Research paper
6th PLATE 2025 Conference
Aalborg, Denmark, 2-4 July 2025

Exploring take-back recovery strategies in the Circular Economy: A Multiple Case Study Analysis

Yoon Jung Choi[a], Jiayuan Dong[b], Jaehoon Pyon[c]
a) Industrial Design, Virginia Tech, Blacksburg, USA
b) Mind Music Machine Lab, Virginia Tech, Blacksburg, USA
c) Echo Lab, Virginia Tech, Blacksburg, USA

Keywords: Take back, Recovery, Return, Responsible disposal, Circular Economy, Design for X.

Abstract: The take-back of end-of-use products has gained increasing importance with the growing focus on the circular economy. However, not all take-back strategies have been thoroughly explored and understood in relation to consumer engagement. This study examines the role of take-back recovery approaches and strategies in the circular economy, integrating a product design and service lens to address consumer return practices. The research identifies four distinct opportunities under the take-back umbrella: Direct Reuse, Ease of Disassembly, Final Recovery, and Safe Disposal. For each opportunity, potential sub-opportunities are identified and expanded upon. Through a multiple case study analysis, these sub-opportunities are further developed using a "Design for X" approach to form nine distinct take-back strategies. This research emphasizes that the appropriateness of a take-back strategy depends on various factors, such as consumer behavior and context, industry specifics, and material flows. The study highlights the critical role of take-back systems and returns behavior in promoting circular product development and consumption.

Introduction

The shift from a predominantly linear economy to a Circular Economy (CE) is increasingly critical due to the environmental challenges associated with resource depletion and waste generation resulting from shorter product life cycles (Bhatia et al., 2020; Gupt & Sahay, 2015). Despite global efforts, only 30% of collected waste materials are recovered and recycled (Singh & Ordoñez, 2016), underscoring the need for more robust closed-loop systems, including effective take-back strategies. Take-back systems, which involve transferring end-of-use products from consumers back to recovery sites for reuse, recycling, or safe disposal (Chouinard et al., 2011; Ghoreishi et al., 2011), are central to the success of the CE.

Companies often face significant challenges in designing and implementing these systems (Abdessalem et al., 2012; Singh & Ordoñez, 2016). These challenges stem from a shortage of skilled professionals experienced in take-back practices (Waqas et al., 2018) and limited consumer awareness and participation (Jena & Sarmah, 2015). Historically, resource collection and reuse were common, supported by local charity shops or small businesses; however, industrialization has largely displaced these sustainable practices, leading to a reliance on virgin material extraction (Cooper, 1994). Furthermore, take-back behaviors are sometimes associated with socioeconomic status, impacting broader adoption (Iyer & Kashyap, 2007). In recent years, the growing environmental challenges have renewed interest in take-back systems as essential components of the CE (Bockholt et al., 2020; Ghoreishi et al., 2011; Paut Kusturica et al., 2020; Vegter et al., 2020). These systems are now recognized as viable solutions to modern consumption patterns, encouraging resource recovery and responsible disposal.

This research seeks to expand the understanding of take-back systems from a design perspective, focusing on strategies that maximize value recovery while minimizing harm to humans and the environment. Adapting the Reuse framework by Franconi et al. (2023), we employed a "Design for X" approach to analyze four critical take-back strategies—Direct Reuse, Ease of Disassembly, Final Recovery, and Safe Disposal —to identify the core components and factors that contribute to successful initiatives. Additionally, this research explores the role of consumer return behavior and awareness in shaping the take-back system. By examining multiple case studies, we provide insights into future developments and best practices for designers and stakeholders interested in implementing effective take-back strategies.

Approach and methodology

This study employs a qualitative exploratory approach with multiple-case study approach to examine take-back strategies and their implications within a CE framework. The research aims to identify and classify different recovery strategies by integrating a Design for X (DfX) approach. The methodology follows four key stages: (1) data collection through literature review (2) development of criteria for analysis, (3) case study investigation (4) synthesis of findings into distinct take-back strategies.

