

ECONOMIC FEASIBILITY OF ASRS IMPLEMENTATION: EX-POST ANALYSIS OF WAREHOUSE AUTOMATION IN INDONESIA DISTRIBUTION SYSTEM

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ABSTRACT

This study evaluates the economic feasibility of post-implementation ASRS in a distribution warehouse in Indonesia by integrating financial and operational automation perspectives. The increasing adoption of warehouse automation technologies, particularly ASRS integrated with Warehouse Management Systems (WMS), often emphasizes operational efficiency without comprehensive financial validation. This research employs a quantitative case study approach with an ex-post analysis using actual operational data. The evaluation framework applies TCO, NPV and Payback Period, while financial benefits are estimated using an avoided cost approach, including warehouse space optimization and labor efficiency. The findings reveal that the total TCO over a 10-year period reaches IDR 91.92 billion, with an NPV of IDR -61.38 billion and a payback period of 29.6 years, indicating that investment is not financially feasible within the analyzed horizon. However, the ASRS implementation significantly enhances storage capacity by 181% through vertical space utilization and system-driven operations, demonstrating its role as a digital infrastructure enabler for long-term scalability. The study concludes that financial metrics alone are insufficient to evaluate warehouse automation investments, and strategic digital value must be incorporated into decision-making frameworks. These findings provide practical insights for distribution and logistics industries in aligning technology investment and economic feasibility.

Keywords: Automated Storage and Retrieval System (ASRS), Economic Feasibility, Net Present Value, Total Cost of Ownership, Warehouse Automation

1. INTRODUCTION

The rapid growth of logistics and distribution activities requires warehouse systems that are increasingly efficient, accurate, and responsive to demand variability. Conventional warehouse operations that rely on manual handling, forklifts, and static racking systems often suffer from operational inefficiencies, including longer picking times, higher error rates, and limited space utilization (Gu et al., 2007; Boysen et al., 2019). These limitations have

encouraged many firms to adopt warehouse automation technologies to improve operational performance.

One of the most widely adopted automation technologies in modern warehousing is the Automated Storage and Retrieval System (ASRS). ASRS integrates mechanical handling equipment, automation control, and Warehouse Management Systems (WMS) to automate storage and retrieval activities with higher speed, accuracy, and storage density (Roodbergen & Vis, 2009; Bartholdi & Hackman, 2019). Prior studies show that ASRS improves throughput, increases storage density, and reduces manual intervention in warehouse operations (Boysen et al., 2019; de Koster et al., 2007). However, these benefits are often accompanied by substantial capital expenditure, making financial feasibility assessment a critical component of investment decision-making.

In practice, many warehouse automation projects are justified primarily on technical and operational grounds, while rigorous financial evaluation is often overlooked. This issue is particularly relevant in Indonesia, where warehouse automation adoption is increasing, but empirical post-implementation financial evaluation remains limited. The global ASRS market continues to expand, driven by e-commerce growth and increasing demand for warehouse automation solutions (Global Market Insights, 2023). In the case of PT ASG, ASRS was implemented as a strategic warehousing solution without formal economic feasibility analysis prior to investment. After approximately 1.5 years of operation, the system had not yet demonstrated sufficient financial return to justify the scale of investment, raising concerns regarding its economic viability.

Most prior studies on ASRS focus on operational design, storage allocation, throughput optimization, and technical efficiency (Gu et al., 2007; Roodbergen & Vis, 2009; Bartholdi & Hackman, 2019; Boysen et al., 2019). Although these studies confirm the operational benefits of automation, limited research evaluates ASRS investment feasibility using real post-implementation operational data, particularly in emerging distribution markets such as Indonesia, where recent empirical evidence remains limited (Nurdien et al., 2025). This study addresses that gap by conducting an ex-post economic evaluation of ASRS implementation using actual operational data and integrated financial metrics, including Total Cost of Ownership (TCO), Net Present Value (NPV), and Payback Period.

This study is intended to evaluate the economic feasibility of ASRS implementation in an Indonesian distribution warehouse and to examine whether operational gains from automation are sufficient to justify long-term investment under actual operating conditions. The findings from this study are expected to provide practical insights for logistics and distribution firms in evaluating warehouse automation investment from both financial and strategic perspectives.

2. LITERATURE REVIEW

2.1 Warehouse System

Warehouse is an important component in logistics and distribution systems that functions as a temporary storage facility before goods are distributed to customers. In addition to storage activities, warehouses also support operational processes such as receiving, storing, picking, and shipping. Warehouse operational efficiency significantly affects overall supply chain performance, particularly in terms of service speed, inventory accuracy, and distribution responsiveness.

