

UDC 338.4

JEL E22, E29

DOI: 10.32782/2786-8273/2025-10-4

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COMPARATIVE EVALUATION OF CLASSICAL DECISION MAKING CRITERIA IN THE OIL REFINING SECTOR

ПОРІВНЯЛЬНИЙ АНАЛІЗ КЛАСИЧНИХ КРИТЕРІЇВ ПРИЙНЯТТЯ РІШЕНЬ У НАФТОПЕРЕРОБНОМУ СЕКТОРІ

Abstract. This study evaluates the applicability of four classical decision-making criteria such as Wald's maximin, Laplace's principle of insufficient reason, Hurwicz's optimism–pessimism index, and Savage's minimax regret in assessing investment alternatives for refinery enterprises. A decision matrix was constructed to compare three strategic options: modernization of refining equipment, ecological investment in cleaner technologies, and diversification into petrochemicals, under scenarios of high, stable, and declining oil prices. The results demonstrate that different decision rules produce divergent recommendations. The novelty of the study lies in adapting classical decision-making frameworks to the context of oil refining, providing a structured methodology for evaluating complex investment choices.

Keywords: decision-making under uncertainty, Wald criterion, Laplace criterion, Hurwicz criterion, Savage criterion, oil refining industry, investment strategies; risk management.

Анотація. Проблематика прийняття управлінських рішень в умовах невизначеності набуває особливої актуальності для капіталомістких галузей, зокрема нафтопереробної промисловості, діяльність якої значною мірою залежить від коливань світових цін на нафту, динаміки попиту на нафтопродукти, регуляторних вимог та геополітичних ризиків. У дослідженні здійснено оцінку застосовності чотирьох класичних критеріїв прийняття рішень в умовах невизначеності (максимінного критерію Вальда, принципу недостатньої підстави Лапласа, песимістично-оптимістичного індексу Гурвіца та мінімаксу жалю Севіджа) до процесу стратегічного інвестування на нафтопереробних підприємствах. Для досягнення поставленої мети було побудовано матрицю рішень, яка охоплює три можливі інвестиційні стратегії: модернізацію обладнання, екологічні інвестиції у чистіші технології та диверсифікацію у напрямі нафтохімічної продукції. Розглянуто три сценарії розвитку зовнішнього середовища: високі ціни на нафту, стабільні ціни та їх зниження внаслідок надлишкової пропозиції або зменшення попиту. Застосування зазначених критеріїв дало змогу виявити відмінності у виборі оптимальної стратегії залежно від підходу до трактування ризику та невизначеності. Результати дослідження показали, що критерій Вальда та Лапласа орієнтують управлінські рішення на екологічні інвестиції як найбільш збалансовану та стійку стратегію, критерій Гурвіца за умов помірної оптимізму віддає перевагу диверсифікації, тоді як критерій Севіджа акцентує на модернізації обладнання як засобі мінімізації можливих втрат від нереалізованих можливостей. Це підтверджує залежність управлінських рішень не лише від зовнішніх умов функціонування підприємств, а й від індивідуальних характеристик та схильності керівників до ризику. Наукова новизна роботи полягає у поєднанні класичних теоретичних моделей прийняття рішень з практичними умовами інвестиційної діяльності нафтопереробних підприємств, що дозволяє сформувати методологічно чіткий інструментарій для оцінки альтернатив у нестабільному середовищі.

Ключові слова: прийняття рішень в умовах невизначеності, критерій Вальда, критерій Лапласа, критерій Гурвіца, критерій Севіджа, нафтопереробна промисловість; інвестиційні стратегії; управління ризиками.

Statement of the problem. Decision-making under uncertainty has become a cornerstone of modern management theory and practice. In environments where information is incomplete, outcomes are unpredictable, and external shocks are frequent, managers need reliable frameworks for selecting strategies that balance risks and opportunities. Classical approaches such as the Wald maximin criterion, the Laplace principle of insufficient reason, the Hurwicz optimism–pessimism index, and the Savage minimax regret rule provide structured methodologies for rational choice when probabilities are either unknown or highly volatile [5; 6; 8–10]. These approaches remain relevant not only in theoretical modeling but also in applied contexts where decisions must be taken despite ambiguity.

The oil refining sector illustrates this challenge particularly well. As a capital-intensive industry with long

investment horizons, refineries operate under conditions of high uncertainty. Their profitability and sustainability are strongly dependent on global crude oil prices, fluctuations in demand for petroleum products, geopolitical risks, environmental regulations, and technological innovations [2; 4]. The combination of external volatility and irreversible investment commitments increases exposure to risks that cannot be mitigated by traditional forecasting methods alone. Consequently, decision-making frameworks designed for uncertainty are especially important for refining enterprises when evaluating modernization projects, diversification strategies, or capacity expansions [1; 7].

