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Research Title:

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

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Abstract

The oil, gas and petrochemical industries operate in a complicated environment along with high risk. These originations have a huge capital, high uncertainty operations, market changes and technological challenges. Hence, risk management and market evaluations are crucial for long term operation stability and business performance. This study evaluates the impact of the Benefit-to-Cost- Ratio (BCR) methodology on risk reduction in the oil, gas and petrochemicals plant by using Petro Rabigh plant in Saudi Arabia as a case study. During the study, quantitative and qualitative methods research were adopted where the quantitative data collected by circulating a unique survey among fifteen experienced members from different relative departments such as engineering, projects, planning and risk management. While the qualitative data were collected by scheduled a semi-structured selected face-face interview. Moreover, illustrative BCR calculation and sensitivity analyses were implemented to evaluate the applicability of using BCR methodology in project evaluation and risk informed decision making. The results support all the six hypotheses that the study was suggested. In addition, the participant in the interviews and surveys was supported utilizing the BCR methodology as a supported tools in project prioritization, decision-making and resource allocation. Moreover, the interview's results demonstrate that the BCR methodology can improve the transparency, lead to project prioritization which produces more value to the organization and then minimize the business risk. The sensitivity analyses and BCR show that the projects with high BCR values are economically viable under uncertainty conditions and have better justify investment decision making. The study concluded that utilizing the BCR methodology along organization decision making process will improve the risk management practice which will enable the companies to better resource allocation, evaluate alternatives and prioritize the investment that led to increase the operational reliability and business risk mitigations. The study contributes to the literature by engaging the engineering economic evaluation and risk management practice to the oil, gas and petrochemical sectors.

Keywords:

Benefit-to-Cost Ratio (BCR); Business Risk Management; Investment Decision-Making; Engineering Economic Evaluation; Oil, Gas, and Petrochemical Industry; PetroRabigh; Saudi Arabia.

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List of Terminology

Benefit-to-Cost Ratio (BCR): An engineering economic indicator that compares the present value of project benefits to the present value of project costs to understand economic viability. A BCR greater than 1.0 indicates that project benefits are greater than project costs.

Business risk: The risk that the business will lose money, have a company disrupted or fail due to internal or external uncertainty.

Risk Management: A way of identifying, assessing, evaluating, mitigating, and monitoring risks to reduce the impact of risks on an organization's goals and objectives.

Economic evaluation: The comparison of the cost and expected benefit of other projects or investments to make decisions.

Cost–Benefit Analysis (CBA): A decision-making process that assesses if the expected benefits of a project exceed its cost. Benefit-to-Cost Ratio (BCR) is one of the key indicators in this regard.

Investment decision-making: The process of selecting investment alternatives based on financial, operational, and strategic evaluation criteria.

Project Prioritization: The process of ranking projects according to specific criteria such as economic value, strategic importance, and risk reduction potential.

Resource allocation: The process of assigning financial, human, and technical resources to projects or activities to maximize organizational value.

Sensitivity Analysis: An analytical approach used to evaluate how changes in project assumptions, such as costs or benefits, affect economic performance and investment decisions.

Decision-support Tool: A quantitative or qualitative tool for managers to assess alternatives and make an evidence-based decision.

Illustrative Project Evaluation Scenario: A realistic but anonymized project example to demonstrate the use of the BCR method and for protecting organizational privacy.

Operational Risk: Losses due to insufficient or failed internal processes, people, systems or external events affecting organizational operations.

List of Abbreviations

BCR: Benefit-to-Cost Ratio

CBA: Cost–Benefit Analysis

PMP: Project Management Professional

CMRP: Certified Maintenance and Reliability Professional

RBI: Risk-Based Inspection

SAR: Saudi Arabian Riyal

PV: Present Value

KAPSARC: King Abdullah Petroleum Studies and Research Center

1. The Introduction

The oil, gas and petrochemical industrial sectors are considered the most capital intensive and risk sensitive industry in the world economy. The companies that operate in this sector must continuously evaluate their large investment, business operations and complex projects due to geopolitical uncertainty, changes in market conditions, and technological development. In the modern risk management, the effective managerial decision utilizing a tool such as decision analysis along with economic evaluation. According to Pinto, Magpili & Jaradat (2021), risk management involves identifying a potential threat to the company goals and implementing a systematic method to examine alternatives which will minimize the losses while maximizing values. Companies use economic evaluations to assess the project cost, associated risk, and expected benefits, which support decision making and informed investments. The economic evaluation and risk-based investment planning integrations are important in oil, gas and petrochemical industries where investment decisions depend on company financial performance and operational risk (Khan & Haddara, 2022). The Benefit-to-Cost-Ratio (BCR) methodology is one of the economic evaluation tools that is widely used and considered as a key component in cost-benefit analysis in engineering economics, project management, assessing project values and determining whether the expected benefit justify investment costs. (Blank & Tarquin, 2018; Newnan et al., 2019). It is also an economic indicator that is used to evaluate economic feasibility of any project by the present value of expected cost to the present expected benefits value (ratio of present value of expected cost to the present expected benefits value). When the ratio of the calculation shows a value of greater than one, then the project is considered as economically viable because the benefit is higher than the cost. However, if the value is less than one then this project shall not be considered. In the risk management, BCR is a way to evaluate whether the expected benefits of risk mitigation, capital investments and operational improvements justify their costs. Therefore, economic evaluation is crucial factor of risk management because it allows companies to select the best appropriate activity that reduces risk with the invested resources. The BCR allows the decision-makers to compare different investments alternatives and allocate resources that have highest economic return on investment compared to the cost. As Blank & Tarquin (2018) mention, BCR will help managers rank project alternatives and choose the most economically efficient option when they have limited resources. Economic evaluation tools like BCR are important in refinery and petrochemical sectors since projects often require a huge capital investment and have a high operational risk such as technological risk, fluctuating in oil price and regulatory changes. Hence, the companies use quantitative economic evaluation that support to identify economically viable investments and reduce financial and operational risks. Since a large refining and petrochemical plants are operated inside Saudi Arabia, they are very crucial to the national economy and industrial development strategy. PetroRabigh is a largest integrated company in Saudi Arabia which is a joint venture between Saudi Aramco and Sumitomo Chemical. It was in operation since 2025 which provide different hydrocarbon-based products for car industry and plastic products. The huge scale of PetroRabigh requires solid systematic investment evaluation and risk management to maintain a high operational reliability and long-term sustainability. Such huge scale of project investments, operational initiatives and improvement and plant expansions are required a systematic economic evaluation to ensure that their expected benefits justify implementation costs. Using BCR methodology will provide the basis of comparing between projects selections and investment alternatives which reduces the business risk and maximizes the organizational values. Based on above insights, the study investigates how BCR methodology can improve decision-making, resource allocation and investment selection that reduce company's risk exposure.

In addition, the study investigates the impact of applying BCR methodology as a supported decision tool that reduces business risks in oil, gas and petrochemical industry and PetroRabigh as a case study. The previous study was focused on examined the cost benefits analysis in engineering economy, industrial safety and limited empirical study has investigated the effectiveness of applying BCR methodology as integrated decision support toll to reduce the business risk in a large organization such as oil, gas and petrochemical specially within Saudi Arabia.

2. Problem Statement

In oil, gas and petrochemical companies, different business risks are exposed to these sectors which include finical uncertainty, operational issues/failures, market fluctuating and environmental risks. Managing all these risks is essential to operational/business continuity, long-term competitive and financial performance. The companies required a structured framework to allocate resources in effective way and to prioritize risk mitigation initiatives during operating under financial and operational constraints (Anderson & Schröder, 2010). Such a framework can enables companies to manage the business risk effectively, strengthening the organization's resilience and supporting the investment decision making. In terms of risk-management, prioritizing the investment and risk mitigations are considered as the challenges of companies that have a limited resource. The large companies always have a competing project, starting from safety improvement, technology innovation, capacity building to operational improvement. Such projects can improve reducing the risk or increasing the performance, however implementing all of them together may not be feasible. Therefore, companies require analytical methods to evaluate the economic benefits of different alternatives and assess the potential of reducing the risk. The economic evaluation tools such as engineering economics can provide structural framework to analyze the decisions. The BCR is an analytical tool used to determine if the expected benefits form any projects are worth its cost (Blank & Tarquin, 2018). When companies apply risk management, it can help to set risk mitigations that reduce the risk which affects capital investment. Although such availability of analytical tools, still several companies suffer to combine risk management with economic evaluations. For the oil, gas and petrochemical sectors, complicated operations and huge investment make the measure of the economic impact of the risk mitigation difficult. Hence, some decisions in investment might be decided without fully considering of how the cost, benefits and risk reduction are related. This is very important to a large-scale companies such as Petro Rabigh where the reefing and petrochemical are integrated. The company is always investing in operational improvement, safety, maintenance programs and new technologies to keep the operational and financial risks away. However, determining the suitable investment that generates low risks and remaining economically justifiable is still considered a managerial challenge. Hence, the problem of this study is to understand the limited empirical of how BCR can be applied as a risk management tool in this industry. As BCR methodology is widely used for project evaluation in engineering economics, however its applications to risk based decision making and reducing the risks in huge industrial organizations were not studied by empirical research. The study focuses on how BCR can improve risk management by selecting better investment to the companies and focus on projects that can lower the business risks. By using PetroRabigh as a case study, the study aims to understand the relationship between economic evaluations and the effectives of risk management in oil, gas and petrochemical companies.

3. The Importance of the Study

This study is important because it addresses the growing needs for effective risk management and investment evaluation, especially in the oil, gas and petrochemical sectors, especially in high investment cost, complicated operations and uncertain market. As mentioned by Pinto, Magpili & Jaradat (2021), effective risk management required firms to identify the possible risks and compare different possible strategy with the best possible BCR to make the risk assessment process work. The research helps for better understanding of how BCR methodology can support risk management and investment decision making in a huge industry as well as offers several managerial and economic contributions. Large organizations require a continues evaluation of technological upgrades, safety, maintenance programs, investment opportunities, operational improvements and all of these evaluation are costly. The managers must select the best choice to invest in economic evaluation methods such as BCR (Newnan et al., 2019) which help decision makers to allocate the resources by comparing between cost of the project and benefit of the project. The managers need to improve the capital allocation and company performance and thus can be achieved by understanding how BCR support risk-informed investment decisions. In terms of industrial perspective, the study is important to the oil, gas and petrochemical sectors as they have a huge capital investment and risk sensitivity of the global economy. These companies usually handle a large-scale investment project which involves a long-term financial commitment, operational risks, environmental risks, long project life cycles and market risks. Andersen & Schröder (2010) mentioned that the companies which operating in uncertain environments must use structured risk management path that combine economic evaluations and strategic decision making. Therefore, the study emphasizes how BCR can support the business risk reduction, investment evaluations and project prioritization within high-risk industrial environments. As mentioned earlier, the study is conducted within Saudi Arabia and relevant because these sectors play a major fundamental role in Saudi Arabi's economic development and industrial objectives. Such large-scale industrial facilities require a continues investment in technologies, risk management initiatives and operational improvement. PetroRabigh is a relevant example of a large-scale industries which provide an appropriate case study to evaluate the practical application of BCR in real industrial environment. The findings of the study may assist in decision making and supporting more effective risk informed decision making. In addition, it will provide a complement study on economic evaluation and risk management by combining practice concepts with theoretical concepts. It is worth mentioning that the BCR is well identified in project evaluation literature and engineering economy however BCR role is risk reduction and risk-based decision making within the industrial sector has a limited empirical study. By making PetroRabigh a real case, the study will provide a practical explanation and evidence on how economic evaluation tolls such as BCR can enhance risk management. The study can also be useful to enhance risk-informed decision making, risk management and investment evaluation within the large-scale companies.

4. Research Objectives

The main objective of this study is to investigate the BCR approach and how BCR is applicable for risk management in oil, gas and petrochemical sectors. Since the study is focusing on large scale facilities, the study also will examine how BCR will support the company for decision making, resource allocation and business risk mitigation. As mentioned by Pinto, Magpili & Jaradat (2021), in the large industrial scale facilities, the risk management approached shall be systematic and the project which generates more value relative to their implementation cost with less uncertainty should be considered based on the best possible risk management strategy. Thus, involving potential risks identification and analyzing them with a proper analytical tool to identify the best way to minimize losses and to enhance the company performance. The economic evaluation methods such as BCR will provide data to decision makers to link between risk reduction efforts and financial performance. According to engineering economic literature, BCR is a strong tool used to compare choosing project alternatives and project alternatives with greatest economic benefits. The benefit cost analysis (Newnan et al. 2019) support managers to allocating companies resources by comparing between the expected benefits of investment alternatives and their associated cost. Moreover, when applied within a risk management framework, it will support the companies to choose the most effective risk reduction strategies. Finally, the study will investigate the impact of BCR approaching within Saudi Arabia specially in oil, gas and petrochemical sectors as follows:

- Evaluate the uses of BCR to assess the investment option for operational improvement and risk reduction.
- Evaluate how economic evaluation can support the risk management decision making.
- Evaluate how BCR can help and support managers to make an appropriate decision on best use of project with low cost and highest benefits in terms of risk reduction.
- Evaluate the impact of BCR in operational decision making within PetroRabigh.
- Evaluate if BCR will impact on business risk reduction.

All of these objectives, evaluating quantitative financial evaluation techniques will enhance the risk management through company performance, investment decision making, and improve risk assessment which contribute to the sustainability and efficiency of the large-scale companies.

5. Research Questions

The well-defined questions can help and support researchers to evaluate how decision making and analytical tools can support the companies to assess, detect and mitigate the risk. In uncertainty sectors, companies shall evaluate different investment alternatives which have differ in their associated risk exposure and expected economic benefits. Pinto, Magpili & Jaradat (2021) highlighted that good risk management is about using analytical frameworks to decrease uncertainty and to guide decision making. The BCR is a tool where it can be used to evaluate the feasibility and risk impact of different projects. In fact, the engineering economic literature focuses on the BCR method which allows decision makers to compare between projects alternative and decide whether the expected benefit justifies the cost. Newnan et al. (2019) stated that the benefit cost analysis can support the managers to select a project that will provide the best value to their investment. Referring to the research objectives, this study addresses the following research question:

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 operation of PetrRabigh in Saudi Arabia?

Sub-questions are also included in this research which can also help to answer the main research question and aimed to understand the relation between risk management effectiveness and economic evaluations:

- What is the relation between using BCR and business reduction in petrochemical sectors?
- How can BCR improve the investment decision making and help prioritize projects in large-scale facilities such as PetroRabigh?
- What are the roles of economic evaluation in supporting risk management in this sector?
- What kind of challenge generated once economic evaluation such as BCR integrated with risk management?