Along with increasing logistics complexity, companies are required to improve warehouse efficiency through the utilization of modern technologies. Conventional warehouse systems that rely heavily on manual operations often experience limitations in storage utilization, picking efficiency, and operational accuracy. Therefore, many companies have started adopting warehouse automation technologies to improve operational performance and warehouse productivity (Faber et al., 2010).

Modern warehouses no longer function solely as passive storage facilities, but also as value-added operational centers within supply chain systems. Warehouse automation enables companies to improve storage density, reduce dependency on manual labor, and support higher operational scalability, particularly in distribution companies with high transaction volumes and diverse product categories (Richards, 2021).

2.2 Automated Storage and Retrieval System (ASRS)

Automated Storage and Retrieval System (ASRS) is one of the most widely adopted warehouse automation technologies designed to automate storage and retrieval activities through integrated mechanical and computerized systems. ASRS generally consists of high-density storage racks, cranes or shuttle systems, and warehouse control systems integrated with Warehouse Management Systems (WMS).

Based on storage characteristics, ASRS is commonly categorized into Unit Load ASRS and Mini Load ASRS. Unit Load ASRS is designed for pallet-based heavy load handling, while Mini Load ASRS is used for smaller items or tote/bin handling with higher picking frequency (Boysen et al., 2019).

ASRS implementation enables companies to significantly improve vertical space utilization and storage density compared with conventional warehouse systems. In addition, ASRS improves operational efficiency by reducing manual handling activities, improving picking accuracy, and accelerating storage and retrieval processes (Gu et al., 2007). However, despite its operational advantages, ASRS implementation requires substantial capital expenditure, making investment feasibility evaluation an important consideration prior to implementation.

2.3 Economic Evaluation of Warehouse Automation

Implementation of warehouse automation technologies not only affects operational performance but also significantly impacts company investment expenditure. Therefore, economic feasibility evaluation becomes an important aspect in warehouse automation investment decisions.

One approach frequently used in warehouse technology evaluation is the avoided cost approach, which estimates measurable costs that can be avoided through the implementation of new systems compared with conventional warehouse configurations (Ellram & Murfield, 2020). In this study, avoided costs include warehouse rental efficiency and labor reduction resulting from ASRS implementation.

Financial feasibility evaluation in logistics investment is commonly conducted using several financial approaches such as Total Cost of Ownership (TCO), Net Present Value (NPV), and Payback Period (Ross et al., 2022). Total Cost of Ownership (TCO) is used to estimate the total lifecycle cost associated with ownership and operation of warehouse automation systems, including acquisition cost, operational expenditure, maintenance, and energy consumption. Meanwhile, Net Present Value (NPV) is used to evaluate whether discounted future benefits generated by investment exceed the initial investment value. Payback Period is used to estimate the required time to recover the initial investment through operational savings or generated cash flow.

2.4 Previous Studies

Previous studies discussing ASRS implementation mostly focus on operational and technical perspectives. Boysen et al. (2019) examined warehouse optimization strategies and throughput improvement in modern warehousing systems. The study highlighted the importance of storage and retrieval optimization in improving warehouse operational performance. However, the analysis mainly focused on operational and technical perspectives without integrating investment feasibility evaluation.

Roodbergen and Vis (2009) conducted a comprehensive literature review related to ASRS layout and configuration design. Their study provided conceptual guidance regarding storage rack configuration, crane utilization, and warehouse layout optimization. Nevertheless, the study did not evaluate the economic implications and investment feasibility of ASRS implementation.

In the Indonesian context, Nurdien et al. (2025) investigated ASRS implementation in a space-constrained warehouse environment and reported improvements in storage capacity, operational efficiency, and labor reduction. However, the economic analysis was still limited to operational cost efficiency and did not include integrated financial approaches such as Total Cost of Ownership (TCO), Net Present Value (NPV), and Payback Period.

Although previous studies confirm the operational advantages of ASRS implementation, empirical studies evaluating post-implementation financial feasibility using actual operational

data remain limited, particularly in emerging distribution markets such as Indonesia. Most existing studies primarily focus on throughput optimization, storage allocation, and operational efficiency rather than integrated financial feasibility analysis.

