessment methods, such as checklists, risk matrices, and sometimes brainstorming, that do not adequately address the moderation of risks surrounding investment in student housing. This indicates the necessity to investigate the knowledge and use of hybrid models that could potentially capture/address the risks in student housing (Opawole et al., 2019). This study deploys a systematic literature review to assess the major investment risks involved in the PPP-BOT student housing projects, the current risk assessment models through which such risks are treated, and features of any hybrid risk assessment model. This study aims to design a hybrid model for risk assessment in BOT student housing.

Given the study's aim, the qualitative insights and numerical data are factored to capture the conditions faced in practice rather than depending on a single aspect. When the risks are considered together, the model makes visible the tangled challenges that investors, universities, and regulators must confront. These risks are rarely simple; they overlap, shift, and cut across categories. In real project settings, the model could serve as a working guide that helps decision makers weigh their options and improve how student housing projects are planned and delivered.

## 2. **Literature review**

This section reviews concepts, empirical applications, and emerging trends in risk assessment in BOT-PPP contexts, including current practices and gaps in the field that relate to student housing projects.

### 2.1 **Risk assessment in BOT-PPP infrastructure**

Risk assessment in BOT projects is a difficult and layered task, as many scholars have observed. Some argue that risk perception varies, and that the same issue may be seen as either a threat or an opportunity depending on the stakeholder involved (Ghadage et al., 2020; Ayodele & Olaleye, 2015). Commonly, risks are grouped by their seriousness (critical or minor), their source (internal or external), and the degree of control over them (controllable or uncontrollable). These categories help explain why risks do not affect infrastructure outcomes in the same way (Shi et al., 2016). Such risks can be classified into various categories: financial risks, such as interest rate fluctuations and exchange rate fluctuations; political risks, including policy switches and instability; legal risks, covering compliance with laws and enforcement of contracts; and operational risks, covering the poor upkeep to the service failures. If not minimized, these risks constitute more than serious threats to the economic viability and operational performance of infrastructure projects (Okudan et al., 2020).

Different risk assessment techniques have been used to mitigate the above risks, such as qualitative methods like expert judgment, structured checklists, and the Delphi technique, in most cases when less data is available, particularly risk prioritization (Fu et al., 2023; Lin, 2018). Quantitative methods, such as Monte Carlo Simulation and the Analytical Hierarchy Process, enable finer risk probability impact modelling (Raisbeck & Tang, 2013). Hybrid methods emerged with the advantage of merging both qualitative and quantitative approaches to develop a framework (Shrestha et al., 2018). Risk assessment in BOTs and other PPP projects is aided by the input of various players, such as project managers, risk analysts, stakeholders, and subject-matter professionals. The decision-making process is accompanied by many tools, such as risk registers, decision trees, simulation tools, and risk matrices, used to reconstruct uncertainties into measurable insights (Budayan, 2019; Shi et al., 2016). It is through these methods that a practical basis for developing effective mitigation approaches is presented alongside assured risk management with respect to the achievement of project objectives.

### 2.2 **Empirical perspectives on risk assessment techniques**

Tolani (2013) and Yahaya et al. (2017) pointed out that poor risk assessment by the public and private partners can lower stakeholders' confidence and lead to project failures. These findings show the need for specific risk assessment and management in student housing PPPs. However, a major gap in the literature is the lack of flexible risk assessment techniques that cater specifically for the unique risks of the BOT student housing model. While techniques are increasingly used in other BOT sectors, their application in student accommodation is still limited.

Previous studies have suggested various risk assessment techniques for different BOT-PPP project phases. These methods fall into three main categories: qualitative, quantitative, and hybrid. Dong et al. (2020) used risk workshops to create a list of over 20 risks, covering financial, technical, economic, environmental, and social angles. Nambiar et al., (2006) deployed a risk matrix to evaluate BOT investments in the Indian maritime sector. Xu et al. (2012) suggested a risk breakdown structure (RBS) for assessing risks by phases of expressway projects. Zhao and Chen (2020) unified Fault Tree Analysis (FTA) with Interval Rough Sets (IRS) for a quantitative risk evaluation. Ameyaw and Chan (2015) applied a fuzzy synthetic evaluation approach to rank and allocate risks in PPP water supply projects in Ghana. AHP was utilized by Zhang et al. (2020), Al-Azemi et al. (2014), and Budayan (2019) in housing and infrastructure projects to provide decision-makers with structured, stakeholder-informed risk rankings.

The McKinsey 7S model has been applied in several studies to understand internal project dependencies (Mazhazhate et al., 2021). Other tools, including PESTLE, RBS, and SWOT, were used by Visconti (2016) to review risks across project types. Researchers have also worked with risk matrices (Aikins et al., 2017), typologies (Guo et al., 2024), and performance-based approaches (Wong et al., 2012). Standards such as ISO 31000 (Chen & Hubbard, 2012) and other flexible frameworks (Kamla et al., 2016) aim to give a broader basis for assessment. For risk allocation, decision methods like AHP, TOPSIS, and Genetic Algorithms have been tested to see how risks can be shared fairly among stakeholders (Ke et al., 2010; Valipour et al., 2018; Shrestha et al., 2019). In a related direction, Chung et al. (2010), Abednego and Ogunlana (2006), and Tolani (2013) combined integrated models and cross-sectoral perspectives by drawing on Principal–Agent Theory and incentive-based tools. Even with this range of methods, PPP-driven BOT student housing remains thinly studied. The lower visibility of this project type and the shortage of data have left a clear gap in the literature.

