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Integrated ABC–VED–AHP Framework for Prioritizing Returned Materials in Electricity Transmission Warehouse Management

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***Abstract*—Returned materials in electricity transmission warehouses represent ex-operational assets that may still contain economic value and operational utility. However, their accumulation can reduce warehouse efficiency, increase storage burden, and delay asset recovery decisions. In PT PLN (Persero) transmission warehouses, warehouse capacity utilization reached an average of 93.29%, exceeding the recommended operational threshold, with several warehouses experiencing overcapacity conditions. Existing classification practices remain administrative and do not provide a systematic basis for determining whether materials should be retained, repaired, reused, transferred, or disposed of. This study proposes an integrated multi-criteria decision framework for prioritizing returned materials by combining ABC analysis, VED analysis, physical condition assessment, reuse potential evaluation, and the Analytic Hierarchy Process (AHP). The framework was applied to 580 returned material items with a total replacement value of IDR 256,057,003,073. The AHP results show that operational criticality is the most influential criterion with a weight of 0.5342, followed by physical condition, economic value, and reuse potential. The consistency ratio was 0.0455, indicating consistent expert judgment. The final prioritization classified 397 items as high priority, 116 items as medium priority, and 67 items as low priority. The proposed framework supports more objective, transparent, and data-driven decision-making in returned material management and contributes to warehouse space optimization, dead stock reduction, and asset recovery improvement in electricity infrastructure systems.**

***Keywords :* AHP, electricity transmission warehouse, returned material, VED analysis.**

I. NTRODUCTION

Inventory management is a critical component of supply chain and logistics systems because it directly affects service level, operational reliability, and total logistics cost [5], [12]. In electricity infrastructure companies, inventory management becomes more complex because the warehouse not only manages new materials, but also returned materials originating from operational activities, maintenance work, and project replacement activities. Returned materials are ex-operational materials or equipment that have been dismantled from field operations and returned to the warehouse for further evaluation regarding their feasibility for reuse, repair, storage, transfer, or asset disposal.

In electricity transmission systems, returned materials may include current transformers, circuit breakers, lightning arresters, disconnecting switches, conductors, and other transmission equipment. These materials often still contain economic value and may remain operationally important, depending on their physical condition, technical feasibility, and future demand. Therefore, returned material management is closely related to reverse logistics, asset recovery, and warehouse capacity optimization.

The accumulation of returned materials has become a significant issue in PT PLN (Persero) transmission warehouses based on internal warehouse capacity records [9], [10]. Based on warehouse capacity data, the average utilization level of transmission warehouses reached 93.29%, exceeding the recommended operational threshold. Several warehouses even experienced overcapacity, indicating that storage space has been heavily occupied by returned materials and inactive assets. A large proportion of these materials are categorized as non-moving or dead stock items, which have remained in storage for long periods without clear handling decisions.

This condition creates several managerial problems. First, warehouse space becomes increasingly limited for materials that are

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operationally needed. Second, companies incur storage and handling costs for materials whose future use is uncertain. Third, valuable materials may not be reused in a timely manner because they are mixed with damaged or obsolete materials. Fourth, decisions regarding retain, repair, reuse, transfer, or disposal remain highly dependent on administrative status and subjective assessment rather than an integrated prioritization framework.

Current returned material classification practices generally rely on administrative categories such as standby, damaged, repair, warranty, or disposal proposal. Although these categories describe the process status of materials, they do not adequately represent economic value, operational criticality, physical condition, and reuse potential simultaneously. As a result, materials with low economic value but high operational criticality may receive insufficient attention, while materials with poor physical condition may continue occupying warehouse space despite having limited practical value.

Several inventory classification methods have been widely used in previous studies. ABC analysis classifies inventory based on economic value and is useful for identifying high-value items that require managerial attention. VED analysis classifies materials based on operational criticality, particularly the consequences of material unavailability. Meanwhile, the Analytic Hierarchy Process (AHP) provides a systematic multi-criteria decision-making approach by assigning relative weights to different criteria. However, previous studies have mostly focused on active inventory or spare parts, while limited attention has been given to returned materials and dead stock in electricity infrastructure warehouses.

This study addresses this gap by developing an integrated ABC–VED–AHP framework for prioritizing returned materials in electricity transmission warehouse management. The proposed framework combines economic value, operational criticality, physical condition, and reuse potential into a single composite priority score. The output of the framework is a priority classification that supports managerial strategies for retention, repair, transfer, or disposal decisions.

