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Selection Of Asset Identification Technology For University Asset Logistics Management Using Fuzzy AHP

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Abstract

Asset logistics management plays a critical role in enhancing operational efficiency, accountability, and decision-making in higher education institutions. Although Universitas Mercubaktijaya has developed an Asset Management Information System, the selection of the most appropriate asset identification technology to support its implementation has not been systematically evaluated. This study aims to identify the most suitable asset identification technology using a Multi-Criteria Decision-Making (MCDM) approach based on the Fuzzy Analytic Hierarchy Process (Fuzzy AHP). The study involved nine experts who evaluated three technology alternatives—Barcode, Radio Frequency Identification (RFID), and Hybrid RFID–Barcode—against eight decision criteria. The results indicate that asset identification accuracy is the most influential criterion, with a weight of 0.1956, followed by reading speed and system integration, each with a weight of 0.1800. The global ranking reveals that the Hybrid RFID–Barcode alternative achieves the highest priority weight (0.4052), followed by RFID (0.3240) and Barcode (0.2708). The findings demonstrate that the hybrid approach is the most suitable asset identification technology for supporting university asset logistics management. The novelty of this study lies in the development of a Fuzzy AHP-based decision-making model that integrates asset management, logistics, and asset identification technologies to support the digital transformation of asset logistics management in higher education institutions.

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Keywords: Fuzzy Analytic Hierarchy Process (Fuzzy AHP); Asset Logistics Management; Asset Identification Technology; Radio Frequency Identification (RFID); Barcode

INTRODUCTION

Asset logistics management is a strategic function in higher education governance that aims to ensure institutional assets are managed effectively, efficiently, and sustainably throughout their lifecycle. From a logistics perspective, assets are not merely institutional property but strategic resources that undergo a series of interconnected processes, including identification, acquisition, storage, allocation, utilization, maintenance, relocation, monitoring, and disposal. Consequently, the effectiveness of asset logistics management largely depends on an organization's ability to generate accurate, up-to-date, and traceable asset information to support operational and strategic decision-making.

In higher education institutions, assets comprise a wide range of resources, including laboratory equipment, information technology devices, operational vehicles, teaching facilities, and other supporting infrastructure distributed across faculties, academic departments, laboratories, and administrative units. The increasing number, diversity, and mobility of these assets have significantly increased the complexity of asset logistics management. Key challenges include asset identification, data recording, location tracking, movement control, maintenance scheduling, auditing, and timely reporting. When these processes are conducted manually or rely on inadequate identification systems, organizations face a higher risk of data inaccuracies, asset loss, delayed information updates, and inefficient asset management.

Universitas Mercubaktijaya has developed a web-based Asset Management Information System (AMIS) to improve institutional asset governance. The system was designed to support integrated asset registration, allocation, relocation, monitoring, maintenance, and reporting. However, previous studies primarily focused on the development of the information system itself and did not systematically evaluate the most appropriate asset identification technology to support its implementation. In practice, the success of digital asset management depends not only on software capabilities but also on the effectiveness of asset identification technologies in providing accurate, timely, and integrated asset information.

Within the context of asset logistics management, asset identification technologies serve as fundamental components for establishing asset visibility and asset traceability.

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Among the most widely adopted technologies are Barcode and Radio Frequency Identification (RFID). Barcode technology offers several advantages, including low implementation cost, ease of deployment, and compatibility with various asset management systems. Nevertheless, barcode scanning requires a direct line-of-sight and each asset must be scanned individually, making it less efficient for managing a large number of assets. Conversely, RFID enables contactless identification, simultaneous reading of multiple tags, and faster, more accurate asset tracking. However, RFID implementation generally requires higher initial investment and infrastructure costs; therefore, selecting the appropriate technology should consider operational requirements as well as asset characteristics.

Recent technological developments have encouraged the adoption of a Hybrid RFID–Barcode approach, which combines the strengths of both technologies to balance operational efficiency and implementation cost. Under this approach, RFID is typically applied to high-value, high-mobility, or mission-critical assets requiring intensive monitoring, while Barcode is used for relatively static and lower-value assets. Such a strategy enables organizations to maximize the benefits of both technologies without requiring full RFID deployment across all institutional assets.

Previous studies have demonstrated that both RFID and Barcode technologies improve asset identification accuracy, enhance asset tracking, and increase operational efficiency across manufacturing, warehousing, healthcare, and supply chain environments. However, most existing studies have focused either on the implementation of a single identification technology or on the development of asset management information systems independently. Research integrating asset logistics management, asset identification technologies, and multi-criteria decision-making within the higher education context remains limited. Consequently, a significant research gap exists regarding decision-making models capable of determining the most appropriate asset identification technology based on multiple technical, operational, and economic criteria.

