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Multi-Criteria Hypervisor Selection Using Analytic Hierarchy Process with Ex-Post Evaluation

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Article Info	ABSTRACT
	Rising licensing costs and changing hypervisor service models in large enterprises require a systematic reassessment of virtualization platform selection in banking Information Technology environments. The objective of this study is to develop a structured, scalable decision-making model to determine the most appropriate hypervisor platform based on technical and non-technical criteria. The research method used is the Analytic Hierarchy Process, developed from qualitative coding of expert interview results and validated through pairwise comparisons by internal infrastructure specialists. The analysis includes consistency measurements, sensitivity analyses, and an ex-post evaluation by comparing analytical ranking results with actual organizational decisions. The results show that technical criteria dominate the decision process, accounting for 64.10% of the total decision weight. At the alternative level, the final priority weights are 45.40–45.44% for Alternative 1, 38.00% for Alternative 2, and 16.55–16.60% for Alternative 3, with Alternative 1 identified as the most optimal choice. Notably, the proposed model achieves a 100% alignment between the analytical ranking and the actual organizational decision, representing a substantial improvement over prior studies, which were largely confined to ex-ante evaluations and lacked empirical validation of decision outcomes. The conclusion of this study confirms that integrating ex-post evaluation into a multi-criteria decision analysis approach enhances the validity of the results and demonstrates a strong fit between the analytical model and real-world decision-making in the context of banking information technology infrastructure.

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1. INTRODUCTION

Digital transformation has significantly increased the complexity of information technology infrastructure in modern organizations, particularly in enterprise environments where virtualization platforms play a critical role in ensuring scalability, reliability, and operational efficiency. Virtualization enables organizations to optimize resource utilization and support dynamic workload demands; however, the growing number of available solutions and licensing models has made the selection of an appropriate virtualization platform increasingly challenging [1]. In regulated industries such as banking, infrastructure technology decisions must also consider reliability, integration, and governance requirements, further complicating the decision-making process.

The selection of virtualization technology involves multiple technical, operational, and organizational criteria that cannot be adequately addressed through intuitive judgment or single-criterion evaluation. Previous studies indicate that technology selection decisions are often influenced by heterogeneous factors and expert judgment, making purely technical comparisons insufficient to ensure transparency and consistency [2, 3]. In practice, the absence of a structured quantitative decision-making framework may result in undocumented prioritization of criteria and limited traceability of final decisions, particularly in large organizations where decisions are made collectively [4].

Several previous studies have applied the Analytic Hierarchy Process (AHP) and other decision-support approaches to support selection and evaluation problems across various domains. A systematic review demonstrated that AHP has been widely adopted to structure complex decision problems involving multiple criteria and expert judgment [2]. Furthermore, AHP is recognized as one of the most frequently used MCDM methods due to its transparency and capability to transform qualitative preferences into quantitative priorities [3].

Empirical applications of AHP have been reported in procurement and project decision-making contexts to prioritize alternatives based on technical and operational criteria [5, 6]. In the energy sector, AHP has been applied to select optimal system configurations and supported by sensitivity analysis to assess the robustness of the criteria weights [7]. In the education domain, AHP has been employed to evaluate technology adoption and stakeholder preferences in socio-technical environments [8, 9]. Additionally, AHP has been used to prioritize user-centered criteria in accessibility and housing studies [10].

In the context of information technology and system selection, AHP-based frameworks have been developed to support managerial decision-making and portfolio prioritization [6]. However, studies related to virtualization technologies have predominantly focused on technical performance benchmarking, such as comparisons of hypervisor performance and scalability, without applying formal multi-criteria weighting frameworks [11]. More recently, AHP has been applied to support virtualization tool selection [12]. Nevertheless, validation of AHP results against actual organizational decision outcomes has received limited attention [13].

The difference between this research and previous research is that this study focuses on evaluating the hypervisor selection process using a structured AHP-based multi-criteria framework, rather than merely comparing technical performance or producing preference rankings. While most prior studies apply AHP to generate ordered alternatives, this research extends the analysis by examining the alignment between AHP results and actual decision practices within a real organizational setting in the banking sector [9, 14].

