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One man's trash is another man's treasure: Actor constellations to prolong the life of 'new waste' resources

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Abstract: The overconsumption of finite resources and the growing climate crisis necessitate innovative manufacturing waste management approaches. This study investigates the untapped potential of redesigning waste materials—specifically, pre-consumer waste or "new waste"—to create value while mitigating environmental impact. Unlike recycling or disposal, this approach leverages the inherent qualities of discarded manufacturing materials derived from virgin resources, aligning with the European Union's waste hierarchy principles. Using a multiple case study methodology, we analysed eight collaborations between manufacturing companies and industrial designers. The actor-resources-activities model was employed to understand how these partnerships foster redesign and prolong material lifespans. Our findings reveal that strategic actor roles and interactions are crucial in activating redesign potential, enabling the transformation of waste materials into new products. The crucial actor roles consist of an industrial designer, a waste owner, a waste processor, and a sales & distribution actor. The results highlight significant business and environmental opportunities, including cost reductions and waste diversion from landfills. However, realising this potential requires targeted interventions to facilitate cross-disciplinary collaborations and align objectives among stakeholders. By illustrating successful constellations of actors and processes, this research provides actionable insights into unlocking new avenues for circular economy practices in manufacturing.

Introduction

The amount of waste materials generated by manufacturing companies is too high, considering our limited resources and the growing climate crisis. Overconsumption of the planet's finite resources severely risks ecosystems, human health, and economies worldwide (Intergovernmental Panel On Climate Change (Ipcc), 2023). Data presented by the World Bank highlights the staggering scale of global waste generation, with projections estimating that, without intervention, waste generation will increase by 70% by 2050 (Kaza et al., 2018). When this projection is combined with the fact that 40% of global waste ends up in landfills (33% in open landfills, Kaza et al., 2018), the environmental impact of waste becomes palpable. This calls for better sufficiency, a concept described as "meeting human needs within planetary limits by curbing excessive consumption levels", (Niessen & Bocken, 2021). In the past, sufficiency has primarily been a consumer-based concept (Jungell-Michelsson & Heikkurinen, 2022). However, there has been a limited focus on sufficiency from a manufacturers point of view e.g., retaining and utilising the value of what may be defined as unavoidable waste from industry. This is also termed pre-consumer waste or 'new waste' materials. New waste, typically viewed as a burden, holds significant opportunities for simultaneous value generation and environmental impact reduction, e.g., by focusing on reusing and remanufacturing (Du et al., 2013; Pacelli et al., 2015). Such recommendations are also laid out in the European Union's five-step waste hierarchy: waste prevention, reuse, recycling, recovery (herein also energy recovery), and safe disposal (Directive 2008/98/EC, 2024). Studies show that recycling new waste can significantly reduce energy consumption and cost (reductions of up to 67% and 40%, respectively, Ali et al., 2019). Thus, there is a considerable untapped value potential in utilising the generated waste materials as *new products* rather than for recycling, energy, or waste dumps.

For example, it is possible to consider such discarded scraps from manufacturing as new waste derived from virgin materials, which opens the possibility of designing products with

what is essentially leftover virgin material. Normalising products made from new waste tackle the primarily consumer-based sufficiency concept from a different angle. By offering consumers easy, alternative new waste products to products made from traditional virgin materials, it may be possible to curb over consumption through better resource use.

Designing products with waste is a new but growing field. It has been described as an inverted process, where one starts from the material and defines a relevant use case/user need based on the qualities of the material, rather than starting from a consumer need and then defining the most suitable materials for the product. Ways to structure such a design process have been described before (Jensen et al., 2024; Pacelli et al., 2015). However, there is a lack of transparency and empirical evidence showcasing how to successfully prolong material lifetime in an industry setting, going beyond singular demonstration cases.

This work aims to study actor constellations and interactions that promote redesigning and reshaping waste resources. For this, a multiple case study methodology has been applied to study 8 cases where manufacturing companies were paired with industrial designers. We examine how different actor constellations interact to advance the redesign process with waste materials, and the conditions for creating new products using waste materials are explored using an *actor*, *resources,* and *activities* model (Ford et al., 2008; Håkansson & Snehota, 1995, p. 35).