## 3. **Methodology**

The review was conducted using the PRISMA 2020 guideline as a framework. Publications were screened and assessed with a view to gathering evidence on hybrid risk-assessment models relevant to PPP-based BOT student housing.

### 3.2 **Search strategy and data sources**

Search strings made use of Boolean operators and wildcard symbols, adjusted to fit the requirements of each database. The primary databases searched were Scopus, Web of Science, Google Scholar, and Dimensions. Additional records were included through manual checks and by reviewing reference lists of the selected studies. The search strings combined keywords such as "risk assessment", "risk evaluation", "risk allocation", "risk prioritization", "hybrid model", "Fuzzy-AHP", "Monte Carlo simulations", "student housing", "student accommodation", "university hostel", "BOT", "build-operate-transfer", "PPP", "public-private partnership" and "infrastructure investment", using Boolean operators such as AND, OR, and wildcards where applicable. Also, a filter was initiated to capture articles published within the timeframe of 2004–2024. This was to exclude articles published on the evolution of PPP models.

3.3 **Eligibility criteria**

Studies were included if they (1) discussed risk assessment techniques in the context of BOT or PPP student accommodation or PPP housing infrastructure specifically, (2) were peer-reviewed journal articles, and (3) were published in English. Exclusion criteria included conference abstracts, non-peer-reviewed sources, and studies outside the scope of infrastructure or housing risk assessment.

3.4 **Selection process**

A total of 475 records were initially identified through database searches, with an additional 68 studies manually identified through backwards snowballing (reference list screening). After removing duplicates (n = 368), 175 records remained. Out of these, 175 were screened based on titles and abstracts, resulting in 120 exclusions. The remaining 70 articles were subjected to full-text review, after which 25 were excluded for not meeting the inclusion criteria. A total of 45 studies were included in the final synthesis. Appendix I (Figure 1) illustrates the PRISMA diagram, showing the selection process of the articles included for the study.

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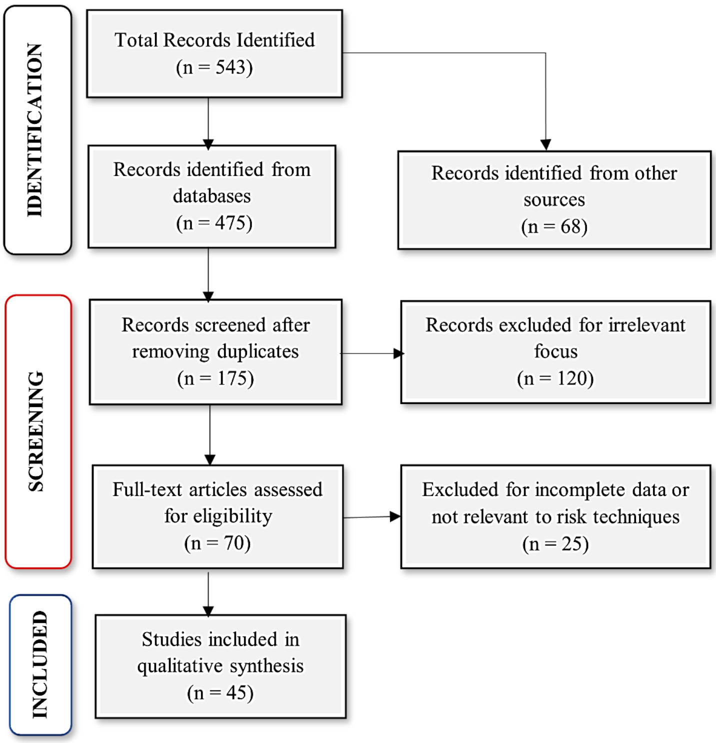


**Figure 1**: PRISMA diagram indicating article selection process
*Source*: Authors' utilization of PRISMA 2020 guidelines

### 3.5 Data extraction and synthesis

Data from selected articles were systematically extracted and synthesized using thematic analysis. Risk assessment techniques were categorized, and contextual variables were identified to understand their applicability (Braun & Clarke, 2019) to student housing PPP-BOT projects. The relevance of each study was also evaluated.

### 3.6 Reliability test

PRISMA guidelines for systematic reviews recommend Cohen's kappa (κ) rule as a statistical measure to assess inter-rater reliability (agreement between two assessors), evaluating how two reviewers consistently screen studies, extract data, and assess risk of bias. To ensure consistency in article selection, two reviewers screened titles/abstracts and full texts using predefined inclusion/exclusion criteria. Inter-rater reliability was measured using Cohen's κ, calculated from a 2×2 agreement table with an outcome of $\kappa = 0.65$ for full-text screening. The agreement levels based on Landis and Koch (1977) suggest Cohen's kappa value of 0.41–0.60 as "moderate", and 0.61–0.80 is considered as "substantial". By indication, the screening result of $\kappa = 0.65$ substantially exceeds the PRISMA threshold of Cohen's kappa value (κ ≥ 0.60) for high reliability. However, discrepancies (n=12) were resolved through consultation and discussion with a third reviewer. This process minimizes bias and enhances the reproducibility of the current systematic review.