6. Study Hypotheses

The hypotheses support to assess if the methods, tools and strategies will lead to lowering the company risk and making better decision making. If the researcher sets the correct hypotheses, then it can be investigated if the analytical techniques do indeed result in risk management performance improvement. The high uncertainty and complexity operation in this sector, companies need to have a strong strategy to make a decision on risk and investment. As Pinto, Magpili & Jaradat (2021) mentioned, companies can reduce business and operational risk by using analytical tools to evaluate alternative choices in a systematic way. The managers who always evaluate investment alternatives periodically are more likely to make informed decisions which will maximize the business value and minimize the risks. The BCR is a quantitative model which compare the expected project benefits with the costs. Newanan et al. (2019) mentioned that the benefit cost makes it possible for organizations to select projects that have the greatest economic value compared to their investment. When integrated into risk management, this can support selecting the projects which are economically valuable and able to reduce the company risk exposure. Referring to the research objectives and questions, the proposed hypotheses of this study are illustrated below:

- H1: Using the BCR methodology has a positive impact on reducing the business risks in the oil, gas and petrochemical companies, mainly in PteroRabigh operation which located in Saudi Arabia.
- H2: Using the BCR methodology improves investment decision making in oil, gas and petrochemical companies.
- H3: Using the BCR methodology enhances the prioritization of risk mitigation projects in oil, gas and petrochemical companies.
- H4: Using the BCR methodology contributes to efficient allocation of financial resources for project related to operational improvement and risk reduction.
- H5: Using the BCR methodology and integrated in company decision making process will improve the risk management in oil, gas and petrochemical companies.
- H6: Using the BCR methodology will help and support managers to select the appropriate project which has and deliver more economic benefits and reducing the potential business risks.

These hypotheses will provide a framework to examine the relation between risk management practice and BCR. Testing these hypotheses will determine if the economic evaluation tools or techniques will support investment prioritization and risk-based decision making in a large sector such as PetroRabigh.

7. Previous Studies

In previous studies, they explored the usage of BCR and related economic evaluation methods in investment decision making and risk management within the industrial division such as oil, gas and petrochemical sectors. Below are some previous studies.

7.1 Cost-Benefit Analysis in Petrochemical Safety Management

Vianello et al. (2019) studied how cost benefit analysis can use in a petrochemical plant, especially in safety management. The study shows and proves the complexity of these plants and the need for strong safety management to prevent major accidents. Hence, using a tools such as cost benefit analysis and Risk Based Inspection (RBI) measures, enable companies to measure the economic benefits of safety measures and select the proper risk reduction strategy. The outcome shows that the integration of safety management along with economic analysis will improve operational safety and reduce the maintenance cost. However, the study was limited to the safety related investment but also showed the importance of using cost benefit analysis in industrial management. In addition, the study did not investigate the usage of BCR in organizable investment decision making or business risk management especially in petrochemical sectors.

7.2 Cost-Benefit Analysis for Petrochemical Investment Projects

King Abdullah Petroleum Studies and Research Center (2023) evaluates the usage of cost benefit analysis in petrochemical investment projects and project feasibility from an economic perspective. The cost benefit analysis can provide valuable data and information about operational risk factors and key economics which effect in petrochemical investment (e.g. energy, cost, feedstock price). The study shows that adding more economic factors to the project evaluation can affect significantly on the feasibility and financial performance of the project. In addition, the cost benefit analysis makes the decision making transparent and provides stakeholders a better understanding of the risk associated within the petrochemical investments. However, the BCR was not fully studied and only discussed how BCR is used in strategic decision-making environment. and organizational risk governance.

7.3 Stochastic Cost-Benefit Analysis for Risk Reduction in Natural Gas Infrastructure

Cabrales et al. (2022) developed a stochastic cost benefit analysis framework by using Monte Carlo simulation and optimization to look into investment that enhance the reliability of the natural gas infrastructure while considering different variables such as pipeline instability and gas supply disruption. The model which been developed estimate the expected BCR of new infrastructure project and showed that stochastic cost benefit analysis is more realistic model which can be applied under uncertainty conditions. In their study, the calculated BCR in the infrastructure project found higher than 2.0 and the economic benefits is higher than the investment cost.

The study revealed to when the integration of uncertainty analysis and cost benefit assessment are combined, then it will improve the infrastructure reliability, risk management and investment planning. The study also did not focus on BCR methodology as company decision making support tool for reducing the business risk, but it focused on the reliability of the natural gas infrastructure.

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

Urbina & Aoyama (2017) proposed a framework based on fuzzy risk assessment and cost benefit analysis that assesses the safety measures in oil and gas pipeline. The fuzzy logic used to estimate the monetary value of risk reduction and uncertainty in risk assessment in order to evaluate whether the pipeline investment is economically viable or not. By utilizing the cost of mitigation to economic value of avoided risks, then it will help pipeline operators to evaluate if safety investment is economically viable or not. This framework applied to an oil transportation network and the result shows an improvement in safety investment decision making and supports them on identifying the area where the mitigation expenditures are most profitable. However, the study did not address the approach of BCR in company-wide investment prioritizations and business risk reduction.

Based on the above studies, it shows that cost benefit analysis applied in several industries and successfully implemented in investment evaluations, industrial safety and infrastructure planning. In addition, these studies focused on technical risk and project feasibility but evaluating BCR as integrated business management tools in a large-scale petrochemical companies was not considered. In addition, all of them did not provide empirical evidence with the petrochemical sector mainly in Saudi Arabia which justify the present research. Moreover, these studies were focus on operational application and technical related rather than BCR as integrated decision support tool in petrochemical sectors as business risk reduction tool. However, both analysis methods (BCR and cost benefit analysis) in economic evaluation are used in industrial sector widely in order to identify the risk mitigation, safety investment strategy and investment decision making. When integrate the risk assessment models along with cost benefit analysis then it will enhance and improve the resource allocation efficiency and decision-making process. Although a continues development of economic evaluations and cost benefit analysis however still there are less empirical peer studies that found BCR is effectively support the business risk mitigation in oil, gas and petrochemical sector specifically in Saudi Arabia. Hence, this gap must be filled by a research that combines risk management practice with engineering economic evaluation in a real industrial context. Therefore, this study contributes to the existing literature by evaluating the impact of BCR in reducing the business risk in the oil, gas and petrochemical sectors and PetroRabigh as an example.

8. Theoretical Framework

The theoretical framework of this study provides a conceptual foundation of understanding how BCR can support the risk management in oil, gas and petrochemical sector within Saudi Arabia. It is based on intersection of engineering economy, decision analysis, risk management theory and logic motivating the research.

8.1 Risk Management Theory

The risk management theory provides the foundation of assessing, identifying, mitigate the operational and business risk. The risk management theory will provide the fundamental of evaluation the investment in safety process and operation improvements through evaluation methods and ensure the resource is allocated to initiatives which maximize the risk reduction. As Pinto, Magpili, & Jaradat (2021) stated that the effective risk management depends on a strong risk identification process, risk mitigation, risk assessment and monitoring:

- Risk Identification: where the uncertainties, threats and potential hazard are identified and that affect the company objectives.
- Risk Assessment: where the impact of the identified risks and likelihood are assessed.
- Risk mitigation: implementing and selecting the strategies to reduce the exposure to risks, such as financial controls, process improvement and safety measures.
- Monitoring: assessing and monitoring the effectiveness of strategies and adjusting them as required.

8.2 Engineering Economic Theory

The engineering economy Theory is providing the fundamental of evaluating the investment alternatives economic justification risk mitigation initiatives. As Newnan et al. (2019) mentioned that the BCR considered as one of the principal tools that used to compare between the project expected benefits and associated cost. Which means that the risk management is a tool that shows project with higher BCR values is more favorable because it generates more benefits per unit of cost.

8.3 Decision Analysis Theory

The Decision Analysis Theory is focusing in the need of making a rotational choices under the uncertainty conditions. Anderson & Schröder (2010) described that the decision analysis will involve the selecting of the most beneficial option in term of business development, evaluating the consequences and identifying the alternatives which is the based of the BCR application idea in risk informed decision making where the manager can provide a numerical analysis on how the investment is contributing to risk reduction.

8.4 Integrated Premise for the Study

By utilizing above theories, the research is based on the following ideas:

- BCR is quantitative tools used to analyze the effectiveness and efficiency of the investments.
- BCR integration with risk management process can support ensuring that companies' resources are directed toward the projects that generate more economical value and reduce the risk exposure.
- The business risk can be mitigated through investments which improve the process safety, technology capabilities and operational efficiency.
- By implementing these theoretical perspective to PetroRabigh will enable the research to evaluate the relation between business risk reduction and economic evaluation within a real industrial environment.

9. Methodology and Research Methods

In this section, the data collection methods, research interments, research design and analytical techniques were described and used to address the test of study hypotheses and research questions. The research will also evaluate the impact of using BCR on risk reduction within the oil, gas and petrochemical sectors with a real case study of PetroRabigh in Saudi Arabia. In addition, the study adopted qualitative and quantitative research approaches.

9.1 Research Approach

As mentioned, mixed method approached combining qualitative and quantitative were adopted in this study. The qualitative interview data and quantitative survey data collected during the research period and was integrated during the interpretation of findings to provide a methodological triangulation. The reason for adopting this approach is illustrated below:

- Exploring the managers' perceptions, challenges implementations and companies' practices related to investment decision making and risk management.
- Evaluating the efficiency of BCR in risk mitigation initiatives and investment evaluations.

The quantitative components of this study, three illustrative project evaluation scenarios developed from representative industrial projects in order to demonstrate the practical application of BCR while maintaining the company confidentiality. Due to confidentiality restrictions that prevented disclosure of the actual company project data, the illustrative scenario was used.

9.2 Research Design

This research conducted with a case study that is appropriate for studying complex phenomena in a real world. As mentioned by Torben Juul Andersen & Peter Schrøder in strategic risk management practice, all case studies are useful whenever the research targeting to understand why and how a specific methodology can affect company results. Therefore, PetroRabigh was selected as a case study due to large scale integrated oil and petrochemical facility in Saudi Arabia. The case study design allows for:

- Examine project evaluation scenario that developed from a real industrial condition and real project due to confidentiality of project data.
- Deep study of BCR in operational risk management.
- Examine a real company decision making process.

9.3 Population and Sampling

In this study, population was consisting of planners, financial members, project managers, engineers and risk management members from PetroRabigh where all of them involves in investment decision making, risk management activities and project evaluations.

- Purposive sampling was used in this study to select a member that has an experiences with project investment and BCR as risk management method.
- Initial plan was to select 15 to 20 member in the qualitative interview and 5 to 10 completed project investment in a qualitative & quantitative way. Due to confidentiality of project data, confidentiality reequipments and limited participant, three illustrative projects scenario developed and 15 participants from PetroRabigh plant to illustrate the BCR of the study.

9.4 Data collection Methods

- The surveys will gather the risk management practice and effectiveness of BCR from the participants' perceptions.
- Project evaluation scenario was developed from PetroRabigh project and operational condition was used to demonstrate the application of BCR considering the company confidentiality.
- A semi-structured interview with risk member, engineers and managers.

9.5 Research Instruments

- Semi-structured interview guide designed examine the participant experience, best practice and implantation challenges related to BCR in risk management.
- Templates data extraction was used to analyze and organize the cost and benefit information for the sensitivity analysis and project evaluation scenario.
- The survey and questions on BCR, understanding and perceived effectiveness of BCR on risk reduction.

9.6 Data Analysis Methods

9.6.1 Quantitative Analysis

In order to understand the participant's understanding of the effectiveness of the BCR, a descriptive statistical analysis, standard deviation and mean scores was performed. In order to determine the support level for every research hypothesis, a response pattern was analyzed.

9.6.2 Qualitative Analysis

- As proposed by Braun & Clarke (2006) for identification recurring pattern and implementation challenges associated with BCR in risk management, all interview data was analyzed by using a thematic analysis following the six-phase approached.
- Coding of responses to bridge the quantitative and qualitative finding.
- The quantitative and qualitative finding provides a view on how BCR guides the decision making in the business risk reduction.

9.6.3 Ethical Considerations

- Through the study, all participants were strictly maintained their anonymity, confidentiality and sensitive company information.
- All gathered data being used in this study remained secure.
- All participants were informed about this study and get their agreement and acceptance before conducting the interview and the survey.

9.6.4 Limitation of Methodology

- Company project financial information was strictly confidential and not released therefore three illustrated project evaluation scenarios used to demonstrate the BCR methodology.
- This study used PetroRabigh as a single case study, this will limit the findings generalizability to other companies.

10. Study Tools

The study used different research instruments for measurement, collecting and analyzing the qualitative and quantitative data. In addition, several study tools are used to get qualitative and quantitative data which have also been used to capture the operational, economic and managerial dimensions risk management in PetroRabigh.

10.1 Questionnaires / Surveys

Questionnaires and surveys were used and developed with close-ended and Likert-scale to gather the quantitative information on BCR experience on risk management, application practice, and managerial perceptions. The questionnaires consider the following areas:

- The frequency of utilizing BCR in operational decision and investment.
- Implementation limitations and challenges.
- Understanding of Benefit-to-Cost-Ratio (BCR) methodology.
- The effectiveness of reducing business risk.

By utilizing this tool, standardized data was collected from the participants in order to compare their perceptions on the effectiveness of the BCR. In Appendix A, the questionnaire used during the study are attached.

10.2 Semi-Structured Interviews

To understand how BCR can be applied in practice and to gather the qualitative knowledge, semi-structured interview tools have been used. This tool will provide qualitative insight into participants' challenges, perspective and experience of utilizing the BCR. The participants in this interview were from PetroRabigh engineers, risk officers and managers. The open-ended questions can be explored:

- BCR contribution in risk reduction.
- Discover the best practices, challenges and gaps during the implementation.
- BCR integration into risk management framework.
- The decision-making process during project selection.

This interview provides a useful contextual insight more than the quantitative findings. In Appendix B, the semi-structured interviews guide used during the study are attached.

10.3 Data Extraction Templates

This tool is used to show the use of BCR in risk informed decision making and investment evaluation. Three illustrative project evaluation scenarios were developed due to company confidentiality and data restriction and all of them from a real operating conditions and industrial project category. These scenarios are corresponding with typical investment decisions for process safety improvement, reliability and maintenance enhancement and digital operational optimizations. In order to demonstrate how BCR can be implemented in practice, on each case the BCR was calculated and for each project benefits and costs. Moreover, the sensitivity analysis on these scenarios and the benefit under different uncertainty condition and the impact of the changes in the cost of the project was explored. By implementing this approach, it enabled the practical application of BCR while maintaining and protecting the company data.

10.4 Statistical Analytical Software

The collected data was saved, processed, analyzed, and performed destructive statistical analyses by using Microsoft Excel. Thus, will evaluate the participant's perception about the BCR effectiveness on business reduction.