Theory

The view on what is considered waste is starting to change, e.g., revealing the role of design in reducing the overall material consumption for consumer products by designing with waste (Feast & Laursen, 2023; Jensen et al., 2024; Pacelli et al., 2015). Waste materials have also been used in the design towards creative applications to create novel and unique aesthetics (Sampah et al., 2024), which in turn may serve as examples of how to elevate the perceived value of the final product. External legislation, such as directives from the European Union regarding environmental, social, and governance (ESG) initiatives, adds further pressure to tackle waste handling and reporting requirements. The European Commission has increased its focus on reducing the environmental impact of consumer products, as evidenced by the European Green Deal (European Commission, 2021). These directives compel organisations to reevaluate their approaches to waste management and explore innovative solutions. Among possible solutions lie the option to design new products from discarded materials.

However, designing with new waste (scraps) has proven difficult. For example, waste typically differs in quantity and size (Pacelli et al., 2015), and one does not necessarily know the end-user or area of application up front, which complicates the product design process. Pacelli et al. focus on designing with waste (defined as scraps) and presented a 3 phase process consisting of i) reducing the occurrence of production waste, ii) identifying the unavoidable waste, iii) starting a design process using the unavoidable waste to find relevant use cases or to create new products (Pacelli et al., 2015). During these phases, one must consider the *production setup* (e.g., how reliably one can expect the flow of material to be), conduct *waste material analysis* (functional, dimensional, mechanical, and physical properties), and consider the *sensorial qualities* (e.g., tactile or visual).

However, using design competencies to help solve issues regarding waste materials in manufacturing environments is an underexplored approach, with only a few examples (See Feast & Laursen, 2023; Jensen, 2024; Pacelli et al., 2015). One notable challenge when designing products using waste materials lies in shifting the traditional paradigm of product development thinking. Typically, product ideation begins with identifying a need or problem and then specifying materials and processes to address it. However, this process is inverted when working with waste materials (Jensen et al., 2024). Thus, material specifications are predetermined, and designers must creatively adapt these materials to fit emerging use cases, e.g. by applying an effectual approach to design (Feast & Laursen, 2023). This reversal poses a significant challenge to traditional product development methodologies.

Jensen et al. (2024) dove deeper into Pacelli's phases ii) and iii) by investigating how to assess potential use cases of waste materials properly. They posit that a linear understanding of the designerly material assessment of waste is viable and proposes that four modes of iteratively converging and diverging methods aid the process once a material's reuse potential: Mode 1 - Material sorting, mode 2 -

material potentials, mode 3 - areas of application, mode 4 - value-ranking utilisations. Moreover, they hint that the outcome of the waste reuse potential seems dependent on the assessors' competencies. Therefore, a deeper understanding of the actors collaborating in the design process of reshaping waste materials is currently missing from the discussions.

The ARA model

In business research, a model describing interactions between *actors, resources,* and *activities* (ARA) has been developed (Håkansson, 1995), which not only stipulates how important the interactions *within* a company are but also the interactions *between* companies (or actors), (Ford et al., 2008). See Figure 1. Ford et al. expressed: *"Interaction can be interpreted as a confrontation process that occurs* between *companies and which* changes *and* transforms *aspects of the resources and activities of the involved companies themselves"* (Ford et al., 2008, p. 3).

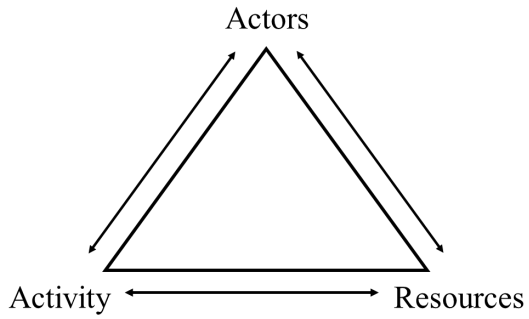

Figure 1 ARA Model from (Håkansson & Snehota, 1995)

In our case, this interaction occurs between different actor roles as *waste owners*, *design professionals*, *waste processors*, and *sale & distributors*, see Figure 2.