### 3.7 **Articles included and journal outlets**

The summary of 45 articles extracted from 22 journal outlets, the number of articles per outlet, and some notable referenced works extracted and analyzed in the systematic literature review are presented in Table 1. The selection showcases the diversity of academic contributions across risk assessment themes. Also, it provides a mix of specific domains such as construction, transport, and water treatment plants, among others. There is consideration for interdisciplinary perspectives, ensuring a comprehensive evaluation of risk assessment techniques in BOT/PPP projects.

**Table 1**: Summary of 45 included articles and journal outlets

| S/N | Journal Outlet | Number of Articles Extracted | Notable Articles Referenced and Research Idea |
|---|---|---|---|
| 1 | Sustainability | 4 | Shrestha et al. (2019): A Principal-Agent Theory Perspective on PPP Risk Allocation. |
| 2 | Buildings | 2 | Rasheed et al. (2022): Comprehensive Risk Frameworks for PPP Projects. |
| 3 | International Journal of Project Management | 4 | Ke et al. (2010): Application of AHP in PPP Risk Prioritization |
| 4 | Journal of Construction Management | 2 | Lyons & Skitmore (2004): Brainstorming Techniques for Risk Identification |
| 5 | Risk Decision-Making Journal | 3 | El-Sayegh & Mansour (2015): Risk Breakdown Structure (RBS) in Construction Projects |
| 6 | Journal of Infrastructure Engineering | 2 | Tan et al. (2013): Life-Cycle Risk Monitoring for BOT Infrastructure |
| 7 | International Journal of Business Excellence | 1 | Ghadage et al., (2020): Risk management of innovative projects using FMEA; A Case Study |
| 8 | Engineering, Construction and Architectural Management | 2 | Jiang & Martek (2023): Strategies for managing the political risk of investing in infrastructure projects, in developing countries |
| 9 | International Journal of Transport Economics | 2 | Chen et al. (2021): Taxonomy of Risks in PPP Transportation Projects |
| 10 | Journal of Civil Engineering and Management | 2 | Al-Azemi et al. (2014): Framework for BOT Risk Management in Kuwait |
| 11 | Journal of Urban Economics | 1 | Kumaraswamy et al. (2004): Stakeholder Incentive Mechanisms in Urban BOT Projects |
| 12 | European Journal of Risk Management | 4 | Askari et al. (2014): Integrating Fuzzy Logic and ANN for Risk Assessment |
| 13 | Development Policy Studies | 1 | Goh et al. (2013): Stage-Based Risk Management in PPP Developments |
| 14 | Housing Studies Quarterly | 2 | Shahzad et al. (2023): Adaptive Risk Mitigation Practices in PPP Housing Projects |
| 15 | Collaboratory for Research on Global | 2 | Farrugia et al. (2008): Government Role in PPP Risk Management |
| 16 | Risk Science Quarterly | 1 | Shi et al. (2016): Adaptive Risk Management in BOT Projects |
| 17 | Infrastructure Financing Review | 2 | Iyer & Sagheer (2012): Optimization of bid-winning potential and capital structure for build-operate-transfer road projects in India |
| 18 | International Infrastructure Journal | 1 | Ullah et al., (2016): Concession-Based PPP Risks |
| 19 | Journal of Infrastructure and Policy Studies | 3 | Valipour et al. (2018): Genetic Algorithms for Optimizing Risk Allocation |
| 21 | Housing Finance Journal | 2 | Zhang et al., (2020): Comparison of cost and schedule performance of large public projects under P3 and traditional delivery models |
| 22 | Management Insights Quarterly | 2 | Mazhazhate, G., Zulu, S., & Temba, T. (2021) - *Application of McKinsey 7S framework for internal risk classification in public infrastructure delivery* |
| | **Total** | **45** | |

*Source*: Authors' Exploration of 45 Articles Included (2025)

## 4. **Findings/results**

This section presents insights from the systematic review, focusing on how risk assessment techniques have been applied in BOT student housing projects delivered through PPP frameworks. The synthesis of 45 selected studies reveals recurring patterns in the types of risks encountered, the frequency with which they appear, and the assessment techniques employed. These findings are discussed with attention to their contextual relevance, methodological orientation, and alignment with the operational realities of student housing in the context of developing economies.

### 4.1 **Descriptive statistics**

The descriptive statistics are on the publication trends, geographical distribution of studies, and the prevalence of various risk assessment methods. The summary in Table 2 provides an overview of the geographic diversity of research contributions to risk assessment in BOT/PPP projects elicited from 19 countries. Countries like the USA, China, and the UK dominate contributions, focusing on advanced and computational approaches to risk assessment. This also highlights the researchers' interests in PPP-related fields within the region. Contributions from emerging economies like Nigeria, the Philippines, Iraq, and Pakistan indicate peculiar challenges in adapting global risk assessment frameworks to BOT models. However, studies from Germany and Lithuania emphasize innovative financial and theoretical tools, such as Principal-Agent Theory and economic risk instruments.

