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Strategic Decision-Making Under Uncertainty in Project-Based Organizations: Theoretical and Methodological Foundations

Abstract

Strategic decision-making under uncertainty represents a fundamental managerial challenge in project-based organizations (PBOs). Unlike traditional functional organizations, PBOs operate through temporary structures and dynamic project portfolios that must respond to ambiguous, rapidly changing environments. This article synthesizes major theoretical perspectives and methodological approaches relevant to strategic decision-making under uncertainty in PBOs. Drawing on strategic management theory, behavioral decision theory, organizational adaptation, and project management literature, the paper argues that hybrid decision frameworks—combining analytical tools and adaptive learning mechanisms—are most suitable for project-intensive contexts.

Keywords: *strategic decision-making, uncertainty, project-based organizations (PBOs), strategic management, behavioral decision theory, organizational adaptation*

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Layihə əsaslı təşkilatlarda qeyri-müəyyənlik şəraitində strateji qərarvermə: nəzəri və metodoloji əsaslar

Xülasə

Qeyri-müəyyənlik şəraitində strateji qərarvermə layihə əsaslı təşkilatlarda (PBO-larda) əsas idarəetmə çağırışlarından birini təşkil edir. Ənənəvi funksional təşkilatlardan fərqli olaraq, PBO-lar qeyri-müəyyən və sürətlə dəyişən mühitlərə cavab verməli olan müvəqqəti strukturlar və dinamik layihə portfelləri vasitəsilə fəaliyyət göstərirlər. Bu məqalə PBO-larda qeyri-müəyyənlik şəraitində strateji qərarverməyə aid əsas nəzəri yanaşmaları və metodoloji çərçivələri ümumiləşdirir. Strateji idarəetmə nəzəriyyəsi, davranış yönümlü qərarvermə nəzəriyyəsi, təşkilati adaptasiya və layihə idarəetməsi ədəbiyyatına əsaslanaraq, məqalə analitik alətləri və adaptiv öyrənmə mexanizmlərini birləşdirən hibrid qərar çərçivələrinin layihə yönümlü mühitlər üçün daha uyğun olduğunu əsaslandırır.

Açar sözlər: *strateji qərarvermə, qeyri-müəyyənlik, layihə əsaslı təşkilatlar (PBO-lar), strateji idarəetmə, davranış yönümlü qərarvermə nəzəriyyəsi, təşkilati adaptasiya*

Introduction

Project-based organizations (PBOs) operate through temporary, goal-oriented structures that deliver complex outputs under strict time and resource constraints. In such environments, uncertainty is not episodic but structural. Strategic decisions concerning portfolio selection, risk allocation, investment timing, and stakeholder alignment must be taken despite incomplete information and dynamic environmental shifts.

Recent literature has significantly advanced the understanding of decision-making under uncertainty. Arend (2024) provides a comprehensive theoretical categorization of uncertainty in strategic contexts, distinguishing between environmental, competitive, and endogenous organizational uncertainties. This classification is particularly relevant for PBOs, where projects often unfold in competitive and technologically unstable environments.

The purpose of this article is to synthesize recent theoretical and methodological developments and apply them to the context of project-based organizations.

Şafizadə (2024) emphasizes that organizations adapt to environmental changes through flexible decision mechanisms, feedback integration, and iterative learning. In PBOs, adaptation is reflected in portfolio reconfiguration, dynamic capability development, and rapid strategic recalibration.

Similarly, Bakhary, Azman, and Elabjani (2024) demonstrate in the renewable energy sector that professionals rely on structured risk models while simultaneously adapting decisions based on emerging regulatory and technological signals. Their findings underline the importance of combining formal analytical tools with contextual managerial judgment.

Arend (2024) deepens the theoretical analysis by arguing that uncertainty must be categorized before it can be strategically addressed. In project-based settings, uncertainty may arise from market volatility, technological ambiguity, stakeholder conflict, or internal coordination problems. Proper categorization enables managers to align decision strategies with the specific type of uncertainty encountered.

Momany (2025) adopts an interdisciplinary approach, integrating economics, psychology, and management theory. The study highlights that cognitive biases, risk perception, and bounded rationality significantly influence strategic decisions under uncertainty. For PBOs, where time pressure and complexity are high, these behavioral factors play a critical role.

Decision-makers in project environments often rely on heuristics rather than purely rational optimization. While heuristics may accelerate decision-making, they can also amplify risk exposure if not supported by analytical validation. Therefore, combining behavioral awareness with structured methodologies becomes essential.

Research

Strategic decisions in project-based organizations (PBOs) are rarely made in isolation; instead, they emerge within complex networks of stakeholders that include clients, contractors, subcontractors, investors, competitors, regulatory authorities, and sometimes public institutions. Each of these actors possesses distinct objectives, risk preferences, and information sets. As a result, strategic decision-making becomes an interactive process shaped not only by internal organizational goals but also by negotiation, competition, cooperation, and regulatory constraints. In such environments, uncertainty is amplified because outcomes depend on the simultaneous decisions of multiple actors whose intentions and capabilities may not be fully observable.