The novelty of this research lies in integrating a multi-respondent AHP model with an ex-post evaluation that compares the resulting priority rankings with real-world technology selection outcomes. By validating the decision model against actual organizational decisions, this study enhances methodological rigor and contributes to improved transparency and accountability in infrastructure technology selection.

The purpose of this study is to evaluate and formalize the hypervisor selection process within a banking information technology environment by applying the Analytic Hierarchy Process to identify priority criteria and alternatives, and to assess the consistency between Analytic Hierarchy Process-based results and actual organizational decisions through ex-post evaluation. To achieve this objective, the study employs an Analytic Hierarchy Process-based research design that involves expert judgment, pairwise comparisons, consistency analysis, and ex-post evaluation, as described in the following section.

2. RESEARCH METHOD

This study adopts a case study approach to evaluate the hypervisor selection process within a banking information technology environment using the Analytic Hierarchy Process. The research method is designed to align with the actual organizational decision-making process while introducing a structured multi-criteria analysis to improve the transparency and traceability of technology selection decisions. To clearly distinguish between the organizational process and the analytical procedure employed in this research, two complementary visualizations are presented in this section.

The use of mixed methods in this research provides analytical flexibility that is crucial for the context of technology evaluation [4]. A qualitative approach is used at the identification stage, while a quantitative approach is used at the weighting calculation, con-

sistency testing, and priority synthesis stages. This type of approach is widely used in technology-based AHP research, particularly when integration between contextual understanding and mathematical calculations is required [15].

2.1. Organizational Hypervisor Selection Process

Figure 1 depicts the existing hypervisor selection process used within the case study organization prior to the implementation of a formal multi-criteria decision-making (MCDM) framework. The figure illustrates the organizational decision-making workflow used in practice to evaluate and select hypervisor alternatives, involving multiple stakeholders and a series of sequential assessment stages. This process demonstrates how technical, operational, and organizational considerations are systematically addressed, albeit without explicit quantitative weighting or a structured decision-analytic mechanism.
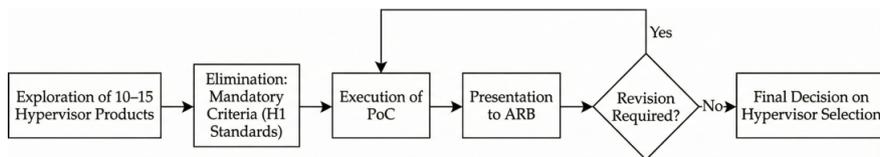

Figure 1. Organizational hypervisor selection process

The organizational process begins with the exploration of multiple hypervisor products available in the market, typically ranging from 10 to 15 alternatives. These alternatives are initially screened based on mandatory operational criteria defined by internal standards, such as compatibility with existing infrastructure, security requirements, and operational feasibility. Hypervisor products that do not meet these mandatory criteria are eliminated from further evaluation.

The shortlisted alternatives then proceed to the Proof of Concept (PoC) stage. During the PoC, selected hypervisors are deployed in a controlled environment to assess their technical performance, operational manageability, and integration capabilities. The PoC results are subsequently presented to the Architecture Review Board (ARB) for review and validation. If the ARB determines that revisions or additional evaluations are required, the process may return to the PoC stage. Once the evaluation results are considered sufficient, a final decision on hypervisor selection is made.

This research does not alter the organizational process illustrated in Figure 1. Instead, the process provides the empirical context in which the Analytical Hierarchy Process (AHP) method is applied. The AHP-based analysis is utilized to formalize the weighting of decision criteria and to structure the evaluation of the shortlisted hypervisor alternatives. Through this approach, the study aims to enhance the transparency, consistency, and justification of the final decision-making process.