Figure 2 Actor roles when designing with waste intended for new consumer products

- **Designer**: The industrial designer paired with the manufacturer based on their experience with either the waste materials or core business area of the manufacturing company.
- **Waste Owner**: The manufacturing company typically generates production waste during their everyday activities.
- **Waste Processor**: Once a waste material is identified, this actor role is responsible for any additional material processing or waste handling to transform the new waste into the proposed product design. It could be the original manufacturing company or a third-party collaborator.
- **Sales & Distribution**: Once the proposed product design has been produced, this actor is responsible for selling and distributing the product. It could be the original manufacturing company or a third-party collaborator.

The *resources* and *activities* relate to waste materials in manufacturing processes and the production processes surrounding those materials. When the right partners are put together, as Håkansson & Johansson put it, a "team effect" occurs, which allows companies to perform activities and use resources that would otherwise not be possible to do alone (Håkansson & Snehota, 1995, p. 37).
To the authors' knowledge, when it comes to designing viable products with waste materials, such a team effect caused by the interactions between these actor roles has not been investigated previously, as the research focus is very nascent and there is a lack of empirical studies.

Methodology

We collaborated with manufacturing companies interested in reducing their waste and were open to new business opportunities, e.g., a product designed from new waste. The manufacturing companies were paired with industrial designers, where the researchers acted as matchmakers and project managers. The rest of the actor constellation emerged (hence the field experiment methodology). As shown in interactive research communities, such a constellation between industry and research has previously garnered rigorous and relevant outcomes for academicians and practitioners alike (Ellström et al., 2020). As such, the research project provided the basis for conducting empirical case studies to research suitable interactions between the actor roles presented in Figure 2.

Data collection

Over 3 years, eight design field experiments were carried out to analyse waste reuse potentials in different manufacturing fields and to arrive at viable product design proposals.

The data collected spans observations at manufacturing plants, voice recordings of initial start-up meetings, preliminary design proposals/ideas, the final design proposals, and closing semi-structured interviews with the involved representatives from the manufacturing company and the industrial designer to capture their experiences and reflections on the process.

Once the collaboration between the design firm and waste owner was concluded with a handover meeting, semi-structured interviews were conducted with the lead designers and the contact person from the manufacturer (typically a production manager or CEO). In total, 14 hours of interviews were conducted after the design phase ended, and on-site field notes, photos, and waste samples were collected. See Table 1.

Table 1 Overview of cases, actors interviewed, and data collected

Method	Cases and informants	Data and processing
Interview	1. Kitchens, 2. Apparel and footwear, 3. Furniture, 4. Powder coated steel, 5. Concrete, 6. Furniture upholstery, 7. Acoustic panels, 8. Mechanical equipment. (7x) Senior Designer, (3x) Technical manager, head of production, CEO, Architect, (2x) Environment and sustainability manager, sales and product manager.	+14 hrs interview data, transcriptions
On-site		Field notes, photos, waste samples

The interviews were conducted using a semi-structured interview guide centred around their participation in the project, their approach to designing with waste materials, the manufacturer's view on waste materials, and their reflections. Where possible, the interviews were conducted straight after the handover meeting. During the research interviews, the waste materials and a process report of their project curated by the research team were provided in front of them according to the artifact elicitation method to make sure to capture finer details otherwise easily omitted when relying on memory alone (Douglas et al., 2015; Wallwey & Kajfez, 2023).

The interviews were coded thematically using a qualitative approach inspired by Braun & Clarke's thematic analysis approach (Braun & Clarke, 2006, 2019).) For the data analysis, we used the ARA model of activities, resources, and actors as an analytical framework and codebook, which made it an abductive approach.