One of the most widely adopted approaches for addressing multi-criteria decision-making problems is Multi-Criteria Decision-Making (MCDM) using the Fuzzy Analytic Hierarchy Process (Fuzzy AHP). Compared with the conventional Analytic Hierarchy Process (AHP), Fuzzy AHP incorporates Triangular Fuzzy Numbers (TFNs) to better accommodate uncertainty and subjectivity in expert judgments, thereby producing more reliable and representative priority weights. In this study, Fuzzy AHP is employed to evaluate three alternative asset identification technologies—Barcode, RFID, and Hybrid RFID–Barcode—based on eight evaluation criteria: implementation cost, asset

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identification accuracy, reading speed, ease of implementation, integration with the Asset Management Information System, system scalability, data security, and maintenance cost.

The novelty of this study lies in the development of a Fuzzy AHP-based decision-making model for selecting the most appropriate asset identification technology to support asset logistics management in higher education institutions. Unlike previous studies that primarily focused on designing asset management information systems or evaluating individual identification technologies, this research proposes a systematic decision-making framework that integrates technical, operational, economic, and logistics perspectives. The proposed model not only prioritizes alternative technologies but also provides an objective basis for universities to formulate phased implementation strategies according to the characteristics and operational requirements of institutional assets.

Based on the above considerations, this study aims to determine the most appropriate asset identification technology for supporting asset logistics management at Universitas Mercubaktijaya using a Multi-Criteria Decision-Making (MCDM) approach based on the Fuzzy Analytic Hierarchy Process (Fuzzy AHP). The findings are expected to facilitate the implementation of more effective asset identification technologies, improve the quality of asset logistics management, strengthen integration with the Asset Management Information System, and contribute to the advancement of knowledge in the fields of logistics management, asset management, and decision support systems.

METHODE

This study employed a quantitative research approach using the Multi-Criteria Decision-Making (MCDM) method based on the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) to determine the most appropriate asset identification technology for supporting asset logistics management at Universitas Mercubaktijaya. Fuzzy AHP was selected because it effectively accommodates uncertainty and subjectivity in expert judgments through the application of Triangular Fuzzy Numbers (TFNs), thereby generating more representative priority weights than the conventional Analytic Hierarchy Process (AHP).

The object of this study was the selection of asset identification technology to support the implementation of the Asset Management Information System (AMIS) in university asset logistics management. Three technology alternatives were evaluated: Barcode (A1), Radio Frequency Identification (RFID) (A2), and Hybrid RFID–Barcode (A3). These alternatives were assessed using eight evaluation criteria: implementation cost (C1), asset identification accuracy (C2), reading speed (C3), ease of implementation

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(C4), integration with the Asset Management Information System (C5), system scalability (C6), data security (C7), and maintenance cost (C8). The evaluation criteria were established through an extensive literature review and subsequently validated by experts with professional expertise in asset management, logistics management, and information technology.

The study utilized both primary and secondary data sources. Primary data were collected through pairwise comparison questionnaires administered to expert respondents using Saaty's linguistic scale, which was subsequently converted into Triangular Fuzzy Numbers (TFNs). Expert respondents were selected using a purposive sampling technique. The selection criteria required respondents to possess more than five years of professional experience and demonstrated expertise in asset management, logistics management, information systems, or information technology within higher education institutions. Secondary data were obtained from institutional asset management documents, Standard Operating Procedures (SOPs) for asset management, asset management reports, and relevant scientific literature supporting the research objectives.

The data analysis was conducted through several sequential stages. The first stage involved constructing the decision hierarchy, consisting of the research objective, evaluation criteria, and technology alternatives. The second stage involved developing the pairwise comparison matrix based on expert judgments. The third stage converted the comparison values into Triangular Fuzzy Numbers (TFNs). The subsequent stages included calculating the fuzzy synthetic extent, performing defuzzification, normalizing the priority weights, and determining the priority weights of both the evaluation criteria and technology alternatives. The resulting priority weights were then used to rank the alternative asset identification technologies in order to identify the most suitable technology for supporting university asset logistics management.

Before performing the weighting process, the consistency of expert judgments was evaluated using the Consistency Ratio (CR). The CR value was calculated based on the Consistency Index (CI) and the Random Index (RI), as presented in Equations (1) and (2).

