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A Strategic Model for Optimizing R&D Project Portfolio Management: Evidence from the Iranian Energy Sector

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Highlights

- Strategic allocation and management of key resources—including knowledge, finances, human capital, and infrastructure—are essential for successful R&D portfolio execution.
- Aligning project costs and timelines with budget constraints ensures efficient resource utilization.
- Using a risk-matrix approach helps organizations identify acceptable risk thresholds and manage them effectively.
- Maintaining a balanced mix of research and development initiatives supports both innovation and operational growth.

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Abstract

Research and development (R&D) projects play a vital role in enabling organizations in the power and energy sector to achieve their strategic objectives. R&D initiatives must be defined and managed in a coherent and integrated manner, aligned with the technology strategy and roadmap of the industry, and structured within a value-focused portfolio. However, a systematic approach to formulating and managing R&D project portfolios is currently lacking, resulting in fragmented project outcomes that generate limited value. Given the simultaneous execution of multiple projects, effective R&D portfolio management has become essential to adapt to environmental changes and maintain competitive advantage.

This study aims to present a qualitative model that identifies the dimensions and components influencing R&D project portfolio management in the electricity and energy industry, thereby supporting managers and decision-makers in defining and overseeing such portfolios. A mixed-method research approach was employed, combining qualitative data obtained from interviews with fifteen energy-sector experts—analyzed through grounded theory using MAXQDA 2020—and quantitative data from 134 managers and specialists, analyzed using Smart PLS v3. In the qualitative phase, 105 codes were extracted and categorized into six dimensions. After factor analysis, 17 codes were removed, resulting in a validated model comprising 88 codes across six dimensions.

The findings show that R&D project selection, evaluation, and definition represent the most critical dimensions of portfolio management in the electricity and energy sector, requiring managers to place significant emphasis on their associated components. A balanced focus on these dimensions can help reduce risk, optimize resource allocation, and increase the likelihood of commercial success. Overall, the study offers a systematic framework tailored to the Iranian energy industry, addressing sector-specific challenges and supporting the alignment of R&D activities with organizational strategies. The results further underscore the importance of domestic R&D investment as a driving force for technological innovation and sustainable economic growth in the energy sector.

Keywords: R&D, Project portfolio management, energy industry, R&D project portfolio management

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1. Introduction

The commercialization of domestic research outcomes has been a major driver of rapid technological advancement in industrialized economies, enabling sustainable innovation and creating value through more effective management of R&D processes (Poormand-Bakhshayesh and Salmani, 2019). As a key engine of economic development, the energy sector faces increasing pressure to continuously innovate. Intensifying competition requires advanced R&D capabilities to address critical challenges such as energy efficiency, resource optimization, and sustainable development (Zarifi et al., 2018). Effective R&D management in this sector not only supports technological progress but also contributes significantly to broader economic and environmental objectives, including reduced energy intensity and increased commercialization of renewable energy technologies.

Project portfolio management (PPM) adds substantial complexity to R&D operations, requiring organizations to maintain a balance among multiple concurrent projects while managing resource constraints, strategic goals, and potential risks. Well-structured R&D portfolios improve alignment with organizational objectives, optimize resource utilization, and enhance risk mitigation, ultimately increasing the likelihood of technical success and commercial impact (Kheyraie et al., 2021).

Innovation portfolio management refers to the systems, processes, and mechanisms used to intentionally manage innovation investments and decision-making in alignment with an organization's mission or strategy (Acebo et al., 2023). In recent years, innovation has increasingly been incorporated into the global discourse and practice of sustainable development (Giunta, 2022). Innovations are typically defined as new or improved products, processes, services, or institutional and policy arrangements designed to create value (Cooper, 2023). They may be technological or non-technological in nature (Toh, 2022) and can vary widely in maturity, ranging from early conceptual ideas to fully deployable solutions (Petrin et al., 2023).

However, not all innovations achieve successful real-world adoption. Many promising ideas fail to withstand political, regulatory, or market pressures outside controlled environments. Decision-making on which innovations to prioritize, pause, or discontinue remains a difficult yet essential component of performance and results management within R&D organizations (Dimos, 2023; Proud et al., 2023).

In Iran's energy sector, the complexities of R&D portfolio management are further amplified by region-specific factors, including limited resources, regulatory barriers, and evolving market conditions (Asghari et al., 2020). Although existing research discusses general principles of R&D management, there is a clear gap in frameworks specifically developed for the operational realities of the Iranian energy industry. Such frameworks must consider key factors such as budget allocation, project prioritization, and the integration of domestic capabilities with international best practices to maximize efficiency and impact (Asari et al., 2019).

This study addresses this gap by developing a strategic model to optimize R&D project portfolio management in the Iranian energy sector. Using a mixed-method design, qualitative insights gathered from expert interviews were complemented by quantitative validation through factor analysis. The resulting model identifies and prioritizes critical dimensions of R&D portfolio management, including project selection, evaluation, definition, budget allocation, portfolio analysis, and integration considerations. By grounding the framework in the specific characteristics of the Iranian industry, the study provides practical guidance for policymakers and managers seeking to enhance R&D performance and outcomes.

Overall, the findings contribute to the existing literature by introducing a comprehensive framework tailored to the challenges and requirements of Iran's energy sector. The study also presents actionable recommendations for improving resource allocation, strategic alignment, and risk management in R&D initiatives, helping support technological innovation and sustainable economic development within one of the country's most essential industries.

2. Theoretical foundations and literature review

2.1. Theoretical foundations

Effective management of research and development (R&D) activities requires a strong theoretical foundation. This section examines the core concepts underpinning R&D, R&D management, project portfolios, and R&D project portfolio management, establishing the conceptual framework for this study.

2.1.1. Research and development (R&D)

New business practices and the globalization of markets have compelled firms to position innovation at the core of their competitive strategies. Research and development (R&D) is a key driver of innovation, particularly as technological advancements accelerate and product life cycles shorten, prompting firms to rely more heavily on R&D to sustain growth and competitiveness (Mehdi Namazi et al., 2023). From a business perspective, R&D includes basic and applied research, as well as experimental development aimed at solving specific problems or creating new market opportunities (Fadaeimanesh and Kumar, 2007). In the energy sector, R&D activities are essential for improving efficiency, reducing costs, and addressing environmental challenges, reinforcing their importance in achieving sustainable development (Poormand-Bakhshayesh and Salmani, 2019).

2.1.2. R&D management

R&D management involves the strategic planning, execution, and oversight of research and technological innovation activities. It includes processes ranging from basic and applied research to technology development, concept generation, and new product or process development. Effective R&D management ensures alignment between research objectives and organizational strategy while optimizing resources and improving outcomes (Fadaeimanesh and Kumar, 2007).

A key component of R&D management is its ability to enhance operational accuracy, reduce costs, and improve quality (Asari et al., 2019). In the energy sector, R&D management is essential for driving innovation, advancing sustainable technologies, and maintaining competitive advantage. Achieving these goals requires a comprehensive approach that integrates resource planning, risk management, and performance evaluation to maximize the contribution of R&D activities to organizational success (Asghari et al., 2020).

