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Research Title:

The Impact of the Benefit _To _Cost Ratio Methodology on Reducing The
Business Risk on Oil, Gas and Petrochemical Industry in Saudi Arabia (Case
Study of PetroRabigh Plant)

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1. The Introduction:

The oil, gas and petrochemical industry is one of the most capital-intensive and risk-sensitive sections in the global economy. Organizations operating in this industry must continuously evaluate large investments, complex projects, and operational strategies under conditions of uncertainty related to market fluctuations, technology changes, and geopolitical factors.

Within modern risk management practices, decision analysis and economic evaluation methods play a critical role in supporting effective managerial decisions. According to the Operational Risk Management by C. Ariel Pinto, Luna Magpili, and Raed Jaradat, risk management involves identifying potential threats to organizational objectives and applying systematic methods to evaluate alternatives that minimize losses while maximizing value. Economic evaluation techniques are essential tools that enable organizations to analyze the trade-offs between costs, benefits, and risks when making investment or operational decisions.

One of the most widely used economic evaluation techniques is the Benefit-to-Cost Ratio (BCR) methodology, which forms a core component of cost-benefit analysis used in engineering economics and project management.

The Benefit-to-Cost Ratio (BCR) is a financial indicator used to measure the economic feasibility of a project by comparing the total expected benefits with the total expected costs over the life cycle of the investment. It is typically calculated as the ratio of the present value of benefits to the present value of costs. If the ratio is greater than one, the project is considered economically viable because the benefits exceed the costs; if it is less than one, the project may not be justified economically. This methodology is widely discussed in engineering economics and project evaluation literature as a tool for evaluating and assessing whether a project delivers sufficient value relative to its investment requirements.

In the context of risk management, the Benefit-to-Cost Ratio methodology provides an important analytical mechanism for evaluating whether the expected benefits of risk mitigation strategies, operational improvements, or capital investments justify their associated costs. When quantifying the relationship between benefits and costs, decision makers can better assess the economic impact of different alternatives and select options that reduce exposure to financial and operational risks. Economic evaluation therefore becomes a supporting element of risk management by enabling organizations to prioritize actions that deliver the greatest risk reduction relative to the resources invested.

In practice, the BCR methodology allows decision-makers to compare multiple investment alternatives and allocate resources to projects that produce the highest economic returns relative to their costs. Engineering economics literature explains that this ratio helps managers rank project alternatives and select the most economically efficient option when resources are limited.

Within the oil, gas and petrochemical industries, economic evaluation tools such as BCR are particularly important because projects often require very high capital investments in refining facilities and petrochemical plants. These projects also involve significant operational risks, including fluctuating oil prices, regulatory changes, and technological uncertainties. Therefore, using quantitative economic evaluation methods helps organizations identify economically viable investments and reduce financial and operational risks.

In Saudi Arabia, the oil, gas and petrochemical sector play a fundamental role in the national economy and industrial development strategy. Large integrated refining and petrochemical complexes represent major investments that support economic diversification and downstream industrial development. One important example is the PetroRabigh plant, a major refining and petrochemical complex established as a joint venture between Saudi Aramco and Sumitomo Chemical. Founded in 2005, this complex operates one of the largest integrated refining and petrochemical facilities in the region and produces a wide range of hydrocarbon-based products used across various industries such as plastics, construction, and automotive manufacturing.

The scale and complexity of such facilities make effective risk management and investment evaluation essential. Decision-makers must ensure that large capital projects, expansions, and operational improvements generate sufficient economic benefits relative to their costs while minimizing potential financial losses. Consequently, methodologies like the BCR can serve as important tools for evaluating projects, prioritizing investments, and reducing business risks in large industrial plants.

Given these considerations, this research investigates the impact of the Benefit-to-Cost Ratio methodology on reducing business risk in the oil, gas and petrochemical industry, with specific reference to PetroRabigh as a case study. The study aims to explore how economic evaluation techniques can support risk management practices by improving decision-making, optimizing resource allocation, and prioritizing investments that contribute to reducing organizational risk exposure.

By examining the application of the BCR methodology within a large petrochemical facility, the research seeks to provide insights into how quantitative economic tools can enhance risk management effectiveness in the oil and gas sector.