Therefore, this study attempts to fill the existing research gap by conducting an ex-post economic evaluation of ASRS implementation using integrated financial approaches consisting of Total Cost of Ownership (TCO), Net Present Value (NPV), and Payback Period based on actual warehouse operational data.

3. METHODS

This study applies a quantitative case study approach to evaluate the economic feasibility of ASRS implementation in a real warehouse environment. The research is designed as an ex-post analysis, meaning that the evaluation is conducted after the system has already been implemented and operated in practice. This approach is appropriate because the ASRS investment had been executed without prior formal financial feasibility analysis, making retrospective evaluation necessary to assess its economic validity (Brealey et al., 2020). The study object is a distribution warehouse operated by PT ASG in Surabaya, Indonesia, which has implemented ASRS as its primary storage system since 2023. The installed system consists of two subsystems: Unit Load ASRS with a storage capacity of 8,424 pallets and Mini Load ASRS with a capacity of 42,120 bins. These systems support pallet storage and high-frequency piece-picking operations, respectively.

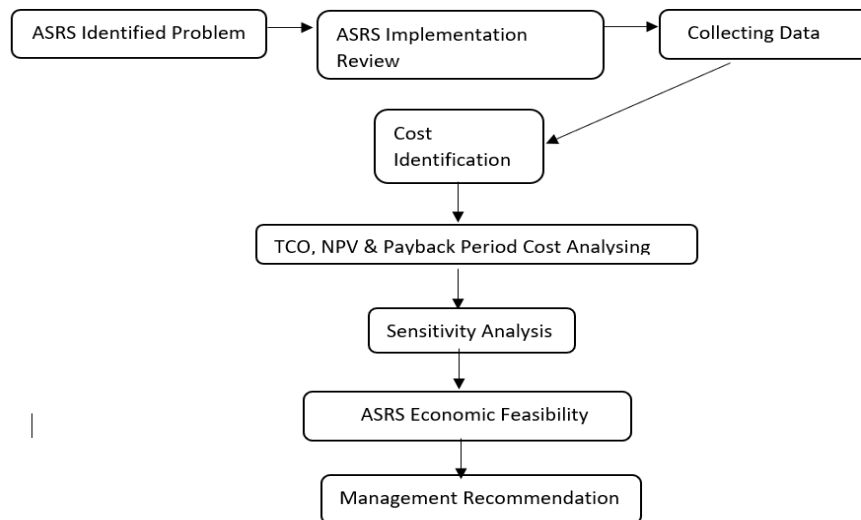
This study uses both primary and secondary data sources. Primary data include warehouse operational data such as labor usage, electricity consumption, maintenance cost, storage capacity, and system utilization. These data were collected through direct observation, interviews with the operations director, and extraction from the Warehouse Management System (WMS). Secondary data were obtained from company internal data, market reports, and relevant academic literature.

The analytical framework consists of five stages: identification of capital expenditure (CAPEX) and operational expenditure (OPEX), calculation of Total Cost of Ownership (TCO), estimation of avoided cost, Net Present Value (NPV) analysis, and Payback Period calculation. TCO is used to calculate the total lifecycle cost of ASRS ownership. Avoided cost is applied to estimate measurable financial benefits from warehouse space efficiency and labor reduction compared with a conventional warehouse system (Ellram & Murfield, 2020). NPV is used to evaluate whether discounted future benefits exceed the initial investment, while Payback Period estimates the time horizon required to recover the capital expenditure of the system (Ross et al., 2022).

This study adopts the following assumptions: a 10-year investment horizon, a 10% discount rate, and 3% annual operating cost escalation. Warehouse rental benchmark, labor wage, and electricity tariff assumptions are based on prevailing industrial market references and company operational records (CBRE Indonesia, 2024; PT PLN, 2025; Bank Indonesia, 2025). These assumptions are used to support consistency in the financial evaluation framework and

operational feasibility analysis. The overall analytical flow of the framework is designing in Fig. 1, while the key research assumptions and matrix used in the financial model are detail numbers in Table 1.

Figure. 1. Research Framework of ASRS Economic Evaluation



The key assumptions and financial parameters used in the economic evaluation are detailed in Table 1.