Phase 1: Exploring and Classifying Take-Back Strategies

We began by establishing a comprehensive understanding of take-back systems and recovery strategies through literature analysis. This exploration focused on product value, design objectives, consumer behavior, and reprocessing methods for returned products. Our review identified that existing literature predominantly addresses take-back through terms like "reverse logistics," "closed-loop supply chain," and "reverse supply chain."
Based on these initial findings, we developed a focused search string: ("take-back" OR "reverse logistics" OR "reverse supply chain" OR "clos* loop supply chain") AND (step* OR stage* OR method* OR process* OR activity OR aim* OR type* OR intention* OR market value* OR consumer behavior*) AND (waste OR "end of life" OR "end of use"). We targeted English-language journal articles published between 2009 and September 2024, excluding content focused on reuse with ownership, perception of refurbished products, or collection center statistics.

Phase 2: Development of Analysis Framework

From our literature analysis, we identified recurring themes and characteristics of take-back systems. This allowed us to develop a structured analytical framework consisting of six key criteria (presented in Table 1) that capture the essential dimensions of take-back strategies: quality considerations, market value implications, type and origin of value, strategic aims, reprocessing methods, and consumer engagement patterns.

Criteria	Description
Quality	The condition and performance of products made from returned materials or components and compares them to products made from virgin materials.
Change in market value	Whether the value of the product increases, decreases, or remains the same compared to its previous life cycle.
Type (product, component, material), origin of value	The type of item being returned and its associated value created.
Aim of the take-back design strategy	The specific objectives driving the design strategy.
Reprocessing methods	The techniques used to enable the recovery of the item, and the entities responsible for carrying out these processes.
Consumer behavior and engagement	The behaviors required to support take-back processes.

Table 1. Key criteria for analyzing take-back strategies. These criteria were derived from recurring themes in the literature and provide a structured framework for evaluating different approaches. An enlarged version of the image is provided in Appendix 1.

Phase 3: Case Study Investigation

To complement the literature review, a multiple case study approach was adopted following Yin's (2009) case study methodology. We identified and examined diverse cases of take-back systems across various industries and product categories using resources like Google Scholar and ScienceDirect. Each case was systematically analyzed using our established criteria. A pattern-matching technique was applied, comparing observed take-back strategies. Once case studies were identified, each was analyzed using the pre-defined criteria (Table 1). The analysis involved Comparing case studies against the key characteristics of take-back strategies (Table 2), identifying similarities and deviations. Assessing the effectiveness of each strategy in terms of product recovery, material flow, and consumer engagement.

Phase 4: Application of Design for X

We then employed the Design for X (DfX) approach to translate our findings into practical design strategies. DfX is a systematic methodology that optimizes both design and process by accounting for various factors (Arnette et al., 2014) ensuring specific characteristics and quality criteria are integrated into final designs (Kuo et al., 2001).

This allowed us to articulate distinct take-back strategies with clear design implications. For each case study, we analyzed how products and systems were designed to facilitate specific recovery pathways, identifying common patterns and unique approaches that could be generalized into design strategies.

Characteristics	Quality	Product market value	Aim	Reprocessing	Consumer behaviour and engagement
Reuse	As is	High	Reuse/ Recycling	Cleaning	Return to retailer or processing facilities
Repair	Almost new	Mid-low	Reuse	Disassembly / Replace or Fix	Return to retailer or manufacture
Re-furbishment	Almost new	High-mid	Reuse/ Restoration	Cleaning / Disassembly repaired / Replace / Restored	Return with or without incentive
Re-manufacture	Like new	High-mid	Renovation	Disassembly / Clean / Inspection / Rebuilt	Return to recycle bin collection
Cannibalization	Almost new	High-mid	Reuse	Disassembly / Salvaging intact component	Return to manufacturer
Recycle	Usually lower than original	Low	Maximum material reuse/ Reproduce	Sort/ Clean/ Reprocessing	Recycle bin
Energy	Transformed	Low	Recover as an energy source	Sort/ Process	Return to manufacturer / Recycle
Safe disposal	N/A	N/A	Safely dispose hazardous material	N/A	Return

Table 2. Main recovery strategies comparison for take-back. Note that the table is based on a broad context and may vary according to the specific case and context. An enlarged version of the image is provided in Appendix 1.