**Table 2**: Geographical distribution of 45 included articles

| Country of Article's Origin | Publication Contributed | Percentage Contribution (%) | Some Notable Articles Referenced and Research Idea |
|---|---|---|---|
| USA | 9 | 20.0 | Lin, J. (2018) – *Risk Libraries in PPP Projects*<br>Lee, C. (2019) – *Financing method for real estate and infrastructure development using Markowitz's portfolio selection model and the Monte Carlo simulation*<br>Zayed, T., & Chang, L. (2002) – *Utility Theory-Based Risk Assessment in BOT*<br>Lin, J. (2003) – *Conflict and Risk Mitigation in Urban BOT*<br>Khallaf, R., Naderpajouh, N., & Hastak, M. (2018) - *A systematic approach to develop risk registry frameworks for complex projects* |
| China | 7 | 15.6 | Dong, Y., Jin, X., & Zhu, X. (2020) – *Fault Tree Analysis in Risk Management*<br>Zhao, L., & Chen, M. (2020) – *Event Tree Analysis in Water PPP Projects*<br>Goh, C., & Zou, X. (2013) – *Stage-Based Risk Management in PPP Developments*<br>Chen, Y., & Zhang, Q. (2013) – *Concession Agreements and Risk Sharing in BOT Contracts*<br>Ke, Y., Wang, S., & Chan, A. P. (2010) – *Application of AHP in PPP Risk Prioritization*<br>Tan, W., Zhang, L., & Li, X. (2013) – *Life-Cycle Risk Assessment in BOT Projects* |
| UK | 5 | 11.1 | El-Sayegh, S., & Mansour, M. (2015) – *Risk Breakdown Structure (RBS)*<br>Shahzad, W., Rotimi, J., & Khalfan, M. (2023) – *Adaptive Risk Mitigation Practices in PPP Projects*<br>Shahzad, W., & Khalfan, M. (2023) – *Housing Risk Mitigation Models*<br>Rasheed, N., Shahzad, W., & Khalfan, M. (2022) – *Comprehensive Risk Frameworks for PPP Projects* |
| Hong Kong | 4 | 8.9 | Jiang, G., & Martek, I. (2023) – *Strategies for managing the political risk of investing in infrastructure projects, in developing countries*<br>Chan, A., Ameyaw, E., & Shen, L. (2014) – *Taxonomy of Risks in PPP Transportation Projects*<br>Lam, P., Wang, S., & Lee, D. (2007) – *Performance-Based Risk Allocation in BOT Models*<br>Osei-Kyei, R., & Chan, A. P. (2015) – *Critical Success Factors for PPP Risk Mitigation*<br>Osei-Kyei, R., & Chan, A. P (2017) – *Risk assessment in public-private partnership infrastructure projects: empirical comparison between Ghana and Hong Kong* |
| Australia | 3 | 6.7 | Lyons, T., & Skitmore, M. (2004) – *Brainstorming Techniques for Risk Identification*<br>Chung, H., Hensher, D., & Rose, J. (2010) – *Risk Matrix Approaches in PPP Toll Projects*<br>Loosemore, M., & McCarthy, C. (2008) – *Financial Risk-Sharing Tools in PPPs* |
| Iran | 2 | 4.4 | Makui, A., Mojtahedi, S., & Mousavi, S. (2007) – Monte Carlo Simulation in PPP Risk Assessment<br>Askari, M., Shokrizadeh, H. R., & Naghdian, M. (2014) – *Fuzzy-Logic-Based Risk Ranking in BOT Projects* |
| India | 2 | 4.4 | Kumaraswamy, M. M., & Morris, D. (2004) – *Stakeholder Incentive Mechanisms for Urban BOT*<br>Budayan, C.. (2019) – *Application of AHP in delay risk assessment in construction BOT projects: Stakeholder perspectives* |
| Lithuania | 2 | 4.4 | Valipour, A., Sarvari, H., & Tamošaitienė, J. (2018) – *Genetic Algorithms for Optimizing BOT Risk Allocation*<br>Tamošaitienė, J., Martek, I., Hosseini, M. R., & Edwards, D. J. (2019) - *Principal-Agent Theory Perspective on PPP Risk Allocation* |
| Singapore | 1 | 2.2 | Chen, Y., Kho, M. Y., & Mohamed, O. (2024) – *Conceptual Models for PPP Risk Frameworks* |
| Vietnam | 1 | 2.2 | Nguyen, A., Mollik, A., & Chih, Y.-Y. (2018) - *Managing Critical Risks Affecting the Financial Viability of Public–Private Partnership Projects: Case Study of Toll Road Projects in Vietnam* |
| Germany | 1 | 2.2 | Wibowo, A., & Alfen, H. W. (2013) - *Fine-tuning the value and cost of capital of risky PPP infrastructure projects* |
| Iraq | 1 | 2.2 | Rasheed, E. (2015) – *Quantitative Impact Valuation of Risks* |
| Kuwait | 1 | 2.2 | Al-Azemi, K., Bhamra, R., & Salman, A. (2014) – *Framework for BOT Risk Management in Kuwait* |
| Nigeria | 1 | 2.2 | Mohammed, I. Y., Bala, K., & Kunya, S. U. (2021) – *Stakeholder-Centered Risk Sharing Frameworks* |
| Pakistan | 1 | 2.2 | Mubin, S. and Ghaffar, A. (2008) - *BOT Contract: Applicability in Pakistan for Infrastructure Development* |
| Philippines | 1 | 2.2 | Ullah, F., Ayub, B., Siddiqui, S. Q., & Thaheem, M. J. (2016). *A review of public-private partnership: Critical factors of concession period–Concession-Based PPP Risks* |
| South Africa | 1 | 2.2 | Mazhazhate, , V. (2021) – *McKinsey 7S for Internal Risk Classification* |
| Thailand | 1 | 2.2 | Ghadage et al., (2020) – *Using FMEA for Infrastructure Risk Management* |
| UAE | 1 | 2.2 | El-Sayegh, S., & Mansour, M. (2015) – *Risk Breakdown Structure (RBS)* |
| **Total** | **45** | **100.0** | |