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$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$CR = \frac{CI}{RI}$$

where:

- CI = Consistency Index;
- CR = Consistency Ratio;
- RI = Random Index;
- λmax = maximum eigenvalue;
- n = number of evaluation criteria.

A pairwise comparison matrix was considered consistent when the Consistency Ratio (CR) was less than or equal to 0.10, indicating that the expert judgments were sufficiently reliable for further analysis using the Fuzzy AHP method.

The overall research procedure began with the identification of problems related to asset logistics management, followed by the determination of evaluation criteria and asset identification technology alternatives, questionnaire development, expert data collection, Fuzzy AHP analysis, and finally the formulation of recommendations for the most appropriate asset identification technology to support asset logistics management at Universitas Mercubaktijaya. The research procedure consisted of the following stages:

1. Identification of problems related to asset logistics management at Universitas Mercubaktijaya.
2. Comprehensive literature review and determination of the evaluation criteria.
3. Development of the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) decision hierarchy.
4. Design and administration of pairwise comparison questionnaires for expert evaluation.
5. Collection and aggregation of expert judgments.
6. Data processing and analysis using the Fuzzy AHP method.
7. Calculation of priority weights and consistency verification.
8. Ranking of the alternative asset identification technologies.
9. Formulation of implementation recommendations for the selected technology to enhance university asset logistics management.

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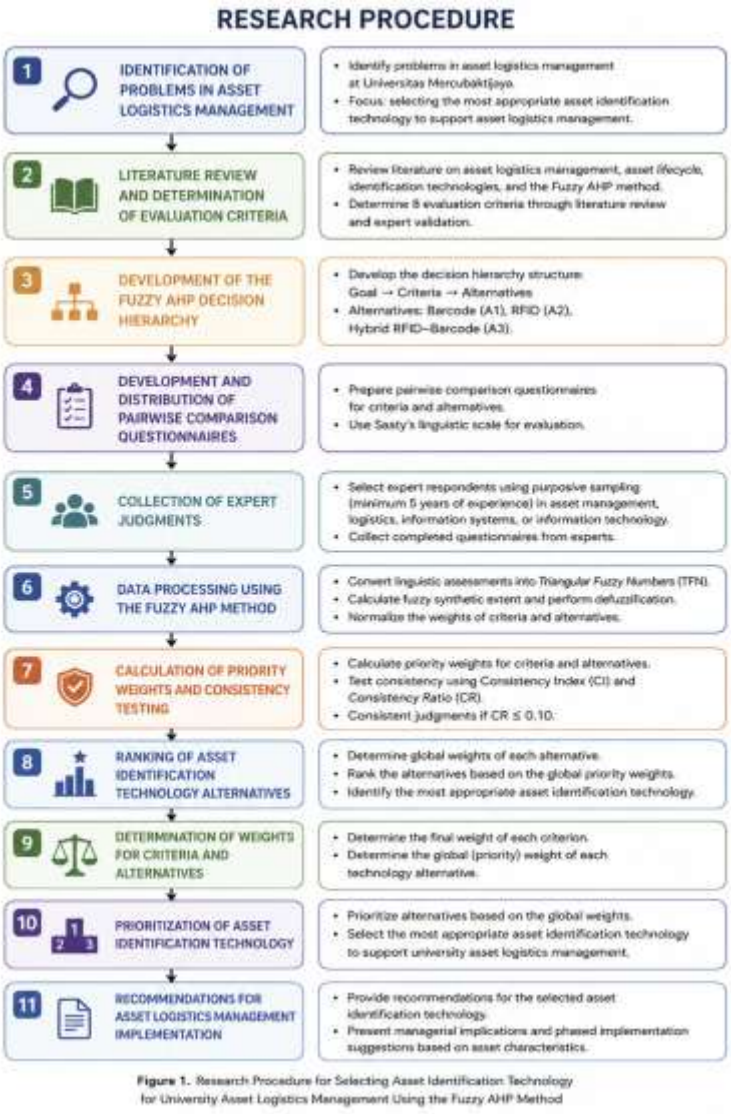


Figure 1. Research Procedure for Selecting Asset Identification Technology for University Asset Logistics Management Using the Fuzzy AHP Method

Figure 1. Research Procedure

RESULTS

Description of Expert Respondents

This study involved nine expert respondents selected using a purposive sampling technique. All respondents possessed more than five years of professional experience in

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asset management, logistics management, information systems, or information technology within higher education institutions. The selection of these experts aimed to ensure that the evaluation reflected diverse perspectives on asset logistics management, ranging from institutional asset administration and information system development to the implementation of asset identification technologies.