Results

Classification of Take-Back Recovery Strategies

Our analysis of sixty-eight studies revealed that existing literature typically approaches take-back from one of two perspectives: a manufacturer-focused perspective and a consumer-focused perspective. The manufacturer-focused perspective follows the definition of take-back by Esenduran et al. (2016) as "an initiative organized by a manufacturer or retailer to collect used products or materials from consumers and reintroduce them into the original processing and manufacturing cycle." In contrast, the consumer-focused perspective emphasizes return behaviors, defining take-back as "all the activities involved in transferring the used product from the customers' possession to the recovery site" (Ghoreishi et al., 2011). This approach focuses on understanding behavioral patterns and consumer engagement (Elzinga et al., 2020). Additionally, Blomsma et al. (2019) present a circular strategies scanner, outlining 32 CE strategies that involve consumer behavior. However, a lack of clarity regarding recovery strategies in relation to both consumers and manufacturers may hinder progress toward a Circular Economy, as both play essential roles in the take-back system.

Categories of take-back based on value changes	Resources Recovery	Product types	Reference (papers)
Direct Reuse (Value remains)	Reuse as it is (product)	Packaging	Muranko et al. 2021 Ellen Macarthur Foundation. 2023 Nakajima and Vanderberg et al. 2006
		Fashion and textile	Tripa and Indrie et al. 2021
Ease of Disassembly (Value retain or increase)	Repair (product)	Fashion and textile	Zhang and Hale et al. 2022
		Consumer electronic	Svensson-Hoglund et al. 2021
	Refurbishment (product)	Furniture	Öhgren et al. 2019
		Fashion and textile	Dang et al. 2023
		Consumer electronic	Fleischmann et al. 2003 Curvelo Santana et al. 2021
	Remanufacture (product)	Transportation	Zhang et al. 2017
		Consumer electronic	Webster and Mitra et al. 2007
Final recovery (Value transform)	Cannibalization (components or material)	Consumer electronic	Ripanti et al. 2016
	Material recycling (components or material)	Fashion and textile	Sandvik and Stubbs et al. 2019
		Consumer electronic	Gu et al. 2021 Sun et al. 2022
		Packaging	Sazdovski et al. 2021
	Energy recovery	Food waste	Kadel et al. 2014
Responsible disposal (Value lost)		electronic	Chandrasekaran et al. 2018
		Medicine	De Filippis et al. 2012
	Safe disposal	Medicine/ pharmacy	Yanovitzky et al. 2016 Lystlund et al. 2014
		Paint packaging	Dursun and Sengul et al. 2006
		Batteries	Wagner et al. 2013

Table 3. Comparison of specific sub-strategies. An enlarged version of the image is provided in Appendix 1.

Thierry et al. (1995) focused on the practical dimensions of take-back, recognizing that consumer awareness and return behaviors are increasingly shaped by Product Recovery Management (PRM) as customers and regulatory bodies press manufacturers to manage product waste. They introduced the concept of "cannibalization" as a way to recover material value during reprocessing. Their work enabled us to categorize take-back into four distinct types based on value retention: Direct reuse (product value retention), ease of disassembly (product or material value retention), final recovery (component or material value decrease), and responsible disposal (no value). Our research expands this framework by categorizing take-back approaches according to distinct value and return pathways. Each pathway comprises specific sub-strategies tailored to different product types and recovery objectives, as summarized in Table 3. This categorization acknowledges the diversity in recovery routes and the varied conditions under which products are returned, providing a more comprehensive framework than previously available in the literature.

Design strategies articulation under take-back

We employed the DfX approach to articulate a range of strategies encompassed within the take-back model. DfX is a systematic design methodology that seeks to optimize both design and process by accounting for various factors (Arnette et al., 2014), ensuring that specific characteristics, functions, or quality criteria are integrated into the final design (Kuo et al., 2001). To achieve this, we created a generic description of the case studies, organized according to different categorization criteria. Then, we employed DfX to generalize and articulate distinct take-back strategies derived from our case studies and definitions. This process involved analyzing each strategy to determine how it could be optimized for different X factors, considering recovery processes and consumer behavior. Additionally, we applied seven specific criteria, as outlined in our methodology, to comprehensively describe each take-back strategy.

Design for Direct Reuse (DfDR)

This strategy focuses on designing products that can be reused and resold “as is” once they are returned. There are two strategies that can be used within DfDR that are:

Design for Return Store (DfRS)

DfRS focuses on enabling efficient product recovery by providing consumers with a convenient method to return used products directly to retail locations for cleaning, reuse, or refilling. This approach facilitates resource recovery by allowing valuable products to be reclaimed and re-entered into the lifecycle. To make the in-store or e-commerce return process seamless, designers should consider clear instructions and providing prepaid labels, ensuring a straightforward and secure experience for consumers and enhancing accessibility and participation. Figures 2 and 3 illustrate a few applications of this strategy.

