System Design for a Sustainable Returned Materials Management System at PT PLN UID East and North Kalimantan

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Abstract. The Indonesian government through Presidential Regulation No. 111 of 2022 encourages the implementation of the Sustainable Development Goals (SDGs), including the efficient and responsible management of material resources. PT PLN (Persero), as a major energy provider, has responded through various sustainable transformation initiatives, including waste management based on the 3R principle. However, challenges are still faced in the management of returned materials, especially demolished materials (ATTB) at the distribution unit level such as PLN UID East Kalimantan and North Kalimantan. Problems such as the absence of standard classification procedures and the accumulation of unutilized materials indicate the need for a more effective system. Based on this, the problem formulation in this study is How is the design of a return material management business process that accommodates the 6R principles (Reduce, Reuse, Recycle, Repair, Refurbish, Remanufacture)? This research adopts the 6R-based closed-loop sustainable manufacturing approach to design a new digital-based business process for managing returned materials. The main focus is on designing a systematic classification mechanism into four categories based on technical, life, warranty, and economic aspects. This approach is expected to improve operational efficiency, support digital transformation, and strengthen PLN's contribution to the national sustainability agenda.

Keywords: *material returns, sustainability, 6R, PLN, digital transformation, closed-loop, SDG 12, material classification.*

1 Introduction

The Indonesian government continues to encourage sustainable development practices through the issuance of Presidential Regulation No. 111 of 2022 on the implementation of the Sustainable Development Goals (SDGs). One important aspect highlighted is the efficient and responsible management of material resources, as part of the transition to a green economy (Bocken et al., in[1]). In this context, state-owned companies such as PT PLN (Persero) are required to contribute concretely to the national agenda and play a strategic role as drivers of sustainable transformation through the integration of environmental, social and governance (ESG) aspects into their business processes.

PT PLN (Persero) as the main energy provider in Indonesia, has adopted a sustainability approach through various organizational transformations and business process innovations. In PLN's Sustainability Report 2023, emphasizing the company's contribution in supporting the Net Zero Emission target in 2060 and the Nationally Determined Contribution (NDC) in 2030 through the Accelerated Renewable Energy Development (ARED) strategy, one of the main initiatives that has been carried out is waste management based on the 3R principle (Reduce, Reuse, Recycle), which is successfully applied in the management of non-B3 waste and other operational materials. This initiative is also in line with SDG 12's goal of responsible consumption and production (Hadi et al. in [2]; Shen et al. in [3]).

In response to these challenges, PT PLN (Persero) has initiated strategic steps through Transformation 1.0 in Figure 1 Transformation 1.0, which includes the establishment of a holding-subholding structure and the implementation of four main pillars: Green, Lean, Innovative, and Customer Focused (Krishnan et al. [4]).

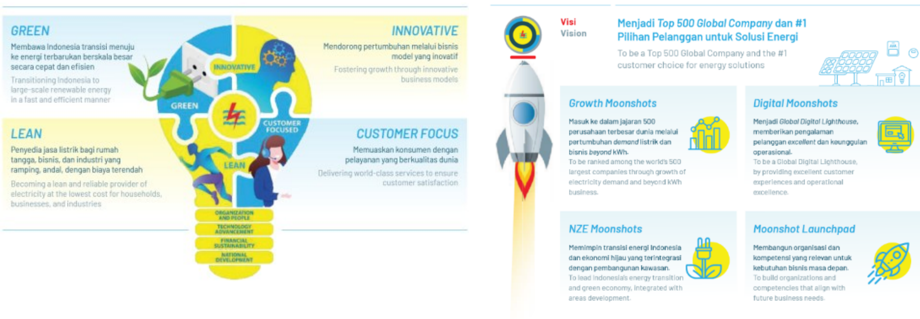

Figure 1 Transformation 1.0 and Transformation 2.0

This transformation is followed by Transformation 2.0 in figure 1 Transformation 2.0 or known as The Next Chapter of Transformation, which focuses on big aspirations namely: Growth Moonshots, NZE (Net Zero Emission) Moonshots, Moonshot Launchpad and Digital Moonshots.

