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Constructing Hypothetical Models of Stakeholder Relationships in Remanufacturing Systems: Insights from SLR and Focus Group Discussion

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Abstract - *Remanufacturing has emerged as a vital component of the circular economy, offering environmental and economic benefits through the restoration of used products to like-new conditions. Among the various types of remanufacturers, independent remanufacturers (IRs) play a particularly significant role, especially in developing countries where remanufacturing is still evolving. This study presents a systematic literature review (SLR) aimed at understanding the roles, interactions, and business models of IRs within the remanufacturing ecosystem, with a specific focus on the heavy equipment industry in Indonesia. The SLR process incorporated 363 articles from ScienceDirect and Google Scholar, which were filtered down to 46 eligible articles based on strict inclusion criteria. To enrich the findings, a focus group discussion (FGD) involving eleven heavy equipment companies operating in Indonesia was conducted. The study identifies distinct interaction patterns between IRs and other remanufacturing actors such as OEMs, outsourced remanufacturers, and contracted remanufacturers. Additionally, this paper proposes hypothetical models for each type of actor to illustrate potential collaborations and conflicts.*

Keywords-*Remanufacturing, Independent Remanufacturer (IR), OEM, Circular Economy, Business Model, Systematic Literature Review, Heavy Equipment Industry, Indonesia*

I. INTRODUCTION

Remanufacturing is one of the circular economy strategies widely adopted in developed countries and beginning to be implemented in several developing countries. Remanufacturing differs from other circular strategies because it is capable of producing products with the same or even better quality than new products [1]. The remanufacturing process is unique as it can guarantee that the resulting products have the same quality as new ones. This is due to the remanufacturing process adhering to specific technical specifications, including engineering standards, quality, and testing. This process yields products that are fully guaranteed [2].

Remanufacturing is more environmentally friendly than the manufacturing process because it reduces the use of virgin materials by up to 70%. Apart from its environmental benefits, remanufacturing is also claimed to result in a reduction in production costs by up to 50% compared to the production costs of new goods [3]. Various studies have also demonstrated that remanufactured products can deliver the same performance as new products but at a significantly lower price [4].

Among several types of remanufacturers (IR, OEM-R, outsourced-R, and contract-R), IR plays a highly significant role in this industry. One significant role of IR is core collection, which, according to several articles, is a crucial issue for the sustainability of remanufacturing [5], [6], [7], [8], [9], [10]. Additionally, the role of IR is significant due to its ability to perform remanufacturing without exchanging information from OEM (relying on reverse engineering) [4], [11]. Furthermore, according to several articles, remanufactured products from IR actually have a larger market growth than other remanufacturers in the second-market [12], [13].

However, behind the significant role of IR, there are threats identified by several articles. According to Duberg et al. (2021), it is identified that there are disadvantages to consumers due to the existence of IR practices, such as IR products lacking OEM warranties and specification changes resulting in potentially lower quality compared to OEM-R remanufactured products [4]. From the OEM perspective, IR actors also cause concern because several factors, including damaging the OEM company's image, competition in remanufactured product sales, non-payment of fee-contracts by IR, and issues related to patents/licenses [14], [15], [16], [17], [18].

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In the past 5 years, around 34 articles on SLR in the field of remanufacturing mostly discussed consumer behavior and market dynamics [19], [20], [21], remanufacturing industry and its policies [22], [23], decision-making strategies in remanufacturing [24], [25], [26], product lifecycle and disassembly [27], [28], [29], sustainability practices and circular economy trend [30], [31], [32], [33], smart technologies and industry 4.0 [34], [35], [36], [37], [38], [39], as well as environmental impacts and material efficiency [40], [41], [42]. However, none has specifically discussed the connection between remanufacturer player. Understanding and delving into remanufacturer player could provide extensive knowledge of potential collaboration opportunities that may arise in the future, as well as the problems that may arise from interactions among stakeholders. Thus, this SLR is conducted to deepen understanding of the hypothetical model for remanufacturer player in Indonesia by taking a case study of the heavy equipment industry in Indonesia [43].