Figure 2. In-store return system at Loop. © Loop.

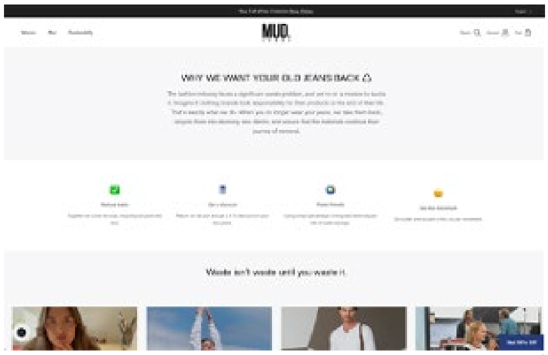

Figure 3. Mail return system at MUD Jeans. © MUD Jeans.

Design for Door-to-door Collection (DfDC)

DfDC aims to enable multiple uses of products through a collection and pick-up system, where products and/or packaging are returned and delivered after being refilled by the company. This strategy focuses on the use of durable materials, such as glass, metal, or heavy-duty plastics, along with refillable designs that support repeated use. The design must support efficient collection logistics, incorporating sustainable transportation practices. Direct collection from consumers allows products to be gathered in bulk and transported directly to processing facilities, minimizing handling and maximizing efficiency in recovery processes. To encourage regular engagement, companies often provide incentives such as discounts or rewards for consumers who consistently return items, fostering long-term participation. Examples are mainly packaging, as shown in Fig. 4.

Figure 4. Product collection and return system at Milk & More. ©Milk & More

Design for Ease of Disassembly (DfED)
DfED is the practice of designing products that are able to retain or increase the value of the end-state of the product and/or material after the collection. DfED strategies include:

Design for Repair (DfR)
DfE aims to design products that can be efficiently broken down into individual components for repair, fixing specific faults or malfunctions, and restoring basic functionality. This approach often involves part replacement and the recycling of components that cannot be fixed. DfR employs non-permanent connections, such as screws or snap fits, instead of adhesives or welds, allowing parts to be separated without damage. Modular designs, which facilitate easy disassembly, are frequently adopted to streamline repairs. Additionally, many companies provide postal or drop-off services for collecting broken products, promoting consumer loyalty through accessible repair options. Examples include brands that accept damaged items or clothing for repair (Figure 5).

Figure 5. Fairphone repair take-back system. ©Fairphone.

Design for Refurbishment (DfRf)
DfRf focuses on restoring a product to a "like-new" or improved condition, making it suitable for resale. Refurbishment typically involves thorough cleaning, inspection, and replacement of worn-out parts. Products designed are often modular, with replaceable parts and durable materials that can endure multiple refurbishment cycles, extending product life. Non-replaceable components may also be recycled as part of this approach. Consumers are encouraged to return items to retail locations, drop-off hubs, or use mail-in services. Patagonia's wear program (Figure 6) and IKEA Local Recovery Hub (Figure 7) accept worn-out products for refurbishment in exchange for store credit or reward. In some cases, refurbishment involves creative methods to give new life to old products.

Figure 6. Patagonia's Wear Program aims to refurbish old products. ©Patagonia

Figure 7. IKEA Local Recovery Hub refurbishing old products ©IKEA

Design for Remanufacturing (DfRm)
DfRm is focused on enabling products to be efficiently disassembled, inspected, restored, and reassembled to a like-new condition. This approach emphasizes the use of durable materials and modular parts designed to endure multiple remanufacturing cycles. For instance, engine blocks are often designed for straightforward disassembly and reassembly, with standardized parts across models to allow component interchangeability, thereby simplifying the process and reducing time and labor costs (Figure 8). Non-reusable components may be recycled. Many companies

offer incentives for consumers to return used products or parts, which are then remanufactured to meet original performance standards.

