

Louvain School of Management

Exploring Innovation in Reverse Logistics and Circular Economy within the Pharmaceutical Industry

A Multiple Case Study on Recycling and Disposal Programs

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I hereby declare that this work is my own, all references are accurately reported, and the work has not been submitted for any other degree or professional qualification.

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Abbreviations and Acronyms

APIs	Active pharmaceutical ingredients
CalRecycle	California Department of Resources Recycling and Recovery
CE	Circular economy
CLSC	Closed-loop supply chain
CRC	Centralized returns center
DiCE	Digital Health in a Circular Economy
EcoAP	Eco-Innovation Action Plan
EoL	End-of-life
EoU	End-of-use
EPR	Extended Producer Responsibility
GSCM	Green supply chain management
IoT	Internet of Things
LCA	Life cycle assessment
PPSWG	Pharmaceutical Product Stewardship Work Group
PSC	Pharmaceutical supply chain
RBV	Resource-based view
RFID	Radio Frequency Identification
Stakeholder-RBV	Stakeholder theory and resource-based view

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1. Introduction

1.1 Research motivations

The insufficient availability of essential resources nowadays leads to significant economic, social, and environmental challenges. This issue is particularly evident in the context of natural resources such as land, non-renewable (oil and gas, minerals, gemstones, timber from old-growth forests), renewable (water, forests, and productive lands; wind, solar, tidal, and hydro energy; wildlife; timber from forestry; fertile soils; biodiversity), and water ([World Bank, 2022](#)). The increased competition over limited natural resources triggers and escalates conflict worldwide ([Homer-Dixon, 1999](#)). Moreover, pollution from landfills can contaminate water, air, and marine systems, leading to serious health problems ([Siddiqua et al., 2022](#)). As stated by the European Commission in 2008, the increasing external risks and environmental awareness pose significant challenges to logistics systems ([European Commission, 2008](#)). Besides the social and environmental impact, the huge amount of economic loss from return expenses also stimulates legislation and innovation on waste management.

In 2019, return delivery costs in North America alone amounted to 363 billion U.S. dollars, with global return expenses exceeding one trillion U.S. dollars ([Topic: Reverse Logistics, 2024](#)). The scale of reverse logistics is becoming increasingly important to a country's economy. Beyond the initial costs of production and transportation, companies also face substantial expenses for reprocessing and disposing of returned products ([Rogers & Tibben-Lembke, 2001](#)). Companies with high-value products or high return rates typically invest significantly more resources into optimizing their return operations ([Rogers & Tibben-Lembke, 1999](#)).

Extended Producer Responsibility (EPR) is a typical political instrument emerging in Europe in the 1990s and early 2000s, and expanding worldwide, in response to environmental concerns and the need for more sustainable waste management practices ([Wikipedia, 2024](#)). It aims to shift responsibility for the whole product lifecycle, including disposal and recycling, especially for packaging waste, from consumers to producers. This motivates producers to design products that are easy to recycle and dispose of, thus promoting resource conservation and waste reduction. The European Union's Packaging and Packaging Waste Directive,

adopted since 1994, officially introduced the concept of EPR for packaging materials, requiring producers to finance or organize the collection and recycling of packaging waste, and leading to the constant need for reverse logistics capabilities growth ([Packaging Waste, 2024](#)). The integration of waste disposal and recycling processes into extended logistics chains is an increasing focus for governments, necessitating the development of reverse logistics concepts.

What role does reverse logistics play in the circular economy (CE)?

Under the sustainability trend, governments and organizations around the world are increasingly focusing on transitioning to a CE model, which emphasizes sustainability through resource efficiency (recycle), waste minimization (reduce), and the continuous use of materials (reuse) ([Khan & Ali, 2022](#)). This model seeks to create a closed-loop system where products, materials, and resources are maintained at their highest utility and value for as long as possible, thus reducing the need for new resource extraction and minimizing environmental impact ([Ellen MacArthur Foundation, 2013](#)).

Traditional distribution networks are often viewed as ‘one-way’ objects, whereas reverse logistics introduces a bilateral flow inside the supply chain. As it facilitates the return of products and materials back into the supply chain, thus supporting to create the closed-loop system in the CE. The primary objective of reverse logistics is to improve and streamline aftermarket activities, which lead to cost savings and long-term environmental conservation. Consequently, reverse logistics is crucial for applying advanced green supply chain management (GSCM) principles and practices in nowadays rapidly developing sustainability area ([Srivastava, 2007](#)).

And why is it necessary to study the pharmaceutical industry within this context?

The pharmaceutical industry is one of the biggest industries in the world that has experienced significant growth over the past few decades. Since the pandemic, its importance has increased even further, as it provides critical medical solutions ([RBC Capital Markets | Navigating the Changing Face of Healthcare Episode, n.d.](#)). The pharmaceutical industry is highly resource-oriented, relying extensively on natural resources, including plant-based

substances, minerals, and water, for the development and manufacturing of medications ([De Soete et al., 2014](#)). Notably, the industry depends heavily on water for various stages of production, such as synthesis, purification, and cooling, which further increases its resource demands ([Belkhir & Elmeligi, 2019](#)). ‘How to balance the resource consumption and environmental impact’ presents a major challenge for the sustainable development in the pharmaceutical industry.

The pharmaceutical industry not only consumes many resources but also produces significant emissions, posing serious environmental and health risks ([Taylor & Senac, 2014](#)). According to [MacDonald \(2024\)](#), the biotech and pharma industry has a notable carbon footprint, with total carbon emissions of 193 million tons of CO₂ equivalent in 2022. Given the sector's rapid growth, with an expected compound annual growth rate of 13.9% from 2023 to 2030, the environmental impact is anticipated to increase accordingly ([Grand View Research, 2023](#)).

