HALAL DETECTION KIT PRODUCTION: ECONOMIC FEASIBILITY AND RISK-BASED INVESTMENT PLANNING

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Article history:

Received
17 February 2025

Revised
17 June 2025

Accepted
1 September 2025

Available online
30 September 2025

ABSTRACT

Background: Background: Indonesia's halal industry offered strong growth potential, yet investment in halal detection tools remained limited. Strengthening this sector could improve independence and competitiveness in domestic biotechnology.
Purpose: The study evaluates the financial feasibility of investing in the development of halal detection kit products and integrates risk management to enhance decision-making in biotechnology investments.
Design/methodology/approach: A quantitative analysis was conducted using primary data (semi-structured interviews with PT XYZ's management and company financial statements) and secondary data (literature, market reports, and internal documents). Investment feasibility was assessed through Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP). Monte Carlo simulations were applied to model uncertainty and integrate risk analysis into the NPV-at-Risk framework.
Findings/Result: The study results show that the investment in developing halal detection kit products is economically feasible, as indicated by a positive NPV, an IRR above the discount rate, and a relatively short PBP. Monte Carlo simulations highlight the sensitivity of investment profitability to fluctuations in raw material prices and currency exchange rates, emphasizing the importance of effective risk management strategies.
Conclusion: PT XYZ can reduce cost risk by collaborating with local partners to increase the Domestic Component Level (TKDN) and minimize reliance on imported raw materials affected by currency fluctuations. Implementing risk mitigation strategies based on the NPV-at-Risk method can optimize operations, improve cost efficiency, and expand market reach.
Originality/value (State of the art): This research combined financial feasibility with risk-based analysis using the NPV-at-Risk method in biotechnology.

Keywords: biotechnology, risk-based investment, halal detection kit, risk management, Monte Carlo simulation

How to Cite:
Sigit, A. M., Priyarsono, D. S., & Jahroh, S. (2025). Halal detection kit production: Economic feasibility and risk-based investment planning. Indonesian Journal of Business and Entrepreneurship, 11(3),746. https://doi.org/10.17358/ijbe.11.3.746

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INTRODUCTION

The global halal industry has experienced significant growth over the past decade, driven by the increasing Muslim population and rising awareness of halal standards in food, pharmaceuticals, and cosmetics. As one of the largest Muslim-majority countries in the world, Indonesia offers promising opportunities for the development of the halal industry ecosystem (Mujahidin 2020), especially with Indonesia's position as a key player in the growth of the global halal market worth $2.537 billion in 2019 (Adiweno et al. 2018). Halal-certified products ensure that sourcing, production, packaging, and distribution occur in a clean and sanitary, aligning with values such as safeguarding animal rights and promoting a healthy climate and social justice (Mustun, 2021). Furthermore, the increased demand for halal products from non-Muslim consumers stems from their perception of these products as high-quality, safe, and ethical.

The rapid expansion of the halal industry, particularly within biotechnology, has created significant opportunities for innovation in compliance and certification. The potential of this halal industry needs to be supported by government initiatives and policies, such as the development of halal detection kits, which represent both a challenge and an opportunity. One critical challenge is the availability of reliable halal detection methods, especially for food and pharmaceutical products that require scientific verification. The challenge lies in developing reliable, scientifically validated, and regulatorily accepted detection methods. Local producers must meet strict requirements set by authorities such as the Indonesian Ulama Council (MUI) and the Halal Product Assurance Agency (BPJPH), as well as align with global halal certification frameworks, which has long been a source of confusion and concern for producers and exporters (Widiastuti et al. 2020), thus the certification process needs to be simplified to facilitate industry growth. Another challenge is ensuring product competitiveness, particularly in accuracy, affordability, and compliance with standards. The halal industry development in Indonesia also faces the challenge of a lack of investment in research and development of halal detection tools (Ratanamaneichat and Rakkarn 2013). Investment in the production of halal detection tools is crucial to ensure the integrity of halal products. On the other hand, the opportunity is substantial. The increasing demand for halal products and the need for reliable and accurate detection products can create profitable market opportunities for halal detection. Government initiatives to accelerate halal certification and the implementation of Halal Product Assurance Law No. 33/2014 create a favourable regulatory environment. Additionally, policies promoting local content (Tingkat Komponen Dalam Negeri) through Presidential Regulation No. 18 of 2020 regarding the National Medium-Term Development Plan (RPJMN) for 2020-2024 encourage domestic innovation and reduce reliance on imports. One of the targets is to increase the Domestic Component Level (TKDN) from 43.3% in 2019 to 50% in 2024 and to increase the number of products certified with TKDN ≥25% from 6,097 products to 8,400 products (Pantow and Istiqomah 2022).

PT XYZ, a medium-sized biotechnology company in Indonesia, is exploring the development of a halal detection kit based on real-time PCR technology. This initiative responds to growing domestic and global demand for halal assurance and supports national efforts to strengthen local biotechnology capabilities. Investment planning ensures product development aligns with market opportunities while maintaining financial sustainability. At the international level, halal-certified biotechnology products have the potential to access growing export markets, strengthening Indonesia's position in the global halal value chain.