This systematic literature review (SLR) aims to explore the patterns of interaction within remanufacturing systems. Specifically, it seeks to address the following research question: What are the patterns and mechanisms of interaction among key actors in the remanufacturing industry?

II. METHODOLOGY

The SLR begins by breaking down the research question using the PICO framework (Population, Intervention, Comparator, and Outcome). PICO is employed not only as a basis for the search strategy but also to define the study's inclusion criteria. Additionally, the overall framework of this SLR follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a transparent and structured review process. The PICO components used in this study are as follows:

- P: Stakeholders in remanufacturing (e.g., OEMs, third-party remanufacturers, consumers, government)
- I: Interaction, collaboration, coordination, or relationship mechanisms
- C: Comparation across industries or regions
- O: Understanding of interaction patterns, value co-creation, barriers/facilitators of collaboration.

The next step is the literature search. Initially, the authors used a Boolean search query derived from the PICO framework: (Remanufacturer OR OEM OR third-party remanufacturer OR TPR) AND (interaction OR collaboration OR coordination OR relationship) AND (model OR pattern OR value). However, when applied in Publish or Perish, no relevant articles appeared, even without a time frame restriction. To address this issue, the authors revised the search strategy by using two specific keywords: "independent remanufacturer" and "remanufacturer". The term "independent remanufacturer" was used to target studies focused on this particular actor, while "remanufacturer" was intended to capture broader studies involving other players in the remanufacturing ecosystem besides IR. The literature search was conducted using two databases: ScienceDirect and Google Scholar. No restrictions were applied to the publication year in order to explore research trends over time. This search yielded a total of 363 articles for further screening.

To ensure that the constructed PICO has been accurate in screening articles, a consistency check is conducted for both titles, abstracts, and full papers. By comparing the Kappa values (the agreement value between one reviewer and another) and obtaining a minimum value of 0.6, it indicates good agreement between the two reviewers [44]. In this SLR, a Kappa value of 0.8 was obtained, indicating that the constructed PICO has been accurate in assisting the consistency of both reviewers in article selection.

From the duplication screening results (see Figure 1), 248 articles were included in the title and abstract screening. A total of 87 articles were excluded due to not fitting the predetermined PICO criteria. 161 articles proceeded to full-paper selection. Among these, 114 articles were excluded due to lack of full-paper access. Thus, at the end of the screening process, 46 articles were identified for data extraction.

After selecting the articles, data extraction is carried out. However, before conducting data extraction, the author first establishes critical appraisal criteria to ensure minimal research bias. There are three biases focused on in SLR, namely selection bias, location bias, and evidence bias. To prevent selection bias, the author uses inclusion and exclusion criteria. First, the research had to explicitly address the role of independent remanufacturers or other key actors within the remanufacturing industry. Second, eligible studies employed appropriate research methods, including literature reviews, empirical investigations, or case studies. Third, only articles written in English or Indonesian were considered to maintain accessibility and comprehension. Fourth, all selected publications were required to be peer-reviewed to ensure academic rigor. Finally, to avoid individual bias and enhance validity, this article was reviewed collaboratively by two authors, ensuring that the content reflects a comprehensive and shared understanding. To minimize location bias, the authors used two different databases: ScienceDirect and Google Scholar. To reduce evidence bias, relevant sources were cited for each finding/ statement, allowing for direct reference to the corresponding findings. Figure 2 presents a list of journals related to independent remanufacturers (IR) and other types of remanufacturing actors, including the number of published articles. The results of the systematic literature review (SLR) were then integrated with the findings from a focus group discussion (FGD) involving eleven heavy equipment companies operating in Indonesia. This FGD was conducted on September 3, 2024.