This initiative redefines PLN's role as a technology company based on digital innovation, not just as a conventional electricity provider. One of the strategic projects in Digital Moonshots is Smart Materials Management, which is designed to digitize the entire asset management chain, including return materials, which are materials returned from the field due to damage, project leftovers, or unused materials. The system aims to increase transparency, efficiency, and financial value through accurate classification of returned materials. This research focuses on one of the initiatives, namely the management of returned materials.

However, the management of returned materials, especially materials from the dismantling of Non-Operating Fixed Assets (ATTB), still faces various challenges, especially at the regional unit distribution level. One of them occurs at PT PLN UID East Kalimantan and North Kalimantan, where the absence of a standard classification procedure causes returned materials to be only visually seen without testing, and piles of materials are not utilized in the warehouse. This shows that there are gaps in business processes that can hinder operational efficiency and the achievement of sustainability.

This research adopts the 6R-based closed-loop sustainable manufacturing approach introduced by Jawahir and Ryan Bradley [5], which includes six principles: Reduce, Reuse, Recycle, Repair, Refurbish, and Remanufacture. This approach emphasizes on optimizing the product life cycle so that waste is minimized and economic value can be maintained. With the integration of the 6R principles into PLN's digital system, the return material classification process not only focuses on waste reduction, but also on the maximum recovery of the material's functional value, in accordance with sustainable industrial practices (MahmoumGonbadi et al., in [6]; Barakat et al. in [7]).

This research focuses on the development of new business processes in the management of returned materials within PT PLN UID East Kalimantan and North Kalimantan. The main focus is to design a systematic classification mechanism of returned materials into four categories: (1) standby materials, (2) guaranteed materials, (3) materials needing repair, and (4) materials proposed for deletion based on technical aspects, service life, warranty, and economics. With this approach, it is expected that the return material management system can support the company's cost efficiency, digital transformation, and sustainability goals.

To provide a stronger technical and conceptual context, the following subsections describe two important aspects of this research: (1) Miniature Circuit Breakers (MCBs) as a frequently found return material component, and (2) a 6R principle-based sustainability framework, including a comparison of versions used in industrial approaches.

1.1 Miniature Circuit Breaker

Miniature Circuit Breaker (MCB) is a mechanical circuit device that can flow and break the current under normal circuit conditions and can flow for a certain time and cut off the current automatically in certain abnormal circuit conditions such as short circuits. The advantage of an MCB over a conventional fuse is that it can be reused after a trip, no need to replace it.

In the context of SPLN 108:1993 in [8], MCBs are emphasized as a major component in medium and low voltage installation protection systems. The placement and specifications of MCBs are set to match the current-carrying capacity of the conductor as well as the characteristics of the load being served. In addition, MCBs must also be installed taking into account ease of access for periodic inspection and testing.

1.2 Sustainability

Sustainability is a strategic approach that aims to meet the needs of current generations without compromising the ability of future generations to meet their needs. This approach emphasizes a balance between economic, social and environmental aspects to reduce the negative impacts of climate change and damage to global ecosystems. According to Plan A Academy [9], the essence of sustainability is making decisions that not only provide short-term benefits but also ensure the sustainability of life in the long term. As such, sustainability demands changes in ways of life and economic activity, including wise management of resources and respect for human rights.

One framework that is widely used in the implementation of sustainability in the industrial sector is the 6R principle, which consists of: Reduce, Reuse, Recycle, Rethink, Refuse, and Repair. This principle not only focuses on reducing waste but also encourages the transformation of production and consumption systems towards a more circular and sustainable model.