Table 1. Research Assumptions and Parameters

Parameter	Value	Source
Initial Investment	IDR 80,000,000,000	Company Internal Data
Investment Horizon	10 Years	Study Assumption
Discount Rate	10%	Company Financial Assumption
OPEX Escalation	3% p.a.	Study Assumption
Warehouse Rental Benchmark	IDR 375,000/m ² /year	Industrial Market Benchmark
Labor Wage Benchmark	IDR 4,961,753/month	Regional Wage Standard
Electricity Tariff	IDR 1,114.74/kWh	Industrial Tariff Benchmark

4. RESULTS AND DISCUSSION

The total capital expenditure for ASRS implementation is IDR 80 billion. This investment includes procurement, installation, automation infrastructure, and system integration. Annual operational expenditure consists primarily of labor, electricity, and maintenance cost, totaling

approximately IDR 1.04 billion in the first year. Assuming 3% annual cost escalation, cumulative operational expenditure over 10 years reaches IDR 11.92 billion.

Accordingly, the Total Cost of Ownership (TCO) of the ASRS system over a 10-year period is IDR 91.92 billion, of which 87% is attributable to initial capital investment and only 13% to operational expenditure. This result indicates that ASRS economic feasibility is predominantly influenced by upfront capital cost rather than recurring operational expenses, which is consistent with prior findings on capital-intensive warehouse automation systems (Ellram & Murfield, 2020).

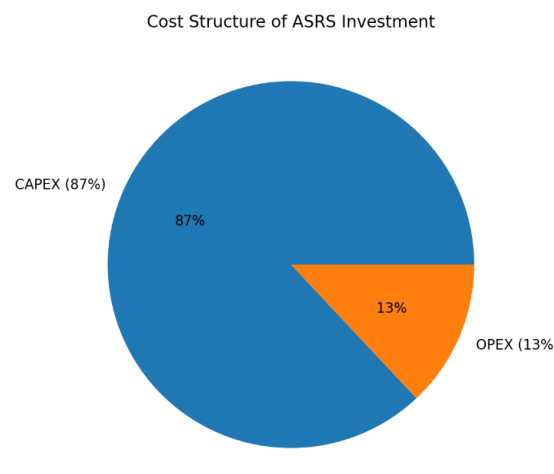
A summary of the key financial metrics used in the evaluation is presented in Table 1.

Table 2. Cost Structure and TCO Composition

Cost Component	Value (IDR bn)	Share (%)
Initial CAPEX	80.00	87
10-Year OPEX	11.92	13
Total TCO	91.92	100

The dominance of capital expenditure in the ownership structure is further illustrated in Figure 2, confirming that procurement cost remains the principal driver of investment burden.

Figure. 2. Cost Structure of ASRS Investment



4.2 Avoided Cost Analysis

To quantify measurable economic benefits, this study applies an avoided cost approach by estimating the cost that would have been incurred under an equivalent conventional warehouse configuration (Ellram & Murfield, 2020). Two measurable avoided cost components are identified: warehouse rental savings and labor savings.

First, ASRS significantly improves vertical space utilization. With ASRS, the warehouse accommodates 8,424 pallets within 8,000 m². Under a conventional selective racking system with similar throughput requirements, equivalent storage capacity would require approximately 16,400 m² due to aisle width and lower storage density. This implies an avoided warehouse area of approximately 8,400 m². Using a warehouse rental benchmark of IDR 375,000/m²/year, the avoided warehouse rental cost is estimated at IDR 3.15 billion annually.

Second, labor efficiency is improved through automation. Based on throughput benchmarking, a conventional warehouse with equivalent volume would require approximately 22 workers, whereas the ASRS configuration operates with only 12 workers. This implies avoided labor of 10 workers. Using prevailing labor cost assumptions, annual avoided labor cost is estimated at IDR 0.60 billion.

Total annual avoided cost is therefore estimated at IDR 3.75 billion, consisting of warehouse rental efficiency and labor cost reduction.

Table 3. Annual Avoided Cost Components

Avoided Cost Component	Basis of Estimation	Annual Value (IDR bn)
Warehouse rental saving	8,400 m ² × IDR 375,000/m ² /year	3.15
Labor saving	10 avoided workers	0.60
Total Annual Avoided Cost		3.75

4.3 Financial Feasibility Analysis

The economic feasibility of ASRS investment is evaluated using Net Present Value (NPV) and Payback Period over a 10-year analysis horizon. Using a 10% discount rate, the cumulative discounted cash flow generated from annual avoided cost is insufficient to recover the capital investment.

The analysis yields an NPV of IDR -61.38 billion at the end of year 10, indicating that the discounted economic benefits generated by the ASRS are insufficient to offset the total investment cost. In practical terms, this means that the project does not create positive economic value under the evaluated assumptions and remains financially unattractive under conventional capital budgeting criteria (Ross et al., 2022).