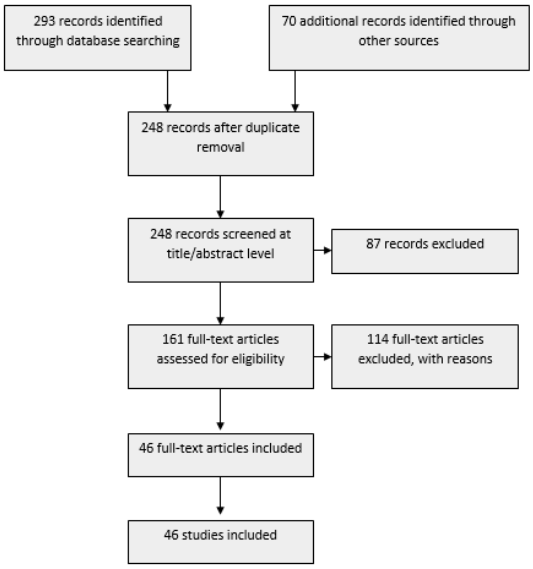

Figure 1 Prisma flow diagram

Table I List of Journals Related to IR And Other Remanufacturers

No	Name of the journal	Number of articles	Year of publishing
1	Applied Mathematical Modelling	1	2016
2	Blockchain: Research and Applications	1	2023
3	Decision Analytics Journal	1	2023
4	European Journal of Operational Research	3	2020,23,24
5	IEEE Access	1	2019
6	International Journal of Environmental Research and Public Health	1	2022
7	International Journal of Logistics Research and Applications	2	2022
8	International Journal of Production Economics	2	2021
9	International Journal of Production Research	1	2020
10	Journal of Cleaner Production	6	2015,20,21,23
11	Journal of Management Science and Engineering	1	2022
12	Procedia CIRP	18	2015,16,17,18, 20,21,22,23
13	Procedia Economics and Finance	1	2016
14	Procedia Manufacturing	2	2018,2
15	Proceedings of the 2000 NSF Design & Manufacturing	1	2000
16	Sustainability (Switzerland)	2	2020
17	Sustainable Production and Consumption	1	2021

III. FINDINGS AND DISCUSSION

A. IR Hypothetical Business Model

IR (see Figure 2) are entities that engage in remanufacturing products without the involvement of the Original Equipment Manufacturer (OEM) [45]. IRs restore products by independently collecting cores and refurbishing them, thus producing products that approach new condition [46]. They lack direct access to OEM technical specifications and often rely on reverse engineering or internal data sources [14]. IRs frequently compete with OEMs and other third-party remanufacturers, and they do not receive warranty support from OEMs [47], [48]. Some IRs operate in smaller markets, working locally, and directly sourcing cores from users or core suppliers [49].

Based on the results of the literature review, the business process of Company B closely aligns with that of an independent remanufacturer (IR). In the IR model, a distinctive characteristic is that the company undertakes product recovery processes without holding a license from the original equipment manufacturer (OEM). Findings from the conducted interviews indicate that Company B engages in product recovery activities without obtaining licenses from the OEMs. As illustrated in Figure 2, Company B is positioned on the consumer side, as it purchases heavy equipment—both new and remanufactured products—from other companies such as Company S, Company T, and others. Furthermore, Company B is categorized as a consumer because the recovered products are intended for internal use rather than for resale to external customers

B. OEM- Remanufacturer Hypothetical Business Model

OEM-R (see Figure 3) is an OEM company that has a manufacturing subdivision known as remanufacturing. Therefore, it can be said that OEM-R is a remanufacturing company that sells both new and remanufactured products. Sometimes, new products from the OEM tend to be cannibalized by remanufactured products because consumers prefer purchasing remanufactured products, which offer the same quality as new products but at a lower price. One of the efforts made by OEMs with a remanufacturing subdivision is through PSS (Product Service System). By marketing remanufactured products as PSS, where there is no transfer of ownership, similar to leasing, the new products owned by the OEM are not cannibalized by the remanufactured products [47], [48], [50]. Based on the results of the SLR, companies K1, L, and H illustrate the OEM remanufacturer. They are both OEM and remanufacturer for their own products (see Figure 3).