2. Problem Statement:

Organizations operating in the oil, gas and petrochemical industry experience a wide range of business risks, including financial uncertainty, operational disruptions, technological failures, environmental hazards, and market fluctuations. Managing these risks effectively is essential to ensure operational continuity, protect financial performance, and maintain long-term competitiveness. According to Strategic Risk Management Practice by Torben Juul Andersen and Peter Schröder, effective risk management requires organizations to adopt systematic decision-making processes that evaluate alternative strategies and allocate resources in ways that reduce uncertainty and enhance organizational resilience.

A key challenge in risk management is determining how organizations should prioritize investments and risk mitigation strategies when resources are limited. Large industrial organizations often face multiple competing projects, such as equipment upgrades, safety improvements, technological innovations, and operational enhancements. Each of these initiatives may contribute to reducing risk or improving performance but implementing them simultaneously may not be financially feasible. Therefore, organizations must rely on analytical methods that allow them to evaluate the economic value and risk reduction potential of different alternatives.

Economic evaluation tools, particularly those used in engineering economics, provide a structured approach for analyzing such decisions. The Benefit-to-Cost Ratio (BCR) is one of the key techniques used to assess whether the expected benefits of a project justify the required investment. According to Engineering Economy by Leland Blank and Anthony Tarquin, the BCR method enables decision makers to compare alternative projects and identify those that provide the greatest return relative to their cost. When applied within a risk management context, this method can also help determine which initiatives produce the most effective reduction in risk exposure per unit of investment.

Despite the availability of these analytical tools, many organizations are still exposing difficulties integrating economic evaluation methods with risk management practices. In the oil, gas and petrochemical industry, the

complexity of operations and the scale of investments often make it challenging to evaluate the economic impact of risk mitigation strategies.

As a result, some investment decisions may be made without fully understanding the relationship between their costs, benefits, and risk reduction outcomes. This challenge is particularly relevant for large integrated petrochemical facilities such as PetroRabigh and manages extensive refining and petrochemical production processes. The facility requires continuous investment in operational improvements, maintenance programs, safety systems, and technological upgrades to manage operational and financial risks effectively. However, determining which investments provide the most effective balance between cost and risk reduction remains a complex decision-making problem.

Therefore, the core research problem addressed in this study is the limited understanding of how the BCR methodology can be effectively used as a decision-support tool within risk management practices in the oil, gas and petrochemical industry. While BCR is widely used for project evaluation in engineering economics, its role in supporting risk-based decision making and reducing business risk in large industrial facilities has not been sufficiently explored in empirical research.

Accordingly, this study seeks to examine how the application of BCR methodology can support risk management by improving investment decision-making and prioritizing projects that contribute to reducing business risks. Using PetroRabigh as a case study, the research aims to analyze the relationship between economic evaluation methods and risk management effectiveness in the oil, gas and petrochemical sectors.

3. The Importance of the Study:

The importance of this study stems from the increasing need for effective risk management practices in the oil, gas and petrochemical industry, particularly in environments characterized by high investment costs, operational complexity, and market uncertainty.

First, this study is important from a risk management perspective. The modern risk management emphasizes the use of structured analytical methods to support decision-making and reduce uncertainty. According to Operational Risk Management by C. Ariel Pinto, Luna Magpili, and Raed Jaradat, effective risk management requires organizations to identify potential risks and evaluate alternative actions using systematic tools that balance potential benefits with

associated costs. By examining the BCR methodology, this study contributes to understanding how economic evaluation techniques can support risk management practices and help organizations prioritize risk mitigation initiatives.

Second, the study has significant economic and managerial importance. Large industrial organizations frequently experience many competing investment alternatives, such as technological upgrades, safety improvements, maintenance programs, and operational enhancements. Each of these initiatives requires financial resources, and managers must determine which alternatives deliver the greatest value. As explained in *Engineering Economic Analysis* by Donald G. Newnan, Ted G. Eschenbach, and Jerome P. Lavelle, economic evaluation methods such as the Benefit-to-Cost Ratio help decision-makers allocate resources efficiently by comparing the expected benefits of a project with its associated costs. Therefore, understanding how BCR can support risk-informed investment decisions can help managers improve resource allocation and enhance organizational performance.

Third, the study is important for the oil, gas and petrochemical industry, which is one of the most capital-intensive and risk-sensitive sectors in the global economy. Projects in this industry often involve large-scale investments, long project lifecycles, and exposure to multiple sources of uncertainty, including market fluctuations, operational disruptions, and technological challenges. As highlighted in *Strategic Risk Management Practice* by Torben Juul Andersen and Peter Schröder, organizations operating in uncertain environments must adopt structured risk management approaches that integrate economic evaluation with strategic decision-making. Therefore, this research contributes to understanding how analytical financial tools can strengthen risk management practices in high-risk industries.

