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Research Paper

Risk Assessment in Mega IT Projects Using Fuzzy Logic and Interdependency Modeling[1]

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1. Introduction

In today's rapidly evolving technological environment, large-scale information technology (IT) programs are increasingly regarded as strategic vehicles for organizational transformation and public-sector modernization. Such programs often consist of multiple interdependent projects that pursue common goals, such as enhancing digital governance, improving operational efficiency, and enabling socio-economic innovation. Despite their potential, however, large IT programs are inherently risky due to their scale, complexity, and exposure to diverse uncertainties. Traditional risk management approaches are typically designed for individual projects. They often focus on identifying risks, estimating probabilities and impacts, and prioritizing mitigation strategies. Yet, when applied to large-scale IT programs, such methods reveal significant limitations. Programs not only face project-level risks such as budget overruns, technical failures, and schedule delays but also higher-level risks arising from strategic misalignment, political

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or policy changes, inter-organizational coordination, and environmental uncertainties.

Moreover, risks within programs are not isolated. Dependencies among risks—such as cascading effects between project delays, stakeholder resistance, and reduced return on investment—can amplify overall program exposure. Such interdependencies operate in nonlinear ways, producing systemic vulnerabilities that traditional linear risk matrices fail to capture. This insight suggests that effective program risk management must incorporate methods capable of modeling interdependencies and uncertainty.

Against this backdrop, the present study proposes and applies a fuzzy-based methodology for risk evaluation in large-scale IT programs, integrating expert judgment, fuzzy logic, Shannon entropy, and the Design Structure Matrix (DSM). The Asycuda program implemented in the Iranian Customs Organization was chosen as the case study. This program represents a significant national digital transformation effort, aiming to modernize customs operations through automation, standardization, and integration with global trade networks. By analyzing risks in this context, the study contributes both theoretically and practically to advancing program-level risk management.

2. MATERIALS AND METHODS

This research followed an applied, descriptive–analytical design, combining theoretical foundations with empirical data collection. The methodological framework drew heavily on dependency-based risk assessment, enhanced through fuzzy set theory and multi-criteria decision-making techniques. Participants and Data Collection: Data were collected from program managers, IT experts, and policymakers directly involved in the Asycuda program. Purposive sampling ensured that participants possessed sufficient knowledge of both technical and organizational aspects of program execution. A structured questionnaire was designed to capture risk evaluations along three dimensions: probability of occurrence, potential impact, and interdependencies with other risks. Linguistic variables (e.g., “low,” “medium,” “high”) were used to reflect expert judgment, and these were subsequently converted into fuzzy numbers for quantitative analysis. Risk Identification and Categorization: Drawing on both literature and expert input, six main categories of risks were identified:

- Strategic risks – misalignment with organizational objectives, policy changes, or governance challenges.
- Environmental risks – external political, economic, and regulatory uncertainties.
- Operational risks – inefficiencies in execution, coordination issues, or weak resource management.
- Benefit-related risks – failure to deliver expected performance improvements or return on investment.
- Portfolio risks – challenges arising from dependencies across projects within the program.
- Project-specific risks – technical failures, budget overruns, and schedule delays.

Analytical Techniques:

Fuzzy logic was employed to address uncertainty and ambiguity inherent in expert evaluations. Shannon entropy was used to derive objective weights for impact sub-criteria, including time, cost, quality, performance, coordination, strategic alignment, return on investment, and stakeholder satisfaction. Analytic Hierarchy Process (AHP) helped prioritize risk categories based on weighted scores. Design Structure Matrix (DSM) captured dependencies among risks, enabling identification of cascading effects. Finally, a posterior risk index was calculated to account for both direct and dependent risk influences, offering a holistic measure of overall program risk.

3. RESULTS AND DISCUSSION

The empirical results provided significant insights into the risk landscape of the Asycuda program. Risk Prioritization: Entropy analysis assigned the highest weights to strategic objectives and return on investment, underscoring their importance in determining program success. The analysis confirmed that risks at the program and strategic levels, particularly environmental risks, were more critical than project-level risks. Dominance of Environmental Risks:

Among all risk categories, environmental risks emerged as the most significant. These included policy instability, regulatory uncertainty, and external stakeholder resistance—factors largely beyond the direct control of program managers. Furthermore, cultural and institutional complexities frequently derail digital transformation efforts, even when technical aspects are sound. Interdependencies and Cascading Effects: DSM analysis revealed that interdependencies among risks substantially amplified overall exposure. For instance, policy instability increased the probability of operational disruptions, which in turn diminished stakeholder confidence and weakened strategic alignment. Posterior risk indices captured these cascading effects, demonstrating that the true severity of risks often exceeded their standalone evaluations.

Implications for Practice: These findings underscore the necessity for organizations managing large-scale IT programs to adopt systemic approaches to risk evaluation. Relying solely on traditional probability–impact matrices risks underestimating the combined effects of interdependent risks. Instead, fuzzy–DSM methodologies provide a more accurate picture of program vulnerability, guiding more effective mitigation strategies. For example, establishing specialized teams to monitor environmental and policy risks could reduce their impact by improving early detection and adaptive response.

4. CONCLUSION

This study contributes to the growing body of knowledge on program-level risk management by developing and applying a fuzzy-DSM-based framework that captures both uncertainty and interdependency. Application to the Asycuda program confirmed that environmental and strategic risks represent the most significant threats to large-scale IT initiatives, while project-level risks, though important, are less decisive in determining overall success. From a theoretical perspective, the study validates the need for moving beyond project-centric risk management toward program- and portfolio-level perspectives. From a practical perspective, it offers program managers a robust methodology for evaluating risks, prioritizing mitigation strategies, and aligning resources with the most critical vulnerabilities.

The findings also highlight the importance of inter-organizational coordination, adaptive policy frameworks, and proactive environmental scanning. Organizations engaged in large IT programs should institutionalize specialized risk management teams, integrate fuzzy-DSM analysis into governance structures, and continuously update risk assessments in response to dynamic environmental conditions.

Future research may extend this framework by integrating machine learning techniques for predictive modeling, applying it across multiple programs to test generalizability, and exploring cross-national comparisons to identify cultural and institutional factors shaping program risk dynamics.

In conclusion, effective management of program-level risks—particularly environmental and strategic risks—stands as a cornerstone for the successful execution of large-scale IT programs. By incorporating uncertainty, interdependencies, and systemic perspectives, the proposed methodology provides a valuable tool for both academics and practitioners seeking to improve outcomes in digital transformation initiatives.

Keywords: Program Risk Management; Information Technology; Fuzzy Logic; Design Structure Matrix (DSM); Shannon Entropy

JEL classification: *C44, C61, C65, D81, O32, M15*

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