In this study, we apply the classical decision-making criteria under uncertainty Wald, Laplace, Hurwicz, and Savage to the investment context of oil refinery enterprises. By comparing the results derived from each criterion, we

aim to identify their relative strengths and limitations in guiding managerial choices under conditions of high risk and limited information.

Analysis of recent research and publications. Classical approaches to decision-making under uncertainty have been extensively discussed in economic theory and applied management research. The foundations were laid by Leonard J. Savage in *The Foundations of Statistics*, where he formulated the minimax regret principle that became a cornerstone of rational choice under ambiguity [8]. Later critiques, such as those by Saver G. [9], pointed to the excessive pessimism inherent in the rule, sparking the development of modifications and hybrid models. The Wald maximin principle, further justified in modern contexts by Liu Z. [6], emphasizes robustness in highly adverse environments, ensuring decision-makers focus on the least favourable outcomes. Complementing this, Hurwicz's optimism–pessimism index was refined through mathematical adjustments proposed by Gasparis-Wieloch H. [5], who demonstrated its flexibility when balancing risk and opportunity. More recently, Ulansky V. and Raza A. [10] offered a generalization that integrates maximin, minimax regret, and Laplace criteria under conditions of partial prior uncertainty, providing a unified theoretical perspective.

In parallel with theoretical refinements, the oil and gas sector has provided fertile ground for the application of these decision-making tools. Bickel J.E. and Bratvold R.B. [2] emphasized that while uncertainty quantification in the oil industry has improved, it often does not translate directly into better decisions unless structured frameworks such as decision criteria are applied. Dekker P. [4] similarly underlined the persistent challenge of uncertainty in oil-related investments, noting the interplay of technological, economic, and political risks. More applied research has demonstrated the value of multi-criteria approaches: Nazari I., Alroaia Y., and Bahraminasab S. [7] ranked Iranian oil refining and distribution companies using decision-making techniques that incorporate classical uncertainty criteria. Boachie C. [3] further discussed the integration of decision models into energy systems management, highlighting their importance for supply chain and investment planning. Finally, Ali [1] provided a recent case study on Attock Refinery Limited, demonstrating how forecasting models combined with decision analysis support managerial choices in volatile petroleum markets.

Overall, the literature suggests that while each criterion has its own strengths and limitations, their adaptation to the oil refining sector allows managers to navigate uncertainty more effectively. The combination of theoretical advances [5; 6; 8–10] and practical applications in petroleum industries [1–4; 7] demonstrates the relevance of these methods for guiding investment strategies under high risk and incomplete information.

The purpose of the article. The aim of this study is to evaluate the applicability of classical decision-making criteria under uncertainty for investment decision-making in oil refinery enterprises. The research seeks to systematize the theoretical foundations of these approaches, highlight their methodological differences, and adapt them to the specific conditions of a capital-intensive and risk-prone industry. Particular attention is given to the volatility of crude oil markets, regulatory and geopolitical influences, and the long-term character of investment commitments.

By constructing a decision matrix that reflects alternative investment strategies under varying market scenarios and applying the selected criteria, the study intends to demonstrate their practical relevance, compare the outcomes, and identify the relative advantages and limitations of each method in supporting managerial choices.

Presentation of the main research material. To evaluate investment strategies under uncertainty in oil refinery enterprises, this study employs four classical decision-making criteria: Wald's maximin criterion, the Laplace criterion of insufficient reason, Hurwicz's criterion of optimism–pessimism, and Savage's minimax regret criterion. Each approach provides a distinct rational perspective for guiding managerial choices when probabilities of future states are unknown or unstable.

Wald's Maximin Criterion. Proposed by Abraham Wald, this pessimistic rule selects the strategy that maximizes the minimum payoff. It assumes that the decision-maker prepares for the worst possible scenario [6]. Mathematically, for a strategy a_i , with payoffs u_{ij} , across states s_j :

$$W(a_i) = \max_i (\min_j u_{ij}),$$

The optimal strategy is the one with the greatest of the minimum payoffs.

Laplace Criterion. Also known as the principle of insufficient reason, this criterion assumes that all states of nature are equally probable [8]. The strategy with the highest average payoff is chosen:

$$L(a_i) = \frac{1}{n} \sum_{j=1}^n u_{ij}$$

where n is the number of possible states.