Halal detection kits address a pressing local need for the biotechnology sector and contribute to technological independence. It bridges the gap between regulatory requirements and industrial capabilities, opening avenues for research and development. Paul and Lova (2005) argue that the biotechnology industry has significant growth potential in various fields, ranging from agriculture to healthcare to industrial applications. Previous studies on biotechnology investment and risk analysis have primarily focused on financial evaluation methods such as Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP) (Bierman & Smidt, 1993; Huang et al. 2022). While these tools provide baseline insights into profitability, they are typically deterministic and assume fixed values for costs, revenues, and interest rates.

In reality, those models often fail to capture the uncertainty in volatile markets, exchange rate fluctuations, input cost variability, and unpredictable consumer demand. Several scholars have emphasized the importance of incorporating uncertainty into feasibility studies. Almaktar et al. (2016) demonstrated that investment feasibility can shift dramatically under fluctuating interest rates. Ye and Tiong (2000) and Untoro (2021) further highlighted how cost volatility and exchange rate fluctuations significantly alter project profitability in infrastructure and biotechnology investments. Janeková and Onofrejová (2015) applied triangular distribution models to capture demand growth uncertainty, providing a more realistic representation of potential market scenarios, as this industry is highly susceptible to periodic research and development (Nickisch et al. 2009). It causes many investors to be cautious when investing their money in this sector. Investments carry risks that must be managed well to obtain profits rather than switch to other sectors with a faster capital turnover rate. The high research and development costs, the time required to develop a product, and the risk of failure of already launched products can dampen investor enthusiasm.

Limited research has applied risk-adjusted models, such as NPV-at-Risk, within the halal biotechnology sector. Most halal studies have concentrated on certification processes, consumer perceptions, or supply chain management, leaving a gap in the literature regarding halal biotechnology products' economic feasibility and risk management. This study addresses this gap by applying NPV-at-Risk. This advanced method integrates Monte Carlo simulation with traditional financial analysis to evaluate the investment feasibility of halal detection kit production in Indonesia. The novelty of this research lies in the integration of traditional financial feasibility assessments with probabilistic risk evaluation with Monte Carlo simulation to explicitly model uncertainty and quantify investment risks, thereby creating a more comprehensive framework for investment decision-making in halal detection kit development, providing practical insights that can also be generalized to other biotechnology firms facing similar conditions in emerging markets.

The company will transform from merely being involved in the product distribution of laboratory equipment and medical devices in the Indonesian market to taking on the producer role as the company's business strategy. To ensure this business development's success and long-term profitability, the company needs to evaluate the financial aspects of technology implementation and assess the potential profitability based on a comprehensive investment feasibility analysis (development cost estimates, production costs, operational costs, and expected profit potential).

This study employs a sequential approach beginning with conventional financial feasibility analysis (NPV, IRR, PBP) to establish baseline profitability. A risk-based investment planning model will support PT XYZ in making informed decisions on resource allocation for product development and seizing market opportunities. The analysis is extended through Monte Carlo simulations with 10,000 iterations, applying appropriate probability distributions to critical variables such as market size, selling price, and exchange rate. These simulations are incorporated into an NPV-at-Risk framework to quantify uncertainty and assess the probability of adverse financial outcomes. Furthermore, semi-structured interviews with PT XYZ's management were conducted to refine risk identification and adjust the financial model based on managerial insights, ensuring that the analysis reflected real business conditions.

This study aims to evaluate the financial feasibility of investing in halal detection kit production using real-time PCR technology to ensure that the initiative delivers sustainable long-term benefits for the company. Specifically, the objectives of this study are to: Analyze the financial feasibility of investing in halal detection kit production using real-time PCR technology; Integrate risk management methods that account for uncertainty into investment planning by identifying and evaluating critical risk factors using Monte Carlo simulation and the NPV-at-Risk model; Provide strategic recommendations for PT XYZ and other biotechnology companies to strengthen investment decision-making in uncertain market environments by identifying and mitigating key risk factors influencing investment profitability.

Through these objectives, the study aims to evaluate the investment feasibility of halal detection kit production for PT XYZ and contribute to broader academic and industry discussions on risk-based investment planning in biotechnology. In line with this framework, the study hypothesizes that the production of halal detection kits using real-time PCR technology is economically feasible and capable of generating positive long-term returns for PT XYZ, and that the integration of risk management through the NPV-at-Risk approach enhances the reliability of investment decision-making by addressing uncertainty factors that affect profitability.

METHODS

This study used both primary and secondary data. Primary data were obtained through semi-structured interviews with PT XYZ's management, focusing on strategic, financial, and operational perspectives related to the halal detection kit project. The interviews provided insights into potential risks, operational challenges, and managerial perspectives that shaped the identification of risk factors. Secondary data were gathered from academic journals, books, market reports, company financial statements, and government regulations related to halal certification and biotechnology investment. These secondary sources supported the construction of financial models and the definition of probability distributions for risk variables, ensuring both practical relevance and theoretical grounding for the analysis.