Fourth, the study has particular relevance for the industrial context of Saudi Arabia, where the oil, gas and petrochemical sector play a central role in economic development and industrial growth. Large petrochemical complexes require continuous investment in infrastructure, technology, and operational improvements. One of the most significant examples is PetroRabigh, a major integrated refining and petrochemical complex. Because of the scale and complexity of such facilities, effective investment evaluation and risk management are critical to ensuring sustainable operations. Studying the application of the BCR methodology within this industrial environment can provide valuable insights for managers and policymakers involved in large-scale industrial projects.

Finally, the study contributes to the academic literature on risk management and economic evaluation by bridging the gap between theoretical concepts and practical applications. While the BCR methodology is widely discussed in engineering economics and project evaluation literature, its role in supporting risk reduction and risk-based decision-making in industrial operations has received limited empirical attention. By focusing on a real industrial case study, this research provides practical insights into how economic evaluation tools can enhance risk management effectiveness.

In summary, the significance of this study lies in its potential to contribute to improving risk-informed decision-making, enhancing investment evaluation practices, and supporting more effective risk management strategies in the oil and gas industry, particularly within large industrial facilities such as PetroRabigh.

4. Research Objectives:

The primary objective of this study is to examine the role of the Benefit-to-Cost Ratio (BCR) methodology as a decision-support tool within risk management practices in the oil, gas and petrochemical industry. Specifically, the study aims to analyze how the application of the BCR approach can support investment evaluation, improve resource allocation, and contribute to reducing business risks in large industrial facilities.

Organizations operating in high-risk industries must adopt systematic methods to evaluate alternatives and prioritize projects that generate the highest value relative to their costs while reducing exposure to uncertainty. According to Operational Risk Management by C. Ariel Pinto, Luna Magpili, and Raed Jaradat, risk management involves identifying potential risks and applying analytical tools to evaluate different options that help minimize losses and improve organizational performance. In this context, economic evaluation methods such as the Benefit-to-Cost Ratio can provide valuable insights for decision-makers by linking financial outcomes with risk reduction initiatives.

Furthermore, engineering economics literature explains that BCR is an effective method for comparing project alternatives and selecting those that provide the greatest economic value. As explained in Engineering Economic Analysis by Donald G. Newnan, Ted G. Eschenbach, and Jerome P. Lavelle, benefit-cost analysis helps managers allocate resources efficiently by comparing the present value of project benefits with the associated costs.

When applied within a risk management framework, this method can also assist organizations in prioritizing investments that produce the most effective reduction in risk exposure.

Hence, the objective of this research is to analyze the impact of the BCR methodology on reducing business risk in the oil, gas and petrochemical industry, with a particular focus on the operations of PetroRabigh in Saudi Arabia:

- ✓ To examine the role of economic evaluation methods in supporting risk management decision-making in the oil, gas and petrochemical industry.
- ✓ To analyze how the BCR methodology can be use to evaluate investment alternatives related to risk mitigation and operational improvement.
- ✓ To investigate the relationship between the application of the BCR methodology and the reduction of business risks in large petrochemical facilities.
- ✓ To assess how the BCR approach can assist managers in prioritizing projects that provide the greatest benefits relative to their costs while contributing to risk reduction.
- ✓ To explore the practical application of the BCR methodology within the operational environment of PetroRabigh.
- ✓ To provide recommendations for integrating economic evaluation techniques into risk management practices in the oil and gas sector.

Through these objectives, the study seeks to provide a better understanding of how quantitative financial evaluation methods can strengthen risk management strategies, improve investment decision-making, and enhance the efficiency and sustainability of operations in large industrial organizations.

5. Research Questions:

In the context of risk management research, well-structured questions allow researchers to explore how analytical tools and decision-making frameworks contribute to identifying, assessing, and mitigating organizational risks.

In industries characterized by high levels of uncertainty, such as the oil, gas and petrochemical sectors, organizations must evaluate complex investment alternatives while considering both economic outcomes and potential risk exposure. According to Operational Risk Management by C. Ariel Pinto, Luna Magpili, and Raed Jaradat, effective risk management requires organizations to apply structured analytical approaches that support decision-making and reduce uncertainty.

Economic evaluation methods such as the Benefit-to-Cost Ratio (BCR) can therefore serve as useful tools in assessing the feasibility and risk implications of different projects.