2.1.3. Project portfolio

A project portfolio is a structured collection of projects pursued by an organization to achieve its strategic objectives while optimizing resource utilization (Shoari and Emamjomezadeh, 2008). This approach facilitates effective prioritization, allocation, and monitoring of projects, ensuring alignment with broader organizational goals. Project portfolios are especially important in resource-constrained environments, where careful management of trade-offs between competing priorities is essential.

In the R&D context, a portfolio represents a dynamic system in which project interdependencies must be managed to maximize value and reduce risk (Ghorbani, 2005). This requires evaluating each project based on its strategic importance, potential return on investment, and contribution to organizational objectives. Effective portfolio management demands a comprehensive understanding of resource constraints, risk factors, and project interrelationships to improve overall organizational performance (Kheyraie et al., 2021).

2.1.4. R&D project portfolio management

R&D project portfolio management applies portfolio management principles to the specific needs of research and innovation activities. It involves a systematic process of selecting, prioritizing, and monitoring R&D projects to ensure strategic alignment and effective use of organizational resources (Chiesa, 2000). The process generally includes five essential steps:

1. Budget Allocation: Defining financial resource requirements for R&D based on organizational priorities.
2. Project Definition: Establishing clear objectives, timelines, and resource needs for each project.
3. Project Evaluation: Assessing projects using predefined criteria such as technical feasibility, market potential, and risk.
4. Project Selection: Prioritizing projects to maximize value creation and minimize risks.
5. Portfolio Analysis and Optimization: Balancing and refining the portfolio to maintain strategic alignment and ensure efficient resource utilization (Khamseh and Asari, 2019).

In the energy sector, where R&D initiatives often require large investments and long development cycles, effective portfolio management is critical for risk reduction, performance improvement, and innovation advancement (Asari et al., 2019). A context-specific approach is necessary, taking into account market conditions, regulatory constraints, and organizational capabilities to ensure the sustainability and success of R&D activities (Poormand-Bakhshayesh and Salmani, 2019).

2.2. Literature review

R&D project portfolio management has been widely examined in both academic and industrial settings. This section reviews previous research to identify the key dimensions influencing effective R&D portfolio management and to highlight existing gaps that this study aims to address.

2.2.2. Dimensions of R&D portfolio management

Research has highlighted the critical importance of financial, human, and technological resources in successful R&D portfolio management. Asghari et al. (2020) show that resource availability, commercialization strategies, and intellectual property protection significantly influence R&D capabilities in energy-related industries. Similarly, Kheyraie et al. (2021) stress the need to align R&D portfolio decisions with organizational strategies to enhance competitiveness and achieve long-term goals.

Noemani-Seighalan et al. (2021) advocate for collaborative approaches to attract external funding and develop joint projects, helping to overcome resource constraints and increase R&D impact. In the energy sector, Hazaeli et al. (2019) emphasize the effectiveness of performance-based budget allocation, suggesting that strategically aligning financial resources with organizational objectives can substantially improve R&D portfolio outcomes.

Government support also plays a vital role. In Ireland, the government provides firm-level R&D support through grants and tax credits, with assistance steadily increasing since 2006 to catch up with other OECD countries (DETE, 2021; OECD, 2023). Of these support mechanisms, R&D tax credits account for the largest share, representing 85% of total government support for firm-level R&D in Ireland (Lenihan et al., 2024).

2.2.2. Challenges in R&D portfolio management

Access to high-quality information, data, and metrics is a critical success factor for innovation portfolio management. Huvaj and Johnson (2023) argue that innovation development processes should be measurable both quantitatively and qualitatively. Innovation data can track internal R&D, manufacturing, and distribution processes, as well as associated costs, while also providing a holistic understanding of the broader external innovation environment (Holtzman, 2024). This includes information on competing or collaborating organizations, supply chains, customer needs, and adoption patterns.

Çağlar and Gürel (2019) highlight the challenges of achieving equitable budget allocation across sectors and propose parameterized social welfare functions to address these issues. Relich (2020) examines decision-making difficulties in project-based organizations, introducing a predictive model for portfolio performance evaluation that underscores the complexity of integrating projects with diverse objectives, timelines, and resource requirements. Similarly, Baker et al. (2020) present a robust portfolio decision analysis framework to manage R&D planning uncertainty, emphasizing the importance of synthesizing conflicting information to support informed decision-making.

2.2.3. Advances in R&D portfolio optimization

Recent research has explored innovative approaches to R&D portfolio optimization. Pal et al. (2021) apply clustering algorithms to enhance portfolio diversity and ensure balanced resource allocation, demonstrating that dynamic portfolio adjustments can improve performance over time. Similarly, Wang (2019) investigates the relationship between market performance and access to R&D resources, emphasizing that technology-driven organizations must diversify their product offerings to meet evolving customer demands effectively.

Innovation portfolio management involves making strategic decisions before the potential and outcomes of innovations are fully validated. A critical prerequisite for such decision-making is clarity regarding an organization’s innovation portfolio intent, which encompasses the overarching vision, mission, and goals associated with the portfolio of innovations (Klingebiel and Rammer, 2014; Proud, Schut, and Kumpf, 2023).

Chagas-Brasil and Eggers (2019) examine portfolio management at both micro and macro levels, highlighting its influence on organizational operations and competitive advantage. Their findings indicate that integrating portfolio management with broader organizational functions can drive innovation and support sustainable growth.

2.2.4. Research gap

Despite these advances, there is a significant lack of frameworks that specifically address R&D portfolio management challenges in the Iranian energy sector. Existing studies tend to focus on general principles, often overlooking local contextual factors such as regulatory constraints, market dynamics, and resource limitations (Asari et al., 2019). Additionally, research integrating both qualitative and quantitative methodologies to develop comprehensive models for managing R&D portfolios in resource-constrained environments remains limited.

This study addresses this gap by proposing a grounded theory–based model validated through quantitative analysis. By concentrating on the specific needs of the Iranian energy industry, the research offers actionable insights for optimizing resource allocation, mitigating risks, and enhancing the strategic alignment of R&D portfolios.

3. Methodology

This study employs a mixed-methods approach to develop and validate a comprehensive R&D project portfolio management model for the energy sector. By integrating qualitative and quantitative methodologies, it allows for both an in-depth exploration and a rigorous validation of the factors influencing R&D portfolio management.

3.1. Research design

This applied research aims to provide practical solutions for enhancing R&D portfolio management in the energy sector. The study is conducted in two main phases:

1. **Qualitative Phase:** Grounded theory is employed to identify factors influencing R&D portfolio management through semi-structured expert interviews, qualitative data coding, and the development of a conceptual framework.
2. **Quantitative Phase:** The conceptual framework from the qualitative phase is validated using structural equation modeling (SEM) in Smart PLS v3, involving questionnaire design and distribution to a statistically significant sample.

This sequential mixed-methods approach ensures a systematic exploration and validation of the research problem, in accordance with established methodological guidelines (Bazargan-Harandi, 2008).