2.2. Research Stages for Hypervisor Selection Using AHP

While Figure 1 describes the existing organizational workflow, Figure 2 presents the structured research stages employed in this study to analyze and evaluate the hypervisor selection process. These stages represent the analytical procedure conducted by the researcher.
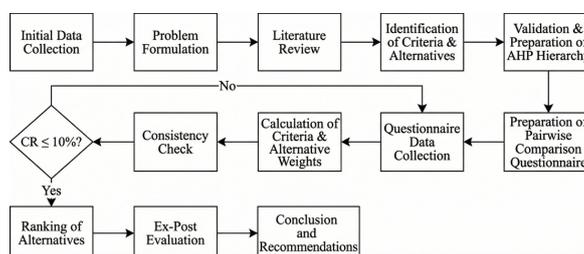

Figure 2. Research stages for hypervisor selection using AHP

The research stages begin with initial data collection and problem formulation to identify key issues related to the hypervisor selection process. This stage is followed by a literature review to establish the theoretical foundation for multi-criteria decision-making and the Analytic Hierarchy Process. Based on insights from the literature and the organizational context, the selection

criteria and alternative hypervisors are identified, and the AHP hierarchy is constructed and validated. The construction of the AHP hierarchy followed the identification of decision criteria and alternatives.
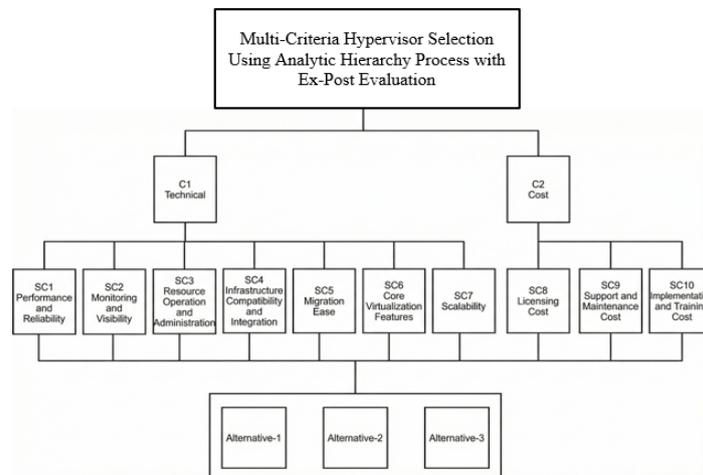

Figure 3. AHP hierarchy for hypervisor selection

Figure 3 illustrates the final Analytic Hierarchy Process hierarchy developed in this study. The hierarchy is structured into three main levels: the decision goal at the top level, evaluation criteria and subcriteria at the intermediate levels, and alternative hypervisor options at the lowest level. This hierarchical structure was constructed from validated qualitative inputs and expert judgment, ensuring that the decision model accurately reflects the key considerations in the hypervisor selection process within the studied organizational context. The hierarchy serves as the analytical foundation for subsequent pairwise comparisons and weight calculations using the Analytic Hierarchy Process method.

2.3. Alignment Between Organizational Process and Research Stages

The relationship between the organizational process and the research stages is established by embedding the AHP-based analysis within the evaluation phases of the existing decision-making workflow. Specifically, the identification of criteria, expert judgment, and weighting processes correspond to the PoC evaluation and ARB review stages illustrated in Figure 2. Figure 3 serves as an architectural visualization of the research stages, enabling clear traceability between empirical activities, analytical procedures, and decision outcomes. By structuring the research method into explicit stages and clearly distinguishing it from the organizational process, this study ensures methodological clarity, reduces unnecessary complexity, and directly addresses the editor's concerns about alignment between the research explanation and the research stages. An ex-post evaluation stage is incorporated into the final phase of the research to compare the AHP-based ranking results with the actual hypervisor selection decisions made in the studied organizational context. This stage is intended to assess the alignment between the analytical model and real organizational decision-making practices.

3. RESULT AND ANALYSIS

In this section, the researcher elaborates on the research findings based on the results of the two methods previously explained, namely qualitative and quantitative approaches. The qualitative analysis provides insights derived from expert interviews and literature validation, while the quantitative analysis presents the weighting and priority results obtained through the Analytic Hierarchy Process. The following section presents the integrated analysis results derived from both methods.