Semi-structured interviews were conducted face-to-face over two months. The flexible nature of the interviews allowed respondents to elaborate on uncertainties in the business environment, provided insights into risk identification, investment priorities, and the company's perception of market opportunities. Financial statement analysis complemented these interviews by providing quantitative information on cost structures, revenue projections, and capital requirements. Secondary data collection included an extensive literature review and analysis of internal company financial statements. The triangulation of these sources enriched the robustness of the findings by aligning financial models with real-world managerial perspectives.

The analysis followed a sequential approach. First, financial feasibility was evaluated using Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP) to establish baseline profitability. Risk identification combined qualitative inputs from interviews and quantitative evidence from literature, yielding twelve risk factors: market size, selling price, market growth, market share, market interest, variable costs (materials), fixed costs, overhead, exchange rate, tax rate, inflation, and bank interest. Each variable was assigned an appropriate probability distribution based on journal data and industry reports.

The net present value (NPV) is obtained by calculating each year's cash flow, from the initial to the final year. The NPV > 0 means the investment benefits the company, making the investment worth pursuing and vice versa. Meanwhile, NPV = 0 means a review is needed because the company does not gain value over a specific period. The formula for NPV can be expressed as NPV = (C1/1+r) + (C2/(1+r)2) + (C3/(1+r)3) + … + (Ct/(1+r)t) – C0, where Ct represent annual cash flow in period t, r is interest rate or discount rate (in %) and C0 is initial investment value in year 0. The alignment of the company's investment value with a project positively correlates with the internal rate of return (IRR) magnitude. Conversely, it negatively correlates with a lower IRR value. The IRR return rate is calculated based on the net value of the NPV and the interest rate associated with the current net value (Siagian et al. 2023). If the IRR > the required interest rate, the business plan is feasible because it is profitable and vice versa. The IRR can be calculated using the following formula: IRR = R1 + (PV1 – PV0/PV1 – PV2) x (R2 – R1).

According to the payback period (PP) approach, profitable investment decisions are characterized by shorter payback periods, which means that investors can recover and regain the investment costs incurred more quickly and show better results in evaluating investment strategies. Instead, the business plan is not feasible because investors will have difficulty recovering the investment costs already incurred. The PP investment evaluation can be expressed as Payback Period = n + (a – b) / c x 1 year, where n is the required payback period for the investment, a is the cumulative cash flow in the final year (n), b is the cash flow in the year following the cumulative cash flow year (n + 1), and c is the difference between the cash flow in the final year (n) and the cash flow in the year following that (n + 1). The sensitivity analysis is used to understand the variations in scenario plans that will affect the Company's revenue, in analyzing the feasibility of business investments from a financial aspect. The criteria used in this method are to measure the impact of a 10% and 20% increase and decrease in selling price, variable costs, and revenue projections on NPV, IRR, and PBP.

Integrating the NPV analysis method with the risk management is carried out according to ISO 31000 standards. At the communication and consultation stage, discussions involve internal company representatives or external experts in the field of risk to communicate the perceptions and understanding of the parties bearing the risk. At the context establishment stage, probability is determined based on the minimum NPV from cash flow calculations. The financial risks directly related to cash flow are identified when the NPV value reaches its minimum or when the NPV value reaches a point that could be detrimental to the company's management (NPV falling below zero or below the company's defined risk appetite). The minimum NPV value obtained from the financial simulation is utilized to categorize operational risk (Untoro et al. 2021).

A Monte Carlo simulation with 10,000 iterations is then performed using Crystal Ball software, integrating uncertainties into the financial model. The simulation generated probability distributions for NPV, IRR, and PBP, from which NPV-at-Risk is derived. Market size, selling price, market growth, market share, consumer acceptance, material prices, fixed and overhead costs, exchange rate, tax rate, interest rate, and inflation are among the twelve major risk factors that are modelled. Each variable is assigned an appropriate probability distribution based on information from prior journal publications and other secondary sources, ensuring alignment with procedures in risk analysis and investment research. The interviews' input is used to construct parameter ranges (optimistic, pessimistic, and most likely) and to consider correlations like the relationship between inflation and overhead or exchange rates and material costs. Sensitivity analysis is also performed to identify the most influential variables affecting investment outcomes.

At the risk analysis stage, a Monte Carlo simulation is run to measure the probability of risk occurrence (likelihood) and the impact that arises if the risk occurs (consequence) from each risk factor. The likelihood value is obtained using the goal seek method, which will calculate the input value in reverse to obtain the output value in a model. The obtained value is then analyzed for its probability based on the distribution results in the previously run simulation, thus yielding the likelihood of that value, shown in Table 1. The consequences of risk factors are then evaluated using the stress analysis method, which identifies the system's response under extreme uncertainty conditions. The principle of stress analysis is to conduct simulations with distributions different from the initial distribution and observe how significantly the impact on the risk variables can affect the outcome without altering the initial model. The risk factor with the highest value is chosen to measure the probability of the worst risk impact, as shown in Table 1. The likelihood and consequence values obtained from each risk factor are used as a reference to create the risk map.