Hurwicz Criterion. Introduced by Leonid Hurwicz [5], this rule balances optimism and pessimism using a coefficient $\alpha \in [0, 1]$. The criterion evaluates each strategy as a weighted combination of the maximum and minimum payoffs:

$$H(a_i) = \alpha \cdot \max_j u_{ij} + (1 - \alpha) \cdot \min_j u_{ij}$$

The parameter α reflects the decision-maker's attitude towards risk: higher values correspond to optimism, lower to pessimism.

Savage's Minimax Regret Criterion. Developed by Leonard Savage, this approach minimizes the maximum possible regret, where regret is the loss resulting from not choosing the best decision ex post [8]. First, the regret matrix is constructed as:

$$R_{ij} = \max_i u_{ij} - u_{ij}$$

Then the criterion is expressed as:

$$S(a_i) = \min_i (\max_j R_{ij})$$

The chosen strategy minimizes the worst-case regret across all possible states.

Together, these criteria provide complementary perspectives: Wald emphasizes caution, Laplace neutrality, Hurwicz flexibility between attitudes, and Savage risk minimization through the concept of regret. Their combined application allows for a nuanced assessment of investment strategies in oil refining under uncertain external conditions [2].

To demonstrate the applicability of classical decision-making criteria, the study considers a hypothetical oil refinery enterprise confronted with three alternative investment strategies under conditions of market uncertainty. The first option, denoted as A₁, involves the modernization of refining equipment. This strategy is highly capital-intensive but promises efficiency gains and potential improvements in production reliability. The second alternative, A₂, focuses on ecological investments, such as the introduction of cleaner technologies. Although requiring a moderate level of investment, this option offers advantages in terms of compliance with environmental regulations and reputational benefits in increasingly sustainability-driven markets. The third strategy, A₃, emphasizes diversification into petrochemical production. While this choice carries substantial risk due to market volatility and technological complexity, it also presents the possibility of high returns in favorable conditions.

Uncertainty is represented through three possible states of nature. The first state, S₁, assumes a period of high global oil prices, which typically enhances profitability and stimulates capital investment. The second state, S₂, reflects a scenario of relative stability, where oil prices remain moderate and predictable, allowing for steady but unspectacular returns. The third state, S₃, considers a decline in oil prices, potentially caused by oversupply, demand reduction, or disruptive shifts in the energy sector. These three scenarios capture the volatility of global energy markets and provide a realistic backdrop for testing decision-making models.

Based on these assumptions, a payoff matrix of expected net benefits (in million USD) was constructed, with values assigned to each combination of strategy and state of nature. The resulting structure forms the basis for the application of Wald's maximin, Laplace's principle of insufficient reason, Hurwicz's optimism-pessimism rule, and Savage's minimax regret criterion [3]. By applying these methods, the study aims to illustrate how managerial choices can vary depending on the decision rule employed, even when the underlying set of alternatives and uncertainties remains constant.

After establishing the payoff structure, the first step was to apply Wald's maximin criterion, which reflects a distinctly conservative attitude toward uncertainty. According to this approach, the decision-maker evaluates the minimum possible payoff for each strategy and selects the option with the most favorable worst-case outcome [6]. In this case, modernization of equipment yields a minimum payoff of 20, ecological investment 40, and diversification –30. As the highest of these minima is associated with ecological invest-

ment, Wald's rule identifies A₂ as the optimal choice. This result suggests that a manager focused on safeguarding the enterprise against the most adverse conditions would prioritize investments in environmental compliance and sustainability, even at the expense of potentially higher profits.

The application of the Laplace criterion leads to a similar conclusion but through a different rationale. By assuming that all states of nature are equally probable, this approach calculates the average expected payoff for each alternative. The results show average values of 50 for modernization, approximately 51.7 for ecological investment, and 43.3 for diversification. The highest average again corresponds to ecological investment, which emerges as the preferred strategy. Unlike the strictly pessimistic perspective of Wald's rule, the Laplace principle reflects neutrality in the face of uncertainty, yet it still directs managerial attention toward the strategy that balances risk and return most effectively [10].

When applying the Hurwicz criterion, which combines elements of optimism and pessimism through a weighting coefficient, the evaluation shifts depending on the degree of risk tolerance. With a coefficient of optimism (α) set at 0.6, the ecological investment produces a score of 52, modernization 56, and diversification 60. Under this assumption, diversification becomes the most attractive option. This outcome underscores the sensitivity of the Hurwicz criterion to managerial attitudes: while cautious leaders may still favor ecological investments, those inclined toward optimism may interpret diversification as a strategic opportunity capable of delivering superior returns under favorable market conditions.