3.2. Qualitative phase

The qualitative phase identified and categorized factors influencing R&D portfolio management. Fifteen experts from the energy sector, including academics and industry practitioners, were selected using snowball sampling. Selection criteria included:

- Industrial experience in R&D management or policy-making, with at least a master's degree in power or electronics engineering.
- Academic credentials of at least a Ph.D. and over five years of experience in R&D-related teaching or research.

Data were collected through semi-structured interviews and analyzed using MAXQDA 2020. The coding process followed Strauss and Corbin's (1998) grounded theory methodology:

1. **Open Coding:** Initial identification and categorization of concepts.
2. **Axial Coding:** Exploration of relationships between categories using the paradigm model.
3. **Selective Coding:** Integration of categories around a central phenomenon.

This process yielded 105 initial codes, which were refined into six dimensions during axial coding. Theoretical saturation was achieved after twelve interviews, ensuring the reliability of the data.

3.3. Quantitative phase

The quantitative phase focused on validating the conceptual framework using structural equation modeling. A structured questionnaire, developed based on the dimensions identified in the qualitative phase, was distributed to 148 managers and experts in the energy sector. The required sample size of 134 was determined using Cochran's formula.

Out of the 148 questionnaires distributed, 123 complete responses were received. The respondents' demographic profile included:

- 30.08% with Ph.D. degrees
- 49.6% with master's degrees
- 20.32% with bachelor's degrees

The average work experience ranged from 10 to 15 years, ensuring adequate representation of the target population.

Data analysis was conducted using Smart PLS v3, chosen for its suitability with small sample sizes and non-normal data distributions. Seventeen indices with factor loadings below 0.7 were excluded, resulting in a validated model comprising 88 indices across six dimensions.

3.4. Ethical considerations

The study adhered to ethical research practices by:

- Obtaining informed consent from all participants
- Ensuring participant confidentiality throughout data collection and analysis
- Allowing participants the option to withdraw at any stage of the study

3.5. Methodological limitations

While the mixed-methods approach provides a comprehensive analysis, several limitations should be considered:

- The qualitative phase relies on expert opinions, which may introduce subjective bias.
- The relatively small quantitative sample size, though appropriate for SEM, may limit the generalizability of the findings.

Future research could address these limitations by employing larger sample sizes and incorporating cross-industry case studies.

4. Results and discussion

4.1. Qualitative phase: grounded theory

The qualitative phase employed grounded theory to systematically identify and categorize factors influencing R&D project portfolio management in the energy sector. Data were collected through semi-structured interviews with fifteen experts, including both academics and industry practitioners. Analysis followed Strauss and Corbin's (1998) three-step grounded theory process.

Step 1: Open Coding

The open coding process involved breaking down qualitative data into discrete concepts immediately after each interview, allowing for continuous refinement of the coding scheme. The process included:

1. **Concept Identification:** Key concepts emerged from the interviews, such as “budget constraints,” “strategic alignment,” “risk assessment,” and “stakeholder engagement.” These concepts were systematically cataloged in a preliminary coding table.
2. **Category Development:** Related concepts were grouped into broader categories, including “resource allocation,” “project prioritization,” “risk management,” and “organizational challenges,” with each category encompassing multiple interrelated concepts.
3. **Category Description:** Each category was defined with detailed characteristics to ensure consistency and clarity, including relationships among constituent concepts and their relevance to R&D portfolio management.
4. **Open Coding Documentation:** All codes and categories were recorded in a comprehensive coding table.
5. **Visual Representation:** A conceptual framework diagram (Figure 1) was created to illustrate the relationships between concepts and categories.

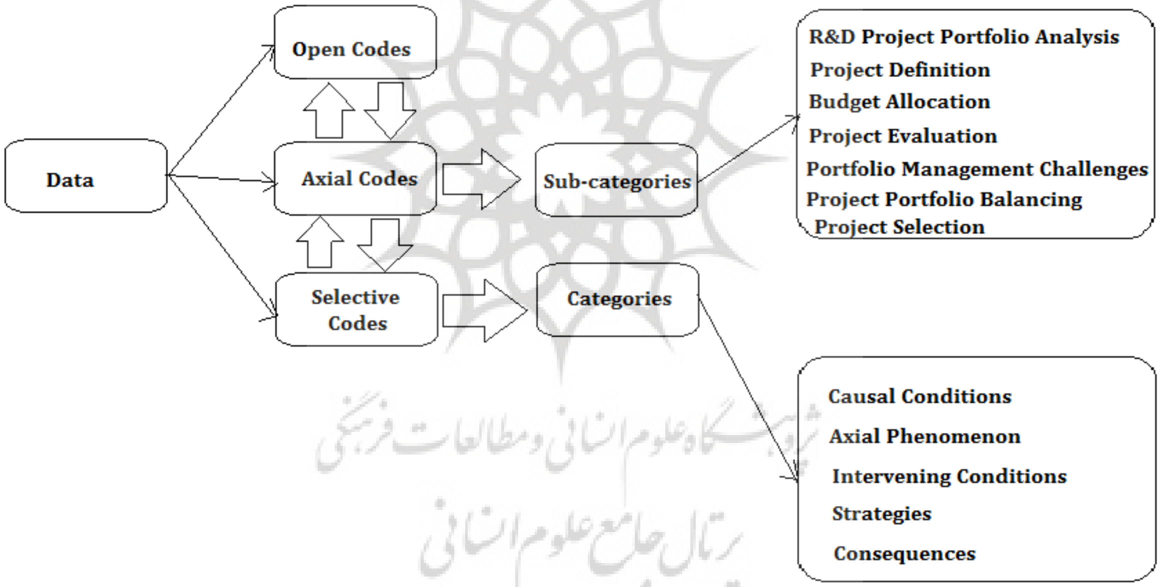

Figure 1

Model of open coding process (Punch, 2004)

The open coding process produced 105 initial codes representing a wide range of factors influencing R&D project portfolio management. These codes formed the foundation for the subsequent axial and selective coding phases.

Step 2: Axial Coding

Axial coding established systematic relationships between categories and subcategories using the paradigm model. This model identifies a central phenomenon (axial category) and maps its connections to other categories through causal conditions, contextual factors, intervening conditions, strategies, and consequences (Corbin and Strauss, 2008). The axial coding process was organized as follows:

1. **Axial Phenomenon:** R&D project portfolio management emerged as the central focus, representing the core process around which other categories are structured (Khadroveysi et al., 2019).
2. **Causal Conditions:** Key factors directly influencing the axial phenomenon included:
    - Project definition
    - Technological localization
    - Academic collaboration
    - Government incentives

Table 1 presents these causal conditions along with their associated interview codes. For example, codes PPd1–PPd22 captured elements such as:

Table 1

Coding of causal conditions (Strauss and Corbin, 1998)

Open codes
• Extending project results to the power industry
• Localizing technologies at the national level
• Collaborating with academic entities
• Utilizing governmental incentives
• Budget capabilities
• Demand for R&D project–derived technologies
• Solving problems in the power industry (problem-solving approach)
• Novelty of ideas and projects
• Intra-organizational project proposals
• Applicability to the power industry
• Consistency of R&D strategy with technology strategy
• Project value addition
• Updates in the research life cycle
• Importance in organizational activity improvement
• Ideas from suppliers and customers
• Demands of the industry as a stakeholder
• Specialized committees
• Current demands of the power industry
• Ideas from organizations
• Project proposals from academics

3. Contextual Conditions: Contextual conditions refer to the specific circumstances or environments that influence the phenomenon. Factors such as budget allocation, comparison with competitors, and the alignment of projects with organizational strategies were identified as key contextual elements. These conditions shape the operational environment in which R&D portfolio management takes place. Table 2 presents the primary contextual factors along with their associated interview codes.