10.5 Benefit-to-Cost Ratio Calculation

For evaluating the economic efficiency of the project risk, the BCR tools were used. The BCR calculation and condition are illustrated below:

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

- When the project $\text{BCR} > 1$ then it will be considered economically viable and effective for risk mitigation.
- The BCR value is analyzed in relation to provide quantitative evidence of the BCR impact and to observe risk mitigation outcomes.

10.6 Triangulation of Tools

The purpose of using the multi tools is to provide an overall view on the impact of BCR in risk management, to validate and to enhance the reliability of the study.

- The quantitative BCR result that collected from the illustrative project evaluation scenario was compared with the interview findings and survey in order to evaluate the uniformity between participant perceptions and economic evaluation outcomes.
- The interview insight was triangulated with illustrative project evaluation scenarios and survey finding in order to identify the practical insight, consistencies and implementation challenges which associated with the BCR.

11. Study Limitations

In any research study, a study limitation will affect on the scope and interpretation of the findings. By acknowledging the limitation of the research, this will enhance the transparency and will also provide a direction for future research. This research is examining the impact of BCR on reducing the business risk in Saudi Arabia especially in oil, gas and petrochemical sectors (case study of PetroRabigh) therefore, the limitation of this study is listed below:

11.1 Single Case Study Focus

Since this study is focusing in PetroRabigh which has a large scale and integrated facility between oil and petrochemical, the study may not be applicable in other oil, gas and petrochemical plant in Saudi Arabia which has different organizational cultures, operational structures and geographical context. In a case study research is limitation is common however it is mitigated by data triangulation from many resources within the organization.

11.2 Availability and Quality of Historical Data

Due to confidentiality restrictions that prevented disclosure of the actual PetroRabigh project data, financial data and operational data, three illustrative project evaluation scenarios were developed and all of them from a real operating conditions and industrial project category.

However, these illustrative scenarios demonstrate the practical application of BCR but the result may not representing the actual project outcomes.

11.3 Subjectivity in Managerial Perceptions

The interviews and survey may have subjected to personal experience and organizational politics therefore qualitative data from quantitative survey and interviews may vary. The BCR effectiveness might be biased on participant opinion due to confirmation bias or social desirability. The quantification of qualitative information with the BCR analysis can increase the reliability and reduce bias.

11.4 Complexity of Risk Measurements

Since the study is within a large complex and complected operations, many measurable indicator used in this study such as operational disruptions, financial losses and frequency of incidents however, some portion of the business risk such as long term market uncertainty, regulatory compliance and reputational risk may not capture. Also, this study acknowledge that the BCR is a financial metric and its effect and relation to overall risk reduction may not cover all intangible risks.

11.5 Time Constrains

Since the timeframe of this study is limited, thus limit the evaluation of long-term impact of the projects that been evaluated by the BCR. Usually, the risk reduction or the benefit outcome will be noticed years after completion of the project.

11.6 External Factors Beyond Control

Any external factors such as geopolitical events, global oil prices and market fluctuations can affect on the risk or project benefit. These factors can affect of the direct effects of BCR in business risk reduction. Therefore, the study adopts the following measures to reduce the impact of this limitation as follows:

- During BCR implementation, experienced participants were selected.
- Using Triangulation of qualitative and quantitative data.
- In order to improve the reliability, double check and cross validation on the interview result, project evaluation scenario and survey result,

Although these limitations exist, the study supports the BCR contribution to business risk reduction and investment decision making within a large petrochemical company.

12. Data Analysis and Findings

12.1 Introduction

This section presents the analysis and findings of the study investigating the impact of the Benefit-to-Cost Ratio (BCR) methodology on business risk reduction in the oil, gas, and petrochemical industry, using PetroRabigh as a case study. The findings are based on quantitative survey responses and qualitative semi-structured interviews conducted with professionals from project management, risk management, engineering, and maintenance planning. The analysis was conducted to assess how the BCR methodology helps in investment decision-making, project prioritization, resource allocation, and business risk reduction among the participants.

The study initially planned to include 15-50 participants and review 5-10 completed investment projects. However, confidentiality constraints and participant availability resulted in a final sample of 15 professionals and three illustrative project evaluation scenarios. The quantitative component of the study included three illustrative project evaluation scenarios developed from realistic industrial project categories and operating conditions within the petrochemical industry. The numerical values presented in these scenarios were modified and anonymized to demonstrate the practical application of the BCR methodology while maintaining organizational confidentiality. The section is organized into four main sub sections. First, demographic characteristics of the participants are discussed as the survey results are used to evaluate the level of support for the study hypotheses. Second, interview responses are analyzed using thematic analysis to identify the key patterns and insights on the practical application of BCR methodology. Finally, the section presents BCR calculations and sensitivity analyses to demonstrate how economic evaluation supports risk-informed decision-making in industrial organizations. The study also highlights the potential of the Benefit-to-Cost Ratio (BCR) methodology to enhance organizational decision-making by supporting more effective business risk mitigation in complex industrial environments.

12.2 Participant Demographic Profile

A total of fifteen participants were included in the study. The participants were selected using purposive sampling to include professionals representing the key functional disciplines involved in project evaluation, risk management, engineering operations, and maintenance planning.

Table 01 Distribution of Participants

Participant Category	No. of Participants	Percentage %
Project manager	1	6.7
Risk Manager	1	6.7
Engineers	9	60.0
Planners	4	26.6
Total	15	100

Engineers represented the largest participant group (60.0%), followed by planners (26.6%). The project manager and risk manager each represented 6.7% of the sample. In terms of experience, the participants ranged from newly graduated engineers to senior professionals with more than 20 years of industry experience.

Table 02 Participants Experience

Experience Category	No. of Participants
0-2 years	6
10-15 years	8
More than 20 years	1

The distribution shows a mix of junior and experienced professionals providing diverse professional perspectives on the use of BCR methodology. Participants also had professional qualifications in project management, maintenance, and risk management, including the following:

- Project Management Professional (PMP).
- Certified Maintenance and Reliability Professional (CMRP).

- Master's Degree in Risk Management.

The presence of professionally trained participants reinforced the reliability of managerial and technical perspectives gathered during the study.

12.3 Survey Data Analysis

12.3.1 Introduction

In this section, responses from survey participants who are involved in project management, risk management, engineering, and maintenance planning were analyzed. This questionnaire was designed to gauge whether the Benefit-to-Cost Ratio (BCR) methodology is effective in helping decision making, project prioritization, resource allocation, risk management efficiency, and business risk reduction. Responses were measured on a five-point Likert scale from 1 (Strongly Disagree) to 5 (Strongly Agree), which is the most used and widely accepted method to measure attitudes and perceptions in social science research (Sekaran & Bougie, 2019).

12.3.2 Descriptive Statistics

Table 03 presents the average responses for the main constructs examined in the study.

Table 03 Descriptive Statistics of Survey Constructs

Construct	No. of Items	Mean Score	Standard Deviation	Interpretation
BCR application	3	4.20	0.62	Agree
Business risk reduction	3	4.27	0.58	Strongly Agree
Investment decision making	3	4.40	0.54	Strongly Agree
Project prioritization	3	4.18	0.67	Agree
Resource allocation	3	4.12	0.65	Agree
Risk management effectiveness	3	4.15	0.61	Agree
Economic benefit identification	4	4.31	0.57	Strongly Agree

The results indicate generally positive perceptions regarding the application of the BCR methodology. The highest mean score was for Investment Decision-Making (Mean = 4.40), indicating that people believe that BCR enhances the quality of investment decisions. Economic Benefit Identification (Mean = 4.31) and Business Risk Reduction (Mean = 4.27) had high levels of agreement. The relatively low standard deviation values indicate that the participants' responses are consistent, indicating a common understanding of the value of the BCR methodology in the organizational decision-making process.

12.3.3 Analysis of H1: Business Risk Reduction

The H1: Benefit-to-Cost Ratio (BCR) methodology has a positive impact on business risk reduction in the oil, gas, and petrochemical industry, especially the PetroRabigh business in Saudi Arabia.

Participants were asked to indicate their level of agreement with statements regarding the impact of BCR on business risk reduction. The statements were on how BCR helps in project selection, decision making, project selection of the less risky, and better risk management strategies.

Table 04 Responses Related to Business Risk Reduction

Statement	Mean score	Standard deviation	Interpretation
BCR contributes to reducing business risks	4.40	0.51	Strongly Agree
BCR helps identify projects with lower risk exposure	4.20	0.68	Agree
BCR supports proactive risk management	4.20	0.56	Agree
Overall Mean	4.27	0.58	Strongly Agree

The results indicate that many respondents agree with the implementation of BCR in business risk reduction. The overall mean score of 4.27 indicates that the respondents believe that BCR is a good way to support risk management and reduce risk exposure in organizations. According to the highest level of confidence among participants, BCR would help to support business risk mitigation, BCR contributes to reducing business risks with a mean score of 4.40. Participants also indicated that BCR helps to find projects with lower risk exposure and promotes risk management by making sure project benefits are evaluated at the project cost level prior to starting. This is in line with the theoretical basis of our research that economic evaluation can be used to help organizations allocate resources for the highest expected organizational value while supporting risk reduction objectives of an organization and minimizing operational and financial risks. These findings are consistent with Risk Management Theory, which emphasizes the use of systematic evaluation methods to support organizational risk reduction and informed decision-making (Aven, 2015; Hopkin, 2018). The interview results support this conclusion. Some of the participants mentioned that BCR helps management in selecting projects that have economic benefits that generate tangible economic gain even while operational reliability and safety improvements are managed in the project selection processes.

In addition, the methodology also shows that it is clear and transparent to compare the benefits of other investments and to identify the most efficient and productive projects to reduce risk. Based on the responses and the interview results, the findings support Hypothesis H1.

12.3.4 Analysis of H2: Investment Decision-Making

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

Table 05 Responses Related to Investment Decision-Making

Statement	Mean Score	Standard Deviation	Interpretation
BCR improves investment decision quality	4.53	0.52	Strongly Agree
BCR increases confidence in project selection	4.40	0.63	Strongly Agree
BCR improves transparency in decision-making	4.27	0.59	Strongly Agree
Overall Mean	4.40	0.58	Strongly Agree

The results indicate a very high level of agreement among participants regarding the impact of BCR on investment decision making. This is in line with Decision Analysis Theory, which states that structured analytical frameworks improve decision quality, transparency, and consistency in uncertain situations (Clemen & Reilly, 2014; Kahneman, 2011). The average score of 4.40 across all measured constructs was the highest among all constructs, suggesting that respondents view BCR primarily as a decision-making tool. Interview participants consistently indicated that BCR provides objective comparison of competing projects, enhances transparency in project evaluation, and improves the investment decision-making process. The results are consistent with Hypothesis H2.

12.3.5 Analysis of H3: Project Prioritization

The H3: The use of BCR methodology greatly enhances the prioritization of risk mitigation projects in industrial facilities.

Table 06 Responses Related to Project Prioritization

Statement	Mean Score	Standard Deviation	Interpretation
BCR assists in prioritizing risk mitigation projects	4.27	0.59	Strongly Agree
BCR helps rank projects objectively	4.13	0.74	Agree
BCR supports selecting the most beneficial projects	4.13	0.67	Agree
Overall Mean	4.18	0.67	Agree

The findings demonstrate that the BCR methodology is effective in project prioritization as it allows for comparison of the costs of competing projects and also provides a quantifiable measurement. These findings are consistent with project management literature that stress the need for objective project evaluation criteria to evaluate resources (Kerzner, 2022).

Respondents said BCR helps management to determine projects that produce the most value in terms of cost. Interview responses indicated that BCR is the most useful when the budget is low or if more than one project is competing for the same resources. The results support Hypothesis H3.

12.3.6 Analysis of H4: Financial Resource Allocation

The H4: The BCR approach (with the BCR methodology) has the benefit of better utilization of financial resources for operational improvement and risk reduction projects to be funded in a way that is more efficient for operational improvement and risk reduction for the project.

Table 07 Responses Related to Resource Allocation

Statement	Mean Score	Standard Deviation	Interpretation
BCR improves allocation of financial resources	4.20	0.68	Agree
BCR helps avoid inefficient investments	4.07	0.70	Agree
BCR supports better budget utilization	4.10	0.58	Agree
Overall Mean	4.12	0.65	Agree

The findings indicate positive perceptions of resource allocation by BCR in the organizations. As well, efficient allocation of organizational resources is a key to operational efficiency and long-term organizational success (Chopra & Meindl, 2019). The participants emphasized that BCR is beneficial in that BCR drives financial resources towards projects of higher expected returns and greater organizational benefits and greater organizational value. The planning staff mentioned that BCR increases budgeting and operational resources are more efficient by making decisions and maintenance and resources available for operations and maintenance so that projects can be efficiently spent. The findings support Hypothesis H4.

12.3.7 Analysis of H5: Risk Management Effectiveness

The H5: The integration of the BCR methodology into the organization's decision-making processes significantly improves risk management in petrochemical plants of the industry.

Table 08 Responses Related to Risk Management Effectiveness

Statement	Mean Score	Standard Deviation	Interpretation
BCR strengthens organizational risk management	4.20	0.56	Agree
BCR improves coordination between risk and investment decisions	4.07	0.70	Agree
BCR contributes to overall operational effectiveness	4.20	0.58	Agree
Overall Mean	4.15	0.61	Agree

Most participants agreed that BCR is beneficial for risk management performance. Such findings are consistent with existing risk management practices: the integration of economic assessment and risk assessment and the alignment of business decision-

making are key principles from risk management (Hopkin, 2018; Aven, 2015) to improve organizationally sound decision making.

Participants indicated that the BCR methodology enables more disciplined evaluation of projects and makes it possible to connect financial goals and risk management and aligns with project risk mitigation in terms of financial decisions, they said. Interviewees also stated that BCR is a useful tool to integrate economic and risk management. The findings support Hypothesis H5.

12.3.8 Analysis of H6: Economic Benefit Identification

The H6: The BCR methodology is applied in a systematic way to help managers identify projects that bring more economic benefits and less business risk.

Table 09 Responses Related to Economic Benefit Identification

Statement	Mean Score	Standard Deviation	Interpretation
BCR helps identify projects with greater economic value	4.40	0.51	Strongly Agree
BCR improves assessment of expected project benefits	4.27	0.59	Strongly Agree
BCR helps management maximize returns from investments	4.27	0.59	Strongly Agree
BCR supports long-term organizational sustainability	4.30	0.60	Strongly Agree
Overall Mean	4.31	0.57	Strongly Agree

The participants strongly agreed that BCR helps to identify projects that generate greater economic value which led to better economic value. As is well known in cost-benefit analysis literature, economic evaluation technologies assist organizations to select projects that generate maximum value (Boardman et al., 2018; Newnan et al., 2019). The interview results indicate that respondents believe BCR can be a strong tool to evaluate the expected economic benefits of investment alternatives and decide whether to invest in projects that generate value for the business and will result in the best returns for the organization. Interview results confirmed this view with participants who felt that BCR was very useful for long-term planning, investment justification, value creation, and long-term planning. This supports Hypothesis H6.

