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A comparative study of remanufacturing practices in the Swedish furniture industry

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Abstract. The Swedish furniture industry is dominated by low-volume, high-variety production, with only a few firms operating high-volume models. Although interest in remanufacturing is increasing, its implementation remains limited. This study aims to strengthen circularity in the Swedish furniture industry, focusing on remanufacturing in SMEs with low production volumes and high product variety. Empirical studies with five manufacturers were conducted as part of a collaborative research project, and the data were analysed through ecosystem, circular strategy, and manufacturing strategy perspectives. The companies exhibit similar product variety, production volumes, and manufacturing strategies, but they adopt circular strategies differently, ranging from reuse and repair to remanufacturing. Multiple intermediaries in the ecosystem reduce product traceability, and the absence of information exchange with customers further constrains circular flows. The study identifies a progression towards remanufacturing that begins with customer-specific remanufacturing, develops into hybrid production combining new and remanufactured products, and ultimately requires strategic decisions on dedicated systems or outsourcing as volumes increase.

1. Introduction

The European furniture industry discards approximately 10 million tonnes of furniture annually, much of which ends up in landfill or incineration.[1,2] This poses significant environmental challenges, particularly considering growing policy pressure to transition toward a circular economy (CE). Circular strategies such as repair, rental, resale, functional sales, centralized renovation, remanufacturing, and material recycling offer pathways to reduce waste and extend product lifecycles.[3,4] Among these, remanufacturing stands out for its potential to combine environmental benefits with economic viability. Remanufacturing is an industrial process turning used products to a condition that is equivalent to, or better than, their original state.[5] This definition emphasizes the systematic and quality-assured nature of remanufacturing, distinguishing it from more informal or ad hoc refurbishment practices. While industrial terminology and practices may vary, this definition provides a clear conceptual foundation for our analysis. To support remanufacturing, design for disassembly (DfD) has emerged as a key enabler.

DfD facilitates the efficient separation of components without damage, thereby improving the feasibility of repair, refurbishment, and recycling design.[5]

In Sweden, the wood processing industry is dominated by small and medium-sized enterprises (SMEs) located in rural areas and employs nearly 53,000 people.[6] Although reuse and basic renovation are common, more extensive refurbishment needs are typically met with material recycling or incineration, both of which prematurely end the CO_2-binding potential of wood. Remanufacturing remains rare, despite its potential to extend product lifespans and reduce environmental impact. However, the demand for sustainable solutions is growing, particularly from public sector actors who are major purchasers of office furniture and are actively revising their business models to support circularity.[3,7] Manufacturers recognize the importance of remanufacturing, but face barriers such as underdeveloped logistics, incompatible product designs, and procurement systems not adapted to circular flows. Most critically, remanufacturing is perceived as economically unviable.[4,8-9]

To scale remanufacturing, companies must address operational challenges including short order cycles, variability in material quality and supply, and the need for flexible production systems.[10] Additionally, cannibalization, where remanufactured products displace new product sales, can undermine profitability, especially when remanufacturing volumes grow but margins remain low.[11] Thus, there is a clear incentive to develop scalable, economically viable remanufacturing models that meet customer expectations while supporting environmental goals. Moreover, the academic literature provides limited knowledge concerning strategies for remanufacturing systems in SMEs. This paper aims to explore the transition toward increased remanufacturing in the Swedish furniture industry by developing knowledge on remanufacturing strategies, conceptualizing critical factors of remanufacturing, and analysing industry practices.

2. Theoretical framework

Theories related to circular ecosystems, remanufacturing typologies, manufacturing strategy, and production system design offer perspectives that influence remanufacturing. These selected theories are used to conceptualise key factors important for remanufacturing practices.

2.1 Circular ecosystems and circular strategies

A CE ecosystem can be defined as "communities of hierarchically independent, yet interdependent heterogeneous set of actors who collectively generate a sustainable ecosystem outcome".[12] Building on Aarikka-Stenroos et al.[12], the CE ecosystem is understood as a community of heterogeneous actors with varying roles, not structured according to traditional value chains or hierarchies. Instead, the focus is on system-level outcomes. The actors are linked through interdependencies, such as flows of physical, economic, and knowledge assets and shared resources that may be technological or cognitive. These interdependencies are handled through coordination mechanisms designed to reach the targeted outcomes. Circularity contributes directly or indirectly to several Sustainable Development Goals (SDGs), including SDG 8 (Decent Work and Economic Growth), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).[13] The CE ecosystem works collaboratively to improve systemic resource efficiency, as described by CE models such as the 3R model.[14] Moreover, each actor in the CE ecosystem should take responsibility for setting and regularly reviewing sustainability-related business goals, covering not just economic, but also environmental and social aspects. The 3R model promotes three core strategies:

1. Reduce: Minimize resource use and waste early in the lifecycle through efficient design, production, and consumption—for example, eco-design and lean/green manufacturing.
2. Reuse: Extend product and component life via repair, refurbishment, and remanufacturing, supported by strategies such as Design for Disassembly, Design for Repair, and reverse logistics.
3. Recycle: Recover materials from used products to replace virgin resources through recycling, upcycling, or, when necessary, energy recovery. Closed-loop systems and DfD enable efficient material reintegration.

2.2 Remanufacturing typologies

Abbey and Guide Jr[15] outline a typology of remanufacturing based on two dimensions: product design and strategic focus. The framework identifies four approaches:

1. Multiple Lifecycle Products combine robust design with a profit-oriented strategy, integrating remanufacturing into core operations and maintaining control over product returns.
2. Durable & Reparable Products are designed for longevity but lack strategic investment in remanufacturing, focusing instead on initial sales.
3. Commercial Returns involve single-use designs and cost-driven strategies, with limited reuse and fragmented reverse logistics.
4. Third-Party Remanufacturing emerges where original manufacturers do not engage in reuse, with external actors acquiring used products and remanufacturing them for profit.

The typology highlights that aligning design and strategy is essential for effective circularity; without commitment from original manufacturers, third parties often dominate the reuse market. Abbey and Guide Jr[15] argue that by examining a firm's product design philosophy and strategic intent, one can understand the different ways companies structure their closed-loop supply chains and remanufacturing systems. Their typology reveals how these choices shape operational priorities, market positioning, and the level of integration between forward and reverse logistics.

2.3 Manufacturing strategy

Manufacturing strategy refers to the long-term plans of a production system to support the company's competitive priorities.[16,17] A manufacturing strategy combines competitive priorities (outside-in focus) and decision categories (inside-out focus), creating a structured framework for evaluating how production decisions support strategic goals, see Figure 1.

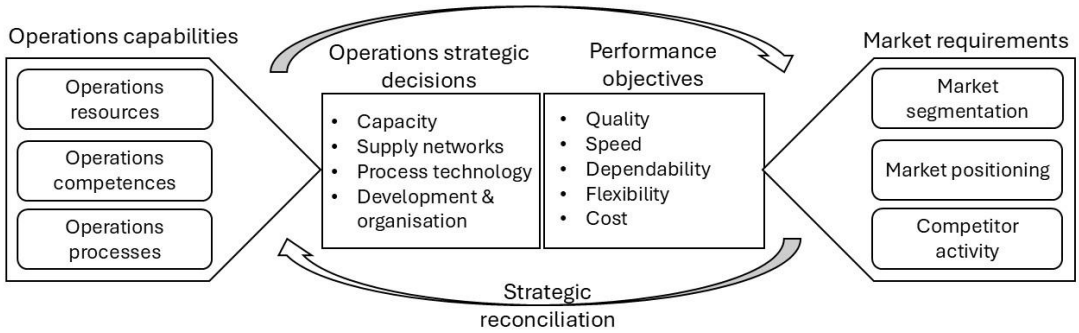

Figure 1. Manufacturing strategy based on Slack & Lewis[17]

The competitive priorities, performance objectives according to Slack and Lewis in Figure 1, serve as guiding principles to focus on to support the long-term strategies and to satisfy the market. The priorities include quality, speed, dependability, flexibility and cost. In some of the manufacturing strategy literature sustainability is included as an evolving competitive priority. In prioritisation between trade-offs Slack and Lewis suggests four key decisions criteria: capacity, supply networks, process technology, and development and organisation.

2.4 Remanufacturing systems

To combine new production with remanufacturing in the same facility and in the same production flow is called hybrid manufacturing–remanufacturing.[18] Figure 2 illustrates schematically how hybrid manufacturing works. New manufacturing or purchasing certain components is usually necessary to replace those that are too deteriorated to be remanufactured. In some cases, remanufactured components are used for new products, while in others, they are only used in remanufactured products. Manufacturing process equipment can be shared to some extent. Final assembly is probably shared if the production system is to be considered a hybrid.