Table 2

Coding of contextual conditions (Strauss and Corbin, 1998)

Open codes	Interview codes
• Comparison with other companies (i.e., competitors) • Expenditure based on an agreed plan • Allocation according to a fixed profit ratio • Current expenditures of the company and the necessity of R&D projects based on previous budget allocations • Adapting the budget to large-scale R&D plans • Current and projected expenditures for the current and next year • Budget allocated to R&D projects • Estimation of resources required for R&D projects • A fraction of sales income • A fraction of the organization’s permanent expenditures and income	pba1, pba2, pba3, pba4, pba5, pba6, pba7, pba8, pba9, pba10, pba11
• Applicability of projects in the power industry • Annual project profits • Project outcomes meeting national and international standards • Differences between project outcomes and similar projects in other countries • Consistency between predicted and actual project costs • Technical risks of projects • Project prerequisites • Business risks of projects • Technological knowledge • Effectiveness prediction • Project effects and sustainability • Open spaces or opportunities created after project completion • Utilization of outcomes from earlier projects and available development space • Research team capabilities in project implementation • Consistency of schedule with the Gantt chart • Contributions of the project to the R&D chain	ppe1, ppe2, ppe3, ppe4, ppe5, ppe6, ppe7, ppe8, ppe9, ppe10, ppe11, ppe12, ppe13, ppe14, ppe15, ppe16, ppe17

4. Intervening Conditions: Intervening conditions are broader structural factors that influence the effect of strategies on the phenomenon. These include challenges such as inadequate strategic planning, unstable regulations, and infrastructural deficiencies, which can either enhance or constrain the success of portfolio management strategies. Table 3 presents these conditions along with their associated interview codes.

Table 3

Coding of intervening conditions (Strauss and Corbin, 1998)

Open codes	Interview codes
• Short-term planning • Non-integrated project management • Insufficient attention to strategic planning in R&D • Routine or daily operational focus over strategic priorities	icm1, icm2, icm3, icm4, icm5, icm6, icm7, icm8, icm9, icm10, icm11,

Open codes	Interview codes
• Improper attitudes toward the power industry among knowledge-based companies and academic researchers • Budget allocation to inefficient or unmonitored projects • Lack of budget allocation for critical initiatives • Public or publicly managed industrial activities competing with the private sector • Rent-seeking behaviors that hinder industry diversity • Unrealistic reports from the capital market • Heavy sanctions and lack of necessary infrastructure • Large fluctuations in exchange rates and infrastructure equipment prices • Unstable import and export regulations • Unstable business rules in Iran • Rent-seeking in project undertakings	icm12, icm13, icm14, icm15

5. Strategies: Strategies represent deliberate actions taken to manage the R&D portfolio effectively. Key strategies identified in this study include portfolio analysis, project prioritization, and balancing long-term and short-term projects. These strategies are designed to optimize resource allocation and ensure alignment of portfolio objectives with organizational goals. Table 4 presents these strategies along with their corresponding implementation methods.

Table 4

Coding of strategies (Strauss and Corbin, 1998)

Open codes	Interview codes
• Number of selected projects in the portfolio • Availability of resources • Association and interdependence of projects • Portfolio synergy • Combination of long-, mid-, and short-term projects in the portfolio • Payback period of R&D projects • Expected profit of the R&D project portfolio • Fulfillment of market and stakeholder expectations • Alignment with company policies within a given time horizon • Project risks within the portfolio • Diversity of projects (inconsistency) • Conflicting resources across projects • Exploiting outcomes of one project as prerequisites for another • Establishing balanced timelines for project implementation • Identification of limitations and objectives • Sales growth • Production growth • Total asset turnover	ppa1, ppa2, ppa3, ppa4, ppa5, ppa6, ppa7, ppa8, ppa9, ppa10, ppa11, ppa12, ppa13, ppa14, ppa15, ppa16, ppa17, ppa18, ppa19, ppa20, ppa21

6. Consequences: Consequences are the outcomes resulting from the implementation of strategies. Examples include enhanced project performance, increased innovation, and improved alignment of R&D projects with organizational objectives. These outcomes reflect the effectiveness of the applied strategies in achieving the intended goals. Table 5 summarizes these outcomes along with their associated codes.

Table 5

Coding of consequences (Strauss and Corbin, 1998)

Open codes	Interview codes
• Difficult objectives	pps1, pps2, pps3, pps4, pps5, pps6, pps7, pps8, pps9, pps10, pps11, pps12, pps13, pps14, pps15, pps16, pps17, pps18, pps19, pps20, pps21, pps22
• Ratio of cost to effectiveness	
• Outcome realization period of R&D projects	
• Reliability of achieving desired outcomes	
• Demand-based prioritization	
• Defined time horizon for projects	
• Project cost-efficiency and usefulness	
• Technical knowledge required to define and execute projects	
• Infrastructure needed for project implementation	
• Readiness of technology development–related organizations resulting from project execution	
• Rules and policies associated with technology development stemming from project definition	
• Involvement of powerful companies in project implementation	
• Payback period of projects	
• Resource availability	
• Contributions of projects to sustainable development	
• Contributions of R&D-derived technology to other technologies	
• Costs of acquiring technical knowledge and project localization	
• Cooperation capabilities between private and public sectors	
• Authority and credibility	
• Employment opportunities resulting from R&D projects	
• Support from public and private organizations for projects	
• Necessity of acquiring technology in Iran	

7. Paradigm Model: The axial coding process culminates in the creation of a paradigm model, which visually depicts the relationships between the axial phenomenon and its associated categories. This model provides a conceptual framework for understanding the dynamics of R&D project portfolio management. Figure 2 illustrates the relationships identified during this phase.

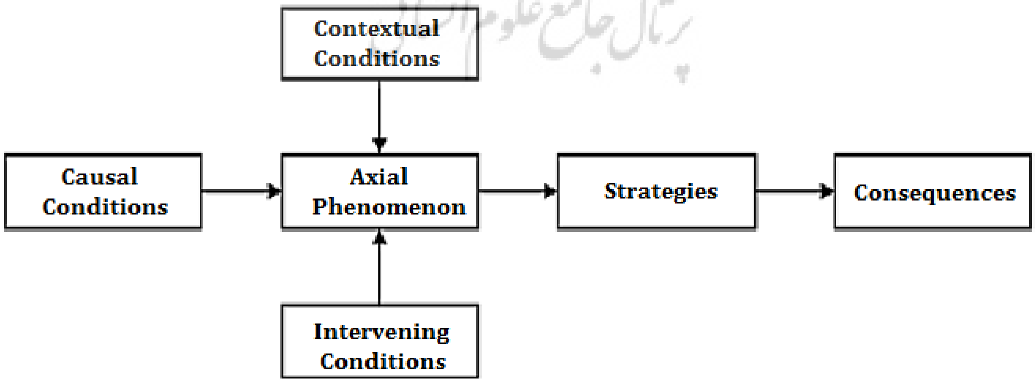

Figure 1

Axial coding paradigm model (Creswell, 2005)

Axial coding provided a systematic and structured approach to organizing the data, allowing the study to identify the complex interplay of factors influencing R&D project portfolio management. Insights from this phase laid the foundation for the final step of selective coding, where these relationships are integrated into a comprehensive theoretical model.