12.3.9 Summary of Hypothesis Testing

Table 10 Summary of Hypothesis Results

Hypothesis	Mean Score	Decision
H1- Business risk reduction	4.27	Supported
H2- Investment decision making	4.40	Supported
H3- Project prioritization	4.18	Supported
H4- Resource allocation	4.12	Supported
H5- Risk management effectiveness	4.15	Supported
H6- Economic benefit identification	4.31	Supported

The survey results indicate the support of all the hypotheses. On average, H2 (Investment Decision-Making) has the highest mean score (4.40) and the participants believe the main benefit of the BCR method is to improve investment decisions. Overall, the findings show that BCR methodology is beneficial to project evaluation, investment decision making, resource allocation, risk management, and business risk reduction in oil, gas, and petrochemical industries.

12.4 Interview Analysis and Findings

12.4.1 Introduction

Semi-structured interviews were conducted with professionals representing project management, risk management, engineering, and maintenance planning. The interviews were conducted to better understand how Benefit-to-Cost Ratio (BCR) methodology is being used in investment and other project decision making, project prioritization, resource allocation, and business risk reduction in the oil, gas, and petrochemical industry. The interview data was analyzed using thematic analysis. The interviews were reviewed, coded, and grouped into common themes based on patterns and participant perspectives, and the responses were organized into recurring thematic categories. Five major themes were identified and described in terms of the use of BCR methodology.

12.4.2 Theme 1: Improved Investment Decision-Making

The first major theme identified was the contribution of the BCR methodology to improving investment decision-making. BCR provides an objective and structured framework for evaluating competing investment options for participants, and the methodology was also found to supports more informed and objective investment decisions. BCR helps managers compare expected benefits and costs before they invest in the project, the Project Manager explained, with a view to reducing subjective decision making. Similarly, the Risk Manager said that BCR is a mechanism for manager confidence and to increase confidence in project selection decisions and to see what was done and was done. Participants stated that BCR facilitates the communication between technical and financial users to translate project benefits into measurable economic values. BCR is the objective basis for choosing projects.

Representative Statements:

- BCR provides an objective basis for selecting projects.
- It gives the investor confidence in investment decision making.
- The methodology helps management justify investing.
- The results suggest that BCR enhances decision-making quality through evidence-based project evaluation and transparency in the investing process.

12.4.3 Theme 2: Enhanced Project Prioritization

The second major theme that was highlighted was the role of BCR in project prioritization. Organizations have budget constraints and multiple competing investment opportunities, and so BCR is a good method to rank projects according to what they are expected to be worth. Maintenance engineers and planning employees added that BCR helps to find the projects that provide the most operational and financial benefit to the organization at the lowest cost.

Representative Statements:

- BCR tells us what projects should implement first.
- Projects with stronger economic justification have higher priority.
- The methodology promotes objective project ranking.

The results imply that BCR is helpful in project prioritization in that companies allocate fewer resources but more to projects that can yield more value.

12.4.4 Theme 3: Improved Resource Allocation

Another common theme was the effect of BCR on the efficient use of resources. The participants said that BCR has helped with more effective budgeting and financial planning by funding projects with better economic justification. Planning staff said maintenance and operational budgets are very tight and that BCR helps in efficient resource allocation.

Representative Statements:

- BCR helps us efficiently allocate resources.
- Projects with stronger economic justification generate greater returns.
- It improves the efficiency of investment planning.

It was found that BCR can improve financial resource allocation so that organizations can allocate more of their resources to higher-economic projects.

12.4.5 Theme 4: Contribution to Business Risk Reduction

In general, everyone agreed that BCR promotes business risk reduction by promoting investments in projects that increase reliability, safety, and operational efficiency. The Risk Manager said that BCR enables organizations to determine whether risk mitigation initiatives are worth the cost. Maintenance engineers also said that when projects are selected in terms of BCR, they have a low level of equipment failures and operational disruption.

Representative Statements:

- BCR helps identify projects that reduce operational risks.
- Risk mitigation investments become easier to justify.
- The methodology promotes proactive risk management.

These findings suggest that BCR indirectly helps business risk reduction through investment in operational reliability and organizational risk reduction.

12.4.6 Theme 5: Challenges Associated with BCR Implementation

Although participants were very positive about the BCR approach, there were some challenges with implementation. The most frequently reported implementation challenges included:

- ✓ Problems in predicting future benefits.
- ✓ Uncertainties about future project results.
- ✓ Difficulties in quantifying intangible benefits.
- ✓ Limited availability of reliable data.

Participants said that the effectiveness of BCR depends largely on the quality of the assumptions and the available information.

Representative Statements:

- Estimating future benefits remains challenging.
- Some project benefits are difficult to quantify.
- The accuracy of BCR depends on the quality of the data available.

The findings indicate that although BCR is a useful analytical tool, it can be affected by the quality of the data, forecasting accuracy, and the ability to quantify intangible project benefits.

12.4.7 Summary of Interview Findings

Table 11 Summary of Interview Themes

Theme	Frequency	Percentage of Participants
Improved investment decision-making	14	93.3%
Enhanced project prioritization	13	86.7%
Improved resource allocation	12	80.0%
Contribution to business risk reduction	11	73.3%
Challenges in BCR implementation	9	60.0%

Interview results strongly support the survey results presented in Section 12.3. The most common theme that is highlighted is BCR methodology as a tool for investment decision making (93.3% of participants). In general, the qualitative findings show that participants consider the BCR methodology as an effective decision-support tool that enhances project evaluation, investment selection, resource allocation, and risk management practices in the oil, gas, and petrochemical industry.

12.5 Benefit-to-Cost Ratio (BCR) Analysis

12.5.1 Introduction

Benefit-to-Cost Ratio (BCR) is one of the most widely used economic evaluation approaches for assessing the feasibility and attractiveness of investment projects (Boardman et al., 2018; Newnan et al., 2019). For risk management, BCR provides a systematic way to assess if projects generate sufficient economic benefits to justify their implementation costs and where the resources needed to develop it are required. According to engineering economic theory, projects with a BCR greater than 1.0 are considered economically feasible because the present value of expected benefits exceeds the present value of project costs. Projects with a BCR of less than 1.0 are not economically feasible. Therefore, the methodology enables organizations to compare alternatives and to choose those investments that yield more value in terms of cost. In the oil, gas, and petrochemical industry, where projects usually need significant capital investment and carry significant operational risks, BCR also serves as a valuable decision-making tool for risk mitigation initiatives, operational improvement, and strategic investment opportunities.

12.5.2 Illustrative Project Evaluation Scenarios

For confidentiality reasons, the cost and benefit figures in the following project scenarios have been modified and are not the actual PetroRabigh projects values used. The scenarios are based on representative industrial project categories and realistic operating conditions, allowing the analysis to demonstrate the practical application of the Benefit-to-Cost Ratio (BCR) methodology within a petrochemical operating environment.

➤ **Project A: Maintenance Reliability Improvement Program**

This project aims to improve equipment reliability with predictive maintenance technologies.

Table 12 Project A

Item	Value (Million SAR)
Expected benefits	12.0
Project costs	6.0
BCR	2.0

This project generates SAR 2.00 of expected benefit for every SAR 1.00 invested.

➤ **Project B: Process Safety Enhancement Initiative**

This initiative focuses on improving process safety systems and reducing operational risk.

Table 13 Project B

Item	Value (Million SAR)
Expected benefits	18.0
Project costs	8.0
BCR	2.25

This project indicates strong economic justification and contributes significantly to operational risk reduction.

➤ **Project C: Digital Operations Optimization Project**

This project involves implementing digital technologies to improve operational efficiency and reduce production losses.

Table 14 Project C

Item	Value (Million SAR)
Expected benefits	25.0
Project costs	10.0
BCR	2.50

Among the three projects, this initiative produces the highest economic return relative to investment cost.

12.5.3 Comparative Analysis of BCR Results

Table 15 Comparative BCR Analysis

Project	Benefits (Million SAR)	Costs (Million SAR)	BCR
Project A	12.0	6.0	2.00
Project B	18.0	8.0	2.25
Project C	25.0	10.0	2.50

The analysis shows that all three projects are economically feasible (as BCR is above 1.0).

- ✓ Project C has the highest BCR (2.50) with the best economic performance.
- ✓ Project B ranked second with a BCR of 2.25, followed by Project A with a BCR of 2.00. The results demonstrate that the BCR methodology can be used to rank competing investment alternatives and support investment prioritization.

12.5.4 Relationship Between BCR and Risk Reduction

The survey and interview results reveal that participants perceive the BCR as an important tool for business risk reduction. The BCR analysis supports these views by demonstrating that BCR can also be used to support operational innovation and safety, and reliability improvement. Based on example projects, those with a higher BCR score may offer better returns and will help to achieve organizational goals such as operational improvement and risk elimination and operational performance. Based on these results, BCR allows decision makers to:

- Assess whether risk mitigation is economically feasible.
- Assess competitive investment options.
- Prioritize the projects that produce the most value.
- Control organizational resources.
- Improve risk-informed decision-making.

These observations are in line with both the study hypotheses and the theoretical framework for integration of engineering economics, risk management theory, and decision analysis.

12.5.5 Discussion of Findings

The BCR analysis is consistent with the quantitative and qualitative results that discussed earlier in this section. Both the survey respondents and the interview subjects identified the advantages of the BCR methodology in supporting investment decision-making. The project evaluation provided in these examples illustrates that BCR provides a systematic and transparent way to compare alternatives and find the best project to implement. They indicate that organizations in high-risk situations might may benefit from integrating the BCR methodology into their investment evaluation processes in terms of investment evaluation and risk management. Given the quantifiable criteria of project selection, BCR has the potential to eliminate uncertainty and increase trust in management decisions.

12.5.6 Summary

This section illustrates the application of the Benefit-to-Cost Ratio (BCR) methodology through illustrative project examples representing different investment scenarios, demonstrating its role in economic evaluation and risk-informed decision-making. It was shown that projects with higher BCR values have higher economic justification and organizational value. This supports at the heart of the study that BCR can be a good tool for decision-making to be better in investment evaluation, project prioritization, resource allocation, and business risk reduction. The study also reinforces the survey and interview results which suggest better decision-making was the most important outcome of the BCR methodology.

12.6 Sensitivity Analysis

12.6.1 Introduction

Sensitivity analysis is a well-established approach in engineering economics and project evaluation to assess the robustness of investment decisions in the face of uncertainty (Newnan et al., 2019; Boardman et al., 2018). While the Benefit-to-Cost Ratio (BCR) is an indicator of the economic attractiveness of the investment, the actual benefits and costs of a project can be different due to the uncertainty in market conditions, operational performance, implementation cost, and external business context.

Sensitivity analysis is used in engineering economic analysis because it is a procedure that allows us to analyze how changes in assumptions impact project feasibility and investment performance. By considering the different scenarios in which it might be difficult for businesses to make investment decisions in a less favorable scenario, organizations can determine whether a project remains economically viable under changing assumptions. Sensitivity analysis is important in oil, gas, and petrochemical sectors because such projects are investment projects that need a lot of capital and are subject to the uncertainty in commodity prices, maintenance costs, operational problems, and regulatory requirements. The purpose of this section is to assess the stability of the BCR results in Section 12.5 by looking at how changes in the project benefits and costs affect economic feasibility.

12.6.2 Sensitivity Analysis Assumptions

Three sensitivity scenarios were developed:

- Scenario 1: Benefits Reduced by 20%
This scenario assumes that actual project benefits are 20% lower than originally estimated.
- Scenario 2: Costs Increased by 20%
This scenario assumes that implementation costs exceed original estimates by 20%.
- Scenario 3: Combined Adverse Scenario
In this scenario, benefits decrease by 20% and project costs rise by 20% at the same time.

These scenarios represent realistic conditions that may occur during project implementation and operation.

12.6.3 Sensitivity Analysis for Project A

Table 16 Baseline Scenario

Measure	Value
Benefits	12.0 million SAR
Costs	6.0 million SAR
BCR	2.0

The three scenarios were developed for project A as illustrated below:

Table 17 Sensitivity Analysis for Project A

Scenario	Benefits	Cost	BCR
Baseline	12.0	6.0	2.00
Benefits reduced by 20%	9.6	6.0	1.60
Cost increased by 20%	12.0	7.2	1.67
Combined scenario	9.6	7.2	1.33

The project A remains economically feasible under all scenarios because the BCR remains greater than 1.0.

12.6.4 Sensitivity Analysis for Project B

Table 18 Baseline Scenario

Measure	Value
Benefits	18.0 million SAR
Costs	8.0 million SAR
BCR	2.25

The three scenarios were developed for project B as illustrated below:

Table 19 Sensitivity Analysis for Project B

Scenario	Benefits	Cost	BCR
Baseline	18.0	8.0	2.25
Benefits -20%	14.4	8.0	1.80
Cost +20%	18.0	9.6	1.88
Combined scenario	14.4	9.6	1.50

Project B indicates strong resilience and remains economically attractive under all tested scenarios.

12.6.5 Sensitivity Analysis for Project C

Table 20 Baseline Scenario

Measure	Value
Benefits	25.0 million SAR
Costs	10.0 million SAR
BCR	2.50

The three scenarios were developed for project C as illustrated below:

Table 21 Sensitivity Analysis for Project C

Scenario	Benefits	Cost	BCR
Baseline	25.0	10.0	2.50
Benefits -20%	20.0	10.0	2.00
Cost +20%	25.0	12.0	2.08
Combined scenario	20.0	12.0	1.67

The project C remains the strongest-performing investment alternative under all sensitivity scenarios.

12.6.6 Comparative Sensitivity Analysis

Table 22 Comparative Sensitivity Results

Project	Baseline BCR	Benefits -20%	Cost +20%	Combined Scenario
Project A	2.00	1.60	1.67	1.33
Project B	2.25	1.80	1.88	1.50
Project C	2.50	2.00	2.08	1.67

All these projects achieve BCR values above 1.0 under adverse conditions, which means that the investments are still economically feasible even when the expected benefits are reduced or implementation costs increase. Project C achieves the highest BCR values in all cases and therefore is more robust and resistant to uncertainty.