At the risk evaluation stage, the classification of likelihood and consequences values for each risk factor is used to create a risk map. The mapping process facilitates the identification and prioritization of risk mitigation based on the level of occurrence and consequences, as shown in Figure 1. The mapping helps evaluate potential risks and determine priorities in risk mitigation planning. The classification of risk levels indicates the urgency of a risk, namely extreme risk, high risk, medium risk, low risk, and very low risk. The next stage of risk mitigation is proposed to prevent and manage risks. Risk mitigation will design strategies to address risk factors deemed critical. Some ways to handle risks according to ISO 31000 are avoiding risks, accepting risks, transferring risks, reducing the likelihood of risks occurring, and mitigating the impact of risks.

Table 1. Classification of likelihood and consequence (Untoro et al. 2021)

Likelihood	Possibility of occurrence	Consequence	Description
Rare	Possibility of occurrence less than 5%	Insignificant	Low financial loss (indicated by correlation in absolute less than 5%)
Unlikely	Possibility of occurrence between 5%-25%	Minor	Medium financial loss (indicated by correlation in absolute between 5%-25%)
Possible	Possibility of occurrence 25%-50%	Moderate	High financial loss (indicated by a correlation in absolute terms between 25%-50%)
Likely	Possibility of occurrence 50%-75%	Major	Significant financial loss (indicated by a correlation in absolute terms between 50%-75%)
Almost certain	Possibility of occurrence is more than 75%	Catastrophic	Huge financial loss (indicated by a correlation of more than 75%)

RISK MAP			Consequences Level				
			Insignificant	Minor	Moderate	Major	Catastrophic
			Low Financial Loss	Medium Financial Loss	High Financial Loss	Major Financial Loss	Huge Financial Loss
Likelihood Level	Almost Certain	P(X) > 75%					
	Likely	50% ≤ P(X) ≤ 75%					
	Possible	25% ≤ P(X) ≤ 50%					
	Unlikely	5% ≤ P(X) ≤ 25%					
	Rare	5% < P(X)					
Note			Extreme Low Risk	Low Risk	Moderate Risk	High Risk	Extreme High Risk

Figure 1. Risk-map (Untoro et al. 2021)

This study's underlying hypothesis is that halal detection kits production using real-time PCR technology is economically feasible and can deliver sustainable profitability, provided key risks such as exchange rate volatility and rising raw material costs are effectively managed. This hypothesis is based on the observed growth of the halal biotechnology sector, the increasing demand for reliable halal assurance tools, and prior research showing that risk-adjusted models improve investment decision-making under uncertainty (e.g., Almaktar et al. 2016; Huang et al. 2022), and that financial feasibility is strongly influenced by uncertainty in market and cost variables.

The conceptual framework (Figure 2) integrates financial feasibility assessment with probabilistic risk management. It begins with evaluating investment opportunities using NPV, IRR, and PBP, then identifying risk factors through interviews and literature, applying Monte Carlo simulation to model uncertainty, and synthesizing the results into an NPV-at-Risk framework. This sequence ensures that both profitability and uncertainty are considered in decision-making.

In summary, the framework demonstrates how investment feasibility must first be established in a deterministic sense, combined with risk-adjusted analysis, to provide a comprehensive approach to assessing the feasibility of halal detection kit production under uncertainty. The outcome is a set of recommendations for PT XYZ that balances profitability with proactive risk mitigation.

RESULTS

Economic Evaluation of Investment Feasibility

From the company's perspective, investment feasibility analysis is a comprehensive assessment considering all revenues and expenses based on domestic prices and current interest rates. This analysis also provides information about the profit rate, payback period, and the interest rate on loans that the company's activities can sustain. The NPV value obtained from this study is IDR8,410,705,866, indicating that the project has positive profitability since NPV > 0. It aligns with Archer and Ghasemzadeh (1999), who emphasized that an acceptable NPV must be greater than zero for a project to be profitable. Comparable findings were also reported by Almaktar et al. (2016), who highlighted the sensitivity of NPV to interest rate fluctuations, reinforcing the importance of evaluating project robustness under varying financial scenarios. In this study, the investment remains feasible at bank interest rates of up to 9% per year, consistent with the thresholds applied in similar biotechnology investment evaluations.

Regarding the internal rate of return (IRR), the project achieves a remarkably high value of 93.86%, suggesting strong financial sustainability and resilience against interest rate increases. This finding aligns with Bierman and Smidt's (1993, cited in Bhattacharyya 2004) assertion that IRR represents the maximum interest rate a project can withstand without incurring losses. Recent literature supports this outcome: Huang et al. (2022) noted that projects with IRR values above the baseline return rate should be accepted. Basnet

(2021) emphasized that high IRR values reflect strong profitability relative to the opportunity cost of capital. Compared to previous studies on biotechnology product investments, which often report IRRs in the 20–40% range, the IRR of 93.86% indicates exceptionally favourable financial conditions for the halal detection kit sector.