Step 3: Selective Coding

Selective coding is the final stage of grounded theory analysis, where the main category is systematically linked with other categories to develop a cohesive theoretical framework. This step involves validating the relationships identified during axial coding, refining underdeveloped categories, and synthesizing the data into a model that explains the central phenomenon.

In this study, selective coding unified the dimensions of R&D project portfolio management identified during open and axial coding. The grounded theory framework provides a comprehensive understanding of the factors influencing R&D project portfolio management in the energy sector, emphasizing the interconnections between categories and subcategories.

1. **Main Category Integration:** The main category, R&D project portfolio management, was systematically connected to causal, contextual, and intervening conditions, as well as strategies and their consequences. This integration illustrates how various factors interact to shape the effectiveness of R&D portfolio management practices in the energy sector.
2. **Validation of Relationships:** Relationships between the axial phenomenon and other categories were validated through iterative analysis and expert review, ensuring logical, consistent, and data-reflective associations. For example:
    - **Causal Conditions:** Factors such as technological localization and strategic alignment were confirmed as critical drivers of the axial phenomenon.
    - **Strategies and Consequences:** Strategies, including balancing project timelines, were found to directly influence outcomes such as enhanced resource optimization and increased innovation.
3. **Conceptual Framework Development:** The grounded theory model was constructed to illustrate the relationships between the main category and associated factors, detailing how causal, contextual, and intervening conditions converge to impact R&D portfolio management.
4. **Integration of Dimensions:** During selective coding, six key dimensions of R&D project portfolio management were finalized and integrated into the model:
    - **Project Selection:** Identifying projects aligned with organizational goals
    - **Project Evaluation:** Assessing projects based on technical and financial criteria
    - **Budget Allocation:** Allocating resources to maximize impact
    - **Portfolio Analysis:** Balancing long-term and short-term projects for synergy
    - **Project Definition:** Establishing clear objectives and timelines
    - **Integration Challenges:** Addressing organizational and external barriers

Each dimension was enriched with concepts and subcategories to capture the complexity of R&D portfolio management.

5. **Proposed Grounded Theory Model:** The final outcome of selective coding is a grounded theory model encapsulating the insights from the qualitative phase. This model illustrates the

dynamic interplay of factors influencing R&D project portfolio management and provides actionable recommendations for practitioners in the energy sector. Figure 3 presents the complete framework, showcasing the relationships among dimensions, strategies, and outcomes.

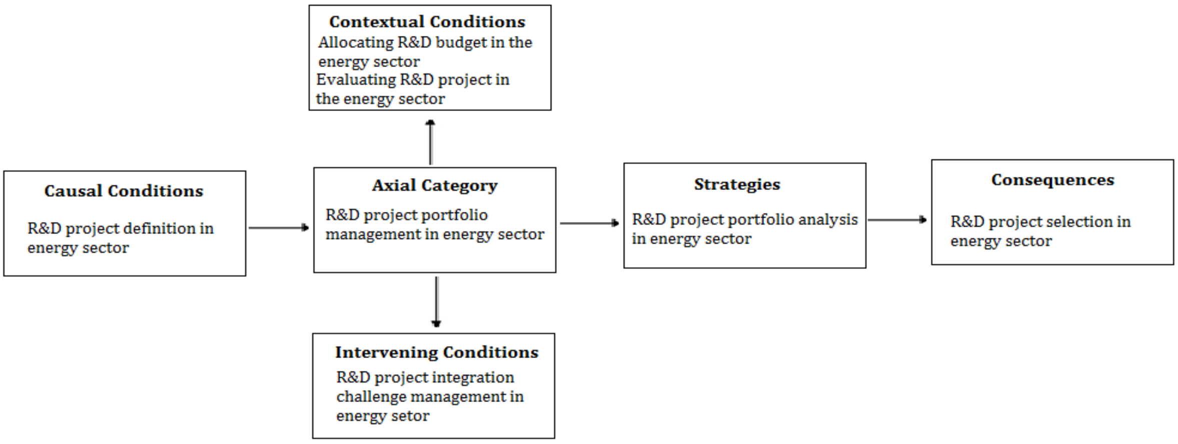

Figure 3

Final grounded theory model

Validity and Reliability of the Qualitative Phase

Ensuring validity and reliability in qualitative research depends on the rigor of methodological procedures and the consistency of results, as standard validation tests do not exist for such studies (Strauss and Corbin, 1998; Corbin and Strauss, 2008). In this study, the validity of the grounded theory model was evaluated using multiple measures:

1. **Expert Validation:** Following the coding process, three independent experts reviewed and verified the paradigm model. Their feedback confirmed that the model accurately reflected the data and addressed the complexities of R&D project portfolio management in the energy sector.
2. **Participant Validation:** The findings were shared with seven interviewees, who confirmed that the model accurately represented their experiences and perspectives. This process ensured that the grounded theory aligned with practical realities in the field.
3. **Validity Criteria:** According to Strauss and Corbin (2008), specific questions can assess the validity of grounded theory research, such as whether the findings resonate with participants, provide meaningful insights, and offer actionable recommendations. Table 6 presents these criteria and their application in this study.

Table 6

Validity criteria of grounded theory research

Criterion	Description	Implementation
Fit	Do the findings reflect the experiences of professionals and participants? Can participants see themselves represented in the findings, even if not every detail corresponds exactly to their experience? Do the findings accurately portray reality from the participants' perspective? Do	The findings were validated by seven interviewees, who confirmed their accuracy and relevance.

Criterion	Description	Implementation
	participants and professionals show emotional engagement with the results?	
Applicability or usefulness	Do the findings provide new explanations or insights? Can they inform policy development, improve performance, or contribute to the existing knowledge base?	They provide power and energy company managers with a framework for implementing a comprehensive R&D project portfolio management model across all stages, from project definition to evaluation. These insights can be applied to enhance existing R&D portfolio management practices.
Conceptual clarity	Concepts are essential for fostering shared understanding and facilitating professional discussion. Findings should be organized around well-defined concepts rather than raw, uninterpreted data. Each concept should have clear characteristics and dimensions to ensure richness and depth.	The findings were organized around well-defined concepts and key factors, each with clear characteristics.
Contextualization	Findings without context lack completeness. Context enables readers to understand events and their specific meanings. Without it, crucial elements of the narrative may be missing.	This study provided findings specifically contextualized within R&D project portfolio management in the power and energy industry.
Logical flow	Is there a coherent progression of ideas? Are the findings meaningful? Are there gaps in logic that could confuse readers? Are methodological decisions clearly explained so their appropriateness can be evaluated?	The study presents the findings with clarity and transparency in methodological decisions, enabling readers to evaluate the appropriateness of the data collection and analysis methods.
Depth	While concepts provide a common language, depth comes from descriptive details that move findings beyond surface-level understanding. Depth distinguishes significant findings with potential impact from those of lesser importance.	The research aimed to provide a common framework for discussion while offering deep insights into factors influencing R&D project portfolio management at each stage.
Variation	Do the findings demonstrate variation? Are there cases that differ from the primary model in terms of dimensions or characteristics?	The model was developed using input from key experts in the energy sector, ensuring differentiation from existing models.