Findings

The outcomes from the field experiments formed different actor constellations between four different actor roles. Our analysis revealed eight different business constellations (more may be possible) and has been mapped out in Figure 3. The grey boundaries represent actor

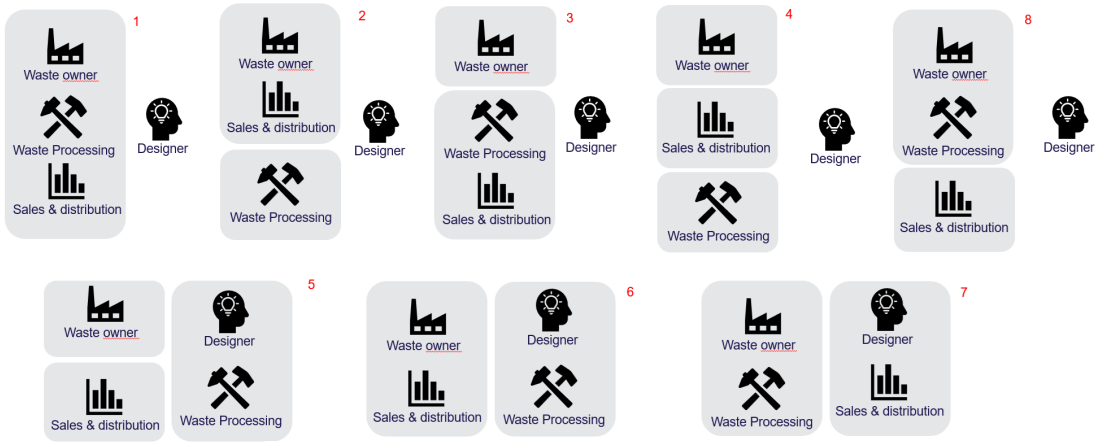

Figure 3. Actor roles and their observed constellation. The grey denotes actor roles within the same company

roles within the same company. For example, constellation 1 explains a situation where the designer works on a product proposal that is targeted to be processed and sold by the waste owner. In contrast, constellation 2 requires a third party to help process/manufacture the product proposal before the waste owner handles product sales and distribution.
Table 2 presents an overview of the cases and which designs went to market. The material-driven process forces designers and businesses to explore alternatives instead of working within existing actor constellations and value chains. Everything is turned upside down and driven by the material, as a designer describes:*"... It's not like I had a list of limitations thrown my way from the companies. That is what one needs to explore. And I think it's in the way that the approach is not 'I need to make a table'. No, it's 'I need to work with concrete'. It turns the design process upside down completely because materials are often some of the last points we decide upon",* Lead Designer, Case 5.

Table 2 Case overview, design proposals, if they have gone to market (GTM), and actor constellations.

Case	Waste material (type)	Design suggestions	Description	GTM?	#
1. Kitchens	Wood, compact laminate Kitchen sink table cutouts	Bedside table	Good product portfolio fit, combined two large waste fractions; is scalable due to a steady supply of standardised sink cutouts.	Y	3
2. Apparel and footwear	Textile, returned pants (customer defects)	Branded Shopper	Good product portfolio fit, fit existing market and sales channels, good fit between actor roles (described as symbiotic)	Y	2
		Travel case for small items	Semi-product portfolio fit, but lacked a proper business case. Good fit between actor roles.	N	
		Wardrobe organiser	Organiser lined with pant-textile material for watches, or a pouch for belts	N	
3. Furniture	Textile, leftover material from furniture upholstery	Cushion	Good product portfolio fit. Idea works in current form. Not able to enter production as is, but possible with additional resources.	Y/N	1
		LED lamp cover	Bad product portfolio fit, required additional materials outside of existing product categories and market. *Missing Sales & Distribution actor role*	N	2
		Wall-hung storage	Semi product portfolio fit. Idea does not work in current form but able to be adapted to their core products. Not able to enter production as is, but possible with additional resources.	Y/N	1
		Foldable stool	Product portfolio fit but required additional materials outside of existing product categories in an already competitive market. *Missing Sales & Distribution actor role*	N	2
4. Powder coated steel	Steel, leftover perforated plates from punch holes/lasercut	Weighted bags with scraps	Bad product portfolio fit. Intended for internal use, not enough scale, and business case not clear. *Missing Sales & Distribution actor role*	N	3
		Interior decoration	Bad product portfolio fit. Would require new sales channels outside of core business. The business case was unclear. *Missing Sales & Distribution actor role*	N	8
		Acoustic panels	Bad product portfolio fit. Would require new sales channels outside of core business. The business case was not clear. *Missing Sales & Distribution actor role*	N	8
5. Concrete		Shelves	Good fit between waste owner, waste processor, and sales & distribution, but the	N	