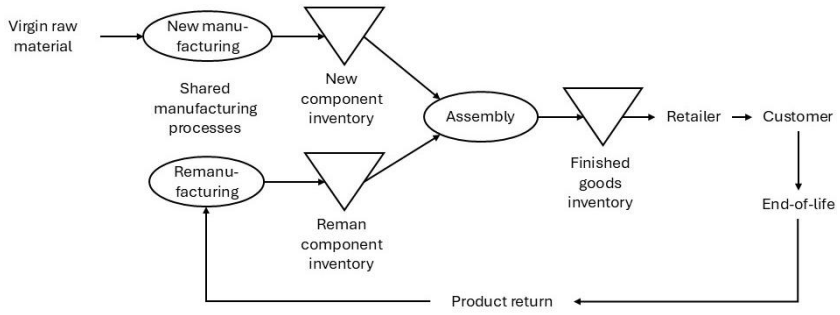

Figure 2. Hybrid manufacturing–remanufacturing model based on Aras et al.[19]

There is substantial research literature on the subject where the focus is on finding the optimal mix of new manufactured products and remanufactured products as well as finding inventory levels to optimize the profitability of the firm. There are a few articles that try to solve a real industrial problem (e.g.[20,21]). However, most articles have merely a vague coupling to actual industrial problems, and the focus is on mathematical modelling, and the data used for calculations and simulations is assumed. There are hundreds of articles about mathematical modeling of hybrid production and the attraction for the research community to this particular problem seems to be the resulting complexity caused by the combination of uncertainty in the in-flow, in terms of both timing and the quality of the cores, and the common uncertainties in demand and in internal processes of any production systems.[18] The strategical opposite of hybrid production is the focused factory concept.[22] The idea of focused factories is to separate production of different products or services into physically separate lines within the same facility or even separate in different facilities (Figure 3). The motivation to increase focus is to improve productivity.[23] The focused factory concept has been applied for remanufacturing in research, for example by Ketzenberg et al.[24] concludes, from a simulation study, that the attractiveness of parallel lines (or focused factories) decrease with the variability of assembly interarrival and processing times, and increase with the variability of remanufacturing processing time, the percentage of demand that is met with remanufactured parts, and line utilization. Thus, it is very

common in practice to invest in a separate line for remanufacturing if the volumes are large enough.

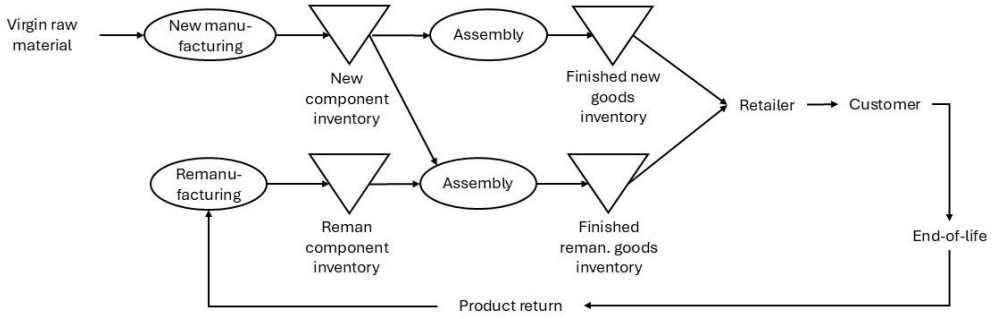

Figure 3. Focused manufacturing–remanufacturing model.

3. Methodology

This study is of qualitative nature and aims at conceptualizing factors of remanufacturing and analysing current practices. Empirical data were collected through semi-structured interviews and observations at five small and medium-sized companies (SMEs) located in southern Sweden. The companies participate in a research project, and they have initial experience with CE practices, particularly in repair, renovation, and remanufacturing for business customers and public institutions.

To support the analysis, a theoretical framework that outlines the remanufacturing factors were developed. The empirical data were analysed using this framework through a two-step process: first, a within-case analysis was conducted for each company, followed by a cross-case comparison to identify commonalities and differences. The findings were then interpreted in relation to existing literature, leading to conclusions and suggestions for future research.

3.1 Data collection

First, an interview guide was developed spanning market, production, and sustainability related questions. The interview guide consisted of a mix of predefined questions and more open questions, with the freedom to ask follow-up questions based on what comes up during the conversation. According to Bell et al.[25] the approach enables a deeper understanding of complex social dynamics by allowing interviewers to adapt to each participant's unique viewpoint. As a result, it supports a thorough investigation of manufacturing strategies and systems, competitive priorities and viewpoint on environmental concern in relation to CE. The interviews were conducted with one to four people and lasted 1,5-2 hours each, see Table 1 for information about data collection at each company. All interviews were recorded and transcribed. To strengthen the findings, additional data were collected through observations and follow up meetings.