*Source*: Authors' Reconnaissance of 45 Articles Included (2025)

### 4.2 **Frequency/Mean Values of Risk Assessment Techniques Across 45 Included Articles**

The summary in Table 3 indicates the mean values of how frequent each risk assessment technique is mentioned in the systematic literature review, along with the application areas, the authors who referenced them, and the number of times each technique was cited across all 45 articles to arrive at their mean values.

Risk workshops/brainstorming and Monte Carlo Simulations were the most frequently cited techniques, scoring the mean values of 0.0826 and 0.0734, respectively. Tools such as Risk Matrices (0.0642) and RBS (0.0642) are ideal for risk prioritization. Considering emerging trends in utilisation assessment techniques, advanced tools like Fuzzy Logic Systems (0.0367), Genetic Algorithms (0.0275), and Blockchain (0.0183) indicate a shift towards computational and adaptive methods for dynamic risk assessment. For context-specific tools, approaches such as PESTLE Analysis (0.0550), Value-for-Money (VfM) Analysis (0.0459), and Availability-Based Payment Models (0.0275) highlight techniques tailored to specific economic, political, and operational contexts in developing economies like Nigeria and the Philippines. However, notable authors such as Tamošaitienė et al. (2019), Rasheed et al. (2022), and Mohammed et al. (2021) are cited multiple times for their work on advanced tools such as PAT, the Delphi Method, and life-cycle risk assessment.

**Table 3**: Frequency of Risk Assessment Techniques Based on 45 Included Articles

| Risk Assessment Technique | Description | Authors Utilized Risk Assessment Technique | Frequency of Technique | Mean Value |
|---|---|---|---|---|
| Risk Workshops/Brainstorming | Collaborative tools involving stakeholders to identify risks and generate mitigation ideas. | Mohammed et al. (2021) | 9 | 0.0826 |
| Monte Carlo Simulation | Uses probabilistic methods to predict uncertainties and model risk outcomes in BOT projects. | Makui et al. (2007); Valipour et al. (2018) | 8 | 0.0734 |
| Risk Breakdown Structure (RBS) | Hierarchically categorizes risks based on dependencies, severity, and project stages. | El-Sayegh & Mansour (2015); Tang et al. (2013) | 7 | 0.0642 |
| Risk Matrices | Quantitatively evaluates risks by ranking them based on probability and impact. | Chung et al. (2010); Shahzad et al. (2023) | 7 | 0.0642 |
| Fault Tree Analysis (FTA) | Identifies root causes and sequential dependencies in technical and operational risks. | Dong et al. (2020); Rasheed et al. (2022); Shi et al. (2016) | 6 | 0.0550 |
| PESTLE Analysis | Categorizes external risks into Political, Economic, Social, Technological, Legal, and Environmental factors. | Jiang & Martek (2023); Askari et al. (2014) | 6 | 0.0550 |
| Multi-Criteria Decision Analysis (MCDA) | Tools like AHP and TOPSIS quantitatively rank risks for prioritization and allocation. | Ke et al. (2010); Kumaraswamy & Morris (2004) | 6 | 0.0550 |
| Failure Mode and Effects Analysis (FMEA) | Prioritizes critical failure points in BOT systems and recommends preventive actions. | Ghadage et al., (2020); Valipour et al. (2018) | 5 | 0.0459 |
| Scenario Planning | Explores future scenarios to identify potential risks and develop contingency strategies. | Goh et al. (2013) | 5 | 0.0459 |
| Principal-Agent Theory (PAT) | Aligns risk allocation with stakeholder incentives and decision-making capabilities. | Tamošaitienė et al. (2019); Farrugia et al. (2008) | 5 | 0.0459 |
| Value-for-Money (VfM) Analysis | Evaluates the cost-efficiency of risk allocation strategies to maximize public-private benefits. | Zhang et al., (2020); Ullah et al., (2016) | 5 | 0.0459 |
| Analytic Hierarchy Process (AHP) | A decision-making tool that ranks and prioritizes risks using pairwise comparisons, enabling systematic classification and allocation in BOT projects. | Ke et al. (2010); Shahzad et al. (2023); Valipour et al. (2018) | 5 | 0.0459 |
| Event Tree Analysis (ETA) | Evaluate sequential risk pathways and mitigation outcomes. | Zhao & Chen (2020); Ullah et al., (2016) | 4 | 0.0367 |
| McKinsey 7S Framework | Organizes risks into organizational elements, such as strategy, systems, and shared values. | Mazhazhate et al. (2021); Ullah et al., (2016); Kaplan (2005) | 4 | 0.0367 |
| Life-Cycle Risk Assessment | Monitors risks throughout the lifecycle of BOT projects, from planning to post-construction. | Tan et al. (2013); Shi et al. (2016) | 4 | 0.0367 |
| Fuzzy Logic Systems | Dynamically classifies and evaluates risks based on changing project conditions. | Askari et al. (2014); Rasheed et al. (2022) | 4 | 0.0367 |
| Adaptive Contract Structures | Introduces flexibility in BOT contracts to accommodate evolving risks. | Nguyen et al. (2018); Farrugia et al. (2008) | 4 | 0.0367 |
| Delphi Method | A consensus-based technique that uses iterative surveys with experts to identify and allocate risks, ensuring inclusivity and robust assessments in complex projects. | Mohammed et al. (2021); Farrugia et al. (2008) | 4 | 0.0367 |
| Genetic Algorithms | Optimizes risk-sharing through simulation-based models. | Valipour et al. (2018); Goh et al. (2013) | 3 | 0.0275 |
| Availability-Based Payment Models | Allocates risks to stakeholders based on performance metrics and service availability. | Rasheed et al. (2022); Tamošaitienė et al. (2019) | 3 | 0.0275 |
| Taxonomy-Based Risk Analysis | Categorizes risks into predefined typologies, such as financial, operational, and regulatory risks. | Chan et al. (2014); Mazhazhate et al. (2021) | 3 | 0.0275 |
| Blockchain for Risk Management | Enhances transparency and accountability by recording contract and risk data on decentralized ledgers. | Zhang et al., (2020); Mohammed et al. (2021) | 2 | 0.0183 |
| | | **Total** | **109** | **1.0000** |