C. Other Hypothetical Business Model

Outsourced-R (see Figure 4) was an independent remanufacturing company before its status changed to Outsourced-R. Outsourced-R is a remanufacturing company appointed by the OEM to enhance the value of its end-of-life (EOL) products and also to minimize existing waste. In this context, the entire process from core collection to sales is carried out by Outsourced-R [51], [52]. Based on the

results of the Focus Group Discussion (FGD), there are two types of outsourced remanufacturers. The first is company T, which has obtained full licensing from the OEM, whereas company U2 is a mix, as some have obtained licensing and some have not, as illustrated in Figure 4. Contracted-R (see Figure 5) is almost similar to Outsourced-R; however, Contracted-R is appointed by the OEM as a partner for the core remanufacturing process. The core collection and the sale of remanufactured products are still carried out by the OEM [50]. The contract remanufacturer is represented by Company C2 as shown in Figure 5. However, a hypothesis was obtained that perhaps contracted remanufacturers could receive cores directly from consumers without going through dealers/retailers.

V. CONCLUSION

This study provides a deeper understanding of the structure and dynamics of remanufacturing actors, with a particular emphasis on independent remanufacturers (IRs) in the Indonesian heavy equipment industry. Through a rigorous systematic literature review and insights gathered from a focus group discussion (FGD) with eleven industry players, this research categorizes four key types of remanufacturers—Independent Remanufacturer (IR), OEM Remanufacturer (OEM-R),