	Concrete test pour / texture sample		product did not match the scale of the waste stream. Waste volume and product did not match.		3
		Outdoor picnic table set	Good fit between waste owner, waste processor, and sales & distribution and a good fit between waste volume and product.	Y	
6. Furniture upholstery	Leather, scraps from furniture upholstery	Add-ons for door handles – stitched	Good product portfolio fit the waste owner. The designer processed waste but with possibility for outsourcing production. *Missing sales & distribution actor role. Missing waste processor at scale.*	N	5
		Add-ons for door handles – woven	Good product portfolio fit for the waste owner. The designer processed the waste but the product requires specialised skillsets to manufacture. *Missing sales & distribution actor role. Missing waste processor at scale.*	N	
		Weaved leather cushion	Good product portfolio fit for the waste owner. The designer processed waste but with possibility for outsourcing production. *Missing sales & distribution actor role. Missing waste processor at scale.*	N	
		Notebook cover	External sales & distribution channel found, and a good product portfolio fit was reached.	Y	
		Napkin rings	External sales & distribution channel found, and a good product portfolio fit was reached.	Y	
7. Acoustic panels	Wood-cement boards, Damaged acoustic panels	Acoustic/decorative panels in small modular shapes: *rhombus, jagged,* and *squares* with milled patterns	Bad product portfolio fit. Required a new production line with dedicated personnel *(missing resources)*. The business case was not clear. *Missing sales & distribution actor role. Missing waste processor at scale.*	N	3
		Small Acoustic panels for hidden placement under tables	Bad product fit, the solution would not provide enough area to contribute to any real noise dampening *Missing sales & distribution actor role. Missing waste processor at scale.*	N	
		Decorative wall-hung letters or tetris shapes	Bad product fit. Would require a new production line with dedicated personnel. The business case was not clear. *Missing sales & distribution actor role. Missing waste processor at scale.*	N	
8. Mechanical equipment	Steel scraps	Roller table	Bad product fit. Required new sales channels in areas where competition is already high and would not be able to compete on price. *Missing sales & distribution actor role. Missing waste processor at scale.*	N	4
		Car creeper	Bad product fit. Required new sales channels in areas where competition is already high and would not be able to compete on price. *Missing sales & distribution actor role. Missing waste processor at scale.*	N	

Discussion and conclusions

The successful realisation of products made from reshaped waste depends on the alignment and collaboration of four critical actor roles: Designer, Waste Owner, Waste Processor, and Sales & Distribution. The interplay between these roles directly influences the proposed products' feasibility, scalability, and market fit.

This study's analysis of eight cases highlights the pivotal factors, challenges, and opportunities in leveraging waste materials for innovative product development without drawing on virgin material supply chains.

Material-Driven Design and Portfolio fit

The material-driven design approach demands designers start with waste materials rather than predefined product ideas. This reversal of traditional design processes is both a challenge and an opportunity. Such open-ended exploration fosters creativity but requires strong alignment with Waste Owners and Waste Processors to ensure scalability and practicality.

Several cases demonstrate how product proposals achieved a good portfolio fit and went to market, such as Case 1's bedside table, Case 2's branded shopper, Case 5's concrete table, and Case 6's notebook cover and napkin rings. These products shared key characteristics:

- They aligned with the Waste Owner's core product categories.
- They fit seamlessly into existing sales channels or identified new distribution opportunities.
- The waste material supply was steady, standardised, or scalable.