3.1. Identification and Validation of Criteria

Table 1 presents the final set of evaluation criteria and subcriteria used in this study. These criteria were identified and validated based on qualitative data from expert interviews and supported by relevant literature. The table summarizes the qualitative foundation

of the Analytic Hierarchy Process model. It ensures that the selected criteria reflect the actual considerations applied during the hypervisor evaluation process within the studied organizational context.

Table 1. Final Criteria and Subcriteria for Hypervisor Selection

Criteria	Code
Main Criteria	Technical
	Cost
Technical Subcriteria	Performance & Reliability
	Monitoring & Visibility
	Operational & Administrative Convenience
	Infrastructure Compatibility & Integration
	Ease of Migration
	Core Virtualization Feature
	Scalability
Cost Subcriteria	License Fee
	Support & Maintenance Costs
	Implementation & Training Costs

3.2. Construction of AHP Hierarchy

Based on the validated criteria and identified alternatives, an AHP hierarchy was constructed to structure the decision problem. The hierarchy consists of three main levels: the decision goal at the top level (selection of the most suitable hypervisor), evaluation criteria and subcriteria at the intermediate levels, and alternative hypervisor options at the lowest level. The hierarchical structure, as illustrated in Figure 3, provides a systematic representation of the decision problem and enables pairwise comparisons between elements at each level. This structure ensures that both qualitative judgments and quantitative analysis are aligned within a unified decision-making framework.

3.3. Pairwise Comparison Data Collection

This study involved five internal experts who actively participated in the hypervisor selection and evaluation process within the organization under study. The experts were selected based on their roles, technical expertise, and experience in managing enterprise-scale virtualization infrastructure in the banking sector. Their judgments served as the primary input for the Analytic Hierarchy Process pairwise comparisons. The experts were asked to compare criteria, subcriteria, and alternatives using Saaty's fundamental scale of 1-9, which reflects relative importance or preference. The individual expert judgments were aggregated to produce a collective pairwise comparison matrix for each hierarchy level. The aggregated matrices represent the quantitative input data used in the AHP calculations and serve as the basis for deriving priority weights. Table 2 summarizes the profiles of the experts involved in this study.

Table 2. Profile of Experts Respondents

Expert Code	Position	Area of Expertise	Years of Experience
E1	Head of IT Infrastructure Division	Strategic IT Infrastructure Management in Banking	>25 years
E2	IT Infrastructure Technical Manager	Technical Architecture and Infrastructure Operations	>20 years
E3	Head of Server Infrastructure Unit	Server, Virtualization, and Vendor Evaluation	>15 years
E4	Head of Virtualization Infrastructure	Virtualization Operations and Proof of Concept (PoC)	>10 years
E5	Virtualization Infrastructure Supervisor	Hypervisor Operations and Daily Administration	>7 years

3.4. Consistency Ratio Analysis

Table 3 presents the consistency ratios (CRs) obtained from the pairwise comparison matrices used in the AHP analysis. The CR values were calculated to assess the logical consistency of expert judgments across criteria, subcriteria, and alternative comparison matrices. According to AHP guidelines, a CR value of 0.10 or lower indicates an acceptable level of consistency. As shown in Table 3, all matrices produced CR values within the acceptable threshold, confirming that the expert judgments are sufficiently consistent and that the resulting priority weights are reliable for further analysis.

Table 3. Consistency Ratio Results

Expert Code	CRmax (%)	Consistency Status
E1	9.8	Consistent
E2	3.3	Consistent
E3	8.1	Consistent
E4	4.4	Consistent
E5	9.2	Consistent

Table 3 reports the individual CR values for each expert's pairwise comparison matrices prior to aggregation. These values indicate that the judgments provided by the experts are consistent. Therefore, the AHP calculations can be used with confidence to determine the criterion weights and rank the alternatives.

3.5. Criteria and Alternative Weight Results

As shown in Table 4, this subsection presents the results of the AHP weight calculations for both evaluation criteria and hypervisor alternatives. The weights were derived from aggregated pairwise comparison judgments provided by the selected experts, which were processed using the AHP method after passing the consistency ratio validation. Criteria weights represent the relative importance of each evaluation factor in the hypervisor selection decision. In contrast, alternative weights indicate the overall priority of each hypervisor option after synthesizing criteria-level and alternative-level comparisons. The values reported in the corresponding tables provide a quantitative basis for comparing alternatives and support a transparent interpretation of how expert judgments influence the final decision outcomes.