Furthermore, engineering economics literature emphasizes that the BCR method helps decision-makers compare project alternatives and determine whether the expected benefits justify the required costs. As discussed in *Engineering Economic Analysis* by Donald G. Newnan, Ted G. Eschenbach, and Jerome P. Lavelle, benefit-cost analysis enables managers to prioritize projects that provide the greatest value relative to their investment. When integrated with risk management practices, this approach may help organizations identify projects that contribute not only to profitability but also to risk reduction.

Based on the objectives of this study, the research seeks to answer the following main questions:

How does the application of the Benefit-to-Cost Ratio methodology contribute to reducing business risks in the oil, gas and petrochemical industry, particularly in the operations of PetroRabigh in Saudi Arabia?

However, several questions may also be included in the research:

- What role do economic evaluation methods play in supporting risk management practices in the oil, gas and petrochemical industry?
- How can the BCR methodology be used to evaluate investment alternatives related to risk mitigation and operational improvement?
- What is the relationship between the use of the BCR methodology and the reduction of business risks in petrochemical facilities?
- How can the BCR approach help managers prioritize projects that generate the highest benefits relative to their costs while reducing risk exposure?
- To what extent can the application of the BCR methodology improve investment decision-making in large industrial facilities such as PetroRabigh?
- What challenges may arise when integrating economic evaluation techniques such as BCR into risk management practices in the oil, gas and petrochemical industry?

These research questions aim to explore the relationship between economic evaluation methodologies and risk management effectiveness within the oil, gas and petrochemical sectors.

6. Study Hypotheses:

In risk management research, hypotheses help determine whether specific tools, methodologies, or strategies contribute to improving decision-making and reducing organizational risks. By formulating clear hypotheses, researchers can systematically examine whether the application of analytical techniques leads to measurable improvements in risk management performance.

In industries characterized by high levels of uncertainty and complex operational environments, such as the oil, gas and petrochemical sector, organizations must rely on structured decision-making methods to evaluate investments and manage potential risks. According to *Operational Risk Management* by C. Ariel Pinto, Luna Magpili, and Raed Jaradat, organizations can reduce operational and business risks by applying analytical tools that support systematic evaluation of alternative decisions. These tools allow managers to assess the potential consequences of different actions and choose options that minimize uncertainty while maximizing organizational value.

Economic evaluation techniques also play an important role in risk-informed decision-making. The Benefit-to-Cost Ratio (BCR) methodology provides a quantitative approach for comparing the expected benefits of a project with the associated costs. As explained in *Engineering Economic Analysis* by Donald G. Newnan, Ted G. Eschenbach, and Jerome P. Lavelle, benefit-cost analysis allows organizations to prioritize projects that generate the greatest economic value relative to their investment. When integrated into risk management practices, this methodology may help organizations select projects that contribute to both financial performance and risk reduction.

Based on the research objectives and research questions, the following hypotheses are proposed for this study:

H1: The application of the BCR methodology has a significant positive impact on reducing business risk in the oil, gas and petrochemical industry, particularly in the operations of PetroRabigh in Saudi Arabia.

H2: The use of the BCR methodology significantly improves investment decision-making in oil, gas and petrochemical organizations.

H3: The application of the BCR methodology significantly enhances the prioritization of risk mitigation projects within industrial facilities.

H4: The use of the BCR methodology contributes to more efficient allocation of financial resources for projects related to operational improvements and risk reduction.

H5: The integration of the BCR methodology into organizational decision-making processes significantly improves risk management effectiveness in petrochemical plants.

H6: The systematic use of the BCR methodology helps managers identify projects that deliver greater economic benefits while reducing potential business risks.

These hypotheses provide a structured framework for examining the relationship between the BCR methodology and risk management outcomes in the oil, gas and petrochemical industry. Testing these hypotheses will help determine whether the use of economic evaluation techniques can effectively support risk-based decision-making and investment prioritization in large industrial organizations such as PetroRabigh.

7. Previous Studies:

Several previous studies have examined the application of cost-benefit analysis and related economic evaluation methods in risk management and investment decision-making within industrial sectors such as oil, gas and petrochemical industries.

7.1 Cost-Benefit Analysis in Petrochemical Safety Management

A study titled “Cost-benefit analysis approach for the management of industrial safety in chemical and petrochemical industry” examined how cost–benefit analysis can support safety management in petrochemical plants. The study emphasized that the complexity of petrochemical facilities requires systematic safety management approaches to prevent failures and industrial accidents. By applying cost-benefit analysis together with Risk-Based Inspection (RBI) methods, organizations can evaluate the economic justification of safety measures and select the most effective risk-reduction strategies. The findings indicated that integrating economic evaluation with safety management can reduce maintenance costs while increasing plant reliability and operational safety.