Within this context, Bahiraie, Mahmoudi, and Lashgari (2024) propose game-theory-based models for strategic decision-making under uncertainty. Their approach conceptualizes strategic interaction as a structured game in which actors select strategies based on anticipated responses from others. By modeling payoff matrices and equilibrium conditions, the authors demonstrate how competitive dynamics and incentive structures influence strategic outcomes. In PBOs, this perspective is particularly relevant for bidding strategies, contract design, partnership formation, and resource allocation across competing projects. Game-theoretic modeling clarifies how cooperation can emerge under uncertainty, how opportunistic behavior may be mitigated, and how strategic positioning can improve long-term organizational performance.

Building on this foundation, Shen et al. (2025) extend the analytical framework through bi-level game theory combined with distributionally robust optimization. Bi-level models are especially suitable for hierarchical decision contexts, where upper-level decision-makers (e.g., portfolio managers or regulators) set strategic parameters while lower-level actors (e.g., project managers or contractors) respond optimally within those constraints. This structure reflects real-world PBO governance systems, where strategic directives cascade downward and operational decisions react upward.

Moreover, the incorporation of distributionally robust optimization addresses a critical limitation of traditional probabilistic models: the assumption that probability distributions are known and stable. In innovative, technologically complex, or high-risk project environments, probability distributions are often ambiguous, incomplete, or subject to rapid change. Distributionally robust models allow decision-makers to optimize performance against a range of possible distributions rather than relying on a single estimated scenario. This enhances resilience and reduces vulnerability to model misspecification.

These advanced modeling techniques are particularly valuable at the portfolio level, where interdependencies among projects create systemic risk. Strategic decisions about investment prioritization, diversification, or project sequencing must account for competitive pressures, shared resources, and external regulatory dynamics. By integrating hierarchical interaction modeling with robust optimization under ambiguity, PBOs can better anticipate adversarial moves, manage cross-project dependencies, and strengthen strategic adaptability in uncertain environments.

Acebes et al. (2024) extend traditional Earned Value Management (EVM) by integrating Monte Carlo simulation and statistical learning techniques, thereby transforming a largely deterministic control tool into a probabilistic forecasting framework. Classical EVM relies on fixed baseline assumptions and point estimates for cost and schedule performance indicators such as CPI (Cost Performance Index) and SPI (Schedule Performance Index). However, these indicators often fail to capture variability, volatility, and the cumulative impact of risk events. By embedding Monte Carlo simulation into EVM, Acebes et al. (2024) generate thousands of possible project performance scenarios based on probability distributions of key variables. This approach produces confidence intervals for completion cost and time rather than single-value forecasts, enabling decision-makers to assess the likelihood of overruns and delays more accurately.

In addition, the incorporation of statistical learning techniques enhances predictive precision by identifying hidden patterns in historical project data. Machine learning algorithms can detect nonlinear relationships between cost drivers, schedule dependencies, and risk factors, improving early-warning capabilities. Instead of reacting to deviations after they occur, managers can anticipate potential performance deterioration and implement corrective measures proactively.

For project-based organizations (PBOs), this stochastic and data-driven approach is particularly valuable. PBOs typically manage multiple interdependent projects under resource constraints and strategic priorities. Deterministic planning models, which assume stable conditions and linear cause-effect relationships, are insufficient in such environments. By incorporating risk distributions, sensitivity analysis, and predictive analytics, the framework proposed by Acebes et al. (2024) supports more informed portfolio-level decisions. Managers can compare projects not only by expected returns but also by risk exposure, probability of delay, and cost variability.

Moreover, stochastic earned value analysis strengthens strategic alignment. When uncertainty is quantified transparently, top management can prioritize projects consistent with organizational risk appetite and long-term strategic objectives. This enhances resilience, facilitates adaptive resource allocation, and improves governance mechanisms in uncertain and dynamic project environments.

Molina-Abril et al. (2025) review heuristic and machine learning techniques for multi-objective strategic optimization in SMEs. Although their focus is not exclusively on PBOs, the methodological insights are directly transferable. Multi-objective optimization supports decision-making where trade-offs between cost, time, sustainability, and innovation must be balanced.

Machine learning models enhance predictive accuracy, detect hidden patterns, and support dynamic adaptation. In project-based organizations managing complex portfolios, these techniques improve strategic alignment and risk forecasting.

Synthesizing the reviewed literature, strategic decision-making under uncertainty in project-based organizations (PBOs) can be conceptualized as a structured four-layer framework that integrates theoretical clarity with methodological rigor.