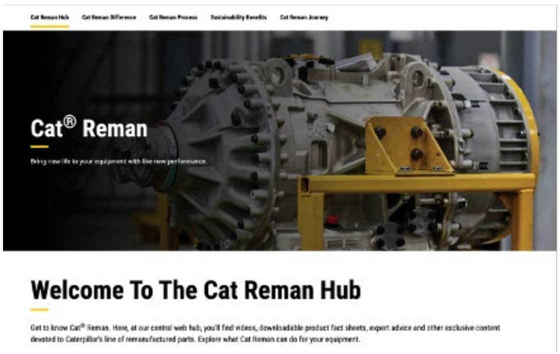

Figure 8. Caterpillar's Cat Reman program where it collects the products for remanufacturers. ©Caterpillar

Design for Cannibalization (DfC)

DfC aims to maximize the recovery and reuse of valuable components from products that are no longer functional or suitable for complete refurbishment or remanufacturing. This approach enables companies to salvage parts from returned, end-of-life products for use in repair, refurbishment, or new production, thereby minimizing waste and reducing the need for new resources. DfC focuses on designing products with modular, easily removable parts -such as processors - that can be salvaged even if the overall product is no longer operational. Many components are designed to be compatible across different models, enabling parts from one model to be used in the assembly of another, thus extending the lifecycle of these components without reprocessing them into raw materials. Companies provide drop-off locations or partner with charity stores, offering incentives to encourage consumers to return used products. Examples include ink and toner recycling programs that recover parts for reuse (Figure 9).

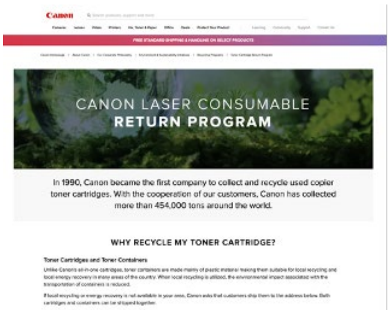

Figure 9. Canon toner recycle program. ©Canon

Design for a Final Recovery (DfFR)

DfFR is the practice of designing products that are able to transform value into new products after collection. DfFR strategies include:

Design for Material Recycling (DfMR)

DfMR focuses on enabling the efficient breakdown of products into raw materials that can be reused to create new products. This approach includes two sub-strategies: Design for “same purpose” and “design for different Purpose”. The "same purpose" strategy emphasizes recycling materials like metals and glass, aiming to reuse them in the production of the same or similar products. The "different purpose" strategy involves recycling materials that undergo a change in value during processing and repurposing them for different applications or products. To support these strategies, clear material labeling and the use of standardized, recyclable material facilitate sorting and processing at recycling facilities. Consumers are encouraged to deposit products in designated collection boxes or mail them back to the company. Some companies provide a QR code along with a prepaid envelope for easy returns, incentivizing customers to participate in the recycling process (Figure 10).

Figure 10. Everywhereapparel.com takes back clothing for recycling. ©Everywhere Apparel

Design for Energy Recovery (DfSR)

DfER aims to safely collect and process waste materials to recover energy, typically through specialized waste-to-energy facilities that prevent toxic emissions. In these facilities, the heat generated from incineration is converted into electricity or thermal energy for industrial applications. This approach also provides a safe disposal option for products, such as pharmaceuticals or food waste, which might otherwise pose an environmental impact (Figures 11 and 12), while simultaneously recovering energy from the waste. Designers should prioritize materials with high calorific values that provide substantial energy during incineration while avoiding toxic materials that could release harmful emissions. Additionally, products should be designed for easy disassembly, allowing parts to be separated from those intended for incineration. Clear material labeling or QR codes further assist waste processors in identifying and managing each component.

Figure 11. Medication collection kiosk at CVS.

Figure 12. Food waste collection kiosk. © Wikimedia

Design for a Safe Disposal (DfSD)
DfSD focuses on ensuring that hazardous products are safely collected and disposed of, reducing risks to human health, soil, and water systems. This approach provides consumers with a secure and environmentally responsible method for disposing of potentially dangerous items, such as batteries, medications, and paint. Key design elements include tamper-resistant, spill-proof packaging that prevents hazardous materials from leaking or causing harm during collection, transportation, and disposal. Specialized facilities with strict emission controls are required to safely incinerate these products. Clear labeling and disposal instructions guide consumers on where and how to return items, whether through drop-off locations or mail-in services. To encourage responsible disposal, many take-back programs provide incentives, such as discounts on new purchases when customers return used products (e.g., batteries, Figure 13).