For the payback period (PP), PT XYZ's management emphasizes a maximum acceptable threshold of three years. The calculated PP for this project is 2 years, well below the stated limit, which confirms the attractiveness of the investment. It aligns with the findings of Yusuf et al. (2020), who argued that shorter payback periods are critical in high-innovation industries where capital recovery time strongly influences investment decisions. Similar results were reported by Rahman and Abdullah (2018) in the context of pharmaceutical projects, where a PP under three years was associated with higher investor confidence and faster reinvestment cycles. Thus, the PP result in this study supports the company's strategic criteria and underscores the viability of the halal detection kit as a competitive product in the biotechnology market.

Overall, the combination of positive NPV, exceptionally high IRR, and a short PBP confirms the project's financial feasibility and positions halal detection kit production favourably compared to benchmarks reported in previous biotechnology and healthcare investment studies. These results suggest that the project is profitable for PT XYZ and holds potential as a scalable model for halal-compliant product innovation in the broader biotechnology sector.

The sensitivity analysis results provide valuable additional information for the company's management in developing the production of halal detection kits, which enables the company to make decisions and develop risk mitigation strategies. Variable cost determinants (including material and labour expenses), selling prices, and revenue forecasts are chosen under the premise that alterations in these three elements would substantially influence the NPV, IRR, and PBP metrics. The market assumption predominantly influences the selling price and variable costs, which can indicate revenue from cash flow estimates in the development of halal detection kit products. A 20% rise in variable costs may decrease the IRR by 30% from its standard value. The sensitivity analysis indicates that variable costs influence IRR less than the selling price. Figure 3 illustrates that in scenarios where variable costs are decreased by 10% and 20%, the IRR values will rise by 98% and 121%, respectively.

Figure 2. Conceptual framework of risk-based investment planning

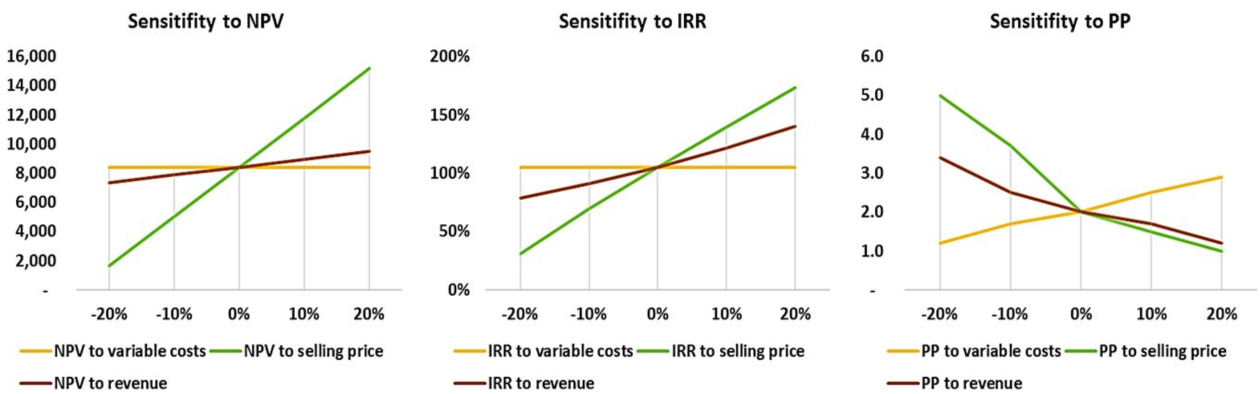

Figure 3. Sensitivity analysis of NPV, IRR and PBP to changes in variable costs, selling prices and revenue projections

The sensitivity analysis result also indicates that NPV, IRR, and PBP of the halal detection kit production are responsive to variations in selling price, particularly the IRR. An increase in the selling price results in a corresponding increase in the IRR. Conversely, a reduction in the selling price results in a fall in the IRR. A reduction in the selling price is by as much as 20% results in a decline in the NPV by as much as 90% from its standard value, and impacts the PBP by as much as 5 years. On the other hand, the sensitivity of NPV, IRR, and PBP to fluctuations in predicted ongoing is not very impactful relative to the other two components. The analysis indicates that the fluctuations in selling prices and anticipated revenues adhere to a similar pattern, making precise forecasting and market analysis essential in decision-making (Towler and Sinnott, 2012).

Application of NPV-at-Risk to risk assessment

The Monte Carlo simulation, conducted with 10,000 iterations using Oracle Crystal Ball, employed NPV as the primary metric for investment viability, incorporating risk factors directly into the cash flow model. This approach integrated risk management principles from ISO 31000 with financial modeling, producing NPV-at-Risk estimates to quantify the effect of uncertainty on project feasibility. Twelve risk factors were parameterized based on expert elicitation and secondary sources, with market size, selling price, market share, and cost-related variables modeled primarily with normal distributions (Ye and Tiong, 2000), market growth with triangular distributions (Janeková and Onofrejová, 2015), and exchange rates with log-normal distributions (Untoro, 2021).