The first layer, Uncertainty Categorization (Arend, 2024), provides the foundational analytical step. Before selecting decision tools or strategic responses, managers must identify the nature and source of uncertainty. Arend (2024) distinguishes among environmental uncertainty (market volatility, regulatory change), competitive uncertainty (strategic moves of rivals and partners), and endogenous uncertainty (organizational capabilities, coordination failures, or information asymmetries). In PBOs, these categories frequently overlap. For example, a large infrastructure project may simultaneously face regulatory ambiguity, supply-chain instability, and internal capability constraints. Systematic categorization prevents misalignment between the type of uncertainty and the chosen decision strategy. It ensures that managers do not apply deterministic optimization models to fundamentally ambiguous or adversarial environments.

The second layer, Adaptive and Learning Mechanisms (Şafizadə, 2024; Bakhary et al., 2024), emphasizes dynamic organizational response. Once uncertainty is identified, PBOs must develop mechanisms for adaptation. Şafizadə (2024) highlights iterative feedback loops, flexible strategic adjustment, and continuous monitoring as central to effective decision-making under environmental change. Bakhary et al. (2024), through empirical insights from renewable energy projects, demonstrate how professionals combine structured risk assessment models with experiential judgment and real-time adaptation. In PBOs, adaptation occurs at multiple levels: project execution, portfolio rebalancing, and strategic repositioning. Learning mechanisms transform uncertainty from a purely disruptive force into a source of strategic refinement and capability development.

The third layer, Strategic Interaction Modeling (Bahiraie et al., 2024; Shen et al., 2025), addresses the relational and competitive dimension of uncertainty. Many strategic decisions in PBOs involve negotiations with contractors, clients, regulators, or competitors. Game-theoretic models proposed by Bahiraie et al. (2024) help analyze payoff structures and strategic incentives under uncertainty. Shen et al. (2025) extend this approach through bi-level game theory and distributionally robust optimization, allowing decision-makers to model situations where probability distributions are partially unknown or adversarially influenced. For PBOs operating in competitive tendering environments or public-private partnerships, such models provide structured ways to anticipate counterpart behavior and design robust strategies.

The fourth layer, Analytical and Predictive Tools (Acebes et al., 2024; Molina-Abril et al., 2025), introduces computational intelligence and probabilistic forecasting into strategic management. Acebes et al. (2024) demonstrate how Monte Carlo simulations and statistical learning enhance earned value analysis, transforming performance monitoring into a stochastic forecasting system. Molina-Abril et al. (2025) show that heuristic algorithms and machine learning techniques improve multi-objective decision-making in complex environments. In PBOs managing diverse project portfolios, these tools support trade-off analysis across cost, time, sustainability, and innovation objectives. Predictive analytics strengthens early-warning systems and enables proactive rather than reactive strategy adjustments.

This integrative four-layer framework reflects Momany's (2025) interdisciplinary perspective, which argues that effective strategic decision-making under uncertainty must combine rational economic modeling, psychological awareness of cognitive limitations, and computational intelligence. Rational analysis structures the decision space; behavioral understanding explains managerial biases and risk perceptions; computational methods enhance predictive capacity and optimization under complexity.

In project-based organizations, strategic effectiveness depends not on reliance upon a single paradigm—whether purely rational planning, behavioral intuition, or algorithmic optimization—but on the coherent integration of these dimensions. Categorizing uncertainty clarifies the problem, adaptive learning sustains flexibility, interaction modeling anticipates strategic dynamics, and predictive analytics supports informed choice. The synergy among these layers enables PBOs to build resilience, align project portfolios with long-term objectives, and sustain competitive advantage in volatile and ambiguous environments (Eisenhardt, 1989).

The reviewed literature demonstrates a clear evolution from purely rational planning models toward hybrid frameworks that incorporate behavioral, computational, and adaptive components. In PBOs, where uncertainty is structural and multi-dimensional, such hybridization is not optional but necessary (Kahneman, & Tversky, 1979).

Game-theoretic models address competitive and stakeholder uncertainty. Stochastic simulations quantify operational risk. Machine learning improves predictive accuracy. Behavioral theories explain managerial biases. Adaptive frameworks ensure continuous recalibration.

Together, these approaches form a comprehensive methodological foundation for strategic decision-making in project-intensive environments (March, 1991).

Conclusion

Strategic decision-making under uncertainty in project-based organizations requires an interdisciplinary and methodologically pluralistic foundation. Recent research provides powerful conceptual and analytical tools for addressing uncertainty, ranging from categorization frameworks and adaptive strategy models to game-theoretic interaction analysis and machine learning optimization.

The synthesis of these approaches suggests that future research and practice should focus on developing integrated decision-support systems capable of combining behavioral insight, probabilistic modeling, and strategic interaction analysis in real time.

Project-based organizations that successfully embed such hybrid frameworks will enhance resilience, strategic alignment, and long-term competitiveness in uncertain environments.

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