1.3 Research by Jawahir and Bradley, 2016

The method used in this research is a case study approach based on the 6R principles (Reduce, Reuse, Recycle, Recover, Refurbish, Remanufacture). This study focuses on analyzing the critical technological elements required to support the implementation of a circular economy. By referring to the 6R principle, this study identifies sustainable manufacturing strategies that can support economic growth while maintaining ecological balance. The model used is 6R-based closed-loop sustainable manufacturing.

2 Methodology

This research begins with interviews and direct observation to the research location which aims to analyze and model the current business process, then conduct a literature study and preliminary study to find out PLN's sustainability history. After that, formulate problems to determine the classification of returned material where the goal is to develop a more efficient returned material classification business process in accordance with Figure 2.1 research methodology below.

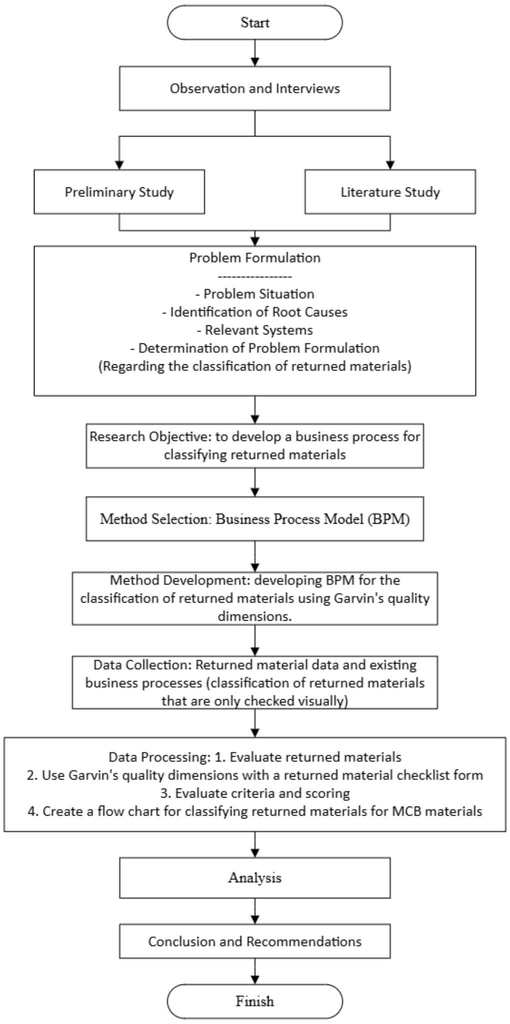

Figure 2.1 Research Methodology

The methodology used

1. Business Process Model (BPM)
2. Garvin's Dimensions of Quality

2.1 Business Process

Business process is a series of actions or stages carried out by a business entity in order to achieve the goals set by the company (Kitsios & Kamariotou, [10]). Meanwhile, according to PLN EDIR regulation 0004.E / DIR / 2023 Business Process is a collection of activities and or decisions that are logically related and required by the company, starting from the activity of receiving input resources to be processed to the activity of delivering outputs that have added value, in order to support the achievement of company goals. Efficient and effective business processes have moved from being a competitive advantage to now being an essential requirement for organizational success (Schuh et al. in [12]).

2.2 Garvin's Dimensions of Quality

In order to support the return material classification system, this research adopts the eight-dimensional quality approach developed by David A. Garvin as a framework for evaluating material eligibility. Garvin [13] argues that quality is not only seen from one side (such as performance or reliability), but from a variety of dimensions that reflect customer expectations and fulfillment of technical and aesthetic product standards. This approach is particularly relevant in assessing return materials such as MCBs (Miniature Circuit Breakers), as it covers technical aspects, service life, economic value, and the perception of technicians in the field.

Here are the eight quality dimensions used in the analysis:

- Performance
  Refers to the basic ability of the product to optimally perform its primary function.
- Features
  Describes additional attributes that increase the value of the product beyond its basic function.
- Reliability
  Measures the likelihood of the product functioning consistently without failure over a period of time.
- Conformance
  The extent to which products meet established technical specifications and standards, such as SPLN 108:1993 in the context of PLN.
- Durability
  Indicates the life of the material until it requires permanent replacement.
- Serviceability

Describes the ease of repairing, maintaining, or inspecting materials when needed.