Table 2. Characteristics of Expert Respondents

Code	Field/Position	Experience	Role in the Study
R1	Head of Asset and Transportation Division	>5 years	Evaluated university asset management, registration, monitoring, and tracking practices.
R2	Head of the Bureau of Administration, Finance, and General Affairs (BAUK)	>5 years	Assessed policy, administrative, budgeting, and technology implementation sustainability aspects.
R3	Asset Management Officer	>5 years	Evaluated operational processes related to asset registration, allocation, relocation, and reporting.
R4	Information Technology Officer	>5 years	Assessed infrastructure readiness, system integration, data security, and technology compatibility.
R5	Information System Developer	>5 years	Evaluated the integration capability of RFID and Barcode technologies with the Asset Management Information System (AMIS).
R6	Lecturer in Logistics	>5 years	Evaluated the alternatives from the perspectives of logistics management, asset flow, and operational efficiency.
R7	Lecturer in Information Systems	>5 years	Evaluated system architecture, digitalization, data security, and technology scalability.

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R8	Laboratory Manager	>5 years	Assessed identification, monitoring, and tracking requirements for high-value laboratory equipment.
R9	Operational Asset User	>5 years	Evaluated usability, scanning practicality, and technology suitability for daily operational activities.

The composition of the expert respondents provided a relatively balanced perspective for the evaluation process. Asset managers assessed requirements related to asset registration and tracking, information technology specialists evaluated system integration and data security, while operational asset users assessed ease of use, practicality, and the long-term sustainability of technology implementation.

Decision Hierarchy Structure

The decision model consisted of three hierarchical levels. The first level represented the research objective, namely selecting the most appropriate asset identification technology to support university asset logistics management. The second level comprised eight evaluation criteria, while the third level consisted of three technology alternatives.

Table 3. Decision Criteria and Technology Alternatives

Code	Criterion	Attribute
C1	Implementation Cost	Cost
C2	Asset Identification Accuracy	Benefit
C3	Reading Speed	Benefit
C4	Ease of Implementation	Benefit
C5	Integration with the Asset Management Information System (AMIS)	Benefit
C6	System Scalability	Benefit
C7	Data Security	Benefit
C8	Maintenance Cost	Cost

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Technology Alternatives:

Code	Alternative
A1	Barcode
A2	Radio Frequency Identification (RFID)
A3	Hybrid RFID–Barcode

The inclusion of the Hybrid RFID–Barcode alternative was based on the diverse characteristics of university assets. RFID is more suitable for high-value, highly mobile, or mission-critical assets that require rapid identification and continuous monitoring, whereas Barcode is appropriate for general-purpose assets that are relatively static and exist in large quantities. Previous studies have also demonstrated that RFID is more effective for simultaneous asset identification and tracking, whereas Barcode provides a more economical solution for individual asset identification. Consequently, the Hybrid approach offers a balanced solution by combining the operational efficiency of RFID with the cost-effectiveness of Barcode, making it more suitable for supporting university asset logistics management.

Fuzzy Evaluation Scale

Expert judgments were obtained using Saaty's pairwise comparison scale. The linguistic judgments were subsequently converted into Triangular Fuzzy Numbers (TFNs) to accommodate uncertainty and subjectivity in expert evaluations.

Table 4. Linguistic Scale and Triangular Fuzzy Numbers (TFNs)

Saaty's Scale	Linguistic Judgment	Triangular Fuzzy Number (TFN)
1	Equally Important	(1, 1, 1)
2	Between Equally and Slightly More Important	(1, 2, 3)
3	Slightly More Important	(2, 3, 4)
4	Between Slightly and Moderately More Important	(3, 4, 5)
5	Moderately More Important	(4, 5, 6)

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6	Between Moderately and Strongly More Important	(5, 6, 7)
7	Strongly More Important	(6, 7, 8)
8	Between Strongly and Extremely More Important	(7, 8, 9)
9	Extremely More Important	(9, 9, 9)

Reciprocal values were applied whenever the element in the row was considered less important than the corresponding element in the column. For example, if a comparison was assigned a value of **3**, its reciprocal comparison was assigned a value of **1/3**.

Aggregated Results of Criteria Evaluation

The judgments provided by the nine expert respondents were aggregated using the geometric mean method. The aggregated pairwise comparison matrix for the evaluation criteria is presented in Table 5.