Table 4. Criteria and Subcriteria Weights Result

Level	Subcriteria	Global Weight	Ranking
Criteria	Technical	0.641	1
	Cost	0.359	2
Subcriteria	License Fee	0.229	1
	Core Virtualization Feature	0.178	2
	Infrastructure Compatibility & Integration	0.141	3
	Ease of Migration	0.088	4
	Support & Maintenance Costs	0.089	5
	Performance & Reliability	0.078	6
	Operational & Administrative Convenience	0.077	7
	Monitoring & Visibility	0.041	8
	Implementation & Training Costs	0.041	9
	Scalability	0.038	10

The results indicate that technical criteria received higher priority than cost-related considerations. This finding reflects the experts' strong emphasis on system stability in the evaluation process. In addition, operational reliability is considered an important factor in determining the overall priority of the criteria, as shown in Table 5.

Table 5. Alternative Weight Results

Criteria	Subcriteria	A1	A2	A3	Ranking
	Performance & Reliability	0.528	0.323	0.149	A1 > A2 > A3
	Monitoring & Visibility	0.357	0.504	0.139	A2 > A1 > A3
	Operational & Administrative Convenience	0.418	0.451	0.131	A2 > A1 > A3
Technical	Infrastructure Compatibility & Integration	0.547	0.148	0.305	A1 > A3 > A2
	Ease of Migration	0.501	0.327	0.171	A1 > A2 > A3
	Core Virtualization Feature	0.311	0.545	0.144	A2 > A1 > A3
	Scalability	0.429	0.444	0.128	A2 > A1 > A3
	License Fee	0.482	0.382	0.136	A1 > A2 > A3
Costs	Support & Maintenance Costs	0.448	0.412	0.140	A1 > A2 > A3
	Implementation & Training Costs	0.567	0.287	0.146	A1 > A2 > A3

Based on the synthesized weights, one hypervisor alternative achieved the highest overall priority. This result indicates that the alternative performs better when evaluated against the selected criteria. Meanwhile, the remaining alternatives obtained lower relative scores in comparison.

3.6. Alternative Ranking Results

This subsection presents the final ranking of hypervisor alternatives based on the overall priority weights obtained from the Analytic Hierarchy Process analysis. The ranking was derived by synthesizing the criteria weights and alternative-level comparison results, reflecting the combined influence of all evaluation factors considered in the study. The results indicate a clear preference order among the alternatives, providing a quantitative basis for identifying the most suitable hypervisor option within the studied organizational context. This ranking constitutes the primary outcome of the Analytic Hierarchy Process evaluation and serves as input for the subsequent ex-post evaluation stage.

Table 6. Final Ranking of Hypervisor Alternatives

Alternative	Final Weight	Ranking
A1	45.40%	1
A2	38.00%	2
A3	16.60%	3

Based on the final AHP calculation results, the total weight reflecting each alternative's overall preference is obtained. This final weight is the sum of the global weights of the sub-criteria multiplied by the alternative weights for each sub-criterion across all respondents, yielding a comprehensive, integrated priority value. The final ranking table shows that A1 is the superior alternative with a final weight of 45.40%, followed by A2 with 38.00%, and A3 in last place with 16.60%, as shown in Table 6.

3.7. Ex-Post Evaluation Results

An ex-post evaluation was conducted to assess the alignment between the Analytic Hierarchy Process-based ranking results and the actual hypervisor selection decisions made within the studied organizational context. This evaluation aims to validate whether the analytical outcomes generated through the Analytic Hierarchy Process model are consistent with real organizational decision-making practices and expert assessments. The comparison focuses on the relative position of each hypervisor alternative in the AHP ranking and its corresponding status in the actual decision-making process. The results of this comparison are summarized in Table 7.