- Aesthetics
  Relates to the physical appearance of the product, such as cleanliness, case condition, and neatness.
- Perceived Quality
  It is the perceived quality perceived by the user based on the brand, reputation, or previous experience.

By using these eight dimensions, the classification process of returned materials can be done more objectively and systematically, and support decision-making based on data and quality, not just visual observation as in the existing system.

3 Data Processing, Results and Discussion

3.1 Data Processing

In order to support this research, the author conducts a series of data processing stages starting with a direct visit to the UP3 Balikpapan Warehouse location. This activity aims to conduct field observations and interviews with UP3 Balikpapan warehouse officers in order to understand the actual conditions of material management, especially MCB (Miniature Circuit Breaker) returned materials. Furthermore, the author collects data related to MCB returned material in Figure 3.1 table of mcb returned material which includes the amount, type, physical condition, and distribution flow of the material. In the existing condition of mcb material returned by field officers to warehouse officers, how to inspect it only from visual conditions, it can be declared that the material is good and ready to use, which can be seen in Figure 3.2 the existing condition of the Business Process Model for Returned Material Management.

The following is a table of MCB return materials available at UP3 Balikpapan warehouse

No.	No Material	Material Name	Not yet Inspected	Inspection Process	Standby Material
1	3250056	MCB;230/400V;1P;20A;50Hz;	0	0	14
2	3250052	MCB;230/400V;1P;10A;50Hz;	0	0	269
3	3250097	MCB;230/400V;3P;10A;50Hz;	2	0	0
4	3250050	MCB;230/400V;1P;6A;50Hz;	0	0	419
5	3250048	MCB;230/400V;1P;4A;50Hz;	104	0	277
6	3250054	MCB;230/400V;1P;16A;50Hz;	46	0	17
7	3250046	MCB;230/400V;1P;2A;50Hz;	5	0	130
8	3250058	MCB;230/400V;1P;25A;50Hz;	0	0	33
9	3250059	MCB;230/400V;1P;35A;50Hz;	2	0	3

Table 3.1 MCB return material table

Figure 3.1 presents the current business process model for returned material management at PT PLN UID East and North Kalimantan. This model shows that material classification is currently conducted through visual inspection only, without standardized testing or technical validation. The process begins with the return of materials to the warehouse and ends with the classification report archiving. This reveals a gap in structured evaluation methods, highlighting the need for improvement through more objective assessment tools.