The final stage of the analysis applies Savage's minimax regret criterion, which approaches uncertainty from the perspective of loss avoidance rather than profit maximization. Instead of evaluating absolute payoffs, this method calculates the potential regret associated with each decision, that is, the difference between the payoff of the chosen strategy and the best possible payoff that could have been achieved under each state of nature. By reframing the decision problem in terms of foregone opportunities, the regret matrix highlights the potential costs of making the "wrong" choice once uncertainty is resolved.

Table 2 presents the regret values for each combination of strategy and state of nature. These values are derived by subtracting the payoff of each strategy from the maximum payoff attainable under the corresponding state. For example, under high oil prices (S₁), diversification yields the highest return (120), making it the benchmark against which other strategies are compared. Modernization, with

Table 1

Payoff Matrix (in million USD, expected net benefits)

Strategy / State	S ₁ : High Prices	S ₂ : Stable Prices	S ₃ : Declining Prices
A ₁ : Modernization	80	50	20
A ₂ : Eco-Investment	60	55	40
A ₃ : Diversification	120	40	–30

Source: developed by the author

Table 2

Regret matrix for investment strategies (million USD)

Strategy / State	S ₁ : High Prices (max=120)	S ₂ : Stable Prices (max=55)	S ₃ : Declining Prices (max=40)
A ₁ : Modernization	40	5	20
A ₂ : Eco-Investment	60	0	0
A ₃ : Diversification	0	15	70

Source: developed by the author

a payoff of 80, therefore carries a regret of 40, while ecological investment, with 60, produces a regret of 60. This procedure is repeated for the scenarios of stable and declining prices, generating a complete regret matrix.

From this matrix, the next step is to identify the maximum regret associated with each strategy, which represents the worst possible loss of opportunity. For modernization (A_1), the highest regret is 40; for ecological investment (A_2), it reaches 60; and for diversification (A_3), it amounts to 70. According to Savage's minimax regret criterion, the optimal strategy is the one with the smallest maximum regret. Consequently, modernization (A_1) is selected, as it minimizes the enterprise's potential exposure to regret in retrospect.

This outcome contrasts with the results obtained under the Wald and Laplace criteria, which both favored ecological investments, and with the Hurwicz criterion, which under moderate optimism pointed to diversification. Savage's approach highlights the importance of psychological and strategic considerations in managerial decision-making: leaders who are primarily concerned with avoiding future regret may prioritize modernization, even if it does not offer the highest expected or worst-case returns.

Conclusions. The comparative analysis of the four classical decision-making criteria reveals the extent to which strategic choices in the oil refining sector depend not only on economic conditions but also on the decision-maker's attitude toward uncertainty. The Wald maximin rule directs attention toward ecological investment (A_2), emphasizing resilience in the worst-case scenario and appealing to risk-averse managers seeking to shield the enterprise from unfavorable market conditions. The Laplace principle, while grounded in a neutral probability assumption, also points to ecological investment, highlighting its balanced payoff profile across different states of nature. In contrast, the Hurwicz criterion demonstrates the influence of optimism on strategic choice. With a moderate optimism coefficient,

diversification (A_3) becomes the preferred strategy, illustrating how managerial confidence in favorable outcomes can tilt decisions toward high-risk, high-reward alternatives. The Savage minimax regret criterion, by reframing the problem in terms of foregone opportunities, selects modernization (A_1) as the option that minimizes potential disappointment, reflecting a decision style motivated by regret avoidance rather than absolute performance.

Taken together, these results underscore that no single criterion provides a universally optimal solution. Instead, each reflects a distinct managerial philosophy: caution and protection against worst-case losses (Wald), neutrality and balance (Laplace), optimism and risk tolerance (Hurwicz), or regret minimization (Savage). For oil refinery enterprises, where investments are both capital-intensive and exposed to volatile global markets, the simultaneous consideration of multiple decision criteria can enrich strategic planning. By comparing the recommendations of different approaches, managers can better align investment choices with their organization's risk appetite, regulatory environment, and long-term sustainability objectives.

In conclusion, this study highlights the continuing relevance of classical decision-making criteria for managing uncertainty in the oil refining sector. The integration of theoretical decision rules into a practical investment evaluation provides both methodological clarity and practical guidance. Beyond demonstrating the diversity of outcomes generated by the four criteria, the findings emphasize that strategic decisions in volatile industries cannot rely solely on predictive models. Instead, they require structured frameworks that accommodate uncertainty, acknowledge managerial attitudes, and balance short-term risks with long-term commitments. This dual perspective strengthens the capacity of refinery enterprises to navigate uncertainty and make informed choices in complex and dynamic environments.

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Стаття надійшла: 22.07.2025

Стаття прийнята: 03.09.2025

Стаття опублікована: 26.09.2025