The empirical data were analysed using the theoretical framework presented in Table 2. Through an inductive coding process, the authors identified a set of factors influencing the strategic decisions for remanufacturing. The factor initially emerged from patterns in the data in relation to the theoretical base according to the authors knowledge. To enable a systematic analysis and comparison of the cases, the factors were conceptualised. The conceptualisation

process involved iterative refinement to align with empirical findings with theoretical insights, forming the basis for the theoretical framework applied in this study.

The theoretical framework was applied in both the within-case analysis of each company and a cross-case comparison across all participating firms. The different companies' views, based on the interviews and follow up meetings, were described individually, forming the basis for within case analysis. Thereafter, a cross-case analysis was conducted to identify commonalities and differences across the participating firms. Finally, the empirical findings were compared with previous literature.

Table 1. Interviews and other data collection at each company.

	Participants at first interview	Additional data collection activities
Company 1	CEO, head of design, marketing and sustainability, quality and sustainability coordinator	2 observations in manufacturing 1 project meeting 1 workshop 1 follow up meeting after interview
Company 2	CEO, production manager, sustainability manager, production technician, design and range manager	2 observations in manufacturing 1 project meeting 1 workshop 1 follow up meeting after interview 1 additional interview
Company 3	Responsible for sales and range development	1 observation in manufacturing 1 follow up meeting after interview 1 additional interview
Company 4	Owner	1 observation in manufacturing 1 follow up meeting after interview 1 additional interview
Company 5	CEO	1 observation in manufacturing 1 follow up meeting after interview 1 additional interview

4. Within-case analysis

All five case companies are similar in several ways. They are small, between 67 and 16 employees, they produce high quality furniture in low volumes with a lot of customer demand-driven variety, the prices are high, they are all located in smaller towns in southern Sweden. Most of the companies let external designers design new products and they all foremost sell to the high-end office market with public and private organisations as end customers. Most customers are located in Sweden, but they also export their products. Most sales goes through retailers and they are both competitors and complement each other in the retailers' assortment.

The analysis of each company based on the collected data is summarized in Table 2. The top row of the table account for basic company information (number of employees, ownership), followed by the competitive priorities (quality, speed, dependability, flexibility, cost) and decision categories (supplier network, process technology, development and organization, and capacity derived from Slack and Lewis.[17]. Continuingly, the sustainability goals for each company are presented together with the 3R strategies adopted.[13,14] Finally, remanufacturing characteristics (design philosophy, remanufacturing typology) and remanufacturing system are accounted for based on Abbey and Guide Jr[15], Reddy and Kumar[18], and Aras et al,[19]

Table 2. Remanufacturing factors and within-case analysis.

Factor	Company 1	Company 2	Company 3	Company 4	Company 5
Employees and ownership	38, Part of a larger group	67, Part of a larger group	20, Private	16, Private	28, Private
Competitive priorities	Design (innovative and sustainable), quality and flexibility	Design, quality and flexibility	Design (durable and sustainable), quality	Flexibility, quality	Quality, flexibility and Design (durable and sustainable)
Supplier network	Local suppliers, a few international	Local suppliers, preferably smaller companies for flexibility	Local suppliers mostly	Local suppliers, have bad experiences from suppliers in low-cost countries	Local suppliers
Process technology	Flexible job shop layout, wood processing, paint shop, assembly	Flexible job shop layout Cutting and sewing, upholstery and assembly	Flexible job shop layout, wood processing, painting and lacquering, assembling	Flexible job shop layout CNC machines and automatised machineries, assembling	Flexible job shop layout, wood processing, painting, upholstery and assembly
Development and organisation	Partly in-house design	Partly in-house design	External designers	External designers	In-house design and product development
Capacity	Small and customer order-driven. Reman. demand is handled with present capacity.	Small and customer order-driven. Reman. demand is handled with present capacity.	Small and customer order-driven. Reman. to increase capacity utilization.	Small and customer order-driven. Reman. to increase capacity utilisation	Small and customer order-driven. Want to increase reman. capacity through focus factory.
Sustainability goals	More sustainable in-house production, using sustainable materials when requested and paid for by customers.	Design-driven, brand for remanufactured products. Full traceability, sustainable materials, and certification.	Durable products and zero use of plastics. Production methods to optimise material utilisation	Focus on sustainable materials and certificates	Become fully circular, fully renewable where possible, and offer services that support circularity in the market
3R strategy	Reduce (durable products). Reuse (reman.)	Reuse (reman.)	Reduce (durable products). Reuse (reman. and refurbish)	Reuse (reman. and refurbish)	Reuse (refurbish as a core offer)
Design philosophy	Modular design concept, flexibility and customer responsiveness	Unique design that shall match and support the customer's brand	Durable furniture in natural materials that ages beautifully and can be refurbished	Well designed, circular and durable wood furniture. Customer responsiveness.	Design for durability and for refurbishment
Remanufacturing typology, present	Durability and reparability, long life	Durability and reparability, long life	Durability and reparability, long life	Durability and reparability, long life	Durability and reparability, several life cycles
Remanufacturing system	Hybrid in small scale, starting up a focused mobile refurbishment shop	Hybrid	Hybrid, stresses the benefit of combining new- and reman.	Hybrid. Refurbish other producers' products too. Upholstery refurbishment is made by a partner	Hybrid, but plan to set up a focused unit in the factory for reman.