4.3 **Thematic synthesis**

Based on the collection of articles in this systematic literature review (SLR), the following thematic analysis aligns with risk assessment techniques for BOT student housing. These themes underscore the complexity of risk mitigation and highlight innovative approaches focused on developing a hybrid model for all-encompassing risk assessment in BOT student housing investments.

**Mapping risk factors and assessment techniques**

Mapping studies reveal that financial risks such as funding gaps, inflation, and exchange rate volatility are most frequently reported, appearing in over 80% of the reviewed studies, for example, Osei-Kyei and Chan, (2012); Tang et al., (2013). The Monte Carlo Simulation and the Analytic Hierarchy Process (AHP), are used as quantitative techniques, allowing for probabilistic analysis and structured risk prioritization based on expert judgment (Zhao & Chen, 2020; Zhang et al., 2020). Political and regulatory risks, like unstable government policies, are prominent in studies from developing economies (Ke et al., 2010). The qualitative tools, such as stakeholder interviews and the Delphi method, are also used to evaluate risks because of subjectivity and context-dependence (Yahaya et al., 2017).

Operational and maintenance risks are not prominent but were acknowledged as having long-term implications for asset performance (Jiang & Martek, 2023). Techniques such as Failure Mode and Effects Analysis (FMEA) and risk scoring matrices are recommended for the evaluation of post-construction risks. Interestingly, social and stakeholder-related risks, including community resistance and pricing disputes, are the least studied, despite their growing impact on project acceptance and utilization. These risks are rarely quantified, and when observed, they are moderated through interviews, thematic analysis, or SWOT frameworks (Visconti, 2016). This underrepresentation signals a methodological gap in capturing intangible and perception-based risks in student housing projects.

The matrix analysis (see Table 4) demonstrates reliance on quantitative techniques for technical and financial risks, with qualitative methods preferred for institutional, social, and political risks. Few studies employ integrated or hybrid techniques, despite growing evidence that such approaches present the basis for decision-making in complex PPP environments (Sun & Zhang, 2005). This supports the need for context-sensitive, multidimensional frameworks that reflect the realities of inherent risks in BOT student housing investments in developing economies.

**Table 4**: Risk categories and assessment techniques in BOT projects

| Risk Category | Frequency Across Studies | Employed Assessment Techniques | Referenced Studies |
|---|---|---|---|
| Financial and Economic Risks | Very High | Monte Carlo Simulation, AHP, Fuzzy Logic, RII, Risk Matrix | Osei-Kyei & Perera, (2012); Tang et al., (2013) |
| Political and Regulatory Risks | High | Delphi Method, Expert Interviews, SWOT Analysis | Ke et al. (2010); Yahaya et al. (2017) |
| Operational and Maintenance Risks | Moderate | FMEA, Risk Scoring Matrix, Descriptive Statistics | Jiang & Martek, (2023); Ghadage et al., (2020) |
| Demand and Revenue Risks | Moderate | RII, Simulation Modelling, Stakeholder Survey | Aziz et al., (2016) |
| Construction and Design Risks | High | Risk Breakdown Structure (RBS), AHP, Checklists | El-Sayegh & Mansour (2015); Tang et al. (2013) |
| Social and Stakeholder Risks | Low | Interviews, SWOT, Thematic Analysis | Visconti (2016) |
| Institutional and Capacity Risks | Moderate | Risk Typology, McKinsey 7S, Systems Dynamics Model | Chan et al. (2011); Kamla et al. (2016) |

***Note:*** The frequency classification is based on the proportion of reviewed studies in which each risk type appears: *Very High* (in 70%+), *High* (50–70%), *Moderate* (30–49%), and *Low* (<30%).