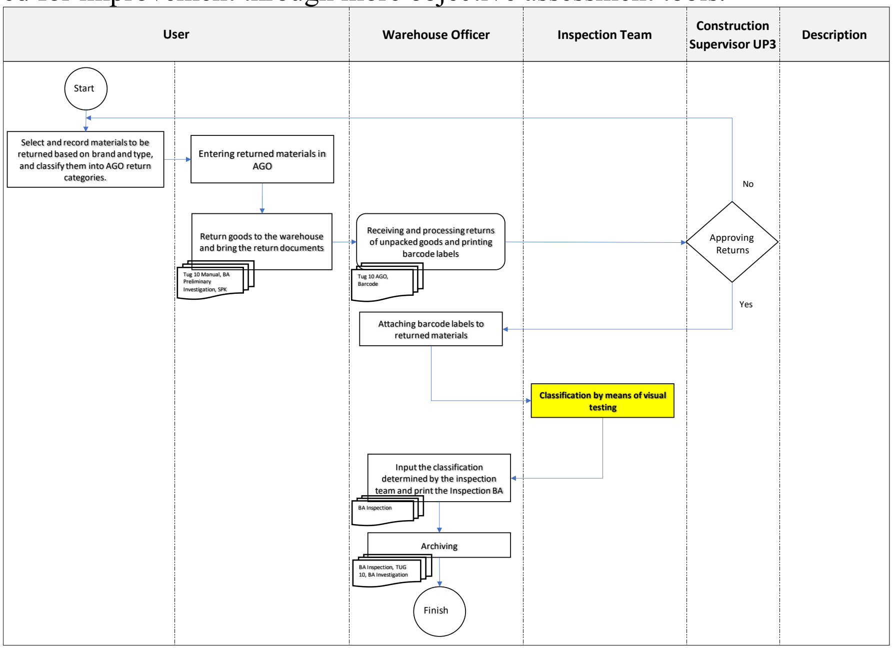

Figure 3.1 Existing condition of Business Process Model of Returned Material Management

3.1.1 The concept of business process improvement

The following is the concept of the mindset of improving the return material business process in Figure 3.3 mindset of the return material business process development.

Figure 3.3 Business Process Development Mindset for Returned Materials

In an effort to enhance operational efficiency and support sustainability targets, PT PLN (Persero) has undertaken the development of a return material business process that is strategically integrated with international, national, and internal corporate frameworks. Historically, the return material process was perceived merely as a passive logistics activity, with classification based solely on visual inspection and without any formal testing procedures. This paradigm shift toward a proactive and strategic system reflects PLN's transformation in recognizing the management of used materials as an integral component of its sustainability and value creation strategy.

The development process aligns with globally recognized standards and frameworks, including the Global Reporting Initiative (GRI), Task Force on Climate-related Financial Disclosures (TCFD), Sustainable Development Goals (SDGs), and the International Sustainability Standards Board (ISSB). At the national level, relevant regulatory references include Presidential Regulation No. 111 of 2022, Ministry of State-Owned Enterprises Regulation No. PER-02/MBU/03/2023 which emphasizes the transformation of SOEs towards greater efficiency and a green economy, and Financial Services Authority Regulation (POJK) No. 51/POJK.03/2017 which mandates the disclosure of environmental, social, and governance (ESG) aspects in sustainability reporting. The Ministry of Finance also supports this agenda through its ESG framework in the context of sustainable infrastructure financing.

Furthermore, the sustainability framework is reinforced by other relevant national regulations. Law No. 32 of 2009 on Environmental Protection and Management provides the legal basis for the application of the precautionary principle and environmental accountability. Indonesia's commitment to the Paris Agreement, ratified under Law No. 16 of 2016, sets forth the national target of reducing greenhouse gas emissions by 29% independently, or up to 41% with international support, by 2030. Development planning documents such as the National Medium-Term Development Plan (RPJMN) 2020–2024 and the National Strategy for Green Economy Development formulated by the Ministry of National Development Planning (Bappenas) further embed sustainability dimensions into national development planning.

Sectoral policies also support this direction, such as Presidential Regulation No. 22 of 2017 on the National Energy Plan (RUEN) and various Ministry of Energy and Mineral Resources regulations on energy efficiency. In parallel, evaluative mechanisms such as the Corporate Performance Rating Assessment Program (PROPER), administered by the Ministry of Environment and Forestry, assess corporate environmental performance on a regular basis. Collectively, these policies demonstrate a strong synergy between global and national regulatory frameworks in driving sustainable business practices, particularly in material and waste management.

In response to these regulatory developments, PT PLN (Persero) has initiated the Transformation 1.0 and Transformation 2.0 programs as part of its adaptation to efficiency and sustainability imperatives. These efforts are in line with the implementation of the 3R principles (Reduce, Reuse, Recycle), as reflected in PLN's 2023 Sustainability Report, and support the achievement of SDG 12 concerning responsible consumption and production. Moreover, the strategy aligns with Indonesia's Nationally Determined Contribution (NDC) target for 2030 and the national vision of achieving Net Zero Emissions by 2060.

Within this framework, the present study focuses on the strategic aspect of return material management, particularly concerning used materials returned from field operations, which hold significant economic potential if managed optimally. Therefore, this research adopts the concepts of refurbishment and repair as key approaches to extend the lifecycle of used materials and to promote the implementation of circular economy practices within the company.