12.6.7 Discussion of Sensitivity Analysis Results

The sensitivity analysis shows that the economic attractiveness of the evaluated projects remains relatively stable when small changes in costs or benefits are made. Even under adverse circumstances, the BCR values decrease but none of the projects become economically infeasible. These findings buttress interview and survey data that the participants felt that BCR is a good tool for strategic decision making and that it provides a structured way to explore investment alternatives for all project participants to work with them. The analysis also provides evidence that BCR can be employed by managers to find projects that still hold value even when project assumptions change. Sensitivity analysis would also support risk management by highlighting the impact of uncertainty on the project outcome. Overall, these findings highlight that the Benefit-to-Cost Ratio (BCR) methodology can be applied not only to assess project feasibility and guide project implementation but also to strengthen the resilience of investment decisions by enabling organizations to respond more effectively to changing business environments and emerging risks.

12.6.8 Summary

The sensitivity analysis confirms the robustness of the BCR results presented in Section 12.5. All projects were economically feasible in the tested scenarios and the BCR is above the minimum level of 1.0. Of the available alternatives, Project C has the best performance over all alternatives and the highest uncertainty stability.

The findings validate the effectiveness of the BCR method to assess investment, prioritize projects and make risk-informed decisions in the oil, gas, and petrochemical industry.

12.7 Integration of Findings

12.7.1 Introduction

For this section, we will integrate the data obtained from the survey, interview analysis, Benefit-to-Cost Ratio (BCR) analysis, and sensitivity analysis. The quantitative and qualitative evidence in the study is integrated to illustrate how the BCR methodology can help in making business risk reduction decisions in the oil, gas, and petrochemical industry by providing a multi-vital basis in decision-making and hence will therefore be beneficial for the businesses. The integrated analysis will allow us to analyze the findings in relation to the research objectives, research questions, study hypotheses, and theoretical framework. The findings are more likely to be valid by identifying a consistent approach to evidence from many sources of evidence.

12.7.2 Integration of Survey and Interview Findings

The survey results were positive for all 6 study hypotheses. Participants generally agreed that the BCR methodology contributes to:

- Business risk reduction.
- Improved investment decision-making.
- Enhanced project prioritization.
- Better allocation of financial resources.
- Improved risk management effectiveness.
- Identification of projects with greater economic benefits.

The most common theme was that BCR was the key factor contributing to better investment decision-making and resource allocation, followed by project priority and allocation. It is clear from the consistent survey and interview results that participants consider BCR as more than just an economic assessment tool but also as a key part of organizational decision-making and risk management processes.

Table 23 Comparison of Quantitative and Qualitative Findings

Study Area	Survey Findings	Interview Finding
Business risk reduction	Strong positive support	Participants reported improved project selection and operational reliability
Investment decision making	Highest Mean score (4.40)	Most frequently identified theme
Project prioritization	Positive support	Frequently cited as a key benefit
Resource allocation	Positive support	Participants reported improved budgeting decision
Risk management effectiveness	Positive support	Respondents indicated stronger risk informed decision
Economic benefit identification	Strong positive support	Participants highlighted improved project evaluation

The convergence of results from both data sources increases confidence in the overall conclusions of the study.

12.7.3 Integration of BCR Analysis and Survey Findings

The BCR analysis demonstrated how economic evaluation can be used to compare other investment opportunities and determine project feasibility. The project scenarios showed that:

- All projects had a BCR greater than 1.0.
- Higher BCR was associated with higher economic performance.
- Projects could be ranked according to their expected benefits and costs.

These findings are in line with the survey results on:

- ✓ Investment decision-making.
- ✓ Project prioritization.
- ✓ Resource allocation.

Participants consistently reported that BCR helps with the quality of investment decisions because it provides objective financial criteria to compare alternatives. The project analysis supports that BCR can be used to support such evaluations in practice.

12.7.4 Integration of Sensitivity Analysis and Risk Management Findings

In sensitivity analysis, all projects examined were economically feasible even though project benefits were lower or costs increased. This supports the belief of the participants about the role of BCR in reducing business risk.

From a risk management perspective, sensitivity analysis provides the most confidence to investors about how project performance can change when things are unknown, in terms of project outcomes in uncertainty. They found that BCR helps mitigate risk through two ways:

- I. Encouraging the selection of economically attractive projects.
- II. Exploring uncertainty through scenario analysis.

Note that these findings are consistent with the concepts of Risk Management Theory, which is based on the importance of structured approaches for assessing alternatives and mitigating uncertainty.

12.7.5 Integration with the Theoretical Framework

The results of this study are consistent with the three theoretical bases laid out in Section 8.

Risk Management Theory

According to Risk Management Theory, organizations can reduce uncertainty through the identification, assessment, and mitigation of risks. The findings demonstrate that the BCR methodology supports these objectives by assisting decision-makers in evaluating alternative investment options and selecting projects that reduce organizational risk. These results are in line with Risk Management Theory, which advocates systematic approaches for evaluating and mitigating uncertainty (Aven, 2015; Hopkin, 2018).

Engineering Economic Theory

Engineering Economic Theory emphasizes the importance of comparing project benefits and costs when evaluating investment opportunities. The BCR analysis found that projects with high benefit-to-cost relationships have more economic justification and greater organizational value. These findings also align with the principles of Engineering Economic Theory, which focuses on investment alternatives in terms of the expected economic return versus the cost (Newnan et al., 2019).

Decision Analysis Theory

According to Decision Analysis Theory, structured analytical approaches enhance the quality of decision-making under conditions of uncertainty. Study and interview results were consistent with this perspective. Participants consistently reported that BCR enhances decision-making transparency, objectivity, and confidence. The results also support Decision Analysis Theory, which states that structured analytical approaches enhance the quality of decision-making and reduce the influence of subjective judgment (Clemen & Reilly, 2014; Kahneman, 2011).

12.7.6 Evaluation of Research Hypotheses

The integrated findings provide support for all six study hypotheses.

Table 24 Final Evaluation of Study Hypotheses

Hypothesis	Result
H1- BCR contributes to business risk reduction	Supported
H2- BCR improves investment decision making	Supported
H3- BCR enhances project prioritization	Supported
H4- BCR improves financial resource allocation	Supported
H5- BCR improves risk management effectiveness	Supported
H6- BCR assists in identifying projects with greater economic benefits	Supported

Of the six hypotheses, H2 received the most support from the quantitative and qualitative results. This indicates that the greatest benefit of BCR methodology is its ability to improve investment decision-making.

12.7.7 Addressing the Research Questions

The main research question asked:

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 operation of PetrRabigh in Saudi Arabia?

The integrated findings reveal that BCR is a risk reduction strategy that allows for business risk reduction in the following ways:

- Improving investment decision-making.
- Enhancing project prioritization.
- Supporting efficient allocation of financial resources.
- Strengthening risk management processes.
- Identifying projects that generate higher economic value.
- Improving organizational confidence in project selection decisions.
- The findings therefore indicate that BCR serves as an effective decision-support tool that can improve both economic and risk management outcomes.

12.7.8 Summary

The integrated survey findings, interview results, BCR analysis, and sensitivity analysis all point to the value of the Benefit-to-Cost Ratio methodology as the main findings. BCR is beneficial for investment evaluation, prioritization of projects, resource allocation, and risk management. The best result was in investment decision making, which was the most prominent theme in all the analytical components. The combined results of the study provide supporting evidence that the Benefit-to-Cost Ratio methodology is a powerful analytical tool for improving decision-making and managing business risk in the oil, gas, and petrochemical industry.

13. Discussion, Conclusions, Recommendations and Limitations of the Study

13.1 Discussion

13.1.1 Discussion of H1: Business Risk Reduction

The study has provided evidence that Benefit-to-Cost Ratio (BCR) methodology is central to risk management decision-making in the oil, gas and petrochemical industry. Survey participants strongly agreed that the application of the BCR methodology contributes to business risk reduction, improves investment decision-making, enhances project prioritization, and strengthens risk management effectiveness. The findings provided empirical support for all six research hypotheses, demonstrating that the BCR methodology is an effective analytical tool for investment evaluation and organizational risk management. These findings are consistent with risk management theory, which emphasizes the use of structured methodologies for risk assessment and organizational decision-making. As Aven (2015) states, risk management should be done through structured analytic methods that enable decision-making in an uncertain environment.

Hopkin (2018) contends that risk management is easier to implement if decisions are made based on objective evaluation and resources are allocated so as to reduce risk exposure at the organization level. The positive perceptions expressed by participants suggest that the BCR methodology provides an objective framework for evaluating risk mitigation investments. The findings also support the theoretical framework developed in section 8 which suggests that economic evaluation can enhance risk through improved resource allocation and investment decision-making. Participants also reported that BCR is used to identify projects with tangible value and thus helps to make the operation more reliable, safe and reduce the organizational risk. Interview results also confirmed the survey results. Participants consistently indicated that the BCR methodology provides an objective and transparent basis for comparing investment alternatives and selecting projects that maximize value while minimizing cost. This is especially important to the oil, gas and petrochemical industry where companies often face multiple competing investment opportunities while operating under limited financial resources. The ability to evaluate projects in a systematic way improves decision making and reduces the likelihood of investing resources in projects that are not of high value to the organization. The BCR analysis presented in Section 12 further supports these findings. The BCR models demonstrated that all project scenarios showed a BCR greater than 1.0, indicating economic feasibility, and the sensitivity analysis revealed that the projects did not become unviable under the uncertainty scenarios evaluated in the sensitivity analysis. This indicates that the BCR method can be beneficial in building organizational resilience by identifying investments that still have value in the face of uncertainty and change in business environment. Thus, the study supports the idea that the inclusion of BCR into risk management processes can improve the quality of managerial decision-making and supports business risk mitigation in very large companies like PetroRabigh.

13.1.2 Discussion of H2: Investment Decision-Making

The findings indicate that the Benefit-to-Cost Ratio (BCR) methodology significantly improves investment decision-making within the oil, gas, and petrochemical industry. Among all the variables in the study, investment decision-making received the highest mean score (4.40), indicating that the BCR methodology contributes to higher-quality, more transparent, and more reliable investment decisions. The findings of this study are in line with Hypothesis H2 that the BCR methodology greatly enhances investment decision-making in oil, gas, and petrochemical companies. The results of this study are consistent with Decision Analysis Theory in which decision-makers do their best when they have structured analyses that back them up and not intuition and subjective judgment as they are making decisions. As Clemen & Reilly (2014) have noted, decision analysis improves the quality of managerial decision-making by providing the method to compare alternatives under the uncertainty of decision-making. Structured evaluation approaches have been shown to reduce cognitive biases and improve decision-making order and consistency (Kahneman 2011). The study results suggest that BCR can do this because it provides a quantitative framework to assess the benefits of a project and the costs of the project before investing it in the investment decision. The survey results were very similar to the statements that BCR improves investment decision quality (confidence in decision-making process and confidence in project selection) and transparency of the decision-making process. This suggests that for managers BCR is a good tool to do the job to assess the investment alternatives in a more objective way.

But decision-makers should not just rely on experience or subjective assessment but rather BCR calculations to justify project selection based on quantifiable economic consequences. This is especially important in capital-intensive industries such as oil, gas, and petrochemicals because investing in these sectors usually means investing in large sums of money and long-term operational costs. The interview results confirmed this conclusion. Participants consistently indicated that BCR is a logical basis for selection and the confidence level in the decision-making process of the businesses and managers as well as justify investment decisions to others. The methodology also helps to communicate between technical, operational, and financial departments as project results can be translated into quantifiable economic values. This shows an organizational benefit of the BCR method: it allows for a common evaluation process that allows decision-making across the organization. The findings are also in line with the research in engineering economics. As Newnan, Eschenbach, and Lavelle (2019) explain, economic evaluation methods such as BCR are designed to promote rational investment choices by comparing the current value of expected benefits with the project costs. In a similar vein, Boardman et al. (2018) also suggest that benefit-cost analysis helps in the allocation of resources by identifying projects that yield the highest value. The theories of BCR was extended to the present study and show that BCR supports economic evaluation as well as better decision-making in risk-sensitive industries. In PetroRabigh, the way managers can evaluate investment alternatives and prioritize projects to allocate resources is guided by BCR methodology. The strong support of Hypothesis H2 indicates that in their opinion BCR is only one of the decision tools that can help to make investment decisions transparent and in alignment with their objective and confidence for the people. Based on the findings of this study, organizations are encouraged to adopt the Benefit-to-Cost Ratio (BCR) methodology as an integral component of their decision-making processes to improve investment evaluation and facilitate more effective managerial decision-making in industrial contexts.

13.1.3 Discussion of H3: Project Prioritization

The results of this research support Hypothesis H3, namely, that the use of Benefit-to-Cost Ratio (BCR) methodology improves the ability to prioritize risk mitigation projects in industrial facilities. The overall mean score is 4.18 and that participants generally agree that BCR supports organizations in prioritizing projects, objectively ranking alternatives and selecting the projects to provide the best benefit compared to their cost. These results suggest that the BCR approach is useful for project evaluation on a large scale, and that decision-makers find a good use of resources in the organization for the best value and the least money invested in the projects. These findings are consistent with Engineering Economic Theory (ECT) that organizations should make their investment decisions based on objective financial criteria to maximize the economic value. As Newnan, Eschenbach and Lavelle (2019) state, Benefit-to-Cost Ratio allows decision-makers to compare the projects (i.e. the expected benefits of projects versus the cost of projects) so that they can rank the best investment and choose the best investment if their cost is low. In this context of limited resources, BCR provides a rational basis for deciding which projects should be prioritized and in what order, with the results also aligning with project management literature which identifies project prioritization as vitally important in strategic resource management. Kerzner (2022) states that organizations can have many competing projects at hand and need certain criteria to decide which one to work on first and how to prioritize those projects.

In the absence of a system of objective evaluation, project selection may be determined by subjective judgment, departmental preferences or short-term factors. The findings of this study suggest that BCR helps to reduce these subjective criteria where it is possible to compare project alternatives to achieve this objective and can be made transparent. Interviews were also evidence for this conclusion. BCR enables management to select projects to do first, especially when budgets are short and multiple projects compete for the same resources. Maintenance engineers and planning personnel said projects with higher economic justification get priority since they are expected to generate more value for the organization. Some respondents also said that the methodology supports objective project ranking as it allows decision-makers to compare the expected returns of different alternatives as a whole using a common evaluation model. This is especially important in the oil, gas and petrochemical industry where the organization regularly evaluates maintenance, process optimization, safety improvement and technology improvements. In such projects large investment is required and therefore the organization should allocate limited resources towards the most value and benefit-adding projects. The BCR approach promotes the idea of selecting projects with good value creation and risk management. These results are further supported by the BCR analysis in section twelve. Project C with a BCR value of 2.50 was selected first, followed by Project B with a BCR value of 2.25, and Project A with a BCR value of 2.00 was presented. The example shows that BCR is a real-world tool to prioritize projects and how it can also help to do so based on evidence-based investment decisions. The results overall support the idea that BCR methodology contributes to project prioritization because it provides a systematic method of assessing competing alternatives and the results of such an evaluation are objective. BCR helps organizations find the best projects based on their value and benefit to their organization while providing better resource allocation and decision making and also the most efficient way to achieve organizational objectives in complex industrial settings such as PetroRabigh.