7.2 Cost-Benefit Analysis for Petrochemical Investment Projects

Another study conducted by researchers at the King Abdullah Petroleum Studies and Research Center investigated the application of cost-benefit analysis in petrochemical investment projects. The study showed that cost-benefit analysis can help identify critical economic and operational risk factors affecting large petrochemical investments, including fluctuations in feedstock prices and energy costs. The analysis demonstrated that incorporating broader economic factors into project evaluation can significantly affect project feasibility and financial outcomes. The research also concluded that applying cost-benefit analysis improves transparency in decision-making and allows stakeholders to better evaluate potential risks associated with petrochemical investments.

7.3 Cost-Benefit Analysis for Risk Reduction in Oil and Gas Infrastructure

A study on natural gas infrastructure reliability explored the use of stochastic cost-benefit analysis to evaluate investments in pipeline infrastructure aimed at improving supply reliability. The study applied probabilistic models and simulation techniques to analyze uncertainties related to gas supply and transportation systems. The results showed that applying cost-benefit analysis under uncertainty can help quantify the expected benefits of infrastructure investments and support policy and managerial decisions aimed at improving system reliability and reducing operational risks.

7.4 Cost-Benefit Framework for Risk Mitigation in Oil and Gas Pipelines

Another research study investigated the use of cost-benefit analysis to evaluate investments in safety and risk-engineering measures for oil and gas pipelines. The study proposed a framework that compares the cost of implementing risk mitigation measures with the economic value of the risks avoided. Using fuzzy logic and risk-assessment variables such as probability of failure and consequence severity, the study demonstrated that cost-benefit analysis can help determine whether safety investments are economically justified while improving risk management effectiveness in pipeline operations.

7.5 Economic Evaluation and Risk-Based Investment Planning in Petrochemical Industries

Another study focusing on petrochemical investment planning developed a multi-objective optimization model that integrates cost considerations and risk factors when planning capacity expansion and new investments. The model aimed to minimize both the overall cost and the hazard level of petrochemical operations. The findings indicated that combining economic evaluation with risk assessment allows decision-makers to identify investment strategies that balance financial performance with operational safety and risk reduction.

In summary, the economic evaluation methods such as cost-benefit analysis and the Benefit-to-Cost Ratio are widely used to support investment decisions in industrial sectors. These methods can help organizations prioritize risk mitigation strategies and safety investments. The integrating cost-benefit analysis with risk assessment models improves decision-making transparency and resource allocation efficiency. Despite the growing use of these tools, there is still a limited number of studies focusing specifically on their role in reducing business risks within large petrochemical facilities, particularly in the context of Saudi Arabia.

Therefore, the current study contributes to literature by examining the impact of the Benefit-to-Cost Ratio methodology on reducing business risks in the oil, gas and petrochemical industry, using PetroRabigh as a case study.

8. Theoretical Framework:

The theoretical premises of this study provide the foundation for understanding how the Benefit-to-Cost Ratio (BCR) methodology can support risk management practices in the oil, gas and petrochemical industry. They are based on the intersection of risk management theory, engineering economics, decision analysis, and explain the conceptual logic guiding the research.

8.1 Risk Management Theory:

Risk management theory provides the framework for identifying, assessing, and mitigating business and operational risks. According to Operational Risk Management by C. Ariel Pinto, Luna Magpili, and Raed Jaradat, effective risk management involves a systematic process of:

- Risk identification: recognizing potential hazards, uncertainties, and threats that can affect organizational objectives.

- Risk assessment: evaluating the likelihood and impact of identified risks.
- Risk mitigation: selecting and implementing strategies to reduce exposure to risk, such as process improvements, safety measures, or financial controls.
- Monitoring and review: continuously evaluating the effectiveness of mitigation strategies and adjusting them as necessary.

In the context of this study, risk management theory supports the premise that investments in operational improvements or safety enhancements should be guided by structured evaluation methods, ensuring that resources are allocated to measures that maximize risk reduction.

8.2 Engineering Economic Theory

Engineering economic theory underpins the quantitative evaluation of investment alternatives and the financial justification of risk mitigation measures. According to Engineering Economic Analysis by Donald G. Newnan, Ted G. Eschenbach, and Jerome P. Lavelle, the Benefit-to-Cost Ratio (BCR) is a central tool in engineering, used to:

- Compare expected benefits with associated costs of a project or initiative.
- Determine project feasibility by evaluating whether the economic benefits outweigh the costs.
- Prioritize projects when multiple alternatives are available, particularly when resources are limited.