Table 5. Aggregated Pairwise Comparison Matrix of the Evaluation Criteria

Criteria	C1	C2	C3	C4	C5	C6	C7	C8
C1	1	1/2	1/2	1	1/2	1	1	2
C2	2	1	1	3	1	2	2	4
C3	2	1	1	2	1	2	2	3
C4	1	1/3	1/2	1	1/2	1	1	1
C5	2	1	1	2	1	2	2	3
C6	1	1/2	1/2	1	1/2	1	1	2
C7	1	1/2	1/2	1	1/2	1	1	2
C8	1/2	1/4	1/3	1	1/3	1/2	1/2	1

The aggregated comparison matrix indicates that asset identification accuracy, reading speed, and system integration were consistently considered more important than maintenance cost and ease of implementation. These findings reflect the university's priority for obtaining accurate, reliable, and rapidly updated asset information through the Asset Management Information System (AMIS). From the perspective of asset logistics management, these criteria are fundamental to improving asset visibility, asset

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traceability, and the efficiency of asset-related decision-making throughout the asset lifecycle.

Consistency Test of the Criteria Judgments

Before performing the fuzzy weighting process, the pairwise comparison matrix was evaluated to determine the consistency of the expert judgments using the maximum eigenvalue (λ_{max}), Consistency Index (CI), and Consistency Ratio (CR).

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

$$CR = \frac{CI}{RI}$$

The consistency test produced the following results:

- Number of evaluation criteria (**n**) = **8**
- $Maximum\ eigenvalue/\ \lambda_{\max} = 8{,}0528;$
- $Consistency\ Index/\ CI = 0{,}0075;$
- $Random\ Index/\ RI = 1{,}41;$
- $Consistency\ Ratio/\ CR = 0{,}0053.$

Since the Consistency Ratio (CR) was 0.0053, which is lower than the acceptable threshold of 0.10, the pairwise comparison matrix was considered consistent. Therefore, the expert judgments were deemed sufficiently reliable for the subsequent weighting process using the Fuzzy Analytic Hierarchy Process (Fuzzy AHP).

Criteria Weighting Results Using Fuzzy AHP

The criteria weights were calculated using the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) based on the fuzzy geometric mean approach. After converting the pairwise comparison values into Triangular Fuzzy Numbers (TFNs), the analysis proceeded through the calculation of the fuzzy geometric mean, estimation of fuzzy weights, defuzzification using the Center of Area (COA) method, and normalization of the resulting weights.

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Table 6. Fuzzy Weights and Final Priority Weights of the Evaluation Criteria

Criteria	Fuzzy Weight (l, m, u)	Final Weight	Rank
C1 Implementation Cost	(0.0581, 0.0960, 0.1781)	0.0996	4
C2 Asset Identification Accuracy	(0.1097, 0.2019, 0.3409)	**0.1956**	**1**
C3 Reading Speed	(0.0956, 0.1852, 0.3198)	**0.1800**	**2**
C4 Ease of Implementation	(0.0560, 0.0837, 0.1424)	0.0846	7
C5 System Integration	(0.0956, 0.1852, 0.3198)	**0.1800**	**2**
C6 System Scalability	(0.0581, 0.0960, 0.1781)	0.0996	4
C7 Data Security	(0.0581, 0.0960, 0.1781)	0.0996	4
C8 Maintenance Cost	(0.0336, 0.0562, 0.1138)	0.0610	8
Total		**1.0000**	

Asset identification accuracy received the highest priority weight (0.1956), indicating that accurate information regarding the identity, location, condition, and operational status of assets is considered the primary requirement for effective asset logistics management. This finding suggests that asset managers place the greatest emphasis on the reliability and accuracy of asset-related information to support operational and strategic decision-making.

Both reading speed and system integration obtained a priority weight of 0.1800, highlighting the importance of selecting an asset identification technology capable of accelerating asset identification and tracking processes while ensuring seamless integration with the Asset Management Information System (AMIS). Efficient integration enables automatic synchronization between identification devices and the institutional database, thereby improving asset visibility, asset traceability, and the timeliness of asset information updates.

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In the previously developed asset management framework, the core business processes include asset registration, allocation, relocation, monitoring, damaged asset reporting, disposal, and reporting. Therefore, integrating asset identification technologies with the institutional database represents a strategic organizational requirement rather than merely an additional system feature. Such integration supports continuous information flow throughout the asset lifecycle, enabling more effective planning, monitoring, and control of institutional assets.