13.1.4 Discussion of H4: Resource Allocation

The results of this study support Hypothesis H4 that Benefit-to-Cost Ratio (BCR) can be used for more efficient utilization of financial resources for projects in operations and risk reduction. The score of the whole survey was 4.12 and the participants agreed that BCR helps to make better use of financial resources and to avoid wasteful investment. Therefore, the BCR methodology can be successful for directing resources of organizations to those projects which have the greatest value for the organization relative to their cost. The findings are consistent with Engineering Economic Theory, which argues that it is very important to allocate resources to projects with the greatest organizational benefit. In Newnan, Eschenbach and Lavelle (2019) economic evaluation techniques such as Benefit-to-Cost Ratio help decision makers determine the best investment alternatives, and which projects have the best economic returns. Similarly, Boardman et al. (2018) argue that benefit-cost analysis facilitates resource allocation so that investments are made to projects with more benefits than they cost. The positive perception from participants indicates that the BCR methodology is a way to consider competing investment opportunities and this is also supported by the findings of the survey. People believe that BCR helps in the efficient allocation of resources and budget utilization and thus managers see BCR as the most useful tool for making investments in projects that will result in tangible results.

In sectors with large capital investments and competing investment demands, such as oil, gas and petrochemical companies, efficient resource allocation is essential to have operational efficiency and achieve strategic objectives. Participants said that BCR helps management to optimize budget allocation and investment planning. Management staff also said maintenance and operational budgets are constrained and companies must make tough decisions to allocate resources to projects that need funding. BCR also gives a transparent, objective basis to evaluate alternatives and allocate resources to projects that are more economically sound. The methodology has been found to improve budgeting efficiency as well as make it easier for companies to make decisions based on evidence-based investment decisions, and it is also in line with supply chain and operations management literature which also identifies effective resource allocation as a key determinant of success in the organization. As Chopra & Meindl (2019) point out, a good allocation of resources helps organizations to have a better performance in their activities, reduce waste and maximize the value of investments. And in PetroRabigh, when the time and money required to maintain operations, improve safety and technology are so large, this kind of resource management is particularly important. The results demonstrate that BCR helps managers to assess alternatives in a systematic way and choose projects that contribute the most to the organization. This is confirmed by the practical application of the BCR methodology as demonstrated in section twelve. The comparison of BCR showed that projects can be ranked from a project's expected benefit to a cost perspective, so decision-makers can allocate resources to the projects that can produce better returns in terms of economic returns. The ability to distinguish between different economic outcomes of projects provides management with a basis for budget allocation and investment planning. The findings from this study support the idea that the BCR methodology has a positive impact on financial resource allocation for project evaluation and budget optimization and is also in support of the effective use of resources and thus helps in avoiding investments that are not good for the company to spend. By providing a systematic comparison of alternatives, BCR will allow managers to make better use of limited resources to achieve the economic and risk management objectives in a complex industrial environment such as PetroRabigh.

13.1.5 Discussion of H5: Risk Management Effectiveness

The results from this study provide evidence of Hypothesis H5 which states that the use of Benefit-to-Cost Ratio (BCR) methodology within organizational decision-making processes significantly improves risk management efficiency for petrochemical plants. This survey results indicated a mean of 4.15 in the general group and BCR enhances risk management effectively; it is more effective for risk management and investment decision-making and is a more efficient management system. These findings indicate that BCR can improve the risk management and organizational decision-making processes by incorporating economic assessment in the process. This research is consistent with Risk Management Theory, and it stresses the need for systematic methods to identify, assess, and mitigate risks. In Aven (2015), one must think in terms of alternative options and decide what to do as a risk manager to meet the organization's goals. Hopkin (2018) argues that risk management is not only about risk but also about integrating risk into strategic and operational decision-making. Positive views from participants indicate that BCR provides the framework for the financial, operational, and risk management perspective by providing a framework for assessment of them as one at the same time.

The survey results showed that participants agreed that BCR enhances organizational risk management and facilitates the alignment between investment decisions and risk management objectives. This suggests that the decision-makers do not take BCR as a financial tool for decision-making but rather as a tool to assess project alternatives, and when they consider the opportunities to make investment and the costs, it is easier for managers to determine which one is the best for business and therefore how much they are going to pay for that investment. BCR often encourages a more systematic and disciplined analysis of investment opportunities, they have found, and in fact, they said. They also noted that the methodology facilitates collaboration between technical, operational, financial, and risk management, and thus a common framework is established for project assessment as technical, operational, and risk management work. The Risk Manager stated that BCR also helps to assess whether proposed risk mitigation measures can be beneficial to the organization and that the cost of implementing them is a business value-based approach. The research provided a theoretical framework for this research that said that engineering economics and risk management can be integrated to improve decision-making. As Pinto, Magpili, & Jaradat (2014) noted, effective risk management involves organizations applying analytical tools that support an analytical analysis of alternatives and reduce uncertainty. The BCR methodology is helpful in that it provides quantitative evidence that can be incorporated into risk assessment and project selection. In this way, economic evaluation is used to support risk management and not to be considered as a separate financial activity. This is further confirmed by the BCR analysis and sensitivity analysis in section twelve. In this study, projects with good BCR results not only provided better economic returns but also brought about operational improvements, safety enhancement, and organizational resilience. It is also demonstrated that the sensitivity analysis showed that in the event of a negative economic environment, the projects that are evaluated are still economically viable. With the development of BCR in these areas, it can assist companies in decision-making with risk management to make a better decision-making process that will lead to better risk management. Thus, the integration of BCR methodology into decision-making processes in organizations will enhance risk management. The findings show that by strengthening the link between economic evaluation and risk assessment and decreasing the level of uncertainty in the project selection process, BCR can improve the ability of organizations to manage risks. In PetroRabigh, the use of BCR in risk management practices will enhance the performance of the organization and its long-term sustainability.

13.1.6 Discussion of H6: Economic Benefit Identification

The findings provide compelling evidence in support of Hypothesis H6, confirming that the systematic integration of the Benefit-to-Cost Ratio (BCR) methodology into organizational decision-making enables managers to identify and prioritize investment opportunities that maximize economic value while reducing business risk. The survey results resulted in an overall mean score of 4.31 for H6 and it was the second most viewed construct after investment decision-making. They also strongly agree that BCR is useful in identifying projects that have greater economic impact, enhance project value, helps in managing returns and maintaining long term business sustainability. The findings are consistent with Engineering Economic Theory, which emphasizes the need to evaluate the investment alternatives based on the expected benefits and associated costs.

As Newnan, Eschenbach and Lavelle (2019) point out, the main objective of economic evaluation of projects such as BCR is to identify projects that produce the highest economic return in relation to funds spent. Similarly, Boardman et al. (2018) argue that benefit-cost analysis helps to make rational decisions and helps organizations to choose projects that will create the most net value. The high level of agreement in the studies indicates that the BCR methodology efficiently plays this role in PetroRabigh. Survey results show that the most experienced BCR respondents have a large opinion of the project benefit and management is more confident in the project's return on investment. This means that project decision makers have a better sense of what the price of alternatives are going to be. From the perspective of project costs and technical feasibility and its value to a company, managers can evaluate if there are well-being and a business case for investing. This is most relevant in capital-intensive industries where financial commitment and long-term impact on a company are high. They also stated that BCR is a good way to support investment justification, long-term planning and value creation for projects. Moreover, many participants stated that in a BCR process management can distinguish the projects with very little value from those with high economic value. BCR also gives confidence to investment decision makers by providing evidence of what you think a project is likely to do. These results indicate that the BCR methodology can benefit them to make informed and economically rational decisions. The use of the BCR method as presented in section twelve provides additional support for these findings. BCR analysis of projects with high BCR value revealed that the cost is less than the return. Project C had the highest BCR value at 2.50 and produced the highest return per unit investment of the alternatives. BCR can also help managers find the right projects for their business and for their operational improvement and risk reduction. These results also corroborate the integrated theory of risk management. The findings indicate that integrating engineering economics with risk management supports a more balanced investment decision-making process by enabling organizations to optimize financial performance while reducing business risk exposure. Projects selected by BCR often result in better operational reliability, efficiency and long-term performance, they said. This means that the method helps to align economic objectives and risk management goals and supports sustainable growth of the organization. Moreover, sensitivity analysis strengthens confidence in these conclusions. Even in the worst-case scenario, which is one of decreasing benefits and increasing costs, all projects were economically feasible and BCRs above 1.0. The results show that projects identified through BCR analysis can still provide economic value with uncertainty and change in business climate. BCR methodology not only enables the identification of economically sound projects but also the identification of business/organizational investment that is resilient to risk and uncertainty. Overall, the results show that the BCR methodology is an effective mechanism for managers to identify projects that yield greater economic results and reduce risk and organizational sustainability. BCR is structured and objective in evaluating what the project results look like and thus enables value creation and investment justification for the long-term strategic decision-making in complex industrial environments such as PetroRabigh. In conclusion, the results of this study suggest that the combination of risk management theory, engineering economic theory and decision analysis theory is useful for understanding more effectively how Benefit-to-Cost Ratio (BCR) approach can enhance investment decision, development of projects, resource allocation, risk management efficiency and business risk reduction in PetroRabigh.

The positive support across all the six hypotheses suggests that the BCR approach is a great decision-support tool to manage investment options, allocate resources efficiently and support risk management in the oil, gas and petrochemical industry. As such, the results demonstrate that if the BCR methodology is systematically deployed, it can lead to better business and risk management results of PetroRabigh.

13.2 Conclusions

13.2.1 Conclusion on the Main Research Question

The main research question of this study was: “How does the application of the Benefit-to-Cost Ratio (BCR) methodology contribute to reducing business risks in the oil, gas and petrochemical industry, particularly in the operations of PetroRabigh in Saudi Arabia?” Based on the survey analysis, interview analysis, BCR evaluation and sensitivity analysis, it found that the Benefit-to-Cost Ratio methodology has a positive impact on business risks and is useful for effective investment decisions, project prioritization, resource allocation and risk management. As a result, BCR provides the framework for assessment of investment alternatives by comparing potential benefits and costs. In doing so, decision-makers are able to identify projects that contribute to the organization's bottom line while also being a good risk-reduction tool. The survey results were positive for all six research hypotheses, indicating that the BCR methodology is an effective tool to support PetroRabigh decisions. Interview findings also demonstrated that BCR enhances transparency, strengthens confidence in project selection, informs which areas of risk mitigation work and how to allocate resources in the organization. Furthermore, the BCR analysis and sensitivity analysis showed that economically attractive projects can remain viable in a variety of business scenarios, and thus BCR helps to ensure risk-informed decision making even in the face of uncertainty. Thus, with the study, the systematic application of the BCR method can contribute to business risk reduction by enhancing the quality of management decision making, investment appraisal and resource allocation to projects that are economically and operationally relevant. In PetroRabigh, the results show that BCR is beneficial to the organization to enhance operational performance and risk management in a challenging industry.

13.2.2 Achievement of Research Objectives

The study achieved all the research objectives. The survey analysis, the interview analysis, Benefit-to-Cost Ratio (BCR) evaluation and sensitivity analysis provide evidence of the BCR methodology for risk management and decision making in the oil, gas and petrochemical industry.

- ✓ The first goal was to explore the role of economic evaluation methods in risk management decision-making in the oil, gas and petrochemical industry. This was achieved in both quantitative and qualitative study which confirmed that the BCR methodology is useful for risk-informed decision making, transparency and organizational risk management is better. The positive support of Hypotheses H1 and H5 confirms the value of economic evaluation methods for risk management.
- ✓ The study analyzed the application of the Benefit-to-Cost Ratio (BCR) methodology for evaluating investment alternatives related to risk mitigation and operational improvement. This was demonstrated through the BCR analysis presented in Section 12, which illustrated how projects can be evaluated and compared based on their expected benefits and costs.

The findings indicate that the BCR methodology provides a structured framework for assessing investment alternatives and identifying projects with stronger economic justification.

- ✓ The study examined the relationship between the application of the Benefit-to-Cost Ratio (BCR) methodology and the reduction of business risk in large petrochemical facilities. This objective was addressed through the analysis of survey and interview findings, which indicated that participants perceived the BCR methodology as an effective tool for reducing business risk by supporting project evaluation, enhancing operational reliability, and improving managerial decision-making. These capabilities enable organizations to identify and prioritize projects that minimize business risk exposure while maximizing economic value. The strong empirical support for Hypothesis H1 further reinforces this conclusion.
- ✓ The fourth goal was to determine how BCR can be used by managers to prioritize projects that provide the most benefits to them in terms of cost and to reduce the risk factor. This was achieved by the survey results and the project evaluation. And everyone who participated said that BCR is useful in project prioritization and that it helped them rank competing projects objectively. The comparison of projects with respect to BCR showed that projects can be prioritized based on their economic attractiveness and expected value in relation to the BCR analysis.
- ✓ The fifth goal was to investigate how BCR methodology is implemented in PetroRabigh's work environment. Through case studies adopted in the research, it can develop the case study approach which was developed. Survey responses, interview results and project examples were derived from an implementation of BCR in the real world on board with a big petrochemical company as an example of how the methodology is perceived and applied in a large petrochemical company. It showed that BCR is a good method for investment evaluation, budgeting, project selection and risk management for investment, budgeting and decision making and is useful for investment evaluation and budgeting.
- ✓ The sixth goal was to provide insights on the integration of economic evaluation and risk management in oil and gas business practices. While the recommendations are expanded later in this section, the study findings are presented as the basis for more extensive application of BCR in investment evaluation, project selection, resource allocation and risk management processes.

Positive responses to all study hypotheses suggest that all the study hypotheses are strongly supported and therefore there are clear benefits for organizations to implement formal economic evaluation methods of risk management as part of their risk management. Overall, the results of the study suggest that all research objectives were achieved. The results are also comprehensive testimony to how the BCR approach is effective at increasing decision making, resource allocation efficiency, risk management and lowering the business risk of PetroRabigh and the oil, gas, petrochemical industry as a whole.