The main contributions of this study are threefold. First, this study develops a returned material prioritization framework specifically designed for electricity transmission warehouses, where most materials are non-moving and conventional movement-based classifications such as FSN are less relevant. Second, this study integrates economic value, operational criticality, physical condition, and reuse potential into a single multi-criteria decision framework using AHP. Third, the proposed framework translates classification results into practical managerial strategies, thereby supporting warehouse optimization and asset recovery in electricity infrastructure systems.

Although this study uses PT PLN (Persero) as a case study, the proposed framework is designed to be applicable to other infrastructure-based organizations that manage returned materials, spare parts, and non-moving assets. Therefore, the contribution of this study is not limited to a company-specific solution but also provides a structured prioritization approach for returned material management in utility and infrastructure warehouse systems.

II. Literature Review

A. *Inventory Management and Reverse Logistics*

Inventory management aims to ensure material availability while minimizing total inventory-related costs. In infrastructure-based industries, inventory management is not limited to new materials but also includes returned materials from maintenance and replacement activities. Returned materials require different treatment because their condition, value, and usability are uncertain.

Reverse logistics refers to the process of moving materials from the point of use back to the organization for reuse, repair, remanufacturing, recycling, or disposal [1], [6], [12]. In the context of electricity transmission, returned materials represent reverse logistics flows because equipment removed from the field is returned to the warehouse for technical and economic evaluation. Effective reverse logistics can improve asset utilization, reduce waste, support circular economy principles, and contribute to more sustainable inventory management [2].

B. *ABC Analysis*

ABC analysis is an inventory classification method based on the Pareto principle and is widely used for inventory grouping based on economic value [7], [8], [11]. It classifies materials into three categories according to their contribution to total inventory value. Category A represents high-value materials that require strict control, Category B

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represents medium-value materials, and Category C represents low-value materials. The economic value of each material can be calculated using replacement cost and quantity.

Although ABC analysis is useful for identifying economically important materials, it has limitations because it only considers financial value. In electricity infrastructure systems, some low-value materials may still be operationally critical. Therefore, ABC analysis should be complemented with an operational criticality assessment.

C. VED Analysis

VED analysis classifies materials based on their operational criticality and is commonly used to identify items whose unavailability may affect operational continuity [3], [4]. Vital materials are items whose unavailability may cause severe operational disruption, system failure, or safety risk. Essential materials are important for maintaining system performance, although temporary unavailability may still be tolerated. Desirable materials have relatively minor operational impact and are easier to substitute.

VED analysis is particularly relevant for electricity transmission systems because operational reliability is a key performance requirement. Materials with high criticality should not be evaluated only from their economic value, but also from their impact on system continuity and maintenance readiness.

D. Analytic Hierarchy Process

The Analytic Hierarchy Process is a multi-criteria decision-making method used to determine the relative importance of criteria through pairwise comparisons [13], [14], [15]. AHP decomposes a complex decision problem into a hierarchical structure consisting of goals, criteria, and alternatives. Pairwise comparisons are conducted using Saaty's scale, and the consistency of expert judgments is evaluated using the consistency ratio.

AHP is suitable for returned material prioritization because the decision involves both quantitative and qualitative criteria. Economic value can be measured from replacement cost, while operational criticality, physical condition, and reuse potential require expert judgment and structured assessment.

E. Research Gap

Previous studies have applied ABC analysis, VED analysis, and AHP in inventory classification and spare parts management. However, most studies focus on active inventory systems where demand movement and consumption patterns are available. In returned material warehouses, many items are non-moving or dead stock, making movement-based classification less relevant.

Furthermore, limited studies have integrated economic value, operational criticality, physical condition, and reuse potential into a single framework for returned material management in electricity infrastructure systems. Unlike previous studies that mainly focus on demand movement or economic value, this study addresses returned materials whose future usability is uncertain. Therefore, this study proposes an integrated ABC–VED–AHP framework by incorporating physical condition and reuse potential as additional criteria for returned material prioritization.

III. RESEARCH METHODOLOGY

F. Research Design

This study uses a case-based quantitative and qualitative approach. Quantitative data are used to evaluate economic value and warehouse utilization, while qualitative assessments are used to evaluate operational criticality, physical condition, and reuse potential. The research framework consists of data collection, ABC classification, VED classification, physical condition assessment, reuse potential assessment, AHP weighting, composite scoring, priority categorization, and managerial strategy formulation.