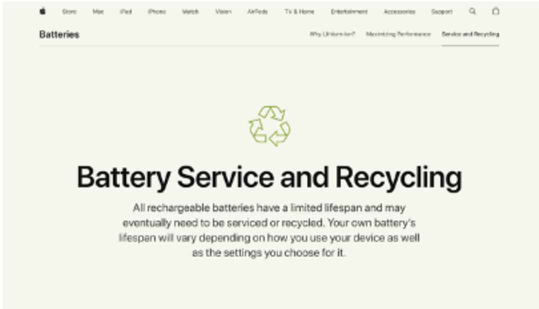

Figure 13. Apple's collection program for lithium-ion batteries. ©Apple Inc

Discussion and future work
This paper explores the essential role of take-back systems in advancing the CE by facilitating the recovery, reuse, and responsible disposal of products. This research contributes to the growing body of knowledge on take-back systems by establishing how a DfX approach can guide the development of take-back strategies that align with CE goals. The successful application of take-back strategies depends on various factors, including contextual conditions, consumer behavior, industry-specific challenges, geographical location, and material flow dynamics. By categorizing take-back strategies into Direct Reuse, Ease of Disassembly, Final Recovery, and Safe Disposal, with nine specific sub-strategies, we identified multiple pathways through which products can be reintegrated into the economy, each with distinct design requirements and operational challenges.

The Direct Reuse strategy focuses on designing products with durable materials to extend their lifespan and promote sustainable consumption behaviors. Ease of Disassembly (DfED) highlights the importance of designing products with modularity and non-permanent connections, enabling repair, refurbishment, remanufacturing, and cannibalization by maximizing the reuse of existing components. Implementing DfED requires close collaboration with manufacturing and logistics partners to ensure that disassembly and reassembly processes are efficient and scalable. The Final Recovery and Safe Disposal strategy centers around designing products to be responsibly processed and minimizing environmental and health risks associated with their end-of-life disposal. Although these strategies serve as last-resort options for non-recyclable or hazardous products, they underscore the need for infrastructure investment and strict regulatory compliance to prevent potential contamination (Svensson-Hoglund et al., 2021). Additionally, the consumer plays a key role in facilitating take back for returning products at the end of their useful life (Sabbaghi et al., 2016). Successful implementation requires efficient logistics and strong consumer engagement practices.

Future research should focus on understanding consumer motivations and barriers to returning products in take-back programs. While incentives, such as discounts or rewards, have been shown to increase participation, further research is needed to understand the psychological and social factors that drive or hinder consumer engagement including how cultural norms, convenience perceptions, and environmental values interact to shape return behaviors. Additionally, exploring how technological advancements, such as digital tracking and product passports, could enhance the efficiency and effectiveness of take-back systems would be beneficial. Furthermore, emerging technologies like blockchain and AI have significant potential to optimize reverse logistics by improving traceability throughout product lifecycles, enabling predictive maintenance to extend product lifespan and creating personalized incentive systems that enhance consumer participation in take-back programs. Future research should also investigate how take-back strategies can be adapted to diverse industries or geographic regions with different infrastructural. The transferability of successful take-back models across varying contexts requires careful consideration of local waste management capabilities, cultural attitudes toward reuse and recycling, and region-specific policy frameworks that may either facilitate or hinder the implementation of circular initiatives

Acknowledgments

This work was partially supported by Virginia Polytechnic Institute and State University under grant number 180584.

References

Abdessalem, M., Alouane, A. B. H., & Riopel, D. (2012). Decision modelling of reverse logistics systems: Selection of recovery operations for end-of-life products. *International Journal of Logistics Systems and Management*, *13*(2), 139. https://doi.org/10.1504/IJLSM.2012.048933

Arnette, A. N., Brewer, B. L., & Choal, T. (2014). Design for sustainability (DFS): The intersection of supply chain and environment. *Journal of Cleaner Production*, *83*, 374–390. https://doi.org/10.1016/j.jclepro.2014.07.021

Blomsma, F., Pieroni, M., Kravchenko, M., Pigosso, D. C. A., Hildenbrand, J., Kristinsdottir, A. R., Kristoffersen, E., Shahbazi, S., Nielsen, K. D., Jönbrink, A.-K., Li, J., Wiik, C., & McAloone, T. C. (2019). Developing a circular strategies framework for manufacturing companies to support circular economy-oriented innovation. *Journal of Cleaner Production*, *241*, 118271. https://doi.org/10.1016/j.jclepro.2019.118271