13.2.3 Overall Study Conclusion

In this study, the application of Benefit-to-Cost Ratio (BCR) methodology to reduce the risk of business risk in the oil, gas, and petrochemical industry of PetroRabigh in Saudi Arabia as a case study and its effect on business risk reduction by PetroRabigh was investigated. The study was motivated to study how economic evaluation techniques can be used to inform risk management practices and improve organizational decision making in a high-risk and capital-intensive and risk-sensitive industrial enterprise. The findings were positive and found that the BCR approach helps to have positive effects on the organization that include, among others, investment decision making and project prioritization, resource allocation, better risk management efficiency, identification of economically effective projects and lower business risk are the most supported in the study with the BCR methodology and the economic process of investment decision-making. The survey results showed a positive response for all six research hypotheses to all of the six hypotheses and the BCR and hence it can be concluded that the implementation of BCR was associated with better investment decision-making, better project prioritization, faster allocation of resources, better risk management and better business risk reduction in which the study showed that in the industrial organizations BCR is an effective decision-making tool. Interview results supported the quantitative results with real-world experiences of how the BCR methodology is used in organizations. Participants were able to describe how BCR improved transparency in a transparent way, made it easier to assess the impact of a project, made it easier to justify investment in it and better to allocate resources. The study also showed that the methodology indirectly contributed to business risk reduction by encouraging investment that improves operational reliability, safety, and overall organizational effectiveness. However, participants also pointed out some challenges in implementation: estimating future benefits, quantifying intangible results, and ensuring that reliable data is available. Those observations reflect the need to have the information right and realistic assumptions when applying the BCR methodology. The BCR analysis and sensitivity analysis also gave the practical value of the approach. The BCR analysis showed that higher BCR and higher BCR projects have higher economic justification and can be better prioritized. A sensitivity analysis also showed that all projects evaluated were still economically feasible even under adverse conditions. In this regard, it shows that BCR can inform decision-making in uncertain business environments and help companies in finding resilient investment opportunities. In conclusion, the Benefit-to-Cost Ratio methodology is an effective tool for decision making which extends beyond financial evaluation. The research shows that BCR can help organizations make decisions that are risk-informed, which helps organizations objectively analyze investment alternatives and prioritize projects, allocate resources and take advantage of risk management. With PetroRabigh, the methodology provides management with a realistic way to balance economic performance and risk reduction objectives. Therefore, the integration of BCR into organizational decision-making systems can improve operational performance, resource utilization, and business risk management in the oil, gas, and petrochemical industry.

13.3 Recommendations

13.3.1 Recommendations for PetroRabigh

Based on the results from this study, several recommendations proposed to implement Benefit-to-Cost Ratio (BCR) methodology in PetroRabigh and strengthen its role in company decision making and risk management.

- First, PetroRabigh should formalize the use of the BCR method in project evaluation/approval processes. BCR was proven to help in investment decisions, project prioritization and resource allocation as well as project choices, and project allocations were found to be effective to be beneficial. Therefore, it is recommended to include BCR evaluation in the justification and approval process as part of project justification and approval process and ensure that investment decisions are made according to the basis of an objective economic analysis and the same evaluation criteria in the context of the project.
- Second, PetroRabigh should improve the integration of economic assessment and risk management. The findings also showed that BCR promotes risk-informed decision-making by allowing management to assess projects with economic benefits and risk reduction. The quality of project evaluations can be improved by better linking project management, finance, engineering and risk management, ensuring that risk is incorporated into the investment decision-making process.
- Third, the organization should establish a standard approach and procedures for BCR analysis. Standards on the evaluation criteria would be consistent across projects and reduce variation in estimates of expected benefits and costs.
- Fourth, PetroRabigh should improve the quality and availability of data from the project for project performance. Interviewers identified data availability and benefit estimation as key challenges for BCR to be accurate. The creation of databases on project costs, realized benefits, operational performance indicators and risk reduction would improve the reliability of future economic evaluations.
- Finally, training programs should be conducted for project managers, engineers, planners and risk management personnel to understand economic evaluation techniques in order to improve their knowledge of BCR practices and implementation.

PetroRabigh should also take sensitivity analysis as a part of its major investment analysis. The research showed that sensitivity analysis provides valuable insight into uncertainty impacts on project results and helps management assess the resilience of investment decisions under changing business conditions. Sensitivity analysis would facilitate decision making and help companies be better prepared for future uncertainty.

13.3.2 Recommendations for Risk Management Practice

The study results show that economic evaluation is instrumental in enhancing organizational risk management. Based on the survey findings, interview results and BCR analysis, it is suggested that risk management should be integrated with economic evaluation techniques which can lead to better risk management.

- First, organizations should take an integrated approach to risk management in which economic evaluation is incorporated in risk assessment and decision making. In risk management activities, risk management should not only be about identifying and mitigating risks but also the economic impact of risk mitigation. BCR can help decision-makers to choose the risk management strategy that has the greatest benefits as compared to its implementation cost.
- Second, risk management professionals should incorporate economic evidence into the assessment of risk mitigation projects. According to the study, BCR helps managers to identify projects that reduce risk, which also generate organizational value. Implementing economic evaluation methods in project assessment will enable the organization to allocate resources where there is the best possible contribution.
- Third, establishing cross-functional evaluation teams is needed to improve investment assessment quality, decision making, and ensure that both economic and risk-related factors are taken into account.
- Fourth, organizations need to develop qualitative and quantitative assessment frameworks. Although BCR is useful for understanding economic data, decision makers must also consider operational, safety, environmental, and strategic factors in the discussion of investment options. More extensive risk assessment methods - including economic analysis - can be used in the context of risk assessment.
- Fifth, organizations must incorporate sensitivity analysis and scenario analysis in their decision-making strategy to mitigate risks. The findings from this study showed that sensitivity analysis helps to understand the project performance under changing conditions and enables more informed decision-making when it comes to uncertainty. With risk management procedures incorporating these methods, organizational preparedness and resilience to future risks is enhanced.

Finally, organizations should foster a culture of evidence-based decision-making by integrating the Benefit-to-Cost Ratio (BCR) methodology and other structured analytical tools into their decision-making processes.

The findings of this study demonstrate that such approaches enhance transparency, objectivity, and consistency in project evaluation, thereby supporting more effective investment decisions and business risk management. Furthermore, advancing data-driven risk management practices promotes greater accountability, more efficient resource utilization, and improved organizational governance. The findings also indicate that integrating economic evaluation techniques with risk management practices enables organizations to make more informed decisions, optimize resource allocation, and strengthen overall risk management effectiveness. Consequently, organizations that adopt these integrated approaches are better positioned to achieve their risk management objectives while enhancing long-term organizational performance and sustainability.

13.3.3 Recommendations for the Oil, Gas and Petrochemical Industry

The results of this study can be of use to PetroRabigh and should be used in companies in the oil, gas and petrochemical industry as well. Based on the survey analysis, interview results, BCR evaluation and sensitivity analysis, there are suggestions that are put forward that are beneficial to investment decision making and risk management practices across the oil, gas and petrochemical industry.

- First, oil, gas and petrochemical organizations must incorporate economic assessment like benefit-to-cost ratio (BCR) into process selection and investment decisions. The findings in this study have shown that BCR plays a role in investment decision making, project prioritization and resource allocation by providing a framework for comparing the expected benefits and associated costs. Uniformity in economic evaluation procedures for projects would enable better transparency and consistency across the industry.
 - Second, industry companies need to enhance the link between economic assessment and risk management. Investment decisions should take into account more than technical and operational requirements but the economic value of risk mitigation. Integrating BCR analysis into risk management frameworks can help organizations to design projects that improve operations and supports business risk mitigation.
 - Third, organizations need to develop quantitative strategies for risk mitigation projects. Most risk management projects require significant capital investment and decision-makers should be sure to justify these investments with sound economic reasons. The systematic application of BCR can help organizations find the projects that are the most valuable and make good use of limited financial resources.
 - Fourth, Industry firms should do better at data collection, performance measurement and project evaluation. An accurate estimate of project cost expected value and operating results are essential to reliable economic evaluation. Developing databases and performance monitoring systems would improve investment analysis and provide more accurate assessment of projects during the entire project lifecycle.
 - Fifth, Managers, Engineers, planners and risk management professionals might be able to be more effective in applying BCR and to promote more evidence-based decision-making in the industry.
 - Sixth, organizations should include sensitivity analysis and scenario analysis in their investment assessment. Sensitivity analysis can give insights into project resilience in changing business environments and decision making in a situation of uncertainty, the findings of this study show.
- With the routine use of these techniques organizations can better understand the risks and be more prepared for future operational and economic challenges.

Finally, the industry can develop integrated decision-making frameworks that integrate economic analysis, risk assessment, operational performance and strategic goals. In this study, economic analysis has been found to have the greatest benefit as part of a decision-support process rather than as a separate financial instrument. This integrated approach can lead to better organizational performance, risk management and sustainable investment decisions in the oil, gas and petrochemical industry. The results suggest that as more companies adopt BCR methodology in the oil, gas and petrochemical industry, project evaluation will be improved, resources will be used more effectively, risk management will be strengthened, and long-term organizational sustainability will be enhanced.

13.4 Limitations of the Study

The limitations of the current research are very similar to any other research and relevant to understanding the findings.

- First, the study was conducted within a single organization in the oil, gas, and petrochemical industry, namely PetroRabigh in Saudi Arabia. Although PetroRabigh represents a significant integrated industrial organization, the findings reflect the experiences, practices, and perceptions of participants within a single organizational context. Consequently, the results cannot be generalized to all organizations operating in the oil, gas, and petrochemical industry, as these organizations may differ in their organizational structures, operational environments, investment strategies, and risk management practices.
- Second, the study was conducted by a small sample of PetroRabigh's staff from different departments at different time periods and positions. Although the sample presented the expertise on engineering, maintenance, planning, finance, project management and risk management, the opinions of those employees may not be representative of the knowledge base for all those at the level of project evaluation and decision making in PetroRabigh. A larger sample of organizations would provide a better understanding of the use of Benefit-to-Cost Ratio (BCR) method in the oil and gas industry.
- Third, the research adopted a case study approach focusing on the practical application of the BCR methodology within PetroRabigh. While this approach provided valuable insights into real-world organizational practices, it may limit the generalizability of the findings to other industrial sectors or geographical regions. Organizations operating in different regulatory environments and market conditions or organizational cultures may experience different results when using economic evaluation techniques.
- Fourth, the study primarily examined participants' perceptions of the effectiveness of the Benefit-to-Cost Ratio (BCR) methodology using survey and interview data. Although these perceptions provide valuable insight into the role of BCR in organizational decision-making, they may have been influenced by participants' professional experience, functional backgrounds, and organizational responsibilities. Therefore, as with other perception-based studies, the possibility of response bias could not be completely eliminated.
- Fifth, the study employed illustrative BCR calculations and sensitivity analyses across several project scenarios to demonstrate the practical application of the methodology. Although these analyses provided useful examples of how BCR can support project evaluation and risk-informed decision-making, they did not represent the full range of investment projects undertaken at PetroRabigh. Variations in project type, investment scale, implementation conditions, and operational context may produce different economic outcomes.

Finally, the research studied Benefit-to-Cost Ratio methodology as an economic evaluation method. Other investment appraisal techniques such as Net Present Value (NPV), Internal Rate of Return (IRR) and multi-criteria decision-making were not investigated in detail. Thus, the study does not provide a comparative analysis of other evaluation methods that can also assist risk management and investment decision making.

However, the analysis is very valuable for the investigation of the BCR methodology in terms of investment decision-making, project priority, resource allocation and risk management in the oil, gas and petrochemical industry. The mixture of quantitative and qualitative data with an illustrative economic analysis gives credibility to the findings and is a good basis for future research in this field.

13.5 Suggestions for Future Research

The results of this study provide an interesting foundation for future research on how economic evaluation methods can be leveraged in risk management and organizational decision making. Although the study focused on benefit to cost ratio (BCR) methodology in PetroRabigh, there are many opportunities for the future to expand and analyze the use of BCR methodology in many other industries such as: power generation, manufacturing, transportation, mining and infrastructure. Similar studies of different companies would be useful to understand how organizational aspects, management and operational conditions affect the accuracy of economic evaluation techniques in risk management and investment decision making. In addition, such studies would also help to see if the relationships found in present research are valid in different industries and organization-based situations.

- In the future, it could analyze the similarities of the BCR methodology and other investment appraisal methods such as Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period and multi-criteria decision-making methods. Such comparative studies would help organizations to assess the relative merits and weaknesses of different evaluation methods and to identify the best tool for specific decision-making situations.
- In the future, it shall investigate the potential of integrating investment evaluation methods with risk assessment methods. Evidence of how BCR can be integrated with quantitative risk analysis, probabilistic modelling, scenario planning and enterprise risk management frameworks may allow for a more comprehensive decision-support system to address complex organizational problems.
- Finally, longitudinal studies would be conducted to examine the long-term impact of BCR investment decisions on organizational performance.

In this way researchers would be able to determine if projects selected using BCR continue to deliver the economic, operational and risk management benefits over time. Better methods in assessing and quantifying the intangible benefits of risk mitigation projects should be developed in the future. Many of the organizational benefits (safety, environmental protection, knowledge improvement, reputation and employee well-being) are not well quantified in monetary terms. It would be of interest for the study to find more reliable methods for incorporating these benefits in economic evaluation models such that the project assessment would be more accurate and comprehensible. Furthermore, the application of digital technologies, artificial intelligence, data analytics, and predictive modelling should also be researched for better economic evaluation and risk management in future research. With organizations taking digital transformation projects on the path of transformation (and that companies are increasingly adopting them as a key to business and business transformation), research for the future that will be able to assess and make the best decision for investment evaluation and risk management and how technology is necessary for better investment evaluation and risk management processes in order to do so.

More generalizing the study of this study and future research will also enhance the validity of this work with expanded study scope, alternatives to evaluation methodologies and new ways of assessing and evaluating the impact of the economy and risk management of business decision making and in the case of the future.

13.6 Summary

This section presents the study's discussion, conclusions, recommendations, limitations, and directions for future research concerning the application of the Benefit-to-Cost Ratio (BCR) methodology to business risk reduction at PetroRabigh. The six research hypotheses were discussed in the discussion and the results showed that the BCR methodology contributes to reducing business risk, investment decisions, project prioritization, resource allocation, risk management and finding economically beneficial projects. The research findings were interpreted in relation to the relevant theoretical framework and existing literature, leading to the conclusion that the empirical evidence is consistent with the principles of risk management, engineering economics, and decision analysis. The results suggested that the BCR methodology is a useful decision-support tool for organizations to make investment decisions, allocate resources and support risk-informed decision making. The main research question was addressed, and the study objectives were accomplished. The findings further indicate that the systematic integration of the Benefit-to-Cost Ratio (BCR) methodology into organizational decision-making enhances the evaluation and prioritization of investment alternatives, thereby supporting business risk reduction and improving the quality of strategic investment decisions. Based on the findings of this study, the following recommendations are proposed for PetroRabigh, risk management professionals, and organizations operating in the oil, gas, and petrochemical industry to promote the integration of economic evaluation into project selection, resource allocation, and risk management processes, thereby enhancing the quality, effectiveness, and governance of organizational decision-making. This section also recognized the limitations of this study including that the study was limited to a single company, the sample size was small, and the BCR methodology was the primary tool for evaluation. This allowed us to identify the areas of future research. Furthermore, future research is encouraged to extend the current study through multi-organizational investigations, comparative evaluations of investment appraisal methodologies, longitudinal studies, and the application of advanced analytical techniques for risk assessment. Such research would contribute to the development of more robust, evidence-based approaches to business risk management and organizational decision-making. The study in total provides a better understanding of the way economic evaluations can help to inform business decision making and risk management in oil, gas and petrochemical industries. The study shows that Benefit-to-Cost Ratio methodology can help in improving investment evaluation and resource allocation as well as supports business risk mitigation in complex industrial environments.