The simulation results show that the probability of a negative NPV is 0.24%, suggesting that outright losses, where PT XYZ will not generate profit (NPV ≤ 0), are improbable. However, when applying PT XYZ's internal risk appetite threshold (NPV ≤ IDR4,205,352,933), the likelihood of an unacceptable outcome rises to 11.93%. It highlights the importance of defining risk tolerance levels, since a project that appears profitable in aggregate may still carry a non-negligible probability of falling below management's minimum acceptable return. Potential elements contributing to the loss encompass unpredictable market demand risk, escalating input costs impacting finances, and reliance on material suppliers that may affect operations, illustrated by the interconnection of several variables in the comprehensive cash flow model. A closer look at the outcome distribution shows that under pessimistic conditions marked by exchange rate volatility, higher material costs, and slower adoption the NPV nears the lower bound, leading to more extended payback periods and reduced profitability, consistent with earlier biotechnology investment studies (e.g., Almaktar et al. 2016). In contrast, optimistic scenarios with strong demand growth and stable costs yield NPVs well above the base case, highlighting the market's scalability, which means that although downside risks exist, the upside potential remains substantial, giving the project a favourable overall risk-return profile.

The probability of occurrence for each risk variable is determined using a goal-seek method based on the NPV simulation outcomes in the Crystal Ball application. In Table 2, the exchange rate variable may yield an NPV lower than the anticipated value if the exchange rate attains IDR24,101 per $1. The likelihood of the exchange rate variable being less than or equal to IDR24,101 is 97.30%, indicating a nearly definite risk level. This goal-seek analysis is performed for all input variables. The exchange rate risk variable, material cost per kit, and selling price exhibit the highest probability of occurrence, with almost certain probability of occurrence if there is no control over these variables. Meanwhile, the market size, selling price, growth, share, and interest are almost impossible to determine, unless there is a substantial alteration in the value of these criteria.

Fixed costs, overhead costs, interest, tax rates, and inflation have a likelihood percentage of 0%. A likelihood value of 0% in the Monte Carlo simulation indicates that no single scenario meets that condition, or it is almost impossible to occur within the range of assumptions used in all iterations of the simulation (Chen and Li 2017). The simulation of fixed costs ≥ IDR1,758,449,113 with a rare occurrence level reveals no scenarios in which fixed costs reach or exceed this amount. This outcome can have significant implications for decision-makers, suggesting that the condition or event being investigated is highly unlikely to occur under the given assumptions. It indicates that, according to the utilized input distribution, the fixed costs are likely lower than this amount. Therefore, the company can subsequently focus on mitigating more likely risks (Mislick and Nussbaum, 2015). The interpretation of a 0% probability in a Monte Carlo simulation can be further understood by considering the role of uncertainties inherent in the simulation process and the limitations of the simulation. In such conditions, the accuracy of the simulation depends on the reliability of the assumptions used and the completeness of the simulation model (Ord et al. 2008).

The data presented in Table 3 illustrates the impact (consequence) level that occurs when a parameter reaches a certain threshold in the Monte Carlo simulation against NPV ≤ IDR4,205,352,933. The percentage of consequence is obtained by simulating the risk variable values from the goal-seek using the principle of stress analysis. The principle of this method is to simulate new input values previously obtained, without changing the original model. The mean value of NPV when the exchange rate is ≤ IDR24,101/$1, derived from the stress analysis of the exchange rate risk factor, is IDR3,966,955,056. This value reduces the expected value of the NPV, resulting in a consequence value of 52.39%, categorizing the consequence level of the currency appreciation as a significant level.

Market size parameters, selling price, market growth, market share, market interest, fixed costs, overhead costs, interest, and tax rates have a moderate impact with a consequence level between 25%-50%. Parameters at this level have the potential to impact the likelihood of NPV not meeting expectations moderately. If the market size falls below the threshold of 538,160, there is a 49.55% chance of impacting the NPV value to be ≤ IDR4,205,352.93. The same impact also occurs if there is a decrease in selling price, market growth, market share, and market interest. Consequently, the organization requires effective marketing and expansion tactics to enhance demand. Conversely, an increase in fixed costs of ≥ IDR1,758,449,113 has a 48.18% chance of impacting the NPV value to ≤ IDR4,205,352.93. An equivalent effect also occurs if there is an increase in fixed costs, overhead costs, interest rates, and tax rates. In this context, organizations must evaluate operational efficiency to manage fixed costs and scrutinize financial performance while optimizing tax incentives or exploring better financing schemes.

Table 2. Likelihood of risk factors

Risk	Parameter	% Likelihood	Level
NPV ≤ 4.205.352.933	Market size ≤ 538,160	6.82%	Unlikely
	Selling price ≤ IDR1,064,269	18.88%	Unlikely
	Market growth ≤ -10.96%	5.64%	Unlikely
	Market share ≤ 7.18%	7.10%	Unlikely
	Market interest ≤ 14.35%	7.13%	Unlikely
	Material cost per kit ≥ $48.11	81.21%	Almost Certain
	Fixed cost ≥ IDR1,758,449,113	0.00%	Rare
	Overhead cost ≥ IDR1,826,576,953	0.00%	Rare
	Exchange rate ≥ IDR24,101	97.30%	Almost Certain
	Interest rate ≥ 54.55%	0.00%	Rare
	Tax rate ≥ 24.20%	0.00%	Rare
	Inflation ≥ 77.21%	0.00%	Rare