3.2 Results

As a further step, the data that has been obtained is processed in the form of a flow chart to systematically map the MCB return material management process. This diagram helps in identifying important points in the flow of material return and reuse. As shown in Figure 3.4 illustrates the proposed flow of MCB material classification, which introduces a more structured decision-making process. Unlike the previous visual-only inspection, this flowchart integrates technical parameters that lead to four classification outcomes: standby, warranty claim, repair, or disposal. This design promotes consistency in categorization and supports better material recovery decisions aligned with the 6R principles.

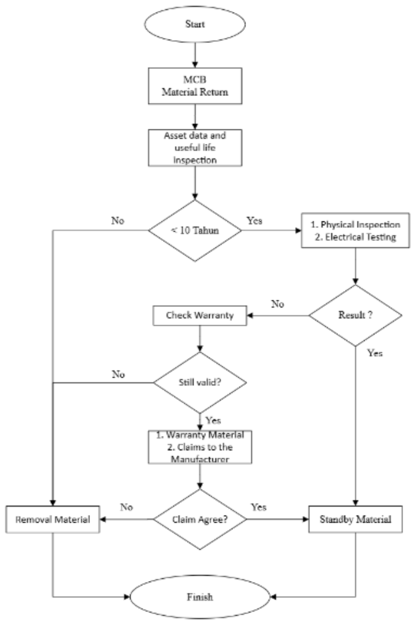

Figure 3.4 Flowchart of MCB Material Classification

To complete the analysis process, the author also developed a checklist form as a tool in verifying the physical condition of returned materials. This checklist is designed to be used by warehouse staff in assessing the feasibility of the material before further processing. An example of a checklist form in Figure 3.5 as below

MCB RETURN MATERIAL PHYSICAL CONDITION CHECKLIST FORM

On this day .... date.............................. Month............... Year two thousand .... has been held MCB return material inspection with the following data:

I. GENERAL INFORMATION

Customer ID: ____________________ Inspection Date: _______________

Customer Service Unit: ______________ Name Of Exminer : _________________

Returned Material from: ________________

II. MATERIAL IDENTIFICATION

- Brand: ___________________________
- Type/Model: ______________________
- Capacity (A): ____________________
- Manufacture Name: _______________________

III. Physical Examination

No	Inspection Parameters	Good	Damaged
1	Marking unremovability testing	[ ]	[ ]
2	Testing of toggle switches	[ ]	[ ]
3	Reliability testing of screws, current-carrying parts and connections	[ ]	[ ]
4	Reliability testing of terminals for external conductors	[ ]	[ ]

IV. Inspection Result

- Inspection Status: FEASIBLE/UNFEASIBLE
- Category: STANDBY / WARRANTY / REPAIR / PROPOSE DELETE
- Inspection Notes: ___________________
- Recommended Action: __________________

Examiner **Approved**

....

Notes:
- Check [√] in the appropriate column.
- If damage is found, include photos as evidence.
- This form is used to evaluate the feasibility of MCB return material before further processing.

Figure 3.5 MCB Material Physical Condition Checklist Form

As shown in Figure 3.5, the MCB material physical condition checklist was developed as a tool to assist warehouse staff in evaluating the feasibility of returned materials. Currently, the checklist is undergoing validation by technical experts to ensure that the assessment indicators align with PLN's operational and technical standards. As part of the initial implementation phase, a pilot project is planned at the UP3 Balikpapan warehouse. This pilot aims to assess the practicality of field usage, the consistency of classification results, and to gather user feedback for refinement prior to broader deployment.

The author also creates a new business process where the classification through the checklist method is carried out before the material is categorized according to Figure 3.6 proposed improvements to the Business Process Model (BPM) of returned material classification in the proposed classification has been updated with a blue mark.