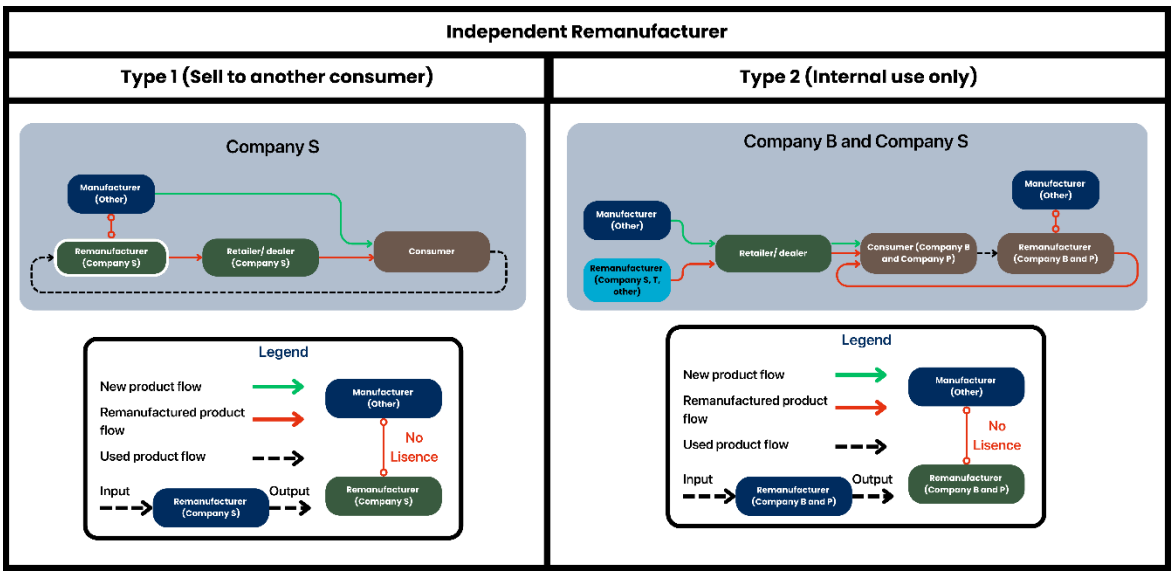

Figure 2 Hypothetical model for independent remanufacturer interaction

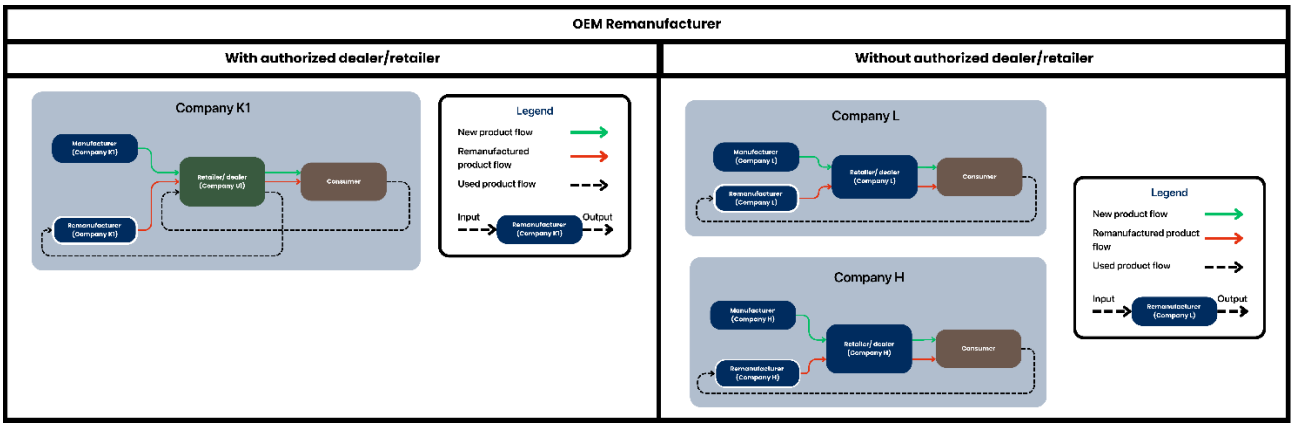

Figure 3 Hypothetical model for OEM remanufacturer interaction

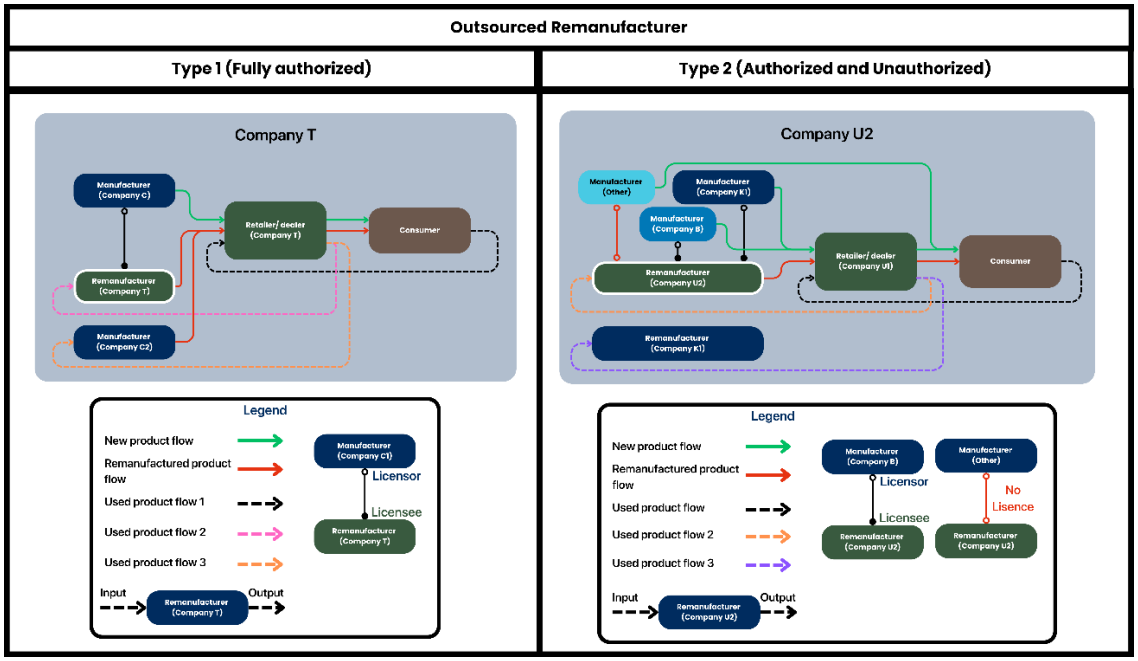

Figure 4 Hypothetical model for outsource remanufacturer interaction

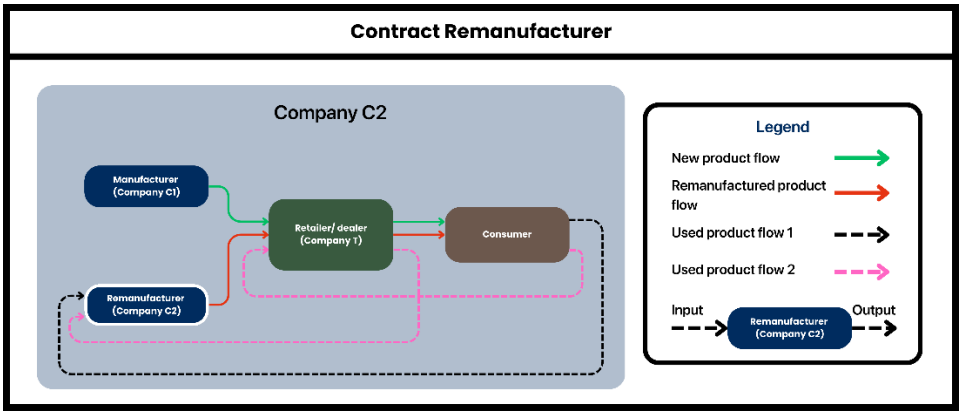

Figure 5 Hypothetical model for contract remanufacturer interaction

Outsourced Remanufacturer (Outsourced-R), and Contracted Remanufacturer (Contracted-R)—and proposes hypothetical models to illustrate their interaction mechanisms within the ecosystem.

The findings underscore the significant, yet often under-recognized, role of IRs. Unlike OEM-R or Outsourced-R, IRs operate without official licenses or technical specifications from OEMs, relying instead on reverse engineering and experiential knowledge to restore products to near-original condition [4], [11]. This independence offers agility and cost-efficiency advantages, especially in contexts where OEM support is limited. IRs also play a crucial role in core collection, a well-documented bottleneck in remanufacturing operations [6], [9].

However, their operations are not without challenges. From the OEM's perspective, IRs may create competitive tension by affecting brand integrity, bypassing licensing agreements, and reducing OEM revenue streams [18], [21]. From the consumer perspective, IR products may be perceived as riskier due to the absence of OEM-backed warranties and potential variation in product quality [4]. In the context of Indonesia, this study finds that IRs such as Company B reflect a consumer-facing remanufacturing model where recovered products are used internally rather than sold externally, reinforcing the diversity of remanufacturing roles in practice. Moreover, the presence of hybrid models—such as partial licensing observed in Company U2—signals the emergence of new governance mechanisms in remanufacturing collaborations.

Future research should focus on validating the proposed hypothetical interaction models through direct application and evaluation within remanufacturing companies.

Additionally, applying these models across different industrial sectors will help assess their adaptability and relevance beyond the heavy equipment industry. These validation efforts will not only strengthen the theoretical robustness of the proposed models but also provide practical insights for policymakers and industry practitioners in designing collaborative strategies that enhance the efficiency and sustainability of remanufacturing ecosystems.

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