5. Cross-case analysis

The companies were analysed using the remanufacturing factors described in Table 3. Companies 3 to 5 have clearly defined sustainability goals, with Company 5 aiming for 100% circular design by 2030. In contrast, Companies 1 and 2 rely more on customer-driven sustainability choices. Despite these differences, all companies emphasize product longevity and demonstrate environmental awareness in branding, production processes, and material selection. Remanufacturing is currently integrated into their regular production systems, and all companies express ambitions to scale up these efforts.

All five companies are original manufacturers, designing and producing their own furniture. Collaboration with external actors is consistent across the companies, particularly in design and sales, involving external designers, resellers, and logistics partners. However, none maintain direct contact with end customers, which restricts traceability and complicates product recovery. Companies 1, 2, and 4 involve suppliers in remanufacturing. Company 4 notably in upholstery. Company 3 operates independently but depends on high-quality, sustainable raw materials. Both Company 3 and 4 remanufacture products from other brands, indicating a broader scope and Company 3 and 5 also sell remanufactured products to private consumers.

In relation to the 3R principles, all companies primarily engage with reduce and reuse, while recycling is less emphasized. Companies 1 to 3 focus on reducing waste through design and production optimization. Company 1 also explores reduction through experimental furniture using innovative biobased materials. Company 3 reuses by remanufacturing products for private customers. Companies 4 and 5 emphasize reuse through renovation services, including for external brands. Company 5 also offers a transparent pricing system for remanufactured products. Overall, remanufacturing is used to extend product lifespans, aligning with circular goals.

All companies emphasize robust design and long product lifespans. Company 1 highlights modularity to support future remanufacturing, while Companies 3 and 5 integrate Design for Disassembly and Repair (DfD/DfR). Their remanufacturing approach focuses on improving durability and reparability, with expressed intentions to move toward Multiple Lifecycle Products, most clearly in Company 5. All currently operate hybrid remanufacturing systems, and Company 5 plans to establish a dedicated remanufacturing unit. Company 5 also experiences challenges in upscaling concerning for example availability of skilled staff. While ambitions to scale up remanufacturing are evident, few firms have made clear strategic decisions regarding specialization, outsourcing, or the establishment of dedicated remanufacturing capacity. An expressed dilemma is also handling of outsourcing in relation to brand reputation since it is seen as a risk of quality problems that another company handles the products.

All companies rely on local suppliers, which improves lead times, flexibility, and traceability. Local sourcing also supports collaboration and strengthens sustainability profiles. Production is small-scale and order driven. Each company uses a flexible production setup with low automation and elements of craft-based techniques, supporting hybrid production. In Companies 1 and 2, remanufacturing development is led by management. Company 3 involves external designers at the product level, while Companies 4 and 5 apply lean principles in a more holistic development approach.

6. Discussion

The companies prioritize design, quality, flexibility, and sustainability. These are competitive priorities, following Slack and Lewis[17], that can support remanufacturing. One company explores leasing and rental models, indicating early steps toward business model innovation. As Slack and Lewis note, aligning competitive priorities with operational decisions is essential for strategic success. In this context, business model innovation will be crucial for scaling remanufacturing beyond hybrid systems.