The theoretical premise is that projects with higher BCR values are more desirable, as they generate more benefits per unit of cost. Integrating this approach into risk management enables organizations to allocate resources efficiently toward initiatives that reduce business risk.

8.3 Decision Analysis Theory

Decision analysis theory emphasizes structured approaches for making rational choices under uncertainty. According to Strategic Risk Management Practice by Torben Juul Andersen and Peter Schröder:

- Decision analysis involves identifying alternatives, evaluating consequences, and selecting options that optimize outcomes.
- Multi-criteria decision-making tools, such as cost-benefit analysis and BCR, allow decision-makers to weigh financial, operational, and risk-related factors simultaneously.

- Incorporating decision analysis into risk management ensures that organizations make rational, informed, and evidence-based choices.

The theoretical premise here is that the integration of BCR methodology into risk informed decision making helps managers not only evaluate economic feasibility but also quantify the contribution of each investment toward risk reduction, which is critical in the oil, gas and petrochemical sector.

8.4 Integrated Premise for the Study

By combining risk management theory, engineering economic theory, and decision analysis theory, this study rests on the premise that:

- Business risks in oil, gas and petrochemical operations can be systematically reduced through investments in operational improvements, safety, and technological upgrades.
- The BCR methodology provides a quantitative tool for evaluating the efficiency and effectiveness of these investments.
- Integrating BCR into risk management processes supports rational decision-making, ensuring that limited resources are allocated to projects that maximize risk reduction and economic value.
- Applying these theories within PetroRabigh allows the study to provide practical insights into the link between economic evaluation and risk mitigation in a high-stakes industrial environment.

9. Methodology and Research Methods:

The methodology of a study defines the approach, strategies, and procedures used to investigate the research questions and test the hypotheses. In this research, the focus is on examining how the Benefit-to-Cost Ratio (BCR) methodology impacts risk reduction in the oil, gas and petrochemical industry, with a case study of PetroRabigh in Saudi Arabia. The methodology combines quantitative and qualitative approaches to ensure comprehensive analysis.

9.1 Research Approach

This study adopts a mixed-methods approach, integrating both quantitative and qualitative research techniques. The rationale for this approach is based on the need to:

- Quantitatively assess the economic and financial effectiveness of the BCR methodology in investment and risk mitigation projects.

- Qualitatively understand managerial perceptions, challenges, and organizational practices regarding risk management and decision-making.

The quantitative component focuses on analyzing BCR data from investment projects within PetroRabigh, measuring how projects with different BCR values correspond to observed risk reduction outcomes. The qualitative component involves semi-structured interviews with managers, engineers, and risk officers to explore how the BCR methodology is implemented, perceived, and integrated into decision-making processes.

9.2 Research Design

The study uses a case study design, which is suitable for investigating complex phenomena in their real-life context. According to Strategic Risk Management Practice by Torben Juul Andersen and Peter Schröder, case studies are particularly effective when the research aims to explore how and why a particular methodology affects organizational outcomes. The PetroRabigh plant is selected as a single-case study due to its size, complexity, and strategic significance in Saudi Arabia's petrochemical industry. The case study design allows for:

- An in-depth examination of the BCR methodology in operational risk management.
- Observation of real-life decision-making processes.
- Analysis of actual project data, including investment costs, benefits, and risk reduction outcomes.

9.3 Population and Sampling

The population includes risk management professionals, project managers, engineers, and financial analysts at PetroRabigh who are involved in project evaluation and investment decisions:

- Sampling Technique: Purposive sampling is employed to select participants who have direct experience with investment projects and the use of BCR in risk management.
- Sample Size: Approximately 15-50 participants will be included for qualitative interviews, while data from 5-10 completed investment projects will be analyzed quantitatively.

9.4 Data Collection Methods

- Semi-structured interviews with managers, engineers, and risk officers.

- Surveys collect perceptions on BCR effectiveness and its influence on risk management practices.
- Historical project data from PetroRabigh, including projected benefits and associated risk reduction metrics.

9.5 Research Instruments

- Questionnaires/Surveys: Structured questions on the application, understanding, and perceived effectiveness of BCR in risk reduction.
- Interview Guides: Semi-structured guide for qualitative interviews, focusing on experiences, challenges, and best practices in using BCR for risk management.
- Data Extraction Templates: Standardized templates to extract cost, benefit, and risk reduction data from historical project reports.