Criterion	Description	Implementation
Creativity	Are findings presented in a novel way? Does the research offer new ideas or combine existing concepts creatively? Innovation in approach is critical, even when addressing established topics.	Findings were presented creatively through iterative data review and analysis.
Sensitivity	Did the researcher demonstrate sensitivity to participants and their data? Were interview questions emergent from the analysis rather than predetermined? Was the analysis guided by data rather than assumptions?	Semi-structured interviews began with initial questions, followed by emergent questions developed during data collection to guide the study.
Evidence of memoing	Since researchers cannot remember all insights, maintaining detailed memos is essential. Memos should evolve in depth and abstraction as the study progresses.	Key insights and observations were documented in notes and recorded using MAXQDA's memo feature throughout the analysis.

The combined use of expert review and participant validation enhanced the reliability of the qualitative phase, ensuring that the proposed model was both methodologically robust and practically applicable.

4.2. Quantitative phase: factor analysis

Building on the validated factors and indices from the qualitative phase, a comprehensive questionnaire was developed to quantitatively evaluate the proposed R&D project portfolio management model. The questionnaire was distributed online to 148 respondents, exceeding the estimated sample size by 10% to ensure robustness. Of the distributed questionnaires, 123 complete responses were received. To accommodate the preferences of some energy sector R&D managers, text file formats were also provided, offering flexibility in response methods.

Data analysis was conducted using Smart PLS V.3, a robust tool for structural equation modeling. The primary measurement model, shown in Figure 4, presents the factor loadings for each index. Indices with factor loadings below 0.7, such as ICm15 (rent-seeking to undertake projects) and PPa20 (production growth), were excluded to maintain the model's reliability and validity (Hair et al., 2018).

4.2.1. Exclusion of low-factor indices

Following confirmatory factor analysis, 17 indices with factor loadings below 0.7 were excluded from the model. These indices spanned various dimensions, including PPa19 (sales growth) and PPe17 (contributions of the project to the R&D chain). After these exclusions, the final R&D project portfolio management model was validated, comprising 88 indices across six main factors.

4.2.2. Reliability and convergent validity

The reliability and convergent validity of the revised model were assessed using Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE). As shown in Table 7, all latent variables demonstrated acceptable reliability and convergent validity, with CR values exceeding AVE, confirming the robustness of the model.

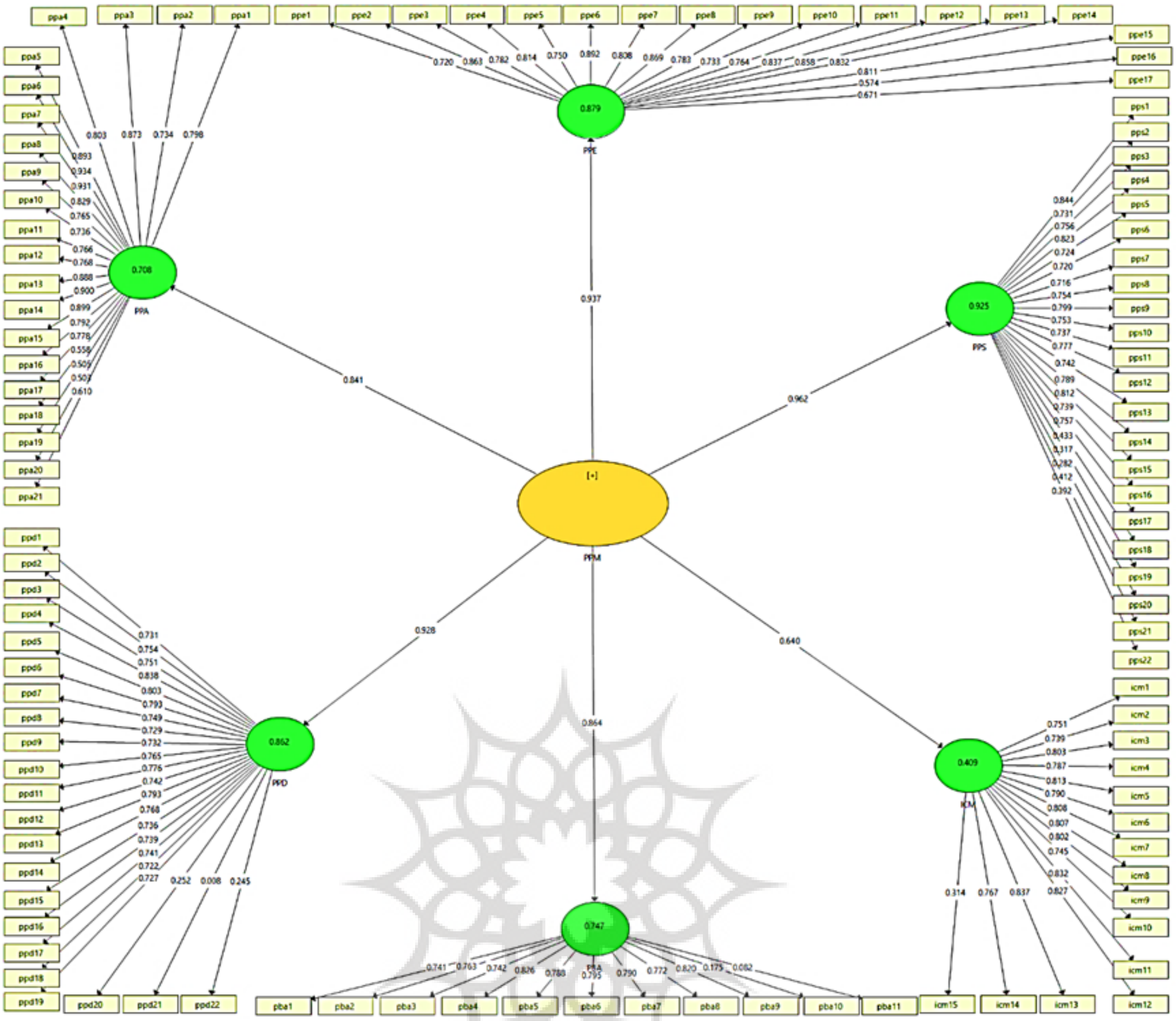

Figure 4

Primary measurement model with factor load

Table 7

Test results of the modified model

Latent variable	T-value	Reliability			Convergent Validity	
		Cronbach's Alpha	Communality	Composite Reliability	AVE	CR>AVE
R&D project portfolio integration challenge management	7.371	0.861	0.655	0.864	0.655	Yes
R&D project budget allocation	43.670	0.922	0.616	0.935	0.616	Yes
R&D project portfolio analysis	29.606	0.865	0.656	0.869	0.656	Yes
R&D project definition	20.931	0.917	0.517	0.929	0.517	Yes
R&D project evaluation	96.417	0.863	0.659	0.867	0.659	Yes
R&D project selection	52.874	0.838	0.520	0.947	0.520	Yes

4.2.3. R² and Q² analysis

The structural model was further evaluated using the coefficient of determination (R^2) and predictive relevance (Q^2). As summarized in Table 8, these metrics demonstrated strong predictive capabilities for the latent variables, including R&D project evaluation ($R^2 = 0.875$, $Q^2 = 0.498$) and R&D project selection ($R^2 = 0.906$, $Q^2 = 0.408$). According to Henseler and Fassott (2011), R^2 values above 0.67 and Q^2 values above 0.35 indicate a strong model fit.