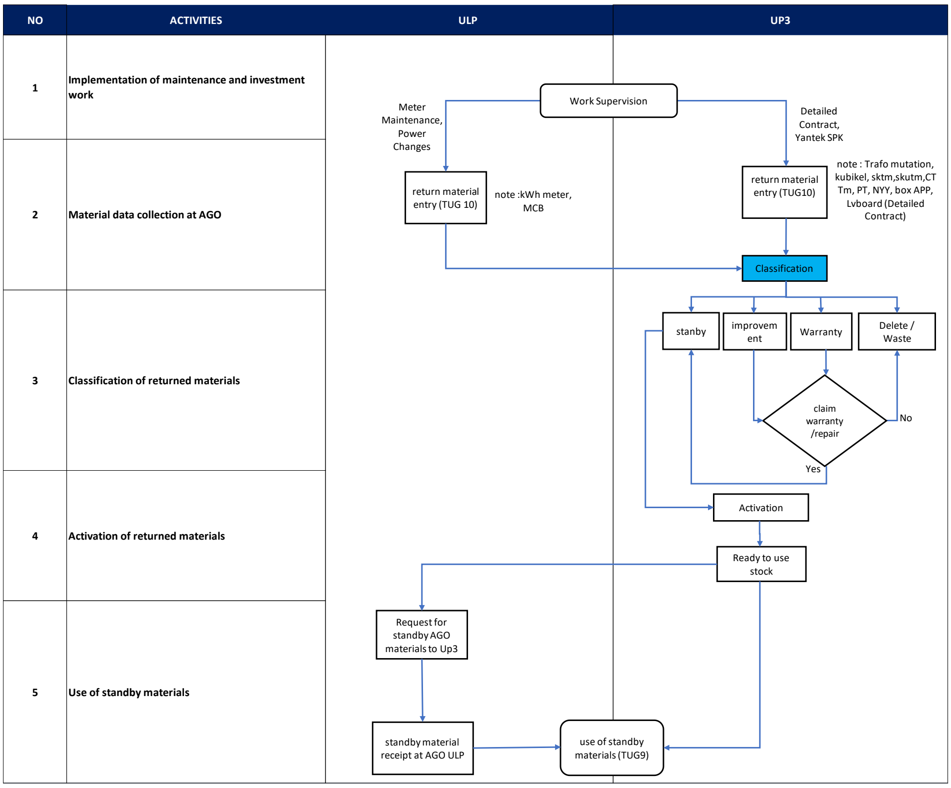

Figure 3.6 Proposed Improvements to the Business Process Model (BPM) Returned Material Classification

3.3 Analysis

The analysis shows that the classification process of returned materials at PT PLN UID Kaltimra is still subjective and not well documented. By utilizing the Business Process Model (BPM) approach and Garvin's eight dimensions of quality, a new classification system was developed that is more systematic and objective, using a checklist to evaluate the condition of materials technically and economically. Classification is done into four main categories, in line with the 6R principles to support efficiency and sustainability. This process also supports the digitization of material management through integration with the Smart Material Management system. The proposed classification system provides a clearer decision path for material disposition and supports warehouse staff in determining the most value-preserving option for each returned item. By enabling integration with PLN's Smart Material Management system, the new model facilitates digital recordkeeping, reduces material waste, and promotes accountability

4 Conclusions

This study designed a sustainable returned material management system at PT PLN UID East and North Kalimantan by emphasizing the 6R principles, with a particular focus on *reuse* and *refurbishment*. Using Business Process Modeling and Garvin's eight dimensions of quality, the proposed framework classifies returned materials into four categories: standby, warranty claim, repair, and disposal. This structured classification enhances operational efficiency, enables digital integration with the Smart Material Management system, and reinforces circular economy practices. Ultimately, the model provides both technical and economic benefits while supporting PLN's broader transformation agenda and contributing to national sustainability targets, including the 2060 Net Zero Emission goal.