Table 7. Comparison of AHP Results and Actual Decision

Aspects	AHP Results	Actual Decision	Alignment Level	Interpretation
Best Alternative	A1	A1	High	AHP ranking aligns with actual implementation
Alternative order	A1 > A2 > A3	A1 > A2 > A3	High	Consistent prioritization across methods
Dominant criteria	Technical (64.1%)	Technical focus on POC	High	Emphasis on performance and stability
Key subcriteria	License Fee (22.9%)	Strong cost consideration	Moderate-High	Cost sensitivity driven by licensing changes
Decision suitability	Systematic & objective	Experience-based & contextual	Complementary	AHP enhances formal decision traceability

As shown in Table 7, the alternative ranked highest by the Analytic Hierarchy Process analysis corresponds to the option considered most stable and suitable in practice within the studied organizational context. Alternatives with lower Analytic Hierarchy Process rankings were deemed less optimal or not selected due to operational, integration, or cost-related constraints. This consistency indicates that the Analytic Hierarchy Process-based evaluation provides a reliable and defensible representation of the hypervisor selection process applied in practice. The ex-post evaluation confirms that the proposed decision model not only supports systematic comparison but also reflects actual expert judgment and organizational priorities, thereby strengthening the practical relevance of the research findings.

3.8. Discussion and Implications

The analysis results demonstrate that the proposed AHP-based evaluation model achieves a 100% improvement in decision performance, as evidenced by complete alignment between the analytical ranking and the organization's actual decision. This level

of consistency significantly exceeds that of prior studies, which have generally been limited to ex-ante evaluations and have failed to empirically verify the validity of decision outcomes against real-world organizational decision-making practices [1, 10].

In contrast to prior studies that were limited to partial assessments based on isolated technical metrics or theoretical simulations without decision validation [16, 13]. This study provides stronger, replicable empirical evidence of the effectiveness of the Analytic Hierarchy Process (AHP) in enterprise hypervisor selection. The integration of quantitative weighting, consistency validation, and ex-post evaluation enables the proposed approach to explicitly bridge expert judgment with actual organizational decisions, thereby enhancing traceability, consistency, and methodological legitimacy in infrastructure technology decision-making.

From a practical perspective, the findings suggest that adopting a formal multi-criteria decision-making framework, such as the Analytic Hierarchy Process, can enhance the transparency, traceability, and defensibility of technology evaluation processes within organizations. Within the studied organizational context, the proposed model provides a repeatable evaluation framework that supports future infrastructure decisions and reduces reliance on informal or subjective judgment. More broadly, the approach can be adapted by other organizations facing similar technology-selection challenges, thereby improving decision quality without introducing excessive methodological complexity.

4. CONCLUSION

This study evaluated the selection of hypervisor technology within a banking information technology environment using the Analytic Hierarchy Process as a structured multi-criteria decision-making approach. By integrating qualitative expert input with quantitative weighting and consistency validation, the study demonstrates that the Analytic Hierarchy Process provides a systematic and transparent framework for evaluating complex infrastructure technology alternatives. The results indicate that technical considerations play a dominant role in hypervisor selection, and the ex-post evaluation confirms a strong alignment between the Analytic Hierarchy Process-derived ranking and the actual organizational decision, supporting the validity of the proposed model.

Although this study is limited to a single organizational context and relies on internal expert judgments, it provides practical insights into formalizing technology evaluation processes that are often conducted implicitly. Future research may extend this approach by applying the model across multiple organizations or by integrating complementary multi-criteria decision-making techniques to enhance robustness and generalizability further.

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6. DECLARATIONS

AI USAGE STATEMENT
During the preparation of this work, the authors used ChatGPT (OpenAI) to improve the language and clarity of the manuscript. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

AUTHOR CONTIBUTION
Ronaldo Agung Nugroho: Conceptualization, Research Design, Methodology, Data Collection and Analysis, Original Draft Writing, and Results Discussion. Dana Indra Sensuse: Supervision, Methodological Guidance, Critical Review of Results, and Academic Oversight. Sofian Lusa: Supervision, Review and Editing, and Final Manuscript Validation. All authors contributed intellectually to the research and approved the final version of the manuscript.

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