G. Data Collection

The data used in this study consists of secondary and primary data. Secondary data are obtained from the warehouse inventory database and include material identification, material type, warehouse location, quantity, replacement cost, administrative status, and warehouse capacity utilization. Primary data are obtained through physical inspection and expert assessment.

Physical inspection is conducted to evaluate the condition of returned materials based on structural condition, component completeness, corrosion or degradation level, and technical documentation availability. Expert assessment is conducted to evaluate operational criticality and reuse potential. Experts are selected from logistics, maintenance, and transmission operation functions because they have direct knowledge of material usage,

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operational risk, and warehouse handling practices.

H. ABC Classification

ABC classification is used to categorize returned materials based on economic value. The economic value of each material is calculated as:

$$EV_i = RC_i \times Q_i \quad (1)$$

Where:
EV_i is the economic value of material (i),
RC_i is the replacement cost of material (i),
Q_i is the quantity of material (i).

Materials are sorted in descending order based on economic value, and cumulative value percentages are calculated. Category A consists of materials contributing the highest cumulative value, Category B consists of medium-value materials, and Category C consists of low-value materials.

For composite scoring, ABC categories are converted into numerical scores as follows:

Table 1. ABC Category Score

ABC Category	Interpretation	Score
A	High economic value	3
B	Medium economic value	2
C	Low economic value	1

I. VED Classification

VED classification is used to evaluate the operational criticality of each material. The classification is based on the potential impact of material unavailability on electricity transmission reliability, maintenance execution, and operational safety.

Table 2. VED Category Score

VED Category	Interpretation	Score
Vital	Severe operational impact if unavailable	3
Essential	Important but temporary unavailability can be tolerated	2
Desirable	Minor operational impact	1

J. Physical Condition Assessment

Physical condition assessment evaluates the technical feasibility of returned materials for reuse or repair. Four sub-criteria are used: structural condition, component completeness, corrosion or degradation level, and technical documentation availability. Each sub-criterion is assessed using a Likert scale and combined into a physical condition score.

Table 3. Physical Condition Assessment Criteria

Sub-criterion	Weight	Assessment Focus
Structural condition	40%	Cracks, deformation, broken parts, physical integrity
Component completeness	30%	Availability of main parts and accessories
Corrosion/degradation	20%	Rust, oxidation, insulation aging, surface degradation
Technical documentation	10%	Nameplate, manual, maintenance record, traceability

The physical condition score is then converted into a 1–3 scale for consistency with other criteria:

Table 4. Physical Condition Score Conversion

Physical Condition	Initial Score	Converted Score
Good / Very good	4–5	3
Fair	3	2
Poor / Very poor	1–2	1

K. Reuse Potential Assessment

Reuse potential measures the feasibility and usefulness of returned materials for future operational use. It is evaluated based on repairability, demand frequency, and market availability.

Table 5. Reuse Potential Assessment Criteria

Sub-criterion	Description	High Score Condition
Repairability	Technical and economic feasibility of repair	Repair cost is relatively low compared to replacement cost
Demand frequency	Historical or expected need for the material	Material is frequently needed for maintenance or replacement
Market availability	Ease of procuring new material	Material is difficult to procure, obsolete, imported, or has a long lead time.

The reuse potential score is converted into three categories: high reuse potential = 3, medium reuse potential = 2, and low reuse potential = 1.

L. AHP Weighting

AHP is used to determine the relative importance of four criteria: economic value, operational criticality, physical condition, and reuse potential. Experts perform pairwise comparisons using Saaty's 1–9 scale. The pairwise comparison matrix is normalized to obtain priority weights. Consistency is evaluated using the consistency ratio (CR). The expert judgment is considered acceptable if CR ≤ 0.10. In this study, the consistency test produced λmax = 4.1229, CI = 0.0410, and CR = 0.0455. Since the CR value is below 0.10, the pairwise comparison

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results are considered consistent and acceptable for further analysis.