Bockholt, M. T., Hemdrup Kristensen, J., Colli, M., Meulengracht Jensen, P., & Vejrum Wæhrens, B. (2020). Exploring factors affecting the financial performance of end-of-life take-back program in a discrete manufacturing context. *Journal of Cleaner Production*, *258*, 120916. https://doi.org/10.1016/j.jclepro.2020.120916

Chouinard, Y., Ellison, J., & Ridgeway, R. (2011). The sustainable economy. *Harvard Business Review*, *89*(10), 52–62.

Cooper, M. L. (1994). Motivations for alcohol use among adolescents: Development and validation of a four-factor model. *Psychological Assessment*, *6*(2), 117. https://doi.org/10.1037/1040-3590.6.2.117.

Elzinga, R., Reike, D., Negro, S. O., & Boon, W. P. C. (2020). Consumer acceptance of circular business models. *Journal of Cleaner Production*, *254*, 119988. https://doi.org/10.1016/j.jclepro.2020.119988

Esenduran, G., Kemahlıoğlu-Ziya, E., & Swaminathan, J. M. (2016). Take-Back Legislation: Consequences for Remanufacturing and Environment.

Decision Sciences, *47*(2), 219–256. https://doi.org/10.1111/deci.12174

Franconi, A., Ceschin, F., Terzioglu, N., Corsini, L., & Ghoreishi, M. (2023). Defining alternative recovery strategies for reuse: An analysis of multiple case studies under the reuse umbrella. *Proceedings 5th PLATE Conference (PLATE 2023)*, 324–331. http://bura.brunel.ac.uk/handle/2438/27057

Ghoreishi, N., Jakiela, M. J., & Nekouzadeh, A. (2011). A cost model for optimizing the take back phase of used product recovery. *Journal of Remanufacturing*, *1*(1), 1. https://doi.org/10.1186/2210-4690-1-1

Iyer, E. S., & Kashyap, R. K. (2007). Consumer recycling: Role of incentives, information, and social class. *Journal of Consumer Behaviour*, *6*(1), 32–47. https://doi.org/10.1002/cb.206

Jena, S. K., & Sarmah, S. P. (2015). Measurement of consumers' return intention index towards returning the used products. *Journal of Cleaner Production*, *108*, 818–829. https://doi.org/10.1016/j.jclepro.2015.05.115

Kuo, T.-C., Huang, S. H., & Zhang, H.-C. (2001). Design for manufacture and design for 'X': Concepts, applications, and perspectives. *Computers & Industrial Engineering*, *41*(3), 241–260. https://doi.org/10.1016/S0360-8352(01)00045-6

Paut Kusturica, M., Golocorbin-Kon, S., Ostojic, T., Kresoja, M., Milovic, M., Horvat, O., Dugandzija, T., Davidovac, N., Vasic, A., & Tomas, A. (2020). Consumer willingness to pay for a pharmaceutical disposal program in Serbia: A double hurdle modeling approach. *Waste Management*, *104*, 246–253. https://doi.org/10.1016/j.wasman.2020.01.029

Sabbaghi, M., Behdad, S., & Zhuang, J. (2016). Managing consumer behavior toward on-time return of the waste electrical and electronic equipment: A game theoretic approach. *International Journal of Production Economics*, *182*, 545–563. https://doi.org/10.1016/j.ijpe.2016.10.009

Singh, J., & Ordoñez, I. (2016). Resource recovery from post-consumer waste: Important lessons for the upcoming circular economy. *Journal of Cleaner Production*, *134*, 342–353. https://doi.org/10.1016/j.jclepro.2015.12.020

Svensson-Hoglund, S., Richter, J. L., Maitre-Ekern, E., Russell, J. D., Pihlajarinne, T., & Dalhammar, C. (2021). Barriers, enablers and market governance: A review of the policy landscape for repair of consumer electronics in the EU and the U.S. *Journal of Cleaner Production*, *288*, 125488. https://doi.org/10.1016/j.jclepro.2020.125488