**Contextualization of hybrid models for BOT student housing**

The focus of this section is to discuss hybrid models that are suitable for risk assessment in BOT student housing investments. This study uses a mix of qualitative and quantitative methods, often applied in international research. While these approaches are often applied separately, few studies combine them, especially for different types of PPP projects. Looking at how the methods work in various contexts; we explore ways to bring them together into flexible hybrid models that can better address the diverse challenges of educational infrastructure in developing countries.

**Predictive and collaborative tools**

As technology and collaboration evolve, approaches to risk assessment are becoming more effective. With tools like predictive analytics, driven by Big Data and Artificial Neural Networks (ANN), project teams can now spot risks in BOT schemes faster than before (Chen et al., 2021; Askari et al., 2014). Early warning tools can pick up issues such as financial fluctuations or conflicts between stakeholders, which are common in long-running projects like student housing. Collaborative techniques like Delphi and Nominal Group methods help bring together expert opinions in a practical way (Mohammed et al., 2021) and are especially useful when multiple stakeholders are involved. In BOT student housing, unique challenges, such as fluctuating student numbers or changing regulations, can be better understood using these approaches.

**Integrating multi-dimensional frameworks**

Risk assessment in BOT projects emerges to moderate multi-dimensional challenges. Taxonomy-Based Analysis was applied in PPP transportation projects to offer a flexible framework for prioritizing technical, financial, and socio-political risks (Chan et al, 2014). This approach can be applied to student housing projects. By combining traditional tools like the Risk Breakdown Structure (RBS) with dynamic methods such as Fuzzy Logic Systems, risks can be assessed in a more adaptive way, using real-time data and adjusting to changing project conditions (El-Sayegh & Mansour, 2015; Askari et al., 2014). Having this integration can help manage risks that shift across project stages, for instance, funding shortfalls during construction or inefficiencies once operations begin.

**Balancing stakeholder interests and capacities**

When it comes to balancing stakeholder interests, older tools like concession agreements provide a starting point by clarifying responsibilities (Chen, 2013). Recent performance-based methods align risk allocation with performance outcomes, reinforcing stakeholder accountability (Lam et al., 2007). Multi-Criteria Decision Analysis (MCDA) methods, including AHP and TOPSIS, rank risks by weighing their likelihood and impact, making the process more transparent (Ke et al., 2010). This means issues like construction delays or revenue gaps can be prioritised more clearly. Principal–Agent Theory (PAT) adds another perspective by matching risks with the stakeholders best placed to manage them. This helps build accountability and can improve practice efficiency (Tamošaitienė et al., 2019).

**Leveraging technology and adaptive frameworks as emerging innovations**

Valipour et al. (2018) note that the use of Genetic Algorithms and Machine Learning marks an important step forward in how risks are assessed in BOT projects. These tools can simulate a range of scenarios and highlight which strategies are most effective. Risk assessment does not end once a project begins; it continues throughout the life cycle, from planning to post-completion, adjusting as circumstances change (Tang et al., 2013). Evidence from infrastructure studies shows that blockchain enhances both the security and transparency of data management (Zhang et al., 2020; Mohammed et al., 2021). In BOT student housing, where agreements can last decades, blockchain offers a reliable means of monitoring compliance and sustaining effective risk management over time.

**Moderating background challenges in student housing projects**

In BOT student housing projects, hybrid risk assessment offers a structured means of managing complex uncertainties. Socioeconomic factors such as fluctuating enrolment rates and affordability pressures call for adaptive mechanisms, including dynamic risk monitoring and scenario planning (Nguyen et al., 2018). While global frameworks provide useful guidance, evidence shows they must be tailored to local economic, cultural, and institutional contexts. Studies from Nigeria underline the importance of reducing regulatory uncertainty and funding risks in BOT student housing (Oyeyoade et al., 2024), while research from the Philippines demonstrates

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that institutional reform is critical for mitigating governance risks in PPP-based educational infrastructure (Ullah et al., 2016).

**Integrating behavioural and stakeholder-centred approaches**

Behavioural approaches, such as stakeholder-centred risk assessment, promote joint decision-making by aligning responsibilities with the expertise and priorities of different actors (Mohammed et al., 2021). Value-for-Money (VfM) analysis further strengthens engagement by testing whether risk strategies create balanced benefits for both public and private partners (Zhang et al., 2020). Evidence from BOT student housing shows that effective risk assessment depends on combining established methods with new innovations. Advanced analytics, collaborative planning frameworks, and stakeholder-focused strategies provide ways to address the layered risks in these projects.

Blending qualitative insights with quantitative evidence allows expert judgement to be integrated while keeping decisions grounded in verifiable data. Findings also show that risk management works best when frameworks are tailored to local conditions and strengthened with supportive technologies. Conventional tools such as FMEA and concession agreements remain central to risk assessment, yet newer approaches, including Genetic Algorithms, Blockchain, and Machine Learning, are broadening the space for innovation. Achieving effectiveness in infrastructure risk assessment requires not only the adoption of these methods but also close attention to local challenges and the active integration of stakeholder perspectives.