Local sourcing is common across the companies and supports CE goals by improving lead times, flexibility, and traceability. However, supplier decisions should align with broader manufacturing strategies.[17]In this study, local sourcing is not always integrated into remanufacturing strategies, indicating a disconnect between procurement practices and circular ambitions.

All companies currently apply hybrid remanufacturing - manufacturing as remanufacturing strategic option, and to some extent they also have competition from third party out of the companies' control. As remanufacturing scales, strategic decisions will be required—whether to establish dedicated focus factories or outsource to third-party providers (figure 4). These decisions reflect movement along the design and strategy dimensions as remanufacturing matures. This aligns with Abbey and Guide Jr's[14] typology, which categorizes companies based on

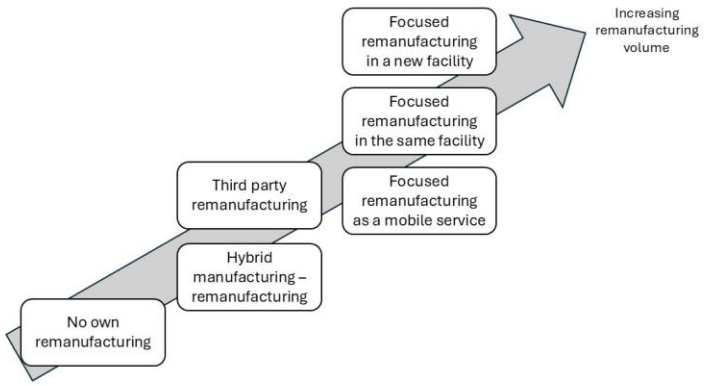

Figure 4. Remanufacturing strategic options.

product design and strategic focus. Currently, the companies position themselves within the durability and reparability category, emphasizing robust design with a profit-oriented strategy. One company, however, stands out by explicitly aiming for Multiple Lifecycle Products, signalling a strategic shift. Most companies have yet to make clear strategic decisions, but as remanufacturing develops, such decisions will become increasingly necessary. To not choose between the strategic options will force the customers to go to third party remanufacturers.

As described by Aarikka-Stenroos et al.[12], circular ecosystems rely on interdependent actors and coordination mechanisms. The studied companies demonstrate informal collaboration with designers, resellers, and logistics partners, but lack direct contact with consumers. This limits traceability and complicates product recovery as key challenges in circular systems. Coordination

is often ad hoc, highlighting the need for more strategically formulated CE goals at the ecosystem level to support systemic circularity. The companies do not articulate explicit CE goals, and there is no shared vision at the ecosystem level. They operate independently, which limits opportunities for systemic circularity.

Customer attitudes and perceptions strongly influence circular behaviour. Companies respond by showcasing sustainable materials and design choices. However, these efforts are often driven by design and branding rather than being embedded in strategic operations. This supports the insight that sustainability is frequently tied to brand identity rather than integrated into core business strategy as some manufacturing strategy literature suggests. As Heshmati[14] notes, the implementation of circular economy principles often faces systemic challenges, including the lack of strategic integration and alignment across organizational functions, which is reflected in the findings of this study.

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7. Conclusions

The study shows that Swedish furniture SMEs are in the early stages of integrating remanufacturing into their production strategies, primarily through hybrid systems. SMEs express ambitions to scale their circular practices, but the implementation is not strategically planned. The study proposes that the transition to more advanced circular models can be achieved developing clearer strategic focus, adapting manufacturing systems, and integrating remanufacturing more deeply into organizational planning and design processes. The transition can require not only operational adjustments but also strategic innovation to support scalable and economically viable remanufacturing. This could, for instance, be achieved by more systematically integrating Design for Remanufacturing principles into product development processes.

Although SMEs collaborate with designers, resellers, and logistics partners, there is no shared vision or goal within the broader ecosystem. Further, direct relationships with consumers is limited. Improved collaboration in the ecosystem is a key to develop scalable remanufacturing by giving access to used products, facilitate data-driven decision-making, and close material loops within the production system.

Future research is needed to evolve the knowledge concerning how SMEs can scale remanufacturing through collaborative models, improve traceability, and digital tools for product

and material information. Longitudinal studies are also needed to understand how strategic remanufacturing maturity evolves over time and which organizational capabilities enable SMEs to progress from linear to more advanced circular production systems. These studies can provide deeper insights into how existing typologies, such as those proposed by Abbey and Guide[15] apply.

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