The criteria used in AHP are:

1. Economic Value (ABC)
2. Operational Criticality (VED)
3. Physical Condition
4. Reused Potential

M. Composite Priority Score

The final priority score is calculated by multiplying each criterion score by its AHP weight:

$$P_i = (W_1 \times E_i) + (W_2 \times O_i) + (W_3 \times P_i) + (W_4 \times R_i) \quad (2)$$

Where:
PS_i is the priority score of material (i),
EV_i is the economic value score,
OC_i is the operational criticality score,
PC_i is the physical condition score,
RP_i is the reuse potential score,
W_1, W_2, W_3, W_4 are AHP weights.

The final score is classified into three priority categories:

Table 6. Final Priority Classification and Handling Strategy

Priority Category	Interpretation	General Strategy
High Priority	High value, high criticality, good condition, or high reuse potential	Retain, repair, strategic stock, or transfer to other units
Medium Priority	Moderate value or moderate operational importance	Selective repair, controlled storage, or further evaluation
Low Priority	Low value, low criticality, poor condition, or low reuse potential	Disposal, scrap, or liquidation

III. RESULTS AND DISCUSSION

A. Warehouse Utilization Condition

The warehouse utilization data indicates that returned materials have significantly occupied the electricity transmission warehouse capacity. The average warehouse utilization reached 93.29%, exceeding the recommended operational threshold. One warehouse experienced overcapacity above 100%, while several others operated close to full capacity. This condition shows that returned material accumulation has become a structural warehouse management issue rather than a temporary storage problem.

Table 7. Warehouse Utilization of Transmission Implementation Units

Warehouse Area	Total Area (m²)	Used Area (m²)	Utilization (%)	Dominant Content
UPT Cikupa	4,804	5,451	113.5	Returned/inactive assets
UPT Cilegon	5,484	5,351	97.6	Returned/inactive assets
UPT Durkos	1,000	500	50.0	Returned and spare materials
UPT Pulogadung	8,670	8,218	94.8	Returned/inactive assets
UPT Cawang	5,253	4,754	90.5	Returned/inactive assets
UPT Gandul	6,404	5,220	81.5	Returned and spare materials
Average	**31,615**	**29,494**	**93.29**	**Non-moving materials**

The high utilization level indicates that warehouse space is being consumed by materials whose future use is uncertain. Without a prioritization framework, valuable and critical materials may not be distinguished from low-value and non-critical materials. Therefore, a structured classification system is needed to support handling decisions.

B. ABC Classification Result

ABC analysis was conducted on 580 returned material items with a total replacement value of IDR 256,057,003,073. The classification results show that 8 items were categorized as A, 457 items as B, and 115 items as C. Category A consists of a small number of materials with very high replacement value, mainly power transformers and other high-value transmission equipment. Although the number of Category A items is relatively small, these materials represent a significant portion of total asset value and therefore require strict managerial control.

Table 8. ABC Classification Results

ABC Category	Number of Items	Percentage of Items	Interpretation
A	8	1.38%	High economic value
B	457	78.79%	Medium economic value
C	115	19.83%	Low economic value
Total	**580**	**100.00%**	

The dominance of Category B indicates that most returned materials have moderate economic

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value. This condition implies that warehouse decisions cannot rely only on high-value materials because a large number of medium-value materials also contribute to storage burden and asset recovery potential. Category C materials, although economically lower, still need to be evaluated together with operational criticality before disposal decisions are made.

C. VED Classification Result

VED analysis was used to evaluate the operational criticality of returned materials. The results show that 408 items were classified as Vital, 108 items as Essential, and 64 items as Desirable. This result indicates that most returned materials are operationally important for electricity transmission reliability, even though they are currently stored as returned or inactive materials.

Table 9. VED Classification Results

VED Category	Number of Items	Percentage of Items	Interpretation
Vital	408	70.34%	Severe operational impact if unavailable
Essential	108	18.62%	Important for operational support
Desirable	64	11.03%	Lower operational impact
Total	**580**	**100.00%**	

The high proportion of Vital materials confirms that returned materials should not be treated merely as obsolete or inactive assets. Some returned materials may still play an important role as backup equipment, emergency replacement materials, or candidates for repair and reuse. Therefore, operational criticality must be included in returned material handling decisions.

D. Integrated ABC-VED Matrix

The combination of ABC and VED produces a 3×3 classification matrix. This matrix provides an initial prioritization map by combining economic value and operational criticality.