5 References

[1] Bocken, N.M.P., Harsch, A., & Weissbrod, I., Circular Business Models for the Fast-Moving Consumer Goods Industry: Desirability, Feasibility, and Viability, Sustainable Production and Consumption, 30, pp. 799-814, Jan. 2022.

[2] Hadi, N.U., Almessabi, B., & Khan, M.I., Leveraging Industry 4.0 and Circular Open Innovation for Digital Sustainability: The Role of Circular Ambidexterity, Journal of Open Innovation: Technology, Markets, and Complexity, 11(2), pp. 100545, 2025.

[3] Shen, C.-Y., Huang, Y.-F., Weng, M.-W., Lai, I.-S., & Huang, H.-F., The Role of Industry 4.0 and Circular Economy for Sustainable Operations: The Case of Bike Industry, Applied Sciences, 13(10), pp. 5986, 2023.

[4] Krishnan, R., Perumal, E., Govindaraj, M., & Kandasamy, L., Enhancing Logistics Operations Through Technological Advancements for Superior Service Efficiency, in Innovative Technologies for Increasing Service Productivity, Sonar, R. M. & Badheka, D., eds., IGI Global, pp. 61-82, 2024.

[5] Jawahir, I.S. & Bradley, R., Technological Elements of Circular Economy and the Principles of 6R-Based Closed-loop Material Flow in Sustainable Manufacturing, Journal of Cleaner Production, https://www.sciencedirect.com/science/article/pii/S2212827116000822, 2016.

[6] MahmoumGonbadi, A., Genovese, A., & Sgalambro, A., Closed-Loop Supply Chain Design for the Transition Towards a Circular Economy: A Systematic Literature Review of Methods, Applications and Current Gaps, Journal of Cleaner Production, 323, pp. 129101, 2021.

[7] Barakat, A.E., Hammad, M.A., & Adel, H., A Literature Review on Closed-Loop Supply Chain, Business Logistics in Modern Management, 21, pp. 533-545, 2021.

[8] PT Perusahaan Listrik Negara (Persero), SPLN 108:1993 - General Provisions for Medium Voltage Electrical Installation, PT PLN (Persero), 1993. (Technical Standard)

[9] Plana Earth, 6R Sustainability: A framework for sustainable living, https://plana.earth/academy/6-r-sustainability, (April 1, 2011). (URL Link)

[10] Kitsios, F. & Kamariotou, M., Business strategy modeling based on enterprise architecture: a state of the art review, Business Process Management Journal, 25(4), pp. 606-624, 2019. https://doi.org/10.1108/BPMJ-05-2017-0122 (Journal)

[11] Perusahaan Listrik Negara (Persero), Circular of the Board of Directors Number 0004.E/DIR/2023 concerning Standard Operating Procedure for Business Process Management of PT PLN (Persero), PT PLN (Persero), 2023 [Standard Operating Procedure].

[12] Schuh, G., Guetzlaff, A., Schmitz, S., Schopen, M., & Obladen, A. (2022). Performance-based Decision Support for Business Process Analysis and Design. 2022 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 1376-1380.

[13] Garvin, D.A., Competing on the Eight Dimensions of Quality, Harvard Business Review, pp. 101-109, Nov.-Dec. 1987. (Book)

[14] Government of the Republic of Indonesia, Presidential Regulation of the Republic of Indonesia Number 111 of 2022 on the Implementation of Achieving the Sustainable Development Goals, State Secretariat, 2022. (Official Government Document)

[15] PT Perusahaan Listrik Negara (Persero), Company Profile of PT PLN (Persero), PT PLN (Persero), 2023. (Corporate Document)

[16] PT Perusahaan Listrik Negara (Persero), PT PLN (Persero) Sustainability Report 2023: Collaboration for Sustainability, PT PLN (Persero), 2023. (Sustainability Report)

[17] PT Perusahaan Listrik Negara (Persero), Moonshot Compile Socialization: The Next Chapter of PLN's Transformation, PT PLN (Persero), 2023. (Presentation Document)