## 5. **Discussion**

### 5.1 **Themes and patterns from the reviewed literature**

Research on BOT student housing under PPP arrangements is following the same pattern of utilizing approaches to how risks are prioritized and managed. Quantitative tools such as Monte Carlo Simulation, Analytic Hierarchy Process (AHP), Fuzzy Logic, and the Relative Importance Index (RII) are used in transport, water, and energy projects (Ke et al., 2010; Zhang, 2005; Sun & Zhang, 2015). While these methods are beginning to gain ground in education PPP-driven projects, their application to student housing remains limited and insufficiently tailored..

Financial and economic risks, including inflation volatility, currency fluctuations, and uncertain revenue from student rents, emerged most frequently as concerns (Opawole et al., 2019). Operational risks, such as long-term maintenance and service delivery issues, were consistently reported, though with less methodological attention (Babatunde et al., 2019). Contextual risks like student affordability, enrolment variability, and academic scheduling were unlikely addressed and usually excluded from mainstream risk models (Oyeyoade et al., 2024).

Again, the review found limited efforts to incorporate stakeholder perspectives through qualitative tools. Where used, methods such as the Delphi technique, expert interviews, and SWOT analysis provided richer contextual understanding, particularly in politically volatile or low-governance environments (Ojo et al., 2022; Bello, 2023). However, these qualitative insights were seldom integrated into quantitative models, reflecting a methodological divide that constrains the development of adaptable risk frameworks.

### 5.2 **Gaps in the application of risk assessment techniques**

Despite increasing recognition of the risks associated with BOT student housing investments, particularly in developing economies, a clear methodological gap persists. Most existing studies either adopt generic infrastructure risk frameworks or apply sector-specific models that are poorly suited to the complexities of tertiary education infrastructure (Opawole et al., 2019). As a result, issues unique to student housing, such as occupancy fluctuation tied to academic calendars, socio-political resistance to rent increases, and weak institutional oversight, are overlooked.

Furthermore, while hybrid risk assessment models are widely recommended in theory, their practical deployment remains scarce (Kamla et al., 2016; Ullah et al., 2024). Few studies attempt to synthesize qualitative stakeholder insights with data-driven models, failing to account for measurable and perceptual risks. The neglect of post-construction phases like operation, maintenance, and user satisfaction further limits the comprehensiveness of many existing frameworks (Askari et al., 2014).

Another critical gap is the lack of cross-country comparative studies. Most empirical investigations are constrained to single-country contexts, which restricts generalizability and limits knowledge transfer across regions. For instance, successful risk assessment models used in Asian or European BOT student housing projects are also quite infrequently being benchmarked with those of the African and Latin American settings (Opawole et al., 2019; Ke et al., 2010).

## 6. **Conclusion**

This study undertook a systematic review of risk assessment techniques applied in BOT student housing projects within PPP frameworks, drawing evidence from 45 peer-reviewed publications. The analysis indicates a heavy dependence on quantitative tools such as Monte Carlo Simulation, AHP, and Fuzzy Logic, with limited attention to contextual adaptability (Osei-Kyei & Perera, 2012; Tang et al., 2013). Although financial and political risks are extensively documented, issues relating to demand-side and social dimensions remain underexplored. The inclusion of qualitative stakeholder perspectives in risk assessment models is mostly absent, despite its critical role in education-sector PPPs, where user behaviour and institutional dynamics strongly influence project outcomes. Meanwhile, Ullah et., (2016) study in Philippines demonstrates that institutional reform is critical for mitigating governance risks in PPP-based educational infrastructure. By exposing these gaps, the study adds to the discourse on PPP risk management and underscores the importance of hybrid approaches that combine technical precision with contextual relevance.

The results reveal significant implications for policy and implementation practice. First, there is a pressing need for the formulation of context-sensitive risk assessment frameworks that accommodate socio-economic realities, demographic characteristics of students, and institutional capacity constraints, particularly in developing regions. PPP policies and regulations for educational infrastructure should ensure active participation of all stakeholders throughout the BOT project lifecycle. This is to improve transparency and the reliability of risk assessments. Building strong institutional capacity is essential, as it helps universities and regulators handle negotiations, apply practical tools for assessing risks, and ensure contract terms are upheld. If this capacity is missing, risks may be shared unfairly, weakening project outcomes.

In response, researchers and practitioners should turn to hybrid risk assessment methods that combine data analysis with stakeholder views. These approaches should reach beyond the project's starting stage to cover daily operations, upkeep, and student satisfaction, so risks are tracked and managed throughout the project. Cross-country comparative studies are also essential to illuminate how governance structures and socio-economic contexts shape risk practices and to facilitate the adaptation of global best practices. At the institutional level, universities should prioritize capacity building to strengthen their engagement in PPP negotiations and the adoption of robust risk management mechanisms. Similarly, national PPP policies must align with sector-specific realities, requiring risk evaluation approaches that incorporate social acceptance and service continuity as determinants of project success.

Although this review offers comprehensive insights and proposes a conceptual hybrid model, it is limited by its reliance on published literature, which may not fully capture on-the-ground realities in regions where project documentation is weak. Excluding non-English sources may also have restricted the geographic diversity of perspectives. Future research should empirically validate the proposed hybrid framework through case studies in different institutional and regional contexts. Further studies are also needed to assess the adaptability of the model to other social infrastructure sectors such as healthcare and public housing, where user's behaviour and policy environments influence project outcomes. Comparative multi-country analyses remain critical for refining the model and improving its practical relevance.

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