Thierry, M., Salomon, M., Van Nunen, J., & Van Wassenhove, L. (1995). Strategic Issues in Product Recovery Management. *California Management Review*, *37*(2), 114–136. https://doi.org/10.2307/41165792

Vegter, D., Van Hillegersberg, J., & Olthaar, M. (2020). Supply chains in circular business models: Processes and performance objectives. *Resources, Conservation and Recycling*, *162*, 105046. https://doi.org/10.1016/j.resconrec.2020.105046

Waqas, M., Dong, Q., Ahmad, N., Zhu, Y., & Nadeem, M. (2018). Critical Barriers to Implementation of Reverse Logistics in the Manufacturing Industry: A Case Study of a Developing Country. *Sustainability*, *10*(11), 4202. https://doi.org/10.3390/su10114202

Yin, R. K. (2009). *Case study research: Design and methods.* (Vol. 5). sage.

Appendix 1

Table 1. Different characteristics present in take-back strategy.

Criteria	Description
Quality	The condition and performance of products made from returned materials or components and compares them to products made from virgin materials.
Change in market value	Whether the value of the product increases, decreases, or remains the same compared to its previous life cycle.
Type (product, component, material), origin of value	The type of item being returned and its associated value created.
Aim of the take-back design strategy	The specific objectives driving the design strategy.
Reprocessing methods	The techniques used to enable the recovery of the item, and the entities responsible for carrying out these processes.
Consumer behavior and engagement	The behaviors required to support take-back processes.

Table 2. Main recovery strategies comparison for take-back. Note that the table is based on a broad context, and characteristics may vary according to the specific case and context.

	Characteristics				
Main Recovery Strategies	**Quality**	**Product market value**	**Aim**	**Reprocessing**	**Consumer behaviour and engagement**
Reuse	As is	High	Reuse/ Recycling	Cleaning	Return to retailer or processing facilities
Repair	Almost new	Mid-low	Reuse	Disassembly/ Replace or Fix	Return to retailer or manufacture
Re-furbishment	Almost new	High-mid	Reuse/ Restoration	Cleaning/ Disassembly repaired/ Replace/ Restored	Return with or without incentive
Re-manufacture	Like new	High-mid	Renovation	Disassembly/ Clean/ inspection/ rebuilt	Return to recycle bin collection
Cannibalization	Almost new	High-mid	Reuse	Disassembly/ salvaging intact component	Return to manufacturer
Recycle	Usually lower than the original	Low	Maximum material reuse/ Reproduce	Sort/ Clean/ reprocessing	Recycle bin
Energy	Transformed	Low	Recover as an energy source	Sort/ Process	Return to manufacturer / Recycle
Safe disposal	N/A	N/A	Safely dispose of hazardous material	N/A	Return

Table 3. Clustering terms based on literature analysis.

Categories of take-back based on value changes	**Resources Recovery**	**Product types**	**Reference (papers)**
Direct Reuse (Value remains)	Reuse as it is (product)	Packaging	Muranko et al. 2021 Ellen Macarthur Foundation. 2023 Nakajima and Vanderberg et al. 2006
		Fashion and textile	Tripa and Indrie et al. 2021
Ease of Disassembly (Value retain or increase)	Repair (product)	Fashion and textile	Zhang and Hale et al. 2022
		Consumer electronic	Svensson-Hoglund et al. 2021
	Refurbishment (product)	Furniture	Öhgren et al. 2019
		Fashion and textile	Dang et al. 2023
		Consumer electronic	Fleischmann et al. 2003 Curvelo Santana et al. 2021
	Remanufacture (product)	Transportation	Zhang et al. 2017
		Consumer electronic	Webster and Mitra et al. 2007
	Cannibalization (components or material)	Consumer electronic	Ripanti et al. 2016
Final recovery (Value transform)	Material recycling (components or material)	Fashion and textile	Sandvik and Stubbs et al. 2019
		Consumer electronic	Gu et al. 2021 Sun et al. 2022
		Packaging	Sazdovski et al. 2021
	Energy recovery	Food waste	Kadel et al. 2014
Responsible disposal (Value lost)		electronic	Chandrasekaran et al. 2018
		Medicine	De Filippis et al. 2012
	Safe disposal	Medicine/ pharmacy	Yanovitzky et al. 2016 Lystlund et al. 2014
		Paint packaging	Dursun and Sengul et al. 2006
		Batteries	Wagner et al. 2013