Table 1

R^2 and Q^2 values of endogenous constructs

Endogenous Latent Variable	Symbol	R^2	R^2-Criterion	Q^2	Q^2-Criterion
R&D project portfolio integration challenge management	icm	0.355	Moderate	0.388	Strong
R&D project budget allocation	pba	0.730	Strong	0.391	Strong
R&D project portfolio analysis	ppa	0.691	Strong	0.395	Strong
R&D project definition	ppd	0.865	Strong	0.309	Strong
R&D project evaluation	ppe	0.875	Strong	0.498	Strong
R&D project selection	pps	0.906	Strong	0.408	Strong

4.2.4. Goodness-of-fit (GOF) index

To assess the overall predictive power of the structural model, the Goodness-of-Fit (GOF) index was calculated. The GOF, derived from the square root of the product of average communality and R^2 values, was 0.663, indicating strong predictive power and confirming the model's suitability for practical application in the energy sector. Figure 5 presents the validated model, highlighting its components and interrelationships.

$$GOF = \sqrt{0.603 \times 0.737} = 0.663$$

The quantitative analysis validated the theoretical framework developed during the qualitative phase. By excluding low-performing indices and confirming the remaining ones, the study established a robust and practical model for R&D project portfolio management in the energy sector. The results reveal significant relationships and strong predictive capabilities, providing valuable insights for practitioners and policymakers to optimize their R&D strategies.

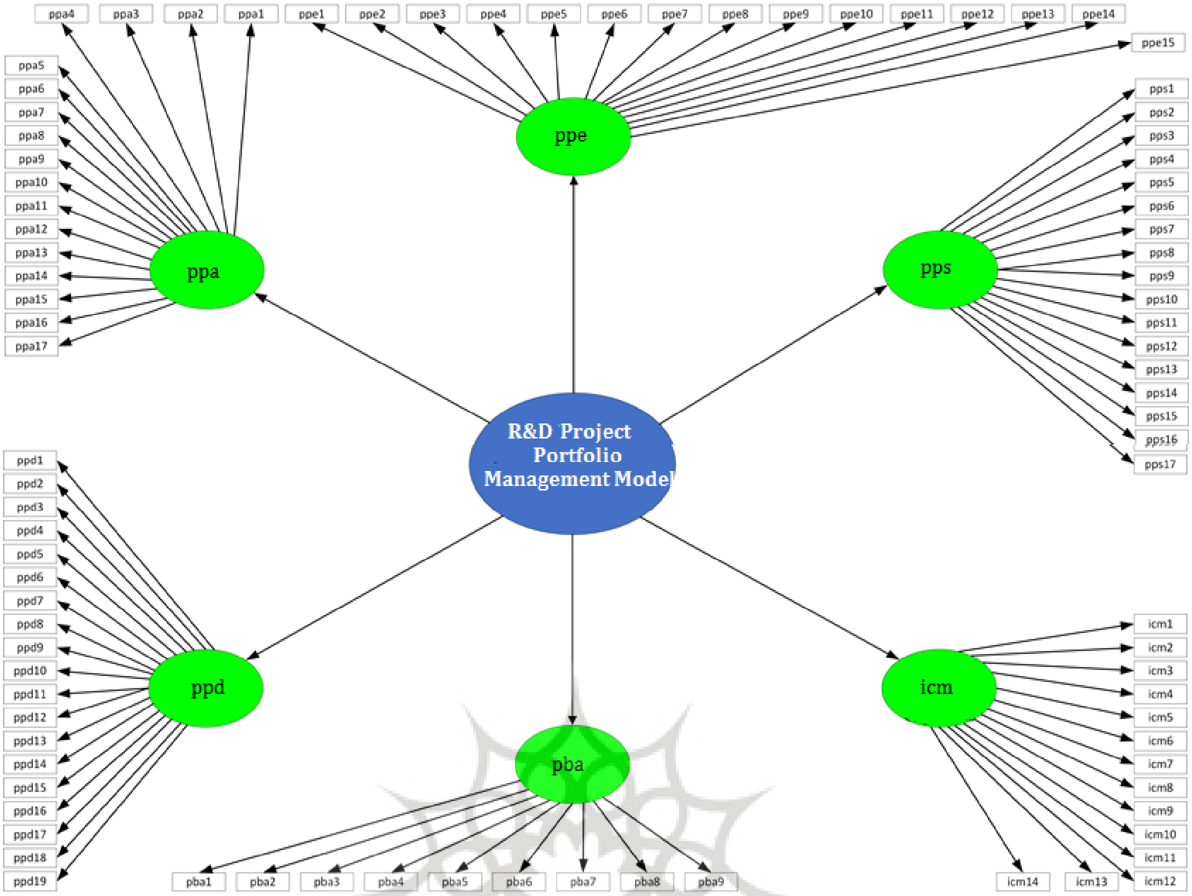

Figure 2

Final model of R&D project portfolio management in the energy sector

5. Conclusions and suggestions

This study developed a comprehensive model for R&D project portfolio management in the Iranian power and energy sector. Six critical dimensions of R&D portfolio management were identified and validated through grounded theory analysis of expert interviews: project selection, project evaluation, project definition, budget allocation, portfolio analysis, and integration challenges. Quantitative validation using structural equation modeling in Smart PLS V.3 resulted in a robust framework comprising 88 indices with significant predictive capabilities.

The findings indicate that effective R&D portfolio management extends beyond resource allocation and project evaluation, emphasizing the strategic alignment of research objectives with organizational goals. Success requires clear project definitions, rigorous evaluation frameworks, and sophisticated risk management strategies to navigate the complexities inherent in energy sector R&D projects. Organizations must balance long-term research initiatives with short-term development objectives to optimize resource utilization while sustaining innovation and competitiveness.

Resource optimization emerged as a critical success factor. Organizations must dynamically allocate financial resources, human capital, and infrastructure to adapt to evolving market conditions and technological trends. This study recommends establishing a fixed percentage of revenue for R&D activities and implementing regular monitoring mechanisms to ensure alignment with strategic objectives.