Challenges in Actor Role Alignment

Despite these successes, many cases faced significant challenges due to misaligned or missing actor roles:

- **Waste Processor Role:** The absence of an efficient Waste Processor was a recurring bottleneck. For example, **Case 6**'s woven leather door handle add-ons and cushions required specialised processing skills and scalable operations that were unavailable during the project. Similarly, **Case 7**'s acoustic panels and **Case 8**'s steel products lacked processing capabilities that matched the product proposal's needs.
- **Sales & Distribution Role:** Products with strong design potential often fail to progress due to missing sales and distribution pathways. Examples include **Case 3's LED lamp cover** and **Case 4's acoustic panels**, which required entirely new sales channels or significant investment in distribution, making them commercially unviable.
- **Strategic Alignment:** In some instances, the lead contact from the Waste Owner did not have the decision-making power or strategic alignment to move the project forward. In **Case 8**, this led to proposals like the roller table and car creeper that did not fit the company's market focus or competitive strengths.

Critical Activities and Resources

The success of reshaped waste products hinges on specific activities and the efficient use of resources by the actor roles:

- **Market Analysis and User Testing:** Identifying potential customers and testing product functionalities (e.g., **Case 2**) ensures market readiness.
- **Standardisation:** Defining standard sizes and properties of waste materials, as seen in **Case 1's sink cutouts**, helps integrate the waste into scalable production processes.
- **Waste Dating and Partnering:** Finding suitable collaborators for waste design and production was instrumental in several cases.
- **Leveraging Existing Supply Chains:** Case 5 demonstrated how minimal changes to existing processes (e.g., using a transportable mould) can reduce costs and simplify scaling.

Portfolio Fit and Business Constellation

The strategic fit of a product proposal is a key determinant of its success. Products with good portfolio fit often align with the Waste Owner's existing offerings and leverage established sales channels, as seen in Cases 1 and 2. In contrast, products like Case 4's acoustic panels or Case 8's car creeper struggled due to misalignment with core business areas and the need for entirely new sales and distribution strategies.

The "right" business constellation is context-dependent and requires early involvement from all actor roles. In Case 3, including Sales & Distribution actors earlier in the process could have expedited the adaptation of wall-hung storage to align with the company's core offerings.

For products to succeed in conventional product design, there must be a so-called strategic fit between the available competencies, the market and end-users, and the company strategy (Møller & Laursen, 2023,

p. 51). Møller & Laursen, 2023 investigated the design challenges between these influencing factors before creating a strategic fit that created long-lasting and successful products. However, past examples of strategic fit did not focus on how one might better utilise available resources, e.g., how existing waste materials could be considered in the product design. This work implies that collaboration between different actors from different disciplines could be very beneficial in better exploiting the untapped potentials for optimising material use, e.g., in the form of products designed from waste materials. The chosen (or available) actor constellations can predict how well the reshaped waste product is positioned for the consumer market. More data is needed to determine whether such a material-driven design approach using new waste materials succeed in offering consumers convenient alternatives to linear, more environmentally harmful products, or, if they only manage to increase overall production volume of products with limited use.

Suggestions for Further Research

1. **Exploring 'Waste Symbiosis':** Developing business models in which Waste Owners achieve higher returns for waste materials and Waste Processors gain affordable resources could enhance valorisation of waste materials. E.g., could this be explored from a sufficiency perspective through a microeconomic lens on business collaboration.
2. **The effect of new waste products in a take-make-waste environment:** How well new waste products perform or succeed over traditional products from virgin materials need further investigation. As a minimum, user needs have to be met before such new waste products are a viable replacement of traditional products.
3. **Actor Role Optimisation:** Understanding how to better integrate Waste Processors and Sales & Distribution roles in the development process, particularly in scaling waste-based products, is critical for successful future projects.

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