Table 10. ABC–VED Matrix and Recommended Strategy

Category	Interpretation	Recommended Strategy
A–V	High value and vital	Top priority: retain, inspect, repair if feasible, strategic stock
A–E	High value and essential	High priority: retain with strict control, repair selectively
A–D	High value but desirable	Review for transfer, sale, or value recovery
B–V	Medium value and vital	High priority: retain as strategic backup
B–E	Medium value and essential	Medium priority: selective repair and controlled storage
B–D	Medium value but desirable	Low priority: evaluate for disposal if the condition is poor
C–V	Low value but vital	Medium priority: retain minimum stock due to operational importance
C–E	Low value and essential	Low priority: retain a limited quantity or replace if damaged
C–D	Low value and desirable	Disposal priority: scrap or remove from the warehouse

The ABC–VED matrix helps identify materials that should be prioritized for retention and repair, as well as materials that should be considered for disposal. The integrated ABC–VED results show that the largest group is B–V with 360 items, followed by B–E with 97 items, C–D with 64 items, C–V with 40 items, C–E with 11 items, and A–V with 8 items.

Table 11. Integrated ABC–VED Classification Results

ABC–VED Category	Number of Items	Percentage of Items	Main Interpretation
A–V	8	1.38%	High value and vital
B–V	360	62.07%	Medium value and vital
B–E	97	16.72%	Medium value and essential
C–V	40	6.90%	Low value but vital
C–E	11	1.90%	Low value and essential
C–D	64	11.03%	Low value and desirable
Total	**580**	**100.00%**	

The dominance of B–V materials indicates that most returned materials have medium economic value but high operational criticality. This finding strengthens the need for a multi-criteria approach because many materials that are not classified as high-value assets may still be critical for system reliability. However, the ABC–VED matrix does not fully capture physical condition and reuse potential. Therefore, AHP-based composite scoring is needed to generate a more comprehensive priority classification.

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E. AHP-Based Criteria Weighting

AHP is used to determine the relative importance of economic value, operational criticality, physical condition, and reuse potential. In electricity transmission warehouse management, operational criticality is expected to receive a high weight because system reliability is a primary concern. Economic value is also important because returned materials represent company assets. Physical condition and reuse potential are needed to determine whether materials are technically and economically feasible to retain or repair.

Based on the AHP calculation, operational criticality obtained the highest weight, followed by physical condition, economic value, and reuse potential. This result indicates that returned material handling should prioritize operational continuity while still considering physical feasibility, asset value, and reuse potential. The consistency ratio was checked to ensure that expert judgments were logically consistent.

Table 12. AHP Criteria Weight Results

Criterion	Weight	Rank
Operational Criticality (VED)	0.5342	1
Physical Condition	0.2286	2
Economic Value (ABC)	0.1646	3
Reuse Potential	0.0727	4

The consistency test produced $\lambda max = 4.1229$, $CI = 0.0410$, and $CR = 0.0455$. Since $CR < 0.10$, the expert judgment is considered consistent. This result indicates that returned material handling decisions in electricity transmission warehouses are primarily driven by operational reliability considerations, while economic value, physical feasibility, and reuse potential serve as supporting criteria.

F. Composite Priority Classification

The composite priority score integrates economic value, operational criticality, physical condition, and reuse potential into a single score. The results show that 397 items were classified as High Priority, 116 items as Medium Priority, and 67 items as Low Priority.

Table 13. Final Priority Classification Results

Priority Category	Number of Items	Percentage of Items	Recommended Strategy
High Priority	397	68.45%	Retain
Medium Priority	116	20.00%	Repair & Reuse
Low Priority	67	11.55%	Disposal
Total	**580**	**100.00%**	

The high proportion of High Priority materials indicates that many returned materials should not be immediately disposed of because they still have operational importance, economic value, acceptable physical condition, or high reuse potential. These materials should be retained as strategic stock or evaluated for transfer to other units that require them. Medium Priority materials should be evaluated for repair and reuse because their condition or reuse potential may still justify recovery actions. Low-priority materials should be prioritized for disposal, scrap, or liquidation because they provide limited operational and economic benefit while continuing to occupy warehouse space.

The physical condition assessment shows that 32 items were categorized as Very Good, 24 items as Good, 412 items as Fair, and 112 items as Poor. This result indicates that most returned materials are not in a completely damaged condition but require further technical evaluation before reuse. Reuse potential assessment shows that 408 items have High reuse potential, 75 items have medium reuse potential, and 97 items have Low reuse potential. These findings support the need for differentiated handling strategies rather than uniform disposal treatment.