Table 3. Consequence of risk factors

Risk	Parameter	% Consequence	Level
NPV ≤ 4.205.352.933	Market size ≤ 538,160	49.55%	Moderate
	Selling price ≤ 1,064,269	49.23%	Moderate
	Market growth ≤ -10.96%	49.55%	Moderate
	Market share ≤ 7.18%	49.09%	Moderate
	Market interest ≤ 14.35%	49.76%	Moderate
	Material cost per kit ≥ $48.11	53.02%	Major
	Fixed cost ≥ 1,758,449,113	48.18%	Moderate
	Overhead cost ≥ 1,826,576,953	49.56%	Moderate
	Exchange rate ≥ 24,101	52.39%	Major
	Interest rate ≥ 54.55%	49.55%	Moderate
	Tax rate ≥ 24.20%	48.70%	Moderate
	Inflation ≥ 77.21%	50.36%	Major

The cost of materials per kit, exchange rates, and inflation can significantly impact (50%-75%) the success of halal detection kits, which will significantly affect the likelihood of a low NPV. The cost of materials per kit becomes one of the main factors that can cause the NPV not to meet expectations if the cost of materials per kit reaches ≥ $48.11 or more. The NPV value will also be affected if the exchange rate rises above IDR24,101/USD, which significantly increases the exchange rate risk. High inflation rates can affect the company's profitability and significantly increase the risk of low NPV if the value exceeds 77.21%. Paradhita in 2024 predicts the inflation rate in Indonesia using a fuzzy algorithm to be 5.3% by the end of 2024, 5.03% in 2025, and 5% in 2026. Although the Monte Carlo simulation results show a significant impact, an inflation scenario of 77.21% is assumed to be highly unlikely to occur given the current economic conditions in Indonesia, which indicate economic stability and the effectiveness of monetary and fiscal policies. Therefore, it is more relevant to consider an inflation scenario that aligns with historical trends and economic projections.

The obtained likelihood and consequence values are then classified by their risk levels and mapped onto the risk map matrix. It can be seen in Figure 4 that variable costs (materials per kit) and exchange rates are categorized as high risk, making both the top priorities to be addressed first. The risks being mitigated here are the uncertainty of the exchange rate of the rupiah against the dollar and the risk of rising material costs as the primary raw material for the production of halal detection kits.

The two risk factors are interconnected because most raw materials still have to be imported from abroad. Hence, the strength of the rupiah exchange rate greatly influences the transaction process. The other risk factors are categorized as extremely low risk and low risk. Although it is not the highest priority in this category, it can still affect the NPV if not mitigated by PT XYZ. Risks in the low-risk category require basic mitigation strategies such as implementing additional controls or increased periodic oversight in internal company discussions.

In addition, hedging is also recommended to reduce interest rate risk. The hedging process is carried out with the bank to agree on the exchange rate at a particular value for a specific period. Hedging schemes can be proposed as mitigations to address exchange rate risk due to uncertainty (Untoro et al. 2021). To obtain clearer information regarding the effects of this scheme, the exchange rate, which is previously normally distributed, is reanalyzed using the principle of stress analysis. The exchange rate assumption is set at IDR18,400/USD. The proposed mitigation against this exchange rate results in an NPV of IDR6,275,167,889, which is higher than the NPV if the exchange rate were IDR24,101/USD. The NPV generated from the proposed mitigation is also valued at 75% of the expected NPV, which means the risk of loss from this exchange rate remains significant if there is no automatic monitoring system. The exchange rate risk, initially high-risk with a significant impact, has decreased to moderate risk with a minor impact on NPV, as shown in Figure 5.

A long-term contract with the manufacturer is proposed as a risk management measure to address the increase in raw materials used to produce detection kits. Entering into long-term contracts with producers allows for a price increase of up to 15% during the contract period, thereby preventing excessive price escalation. To understand the impact of this proposal, a stress analysis is conducted with the assumption of a 15% increase in material prices valued at $36.73, resulting in an NPV of IDR7,155,389,468, which is higher compared to the NPV with a material cost per kit of $48.11. The risk of material costs also changes from initially high-risk with a significant impact to moderate risk with a minor impact on NPV.

The priority of mitigation on the uncertainty of the rupiah exchange rate against the dollar and the increase in material costs as the primary raw material for halal detection kit production shows a change in risk levels, indicating that the mitigation strategy has the potential to reduce the risk of loss of profits and company investments. However, further mitigation plans need to be implemented, as both factors still fall within the moderate risk category. PT XYZ needs to collaborate further with various research institutions to obtain raw material substitutes that play a crucial role in the production of detection kits. PT XYZ can also conduct independent research to find alternative raw materials that are more affordable but still meet quality standards. Another mitigation is that the company can plan to seek different raw material suppliers. In this way, in addition to reducing dependence on a single supplier (by having several different sources of raw materials), the company can also spread the risk due to the uncertainty of the rupiah exchange rate against the dollar by seeking suppliers and consumers in various countries, so the exchange rate risk does not rely too much on a single currency.