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Appendix A

Questionnaire

Research Title

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

Participant Information Sheet

This questionnaire forms part of an academic research study examining the application of the Benefit-to-Cost Ratio (BCR) methodology in reducing business risk within the oil, gas, and petrochemical industry. Your participation is voluntary. All responses will remain confidential and anonymous and will be used solely for academic purposes.

Instructions

Please answer all questions honestly based on your professional experience. For each statement, select one response using the following five-point Likert scale.

1 = Strongly Disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree

Section A: Participant Profile

- Current Position: ☐ Project Manager ☐ Risk Manager ☐ Engineer ☐ Planner ☐ Other
- Years of Experience: ☐ 0-2 ☐ 3-5 ☐ 6-10 ☐ 10-15 ☐ More than 20
- Highest Qualification: ☐ Diploma ☐ Bachelor's ☐ Master's ☐ Doctorate ☐ Other ____
- Professional Certification: ☐ PMP ☐ CMRP ☐ Risk Management ☐ Other _____ ☐ None

Section B: Questionnaire Statements

No.	Statement	1	2	3	4	5
1	The BCR methodology contributes to reducing business risks within industrial projects	☐	☐	☐	☐	☐
2	The BCR methodology helps identify projects with lower business risk exposure	☐	☐	☐	☐	☐
3	The BCR methodology supports proactive business risk management through structured project evaluation	☐	☐	☐	☐	☐
4	The BCR methodology improves the quality of investment decision-making	☐	☐	☐	☐	☐
5	The BCR methodology increases confidence in project selection	☐	☐	☐	☐	☐
6	The BCR methodology improves transparency during investment decision-making	☐	☐	☐	☐	☐
7	The BCR methodology assists management in prioritizing risk mitigation projects	☐	☐	☐	☐	☐
8	The BCR methodology helps rank competing projects objectively	☐	☐	☐	☐	☐
9	The BCR methodology supports selecting projects that provide the greatest organizational value	☐	☐	☐	☐	☐

10	The BCR methodology improves the allocation of financial resources	☐	☐	☐	☐	☐
11	The BCR methodology helps avoid inefficient investments	☐	☐	☐	☐	☐
12	The BCR methodology supports better utilization of organizational budgets	☐	☐	☐	☐	☐
13	The BCR methodology strengthens organizational risk management practices	☐	☐	☐	☐	☐
14	The BCR methodology improves coordination between investment decisions and risk management	☐	☐	☐	☐	☐
15	The BCR methodology contributes to improving overall operational effectiveness	☐	☐	☐	☐	☐
16	The BCR methodology helps identify projects that generate greater economic value	☐	☐	☐	☐	☐
17	The BCR methodology improves the assessment of expected project benefits	☐	☐	☐	☐	☐
18	The BCR methodology supports maximizing long-term organizational value	☐	☐	☐	☐	☐

H1: Business Risk Reduction

H2: Investment Decision-Making

H3: Project Prioritization

H4: Resource Allocation

H5: Risk Management Effectiveness

H6: Economic Benefit Identification

Section C: Additional Comments

1. In your opinion, what is the greatest benefit of applying the BCR methodology within the oil, gas, and petrochemical industry?

2. Please provide any additional comments or recommendations regarding the application of the BCR methodology in project evaluation and business risk reduction

Appendix B

Semi-Structured Interview Guide

Interview Protocol

- Estimated interview duration: 20-30 minutes
- Interview type: Semi-structured
- Target participants: Project managers, risk managers, engineers, and planners.

Introduction to the Participant

Thank you for participating in this interview. The purpose of this interview is to explore your professional views regarding the application of the Benefit-to-Cost Ratio (BCR) methodology in investment evaluation and business risk reduction. Your responses will remain confidential and anonymous and will be used only for academic research.

Interview Questions

1. Please describe your current role and responsibilities related to project evaluation or investment decision-making.
2. How is the BCR methodology applied within your organization when evaluating projects?
3. In your opinion, how does the BCR methodology contribute to reducing business risk?
4. How does the BCR methodology influence investment decision-making?
5. How does BCR support project prioritization when multiple projects compete for limited resources?
6. How does the BCR methodology assist in allocating financial and operational resources?
7. What contribution does the BCR methodology make to overall risk management effectiveness?
8. What challenges have you experienced when applying the BCR methodology?
9. What improvements would you recommend to enhance the use of the BCR methodology?
10. Is there anything else you would like to add regarding the use of the BCR methodology in the oil, gas, and petrochemical industry?

Closing Statement

Thank you for your valuable participation. Your contribution is greatly appreciated and will support the successful completion of this research.

Appendix C

Ethical Approval

This study was conducted in accordance with ethical research standards and guidelines for academic research. Ethical approval for this research was obtained prior to data collection to ensure that the rights, privacy, and confidentiality of participants were protected.

All participants were informed about the purpose of the study, the procedures involved, and the voluntary nature of their participation. Participants were assured that their responses would remain confidential and would only be used for academic research purposes.

The questionnaire did not collect any personal identifying information such as names, contact details, or institutional identifiers. All responses were collected anonymously to protect participant privacy.

Participants were informed that they had the right to withdraw from the study at any time without any consequences. Informed consent was obtained from all participants before they completed the questionnaire.

The collected data was securely stored and was only accessible to the researcher. The data will be used solely for academic research purposes and will not be shared with third parties. This study complies with ethical research principles including voluntary participation, confidentiality, anonymity, and responsible data management.

عنوان البحث/

أثر منهجية نسبة المنفعة إلى التكلفة في الحد من مخاطر الأعمال في صناعة النفط والغاز
والبتروكيماويات في المملكة العربية السعودية (دراسة حالة مصنع بترورابغ)

إعداد الطالب/

عمرو حامد بلو

إشراف/

د. الفیصل عبد الحمید

د. فايز جراد

العام الدراسي:

٢٠٢٦م

الموافقة الأخلاقية للدراسة

تم إجراء هذه الدراسة وفقاً للمعايير الأخلاقية المعتمدة في البحوث العلمية والأكاديمية. وقد تم الحصول على الموافقة الأخلاقية قبل بدء جمع البيانات لضمان حماية حقوق المشاركين وخصوصيتهم وسرية معلوماتهم. تم إبلاغ جميع المشاركين بهدف الدراسة والإجراءات المتعلقة بها، كما تم توضيح أن المشاركة في الدراسة اختيارية بالكامل. وتم التأكيد للمشاركين أن جميع إجاباتهم ستبقى سرية ولن تُستخدم إلا لأغراض البحث العلمي. لا يتضمن الاستبيان أي معلومات تعريفية شخصية مثل الأسماء أو وسائل الاتصال أو أي بيانات قد تكشف هوية المشاركين. وقد تم جمع جميع البيانات بشكل مجهول الهوية لضمان حماية خصوصية المشاركين. كما تم إبلاغ المشاركين بأن لهم الحق في الانسحاب من المشاركة في الدراسة في أي وقت دون أي عواقب. وتم الحصول على موافقة المشاركين قبل تعبئة الاستبيان. تم حفظ البيانات التي تم جمعها بشكل آمن، ولا يمكن الوصول إليها إلا من قبل الباحث. وسيتم استخدام هذه البيانات فقط لأغراض البحث العلمي ولن يتم مشاركتها مع أي طرف ثالث. تلتزم هذه الدراسة بالمبادئ الأخلاقية للبحث العلمي والتي تشمل المشاركة الطوعية، والحفاظ على السرية، وعدم الكشف عن هوية المشاركين، والإدارة المسؤولة للبيانات.

الملخص

تعمل صناعة النفط والغاز والبتروكيماويات في بيئة شديدة التعقيد ومحفوفة بالمخاطر، تتسم بضخامة الاستثمارات الرأسمالية، وعدم اليقين التشغيلي، وتقلبات الأسواق، والتحديات التكنولوجية. ولذلك، يُعدّ كل من إدارة المخاطر وتقييم الاستثمارات عنصرين أساسيين لضمان استقرار الأداء المؤسسي وتحقيق القدرة التنافسية المستدامة على المدى الطويل. تهدف هذه الدراسة إلى استقصاء أثر منهجية نسبة المنفعة إلى التكلفة (Benefit-to-Cost Ratio – BCR) في الحد من مخاطر الأعمال في قطاع النفط والغاز والبتروكيماويات، وذلك من خلال دراسة حالة لمجمع بترورابغ في المملكة العربية السعودية.

اعتمدت الدراسة منهجية البحث المختلط، من خلال الدمج بين الأساليب الكمية والنوعية. وتم جمع البيانات الكمية باستخدام استبيانات وُزعت على خمسة عشر متخصصًا من إدارات المشاريع، وإدارة المخاطر، والهندسة، والتخطيط، بينما جُمعت البيانات النوعية من خلال مقابلات شبه منظمة مع عدد من المشاركين المختارين. بالإضافة إلى ذلك، أُجريت حسابات توضيحية لنسبة المنفعة إلى التكلفة (BCR)، إلى جانب تحليلات الحساسية، لإظهار التطبيق العملي للمنهجية في تقييم المشاريع واتخاذ القرارات الاستثمارية المبنية على المخاطر.

أظهرت نتائج الدراسة دعم جميع الفرضيات الست التي بُنيت عليها الدراسة. كما بينت نتائج الاستبيانات والمقابلات أن المشاركين يرون في منهجية نسبة المنفعة إلى التكلفة أداة فعالة لدعم اتخاذ القرارات الاستثمارية، وترتيب أولويات المشاريع، وتخصيص الموارد، وإدارة المخاطر، وتحديد المنافع الاقتصادية. كذلك أوضحت نتائج المقابلات أن استخدام المنهجية يعزز الشفافية، ويساعد في التقييم الموضوعي للمشاريع، ويسهم في إعطاء الأولوية للمشاريع التي تحقق قيمة تنظيمية أعلى مع تقليل مخاطر الأعمال. كما أظهرت نتائج تحليل نسبة المنفعة إلى التكلفة وتحليل الحساسية أن المشاريع ذات قيم BCR المرتفعة تظل مجدية اقتصاديًا في ظل سيناريوهات مختلفة من عدم اليقين، مما يوفر مبررات أكثر قوة لاتخاذ قرارات الاستثمار.

وخلصت الدراسة إلى أن دمج منهجية نسبة المنفعة إلى التكلفة في عمليات اتخاذ القرار داخل المؤسسات من شأنه أن يعزز ممارسات إدارة المخاطر، من خلال تحسين تخصيص الموارد، والتقييم المنهجي للبدائل، وإعطاء الأولوية للاستثمارات التي تدعم الموثوقية التشغيلية وتسهم في الحد من مخاطر الأعمال. كما تسهم هذه الدراسة في إثراء الأدبيات العلمية من خلال الربط بين التقييم الاقتصادي الهندسي وممارسات إدارة المخاطر في قطاع النفط والغاز والبتروكيماويات.

الكلمات المفتاحية:

نسبة المنفعة إلى التكلفة (BCR)، إدارة مخاطر الأعمال، اتخاذ القرارات الاستثمارية، التقييم الاقتصادي الهندسي، صناعة النفط والغاز والبتروكيماويات، بترورابغ، المملكة العربية السعودية.

قائمة المصطلحات

نسبة المنفعة إلى التكلفة: (Benefit-to-Cost Ratio – BCR) مؤشر اقتصادي هندسي يُستخدم لمقارنة القيمة الحالية لمنافع المشروع بالقيمة الحالية لتكاليفه، بهدف تقييم جدواه الاقتصادية. وتشير قيمة BCR الأكبر من (1.0) إلى أن منافع المشروع تتجاوز تكاليفه.

مخاطر الأعمال: احتمالية تعرض المؤسسة لخسائر مالية، أو اضطرابات تشغيلية، أو الإخفاق في تحقيق أهدافها نتيجة عوامل داخلية أو خارجية تتسم بعدم اليقين.

إدارة المخاطر: عملية منهجية تشمل تحديد المخاطر، وتقييمها، وتحليلها، ومعالجتها، ومراقبتها، بهدف تقليل آثارها السلبية على أهداف المؤسسة وتعزيز قدرتها على تحقيق أهدافها الاستراتيجية.

التقييم الاقتصادي: عملية مقارنة تكاليف ومنافع البدائل الاستثمارية أو المشاريع المختلفة بهدف دعم اتخاذ القرارات الاقتصادية الرشيدة.

تحليل التكلفة والمنفعة: أسلوب لاتخاذ القرار يعتمد على تقييم ما إذا كانت المنافع المتوقعة للمشروع تفوق تكاليفه. وتُعد نسبة المنفعة إلى التكلفة (BCR) أحد أهم المؤشرات المستخدمة في هذا التحليل.

اتخاذ القرارات الاستثمارية: عملية اختيار البدائل الاستثمارية المناسبة استنادًا إلى معايير مالية وتشغيلية واستراتيجية لضمان تحقيق أفضل قيمة ممكنة للمؤسسة.

ترتيب أولويات المشاريع: عملية تصنيف المشاريع وترتيبها وفقًا لمجموعة من المعايير، مثل القيمة الاقتصادية، والأهمية الاستراتيجية، وإمكانية الإسهام في تقليل المخاطر.

تخصيص الموارد: عملية توزيع الموارد المالية والبشرية والتقنية على المشاريع أو الأنشطة المختلفة بما يحقق أعلى قيمة ممكنة للمؤسسة.

تحليل الحساسية: أسلوب تحليلي يُستخدم لتقييم مدى تأثير التغيرات في افتراضات المشروع، مثل التكاليف أو المنافع، على الأداء الاقتصادي وقرارات الاستثمار.

أداة دعم اتخاذ القرار: أداة كمية أو نوعية تساعد المديرين وصناع القرار على تقييم البدائل المختلفة واتخاذ قرارات تستند إلى الأدلة والبيانات.

سيناريو توضيحي لتقييم المشروع: مثال لمشروع واقعي تم إخفاء هويته وبياناته التعريفية، ويُستخدم لتوضيح تطبيق منهجية نسبة المنفعة إلى التكلفة (BCR) مع المحافظة على سرية وخصوصية بيانات المؤسسة.

المخاطر التشغيلية: احتمالية حدوث خسائر ناتجة عن قصور أو فشل في العمليات الداخلية، أو الأفراد، أو الأنظمة، أو بسبب أحداث خارجية تؤثر في العمليات التشغيلية للمؤسسة.