Furthermore, implementation cost, system scalability, and data security each obtained a priority weight of 0.0996, indicating that these criteria remain important considerations in technology selection. In contrast, maintenance cost received the lowest priority weight (0.0610). This finding does not imply that maintenance cost is insignificant; rather, it demonstrates that the expert respondents prioritized system accuracy, operational reliability, and long-term effectiveness over short-term cost savings when selecting the most appropriate asset identification technology.

Evaluation of Technology Alternatives Under Each Criterion

Each technology alternative was evaluated through pairwise comparisons under each evaluation criterion. The local priority weights, obtained after the processes of fuzzification, defuzzification, and normalization, are presented in Table 7.

Table 7. Local Priority Weights of Technology Alternatives Under Each Criterion

Criteria	Barcode	RFID	Hybrid RFID–Barcode	Best Alternative
C1 Implementation Cost	0.5190	0.1730	0.3079	Barcode
C2 Asset Identification Accuracy	0.1508	0.4246	0.4246	RFID and Hybrid
C3 Reading Speed	0.1508	0.4246	0.4246	RFID and Hybrid
C4 Ease of Implementation	0.5190	0.1730	0.3079	Barcode
C5 System Integration	0.2546	0.2546	0.4907	Hybrid
C6 System Scalability	0.1850	0.3790	0.4360	Hybrid

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C7 Data Security	0.2268	0.3866	0.3866	RFID and Hybrid
C8 Maintenance Cost	0.5190	0.1730	0.3079	Barcode

The results reveal a clear performance pattern among the three technology alternatives. Barcode outperformed the other alternatives in terms of implementation cost, ease of implementation, and maintenance cost, reflecting its affordability and operational simplicity. In contrast, RFID demonstrated superior performance in asset identification accuracy, reading speed, and data security, making it particularly suitable for applications requiring high levels of asset visibility and traceability. Meanwhile, the Hybrid RFID–Barcode alternative achieved consistently high scores by combining the technical advantages of RFID with the implementation flexibility and cost-effectiveness of Barcode. This combination enables the Hybrid approach to provide a balanced solution for supporting university asset logistics management across diverse asset categories.

Consistency Test of the Alternative Judgments

Table 8. Consistency Ratio of the Pairwise Comparison Matrices for Technology Alternatives

Criterion	Consistency Ratio (CR)	Result
C1 Implementation Cost	0,0079	Consistent
C2 Asset Identification Accuracy	0,0000	Consistent
C3 Reading Speed	0,0000	Consistent
C4 Ease of Implementation	0,0079	Consistent
C5 System Integration	0,0000	Consistent
C6 System Scalability	0,0158	Consistent
C7 Data Security	0,0000	Consistent
C8 Maintenance Cost	0,0079	Consistent

All Consistency Ratio (CR) values were below the acceptable threshold of 0.10, indicating that the pairwise comparison matrices for all technology alternatives satisfied the consistency requirement. Therefore, the expert judgments were considered sufficiently reliable for the subsequent calculation of the global priority weights using the Fuzzy Analytic Hierarchy Process (Fuzzy AHP).

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Calculation of Global Priority Weights

The global priority weight of each technology alternative was obtained by multiplying the weight of each evaluation criterion by the corresponding local priority weight of the alternative under that criterion. The overall priority of each alternative was then calculated by summing these weighted values across all evaluation criteria.

The global priority weight of each alternative was calculated using the following equation:

$$P(A_j) = \sum_{i-1}^{8} w_i \times p_{ij}$$

where:

- $P(A_j)$= global priority weight of the j-th technology alternative;
- w_i= priority weight of the i-th evaluation criterion;
- p_{ij}= local priority weight of the j-th technology alternative with respect to the i-th evaluation criterion.

Table 9. Contribution of Each Evaluation Criterion to the Technology Alternatives

Criteria	Barcode	RFID	Hybrid RFID–Barcode
C1 Implementation Cost	0.0517	0.0172	0.0307
C2 Asset Identification Accuracy	0.0295	0.0831	0.0831
C3 Reading Speed	0.0272	0.0764	0.0764
C4 Ease of Implementation	0.0439	0.0146	0.0260
C5 System Integration	0.0458	0.0458	0.0883
C6 System Scalability	0.0184	0.0377	0.0434
C7 Data Security	0.0226	0.0385	0.0385
C8 Maintenance Cost	0.0317	0.0106	0.0188
Global Priority Weight	0.2708	0.3240	0.4052

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Final Ranking of Technology Alternatives

Table 10. Final Ranking of Technology Alternatives

Rank	Technology Alternative	Global Priority Weight	Percentage
1	Hybrid RFID–Barcode	0.4052	40.52%
2	Radio Frequency Identification (RFID)	0.3240	32.40%
3	Barcode	0.2708	27.08%
	Total	1.0000	100%

The final ranking indicates that Hybrid RFID–Barcode achieved the highest global priority weight (0.4052), followed by Radio Frequency Identification (RFID) with a weight of 0.3240, and Barcode with a weight of 0.2708. Accordingly, the Hybrid RFID–Barcode approach is recommended as the most appropriate asset identification technology for supporting asset logistics management at Universitas Mercubaktijaya.