From a strategic perspective, these results suggest that PT XYZ should actively hedge or mitigate the most influential risk factors, notably exchange rate volatility and raw material cost escalation, to protect against adverse outcomes. Furthermore, scenario analysis shows that localized sourcing strategies and proactive supplier diversity could lower sensitivity to cost shocks. Moreover, the corporation may maintain margins in challenging circumstances by implementing flexible pricing structures. Overall, the Monte Carlo simulation does not merely confirm project feasibility but provides a nuanced picture of its risk-adjusted viability. The analysis equips PT XYZ with actionable insights for resource allocation, financial structuring, and risk mitigation strategies by quantifying the probability of both downside and upside outcomes.

Managerial Implications

Risk-based investment planning in developing and producing halal detection kits emphasizes the importance of integrating risk-based investment planning into the company's strategic framework. By focusing on risks such as material cost fluctuations, regulatory changes, currency exchange volatility, and shifting market dynamics, PT XYZ can align its operations with market expectations while ensuring compliance with halal principles and identifying and mitigating risks that could affect the company's financial performance. This approach supports business continuity and strengthens the company's position in the emerging halal-certified biotechnology market.

Investment decisions inherently involve uncertainty, and the NPV-at-Risk model addresses this by evaluating a range of possible outcomes rather than a single deterministic scenario. For a medium-sized company such as PT XYZ, this approach helps fill information gaps by offering probability-based outputs supporting more resilient decision-making. With an NPV value at a specific confidence level, the NPV-at-Risk model provides a range of potential outcomes as a foundation for decision-making. Regarding supply chain risk, management interviews revealed that raw materials are currently sourced internationally, making costs susceptible to exchange rate fluctuations. The model indicates that PT XYZ could reduce cost volatility by 5–7% and shorten the payback period by several months if it worked with local suppliers for even 30–40% of its raw material needs. Similarly, local sourcing might raise the IRR above its base case of 93.86% under optimistic demand growth scenarios by lowering susceptibility to import delays and currency shocks. These illustrations show how operational strategies directly result in improved financial feasibility and help the business overcome the challenges that arise when making strategic decisions.

Biotechnology initiatives involving uncertainty can benefit from a broader use of the risk management integration methodology. Developing structured data systems for monitoring risk factors like production costs, demand levels, and raw material prices is crucial for PT XYZ, ensuring that departments work together to make decisions. It fosters long-term sustainable investing and develops a thorough risk perspective. More generally, other biotechnology companies can employ risk-based investment techniques as a model, which can spur innovation and assist in establishing industry standards in product development. In order to assure innovation and sustainable investment in product manufacture, PT XYZ uses risk-based investment techniques to support long-term strategic planning, particularly when making data-driven decisions.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The development project of the halal detection kit can be deemed economically feasible with positive values in financial criteria. From a financial aspect, the investment in this business development is financially feasible with a positive NPV of Rp8,410,705,866, a high IRR of 93.86%, and a favourable Payback Period within 2 years. These results confirm that, from a financial standpoint, the investment offers significant profitability and rapid capital recovery. Nonetheless, changes in main input variables remain possible, making risk analysis an essential component of the investment evaluation process. The study identifies twelve risk factors, with exchange rate volatility and material costs emerging as the most critical. Proactive risk mitigation strategies, such as hedging, long-term supply contracts, and increasing local content (TKDN), significantly improve the robustness and profitability of investment. These strategies improve profitability, provide PT XYZ with a more resilient basis for decision-making in uncertain market conditions, and significantly reduce the risk on variables that initially had a high risk, as shown in the risk map matrix.

Beyond PT XYZ, the findings highlight broader implications for Indonesia's biotechnology sector and other emerging markets. Integrating probabilistic modeling with risk management provides a replicable framework for high-uncertainty investments, from diagnostics to halal-certified products. The NPV-at-Risk approach helps companies anticipate adverse outcomes and design targeted mitigation strategies, while collaboration with local suppliers reduces exposure to volatile global supply chains. For policymakers, the study shows how structured, risk-adjusted planning can strengthen halal biotechnology and support Indonesia's leadership in this field. The framework enables companies to allocate resources more effectively, remain flexible, and stay competitive in uncertain regulatory and market environments.

Recommendations

Future research should expand the scope of investment feasibility analysis beyond financial metrics to include qualitative aspects such as product competitiveness, service quality, market dynamics, organizational readiness, and long-term strategic positioning. In addition, further studies could continue into the design and implementation of sustainable risk mitigation strategies. To enhance methodological robustness, future Monte Carlo simulation applications should clearly detail the setup, including the number of iterations, the probability distributions applied to each risk factor, and the rationale for parameter selection. This transparency will improve reproducibility and allow meaningful comparison with other investment studies in the biotechnology sector. Conducting cost-benefit analyses of long-term supplier contracts or partial localization of raw materials strategies and currency hedging mechanisms would help decision-makers weigh their effectiveness against implementation costs. Additionally, exploring broader industry implications and incorporating qualitative factors like regulation and consumer demand trends would strengthen the risk management strategies.

FUNDING STATEMENT: This research did not receive any specific grant from funding agencies in the public, commercial, or not - for - profit sectors.

CONFLICTS OF INTEREST: The author declares no conflict of interest.

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