9.6 Data Analysis Methods

9.6.1 Quantitative Analysis:

- Calculation of BCR for selected projects.
- Statistical analysis to examine correlations between BCR values and observed risk reduction outcomes.
- Use of regression analysis to test hypotheses regarding the impact of BCR on risk mitigation effectiveness.

9.6.2 Qualitative Analysis:

- Thematic analysis of interview transcripts to identify recurring patterns, perceptions, and challenges in applying BCR in risk management.
- Coding of responses to link qualitative insights with quantitative findings.

The integration of quantitative and qualitative findings will allow a comprehensive understanding of how BCR methodology contributes to reducing business risks.

9.7 Ethical Considerations

- Participants' consent will be obtained before interviews or surveys.
- Confidentiality and anonymity of participants and sensitive company data will be strictly maintained.
- Data will be used solely for research purposes and stored securely.

9.8 Limitations of Methodology

- The study focuses on a single case study, which may limit the generalizability of findings to other organizations.

- Availability and completeness of historical project data may vary.
- Managerial perceptions may include subjective biases, though triangulation with quantitative data will help mitigate this.

10. Study Tools:

The study tools are the instruments and methods used to collect, measure, and analyze data in a systematic and reliable manner. In this research, which investigates the impact of the Benefit-to-Cost Ratio (BCR) methodology on reducing business risk in the oil, gas and petrochemical industry, several study tools are employed to gather both quantitative and qualitative data. These tools are designed to capture the economic, operational, and managerial aspects of risk management at PetroRabigh.

10.1 Questionnaires / Surveys

The purpose of using this tool is to collect quantitative data on managerial perceptions, application practices, and observed effects of BCR on risk management. A structured questionnaire is developed with closed-ended and Likert-scale questions. The questions focus on:

- ✓ Understanding of the BCR methodology.
- ✓ Frequency of use in investment and operational decisions.
- ✓ Perceived effectiveness in reducing business risk.
- ✓ Challenges and limitations in implementation.

By applying this tool, it allows standardized data collection from a larger number of participants. In addition, it will facilitate statistical analysis of perceptions and correlations between BCR usage and risk reduction.

10.2 Semi-Structured Interviews

The purpose of using this tool is to gather qualitative insights and in-depth understanding of how BCR is applied in practice. The interviews are conducted with managers, engineers, and risk officers at PetroRabigh.

➤ Open-ended questions explore:

- ✓ Decision-making processes when selecting projects.
- ✓ Integration of BCR into risk management frameworks.
- ✓ Perceived contribution of BCR to risk reduction.
- ✓ Challenges, gaps, and best practices in implementation.

By applying this tool, it will provide contextual understanding beyond quantitative data. Also, it will capture practical experiences, challenges, and insights not available in reports or surveys.

10.3 Data Extraction Templates

The purpose of using this tool is to collect secondary data from historical project reports and internal documents. The templates are used to systematically extract information from PetroRabigh's project files, including:

- ✓ Expected and realized benefits.
- ✓ Risk reduction outcomes (e.g., incident frequency, operational disruptions prevented).
- ✓ BCR calculations from prior investment evaluations.

By applying this tool, it will ensure consistency, accuracy in collecting project-level data, enables quantitative assessment of BCR values and their relationship with risk reduction.

10.4 Statistical and Analytical Software

The purpose of using this tool is to process, analyze, and interpret collected data. The tool used is Microsoft Excel for descriptive statistics, correlation analysis, and regression testing to evaluate the impact of BCR on risk reduction.

10.5 Benefit-to-Cost Ratio Calculation

The purpose of using this tool is to assess the economic efficiency of risk mitigation projects. The BCR is calculated as:

$$\text{BCR} = \frac{\text{Present Value of Benefits}}{\text{Present Value of Costs}}$$

- Projects with $\text{BCR} > 1$ are considered economically viable and effective for risk mitigation.
- BCR values are analyzed in relation to observed risk reduction outcomes, providing quantitative evidence of the methodology's impact.

10.6 Triangulation of Tools

To enhance the validity and reliability of the study:

- Quantitative BCR data from project reports is cross-validated with managerial perceptions from surveys.
- Interview insights are triangulated with historical project data to identify discrepancies, best practices, and practical limitations.