The ten highest-priority materials are shown in Table 15. The highest scores are dominated by power transformers and current transformers because these materials have high operational criticality, high economic value, and relatively good physical condition. These materials should be retained as strategic assets and evaluated for reuse or transfer to units that require them.

Table 14/ Physical Condition and Reuse Potential Assessment Results

Assessment Aspect	Category	Number of Items	Percentage of Items
Physical condition	Very Good	32	5.52%
Physical condition	Good	24	4.14%
Physical condition	Fair	412	71.03%
Physical condition	Poor	112	19.31%
Reuse potential	High	408	70.34%
Reuse potential	Medium	75	12.93%
Reuse potential	Low	97	16.72%

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Table 15
Top Ten Highest-Priority Returned Materials

Rank	Material ID	Material Type	Location	ABC VED	Physical Condition	Reuse Potential	Priority Score	Strategy
1	12345	TRF PWR	GI 150KV Cawang Lama	A–V	Good	High	3.0000	Retain
2	GJBA-01	TRF PWR	Gudang Terbuka Jatirangon	A–V	Good	High	3.0000	Retain
3	GJBA-02	TRF PWR	Gudang Terbuka Jatirangon	A–V	Good	High	3.0000	Retain
4	GJAA-01	TRF PWR	Gudang Terbuka Jatirangon	A–V	Good	High	3.0000	Retain
5	LSI-001	TRF PWR	Gudang Semi Tertutup Balaraja	A–V	Good	High	3.0000	Retain
6	GJAA-29	TRF PWR	Gudang Terbuka Jatirangon	A–V	Good	High	3.0000	Retain
7	GBP-002A	CT	Gudang Tertutup BSD	B–V	Very Good	High	2.8354	Retain
8	GBP-002B	CT	Gudang Tertutup BSD	B–V	Very Good	High	2.8354	Retain
9	GBP-002C	CT	Gudang Tertutup BSD	B–V	Very Good	High	2.8354	Retain
10	GBP-003A	CT	Gudang Tertutup BSD	B–V	Very Good	High	2.8354	Retain

G. Managerial Implication

The proposed framework provides several managerial implications. First, it supports objective decision-making by replacing purely administrative classification with multi-criteria scoring. Second, it helps warehouse managers identify which materials should be retained, repaired, transferred, or disposed of. Third, it supports warehouse capacity optimization by accelerating disposal decisions for low-priority materials. Fourth, it improves asset recovery by identifying high-value materials with reuse potential. Fifth, the framework can be integrated into digital warehouse systems to support automatic scoring and dashboard-based monitoring.

The framework is also aligned with the Material Return and Warehouse Inventory program because it provides a structured basis for evaluating returned materials. By integrating the framework into warehouse information systems, companies can improve traceability, reduce dead stock accumulation, and support faster managerial decisions.

IV. CONCLUSION

This study proposes an integrated ABC–VED–AHP framework for prioritizing returned materials in the management of electricity transmission warehouses. The framework combines economic value, operational criticality, physical condition, and reuse potential to generate a composite priority score. ABC analysis identifies materials with high economic value, while VED analysis evaluates operational criticality. Physical condition assessment and reuse potential evaluation provide additional technical and practical considerations. AHP is used to determine the relative importance of the criteria and ensure a systematic decision-making process.

The proposed framework classifies returned materials into high, medium, and low priority categories. High-priority materials should be retained, repaired, or transferred for operational reuse. Medium-priority materials require selective repair and further evaluation. Low-priority materials should be considered for disposal, scrap, or liquidation to reduce warehouse burden. The framework supports more objective, transparent, and data-driven returned-material management and contributes to warehouse space optimization, dead stock reduction, and improved asset recovery.

Compared with previous inventory classification studies, this research contributes by integrating economic value, operational criticality, physical condition, and reuse potential into a single prioritization framework for returned materials, particularly for non-moving and dead stock items in infrastructure warehouse systems.

Future research may apply the framework to a larger dataset, incorporate actual cost-benefit analysis, and integrate the model into warehouse information systems for real-time decision support. Further studies may also compare AHP with other multi-criteria decision-making methods, such as TOPSIS, PROMETHEE, or ANP, to evaluate the robustness of returned material prioritization results.

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