The difference in global priority weights between Hybrid RFID–Barcode and RFID was 0.0812, while the difference between Hybrid RFID–Barcode and Barcode was 0.1344. These findings indicate that the superiority of the Hybrid approach is not solely attributable to the advanced capabilities of RFID technology, but also to its ability to balance multiple, and often conflicting, organizational requirements. By combining the high identification accuracy, rapid reading capability, and system integration offered by RFID with the cost-effectiveness and implementation flexibility of Barcode, the Hybrid approach provides a more comprehensive and practical solution for managing diverse categories of university assets.

From the perspective of asset logistics management, the Hybrid RFID–Barcode approach enhances asset visibility, asset traceability, asset monitoring, and asset lifecycle management, while maintaining implementation costs at a reasonable level. Consequently, this approach offers an effective strategy for supporting the digital transformation of asset logistics management in higher education institutions.

DISCUSSION

The criteria weighting results indicate that the selection of an asset identification technology is influenced more by the quality and reliability of asset information than by cost considerations. Asset identification accuracy emerged as the highest-priority criterion because inaccurate asset data may adversely affect asset allocation, relocation,

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monitoring, auditing, maintenance, and reporting processes throughout the asset lifecycle. Previous studies on the Asset Management Information System (AMIS) at Universitas Mercubaktijaya reported several challenges, including duplicate asset records, data entry errors, limited traceability of asset histories, and inefficient reporting processes. Consequently, an asset identification technology capable of minimizing data recording errors represents a strategic requirement for enhancing asset logistics management.

Reading speed received the second-highest priority weight because manual asset identification or one-by-one barcode scanning is relatively time-consuming, particularly when institutional assets are distributed across multiple buildings, departments, and operational units. RFID technology enables the simultaneous reading of multiple asset tags without requiring direct line-of-sight, thereby significantly improving operational efficiency. In contrast, Barcode technology requires each label to be scanned individually and depends on the physical visibility and condition of the barcode label.

System integration also received a high priority weight because asset identification technologies should function as primary data acquisition tools for the Asset Management Information System (AMIS) rather than as standalone devices. Within the existing asset management framework at Universitas Mercubaktijaya, the database already supports asset registration, location management, asset relocation, user management, and reporting. Therefore, data collected through RFID or Barcode scanning should automatically update asset identity, location, condition, and historical records, thereby improving asset visibility, asset traceability, and data consistency throughout the asset lifecycle.

The superior performance of the Hybrid RFID–Barcode alternative was primarily driven by its contribution to system integration (0.0883), asset identification accuracy (0.0831), and reading speed (0.0764). The Hybrid approach enables the university to implement RFID selectively for assets requiring higher levels of monitoring and operational control, including:

- High-value laboratory equipment;
- Laptops, computers, and other information technology devices;
- Assets frequently transferred between departments;
- Operational vehicles and selected operational equipment; and
- Assets requiring intensive auditing and traceability.
-

Conversely, Barcode technology can be effectively applied to:

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- Desks, chairs, cabinets, and office furniture;
- Office equipment with relatively low mobility;
- Assets with relatively low economic value; and
- Large quantities of assets that do not require real-time tracking.

This classification strategy enables the university to avoid deploying RFID tags across all institutional assets. Instead, RFID implementation can be prioritized for critical assets, while Barcode continues to support general asset identification. Such an approach reduces initial investment costs without sacrificing the operational advantages of RFID for high-priority assets. These findings are consistent with previous studies suggesting that integrating RFID and Barcode technologies provides a more effective solution than relying exclusively on either technology.

Although RFID ranked second overall, it demonstrated outstanding performance in terms of asset identification accuracy, reading speed, data security, and system scalability. However, its overall ranking was reduced by relatively lower performance in implementation cost, ease of implementation, and maintenance cost. A full RFID deployment requires substantial investment in RFID tags, readers, antennas, communication infrastructure, middleware configuration, and user training. Therefore, implementing RFID across all university assets is not yet the most cost-effective strategy under current institutional conditions.