Integration challenges, particularly insufficient coordination between research and development teams, represent significant barriers. Addressing these challenges requires establishing cross-functional committees, leveraging external resources, and fostering public-private collaboration. Organizations should invest in training and capacity-building programs to develop the expertise necessary for managing complex R&D projects.

Technological localization was identified as a key driver of national competitiveness, particularly in the Iranian energy sector, where external factors such as economic sanctions and market volatility add constraints. Stronger academia-industry collaboration and government support through grants, incentives, and infrastructure development are essential. Strategic partnerships between universities and industry can accelerate innovation commercialization by bridging theoretical research and practical applications.

Resilience against external risks emerged as another critical factor. Organizations must develop robust contingency plans to mitigate the impact of regulatory changes, exchange rate fluctuations, and market uncertainties. Diversifying R&D investments across various project types and timelines can enhance portfolio stability while reducing overall risk exposure.

Advanced portfolio analysis was also emphasized. Organizations can optimize their portfolios by implementing data-driven decision-making tools and analytics. The integration of predictive models and machine learning techniques can enhance decision accuracy and improve resource allocation efficiency.

This research contributes to both theory and practice by providing a comprehensive framework tailored to the specific needs of the Iranian power and energy sector. By integrating qualitative insights with quantitative validation, the model bridges the gap between theoretical understanding and practical implementation, offering valuable guidance for policymakers, managers, and researchers.

Future research opportunities include:

- Extending the model’s applicability to other industries facing similar challenges.
- Investigating the integration of emerging technologies, such as AI and blockchain, into R&D portfolio management.
- Conducting longitudinal studies to track model implementation and its impact.
- Exploring cross-cultural applications and adaptations of the framework.
- Developing specific metrics for measuring portfolio management effectiveness in diverse contexts.

This study advances the field by providing an adaptable, practical solution for managing R&D portfolios in complex environments, ultimately supporting innovation and sustainable development in the energy sector and beyond.

One notable limitation of this study is its exclusive focus on the electricity industry, excluding other areas of the energy sector. Future researchers are advised to consider additional energy production areas and compare their findings with the results of this study.

Nomenclature

DETE	Department of Enterprise, Tourism and Employment
MAXQDA	Qualitative data analysis
OECD	Organization for Economic Co-operation and Development
PPM	Project portfolio management
R&D	Research and development
SEM	Structural equation modeling

References

Acebo, E., Angel, J., Dávila, M. (2023). Multilevel Innovation Policy Mix: Impact of Regional, National, and European R&D Grants. Science & Public Policy, 51 (2), 218–235.

Asari, M., Khamseh, A., Radfar, R., and Shadnoosh, N. (2019). Identifying and evaluating key factors affecting future R&D project management capabilities in industries with advanced aerospace technologies. Defensive Future Studies, 12(4), 109–14.

Asghari, M., Khamseh, A., and Pilevari, M. (2021). A model to enhance R&D capabilities with a mixed methodology for power plant equipment manufacturing industries and energy sector. Quarterly of Innovation Management in Defensive Organizations, 3(10),125-150.

Baker, E., Bosetti, V., and Salo, A. (2020). Robust Portfolio Decision Analysis: An Application to the Energy Research and Development Portfolio Problem. European Journal of Operational Research, 284(3), 1107–1120.

Çağlar, M., and Gürel, S. (2019). Impact assessment based sectoral balancing in public R&D project portfolio selection. Socio-Economic Planning Sciences, 66(3), 68–81.

Cerulli, G., Corsino, M., Gabriele, R., and Giunta, A. (2022). A Dose–Response Evaluation of a Regional R&D Subsidies Policy. Economics of Innovation & New Technology, 31 (3),173–190. DIO:10.1080/10438599.2020.1792604

Chagas-Brasil, V., and Eggers, J.P. (2019). Product and Innovation Portfolio Management. Product and Innovation Portfolio Management. DOI:10.1093/acrefore/9780190224851.013.28

Cooper, R. G., and Sommer A.F. (2023). Dynamic Portfolio Management for New Product Development. Research-Technology Management, 66 (3), 19–31.

Dimos, C., Fai, F., and Tomlinson P.R. (2023). The Speed of the Effects of Publicly Funded Research on Business R&D, Innovation and Innovation Behavior: Evidence from UK Firms. British Journal of Management.DOI:10.1111/1467–8551.12767

Hazaeli, F., Arman, M., and Zare, M. (2019). Budget allocation based on project usefulness performance. 14th International Conference of Project Management.

Khadroveysi, H., Rangriz, H., Salavati, A., and Soltanpanah, H. (2019). Identifying and investigating a transformational organizational performance model. Quarterly of Innovation Management in Defensive Organizations, 2(1), 135-158.

Khamseh, A., and Asari, M. (2019). R&D Management. Sarafraz Publications, 1st Edition.

Kheyraie, H., Mirhosseini, M., and Allah Zeyghami, E. (2021). Proposing a comprehensive portfolio management model for contractor companies in construction industry using multi-criteria decision-making techniques and fuzzy logic. IT in Industry, 9(1), 10-03.

Relich, M. (2020). Model for Formulating Decision Problems Within Portfolio Management, in book: Decision Support for Product Development. Computational Intelligence Methods and Applications. DOI: 10.1007/978-3-030-43897-5_2

Noemani-Seighalan, A., Khamseh, A., and Torabi, T. (2021). Formulation of research and development strategy in power plant equipment's manufacturing industries. Journal of Energy Management and Technology, 5(2). DOI: 10.22109/jemt.2020.214268.1222

OPSI. (2022). Innovation Management. Harnessing systemic support for innovation May Retrieve from: https://oecd-opsi.org/work-areas/innovation-management.

Pal, R., Chaudhuri, T., and Mukhopadhyay, S. (2021). Portfolio formation and optimization with continuous realignment: A suggested method for choosing the best portfolio of stocks using variable length NSGA-II. Expert Systems with Applications 186.

Petrin, T., and Radicic, D. (2023). Instrument Policy Mix and Firm Size: Is There Complementarity Between R&D Subsidies and R&D Tax Credits? The Journal of Technology Transfer ,48 (1),181–215. DOI:10.1007/s10961-021-09908-8.

Poormand-Bakhshayesh, T., and Salamni, B. (2019). Spatial investigation of domestic R&D and technology spillover on energy intensity in Iranian provinces. Quarterly of Energy Policymaking and Planning, 15(4), 171–210.

Proud, E., Schut, M., and Kumpf. B. (2023). Innovation Portfolio Management in the Public Sector: A Matter of Methods. Mindsets and Mechanisms. Observatory of Public Sector Innovation (OPSI), Organization for Economic Co-operation and Development (OECD)

Toh, P. K., and Ahuja, G. (2022). Integration and Appropriability: A Study of Process and Product Components Within a Firm's Innovation Portfolio. Strategic Management Journal, 43 (6), 1075–1109.

Wang, J. (2019). A System Dynamics Model for R&D Portfolio Management. Proceedings of International Conference on Technology and Social Science.

Zarifi, S., Mousakhani, M., Azar, A., and Alvani, S. (2018). Commercialization of entrepreneurial ideas in renewable energy. Quarterly of Energy Policymaking and Planning Research, 4(10), 193–219.