- This multi-tool approach ensures a comprehensive understanding of the impact of BCR on risk management

11. Study Limitations:

Every research study faces inherent limitations that may affect the scope, generalizability, and interpretation of findings. Identifying these limitations is essential for transparency and for guiding future research. The present study, which investigates the impact of the Benefit-to-Cost Ratio (BCR) methodology on reducing business risk in the oil, gas and petrochemical industry (case study of PetroRabigh), acknowledges the following limitations:

11.1 Single Case Study Focus

The study focuses solely on PetroRabigh, a major petrochemical plant in Saudi Arabia. While this allows for in-depth analysis, the findings may not be fully generalizable to other oil, gas and petrochemical facilities, especially those with different operational structures, organizational cultures, or geographic contexts. This limitation is common in case study research but is mitigated by using robust data triangulation from multiple sources within the organization.

11.2 Availability and Quality of Historical Data

The study relies on historical project data to calculate BCR values and assess risk reduction. Some records may be incomplete, inconsistent, or outdated, which could affect the accuracy of quantitative analysis. Efforts to minimize this limitation include cross-referencing multiple sources (project reports, financial records, and risk assessment documents).

11.3 Subjectivity in Managerial Perceptions

Qualitative data collected from interviews and surveys may be influenced by subjective biases, personal experiences, or organizational politics. Respondents may overestimate the effectiveness of BCR due to social desirability or confirmation bias. Triangulating qualitative insights with quantitative BCR calculations helps reduce bias and improve reliability.

11.4 Complexity of Risk Measurement

Risk in industrial operations is multifaceted and difficult to quantify precisely. While the study uses measurable indicators such as incident frequency, operational disruptions, and financial losses, some aspects of business risk (e.g., reputational risk, regulatory compliance, long-term market uncertainty) may not be fully captured.

The study acknowledges that BCR is a financial metric, and its link to overall risk reduction may not cover all intangible risk factors.

11.5 Time Constraints

The study is conducted within a limited timeframe, which may restrict the ability to analyze long-term impacts of projects evaluated with BCR. Some benefits or risk reduction outcomes may only become observable years after project completion, and such delayed effects may not be fully reflected in the analysis.

11.6 External Factors Beyond Control

External factors, such as market fluctuations, government regulations, global oil prices, and geopolitical events, can influence both project benefits and risk levels. These factors may confound the direct impact of the BCR methodology on business risk reduction.

In summary, while these limitations exist, the study mitigates their impact through:

- Triangulation of quantitative and qualitative data.
- Careful selection of participants with direct experience in BCR implementation.
- Cross-validation of historical project data to ensure reliability.

Despite these limitations, the study provides valuable insights into the use of BCR in risk management and its role in guiding investment decisions in large-scale petrochemical operations.

12. References:

- Ahmadi, S. and Ghahramani, A. (2018) ‘Cost–benefit analysis approach for the management of industrial safety in chemical and petrochemical industry’, *Journal of Loss Prevention in the Process Industries*, 55, pp. 196–205.
- Andersen, T.J. and Schröder, P. (2010) *Strategic risk management practice*. Cambridge: Cambridge University Press.
- Blank, L. and Tarquin, A. (2018) *Engineering economy*. New York: McGraw-Hill Education.
- Boardman, A.E., Greenberg, D.H., Vining, A.R. and Weimer, D.L. (2018) *Cost–benefit analysis: concepts and practice*. Cambridge: Cambridge University Press.

- Khan, F.I. and Haddara, M. (2022) ‘Economic evaluation and risk-based investment planning in petrochemical industries’, *Computers & Chemical Engineering*, 164, pp. 107–121.
- King Abdullah Petroleum Studies and Research Center (KAPSARC) (2023) Cost–benefit analysis for petrochemical projects. Riyadh: KAPSARC Research Report.
- Mahdavi, M. and Zanjirani Farahani, R. (2022) ‘Stochastic cost–benefit analysis for risk reduction in natural gas infrastructure’, *Energy*, 239, pp. 122–136.
- Newnan, D.G., Eschenbach, T.G. and Lavelle, J.P. (2017) *Engineering economic analysis*. Oxford: Oxford University Press.
- Pinto, C.A., Magpili, L. and Jaradat, R. (2021) *Operational risk management*. Boca Raton: CRC Press / Taylor & Francis.
- Tohoku University Research (2021) ‘A cost–benefit analysis of investing in safety and risk engineering measures for oil and gas pipelines’, *Journal of Loss Prevention in the Process Industries*, 69, pp. 104–119.