Barcode ranked third despite outperforming the other alternatives in terms of implementation cost, ease of implementation, and maintenance cost. This result does not imply that Barcode is an unsuitable technology. On the contrary, Barcode remains a practical and reliable solution for supporting asset logistics management, particularly because of its low cost, ease of label production, and compatibility with relatively simple scanning devices. Nevertheless, its dependence on line-of-sight, individual scanning, and vulnerability to label damage limits its effectiveness when used as the sole identification technology in complex asset management environments.

Overall, the Fuzzy AHP results demonstrate that the optimal strategy is not to replace Barcode entirely with RFID, but rather to implement both technologies selectively according to asset characteristics, economic value, operational risk, mobility, and monitoring requirements. This segmented implementation strategy forms the basis for recommending the Hybrid RFID–Barcode approach as the most appropriate asset identification technology for supporting asset logistics management at Universitas Mercubaktijaya. Beyond providing the highest global priority weight, the Hybrid approach offers the best balance between operational efficiency, technological capability,

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implementation cost, and long-term sustainability, making it the most suitable solution for the digital transformation of university asset logistics management.

CONCLUSION

This study aimed to determine the most appropriate asset identification technology to support asset logistics management at Universitas Mercubaktijaya by applying a Multi-Criteria Decision-Making (MCDM) approach using the Fuzzy Analytic Hierarchy Process (Fuzzy AHP). The findings indicate that asset identification accuracy is the most critical evaluation criterion, with a priority weight of 0.1956, followed by reading speed and integration with the Asset Management Information System (AMIS), each receiving a priority weight of 0.1800. These results suggest that the effectiveness of asset logistics management depends primarily on the capability of identification technologies to provide accurate, timely, and integrated asset information rather than solely on implementation costs.

The ranking of technology alternatives revealed that the Hybrid RFID–Barcode approach achieved the highest global priority weight (0.4052), followed by RFID (0.3240) and Barcode (0.2708). Accordingly, the Hybrid RFID–Barcode approach is recommended as the most suitable asset identification technology for supporting asset logistics management at Universitas Mercubaktijaya. This approach enables RFID to be selectively deployed for high-value and highly mobile assets, while Barcode is applied to relatively static general-purpose assets, thereby achieving an effective balance between operational efficiency and implementation cost.

From the perspective of Asset Logistics Management, the implementation of the Hybrid RFID–Barcode approach contributes to improving asset visibility, asset traceability, asset movement, asset utilization, and asset monitoring, thereby supporting more effective asset management throughout the asset lifecycle, including acquisition, identification, inventory, utilization, maintenance, relocation, and disposal. Consequently, asset identification technology should not be regarded merely as a tool for asset registration but as a strategic component that supports the digital transformation of asset logistics management in higher education institutions.

The novelty of this study lies in the development of a Fuzzy AHP-based decision-making model that integrates the principles of Asset Logistics Management with asset identification technologies to support university asset logistics management. The proposed model provides an objective framework for selecting asset identification technologies by simultaneously considering technical, operational, economic, and

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logistics-related criteria. Therefore, it can serve as a practical reference for higher education institutions and other organizations with similar asset management characteristics.

Despite these contributions, this study has several limitations. First, the weighting of evaluation criteria and technology alternatives was based on expert judgments, meaning that the results are influenced by the respondents' knowledge and professional experience. Second, the study did not conduct a full-scale operational implementation to compare the real-world performance of Barcode, RFID, and Hybrid RFID–Barcode technologies. Third, several important factors, including cost–benefit analysis, infrastructure readiness, user acceptance, and integration with other digital technologies, were beyond the scope of this research.

Future studies are therefore encouraged to implement the Hybrid RFID–Barcode approach through a pilot project in an operational environment to evaluate its impact on asset visibility, asset tracking efficiency, asset data accuracy, inventory processing time, and the overall effectiveness of university asset logistics management. Furthermore, future research may extend the proposed decision-making framework by integrating other Multi-Criteria Decision-Making (MCDM) methods, such as Fuzzy TOPSIS, the Analytic Network Process (ANP), or the Best–Worst Method (BWM). The integration of RFID technology with emerging digital technologies—including the Internet of Things (IoT), Artificial Intelligence (AI), and Digital Twin—also represents a promising direction for developing more intelligent, adaptive, and sustainable asset logistics management systems.

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