The simple Payback Period is estimated at 29.6 years, substantially exceeding both the 10-year evaluation horizon and the expected economic life of the system. This indicates that although operational savings are measurable, they are insufficient to recover the investment within a financially acceptable period.

These findings confirm that ASRS implementation is not financially feasible under conventional discounted cash flow criteria.

Table 4. Financial Feasibility Summary

Indicator	Value	Interpretation
NPV (10 years)	(61.38) IDR bn	Financially infeasible
Payback Period	29.6 years	Exceeds asset life
Annual Avoided Cost	3.75 IDR bn	Operationally beneficial

4.4 Operational and Strategic Implications

Although the financial results indicate infeasibility under conventional discounted cash flow criteria, the operational impact of ASRS is substantial. The system increases storage capacity from approximately 3,000 pallets under conventional configuration to 8,424 pallets, representing a 181% increase in storage capacity within the same warehouse footprint. This demonstrates that ASRS successfully addresses the company's critical space constraint and significantly improves storage density.

From an operational perspective, ASRS also reduces labor dependency, improves system control, and supports more standardized warehouse execution. These benefits strengthen process consistency and enable long-term operational scalability.

This creates an important investment paradox: ASRS is financially unattractive in the short to medium term, yet strategically valuable as a capacity-enabling digital infrastructure (Chopra & Meindl, 2022). In this context, the system should not be interpreted solely as a cost-saving mechanism, but as a strategic investment supporting long-term distribution scalability.

Table 5. Strategic Operational Implications of ASRS

Operational Indicator	Before ASRS	After ASRS	Impact
Storage Capacity (pallets)	3	8,424	181%
Warehouse Footprint (m ²)	16,400*	8	-51%
Labor Requirement (workers)	22	12	-45%

4.5 Sensitivity Analysis

Sensitivity analysis shows that initial capital expenditure is the most influential variable affecting financial feasibility. A $\pm 20\%$ change in CAPEX produces the largest NPV variation compared with other variables, including avoided cost, OPEX, inflation, and discount rate. This indicates that ASRS financial feasibility is highly sensitive to procurement cost and technology acquisition strategy.

The analysis suggests that capital cost negotiation is the most critical determinant of financial viability. While operational improvements contribute positively, their impact remains insufficient to materially alter project feasibility unless initial investment cost is significantly reduced or strategic revenue benefits are monetized.

This finding is consistent with the cost composition shown in Figure 2, where capital expenditure accounts for the dominant share of total ownership cost.

5. CONCLUSION AND LIMITATION

This study evaluates the economic feasibility of Automated Storage and Retrieval System (ASRS) implementation in an Indonesian distribution warehouse using an ex-post case study approach. The findings show that ASRS implementation is not financially feasible under conventional investment criteria, as indicated by a 10-year Total Cost of Ownership (TCO) of IDR 91.92 billion, Net Present Value (NPV) of IDR -61.38 billion, and Payback Period of 29.6 years. These results indicate that measurable operational savings alone are insufficient to justify the scale of investment within the evaluated horizon.

However, ASRS delivers significant strategic value through a 181% increase in storage capacity, improved warehouse space utilization, and enhanced operational scalability. These findings suggest that warehouse automation investment should not be evaluated solely through short-term financial metrics, but also through long-term strategic and capacity-oriented perspectives. In this context, ASRS should be interpreted not only as a cost reduction mechanism, but also as a strategic infrastructure investment supporting long-term business growth and warehouse expansion capability.

This study contributes empirical evidence to the limited literature on ex-post financial evaluation of warehouse automation investment in emerging distribution markets such as Indonesia. For practitioners, the findings highlight that ASRS implementation should be justified not only through operational efficiency objectives, but also through long-term strategic business considerations.

This study has several limitations. First, the study is limited to a single case study, therefore the findings may not fully represent other warehouse environments with different operational characteristics. Second, the avoided cost model only includes measurable components such as warehouse rental savings and labor reduction, while other strategic benefits including revenue enablement, inventory accuracy improvement, and operational resilience were not quantitatively evaluated due to data limitations. Third, historical pre-ASRS operational data were unavailable, requiring the study to rely partially on industrial benchmarks and operational assumptions. In addition, several investment-related data were obtained through operational director interviews due to confidentiality limitations regarding procurement information.

Future research is recommended to develop a decision-making framework for evaluating ASRS investment feasibility by integrating financial and operational considerations prior to implementation.

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