Active pharmaceutical ingredients (APIs) and other chemical substances, whether natural or synthetic, can contaminate water bodies and soil. They may potentially enter drinking water supplies and the food chain through manufacturing discharges, improper disposal of unused and expired medications, and patient excretion ([Ashiwaju et al., 2023](#); [Boxall, 2004](#); [Kümmerer, 2009](#)). Pharmaceuticals vary from other emerging contaminants because they have been designed to be biologically active, therefore the waste of broken products and the mixture of multiple biologically active substances may have unexpected impacts on the environment ([Boxall, 2004](#)). Consequently, they will be significantly more harmful to lives than any other substance.

Due to the huge consumption of medicines worldwide, a considerable amount of waste is generated by the industry. According to the World Health Organization (WHO), this paper categorizes waste into two main types: medical device waste or sharps waste, which includes needles and blades; and pharmaceutical waste, which encompasses any unwanted medications, including unused, expired, or contaminated drugs and vaccines ([World Health Organization: WHO, 2018](#)). Effective waste management is crucial to mitigate their impacts and enhance public safety ([Kabir, 2013](#); [Khan & Ali, 2022](#)). The industry should adopt closed-loop supply chain (CLSC) to ensure that used medical devices and unwanted

medications are properly disposed of, remanufactured, or recycled (Khan & Ali, 2022). Reverse logistics in the pharmaceutical industry is extremely important, not only from an economic perspective but also from environmental and regulatory standpoints (Kabir, 2013). This importance stems from the complex nature of the pharmaceutical supply chain (PSC), which is concerned with human life and involves numerous stakeholders (Khan & Ali, 2022).

However, there are several impediments the industry faces in the adoption of CLSC. One significant impediment is the unavoidable pollution from the excretion from patients, which cannot be easily controlled or mitigated. In contrast, pollution from manufacturing discharges and improper disposal of pharmaceutical waste and sharps waste can be addressed with innovative solutions. Innovation is critical in advancing reverse logistics within the pharmaceutical industry, focusing on resource efficiency, waste minimization, and the continuous use of materials in the CE model. This paper emphasizes the importance of reverse logistics innovation in enhancing sustainability and reducing the environmental impact of pharmaceutical operations.

1.2 Research gap and research questions

The *research gap* can be:

Due to the resource scarcity, safety concerns and environmental impacts within the pharmaceutical industry, innovation in the reverse logistics processes is essential to achieve the goals of the CE. Recently, there are gradually more and more companies in the pharmaceutical industry beginning to implement recycling and disposal programs. This paper aims to get a comprehensive view by comparing the different reverse logistics practices and propose possible innovation actions from economic, environment and regulatory aspects.

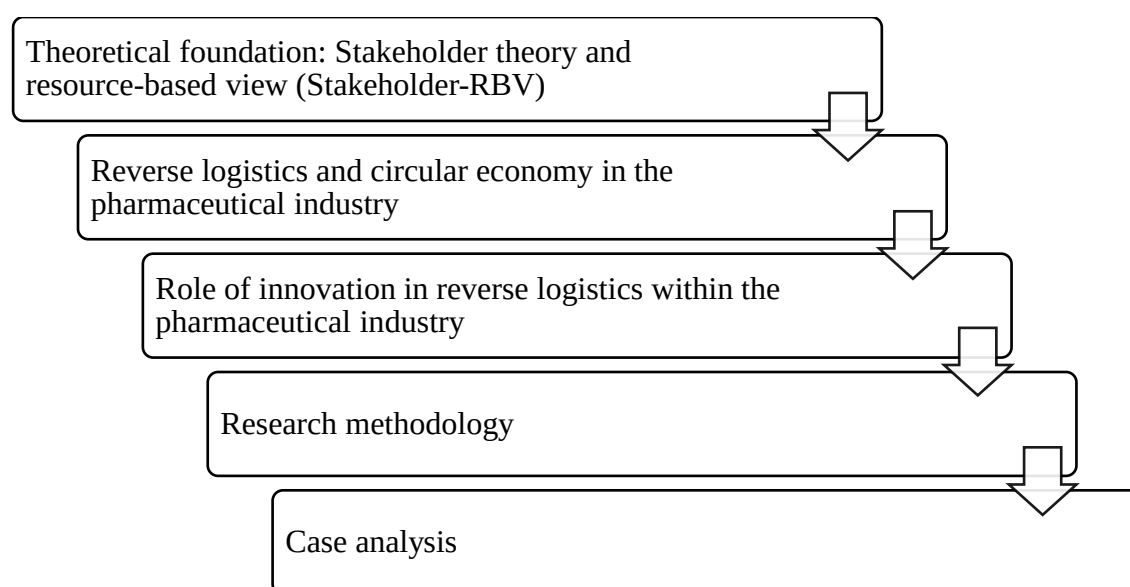
The *research questions* can be:

1. How are reverse logistics programs for recycling and disposal designed and implemented in leading pharmaceutical companies?
2. What are the key drivers and barriers influencing the effectiveness and efficiency of reverse logistics in pharmaceutical recycling and disposal programs?
3. How can innovation promote the reverse logistics practices in the pharmaceutical industry?

1.3 Thesis structure

The structure of this master's thesis will be organized as shown in **Figure 1**. Stakeholder theory and resource-based view (Stakeholder-RBV) supports the theoretical framework in Chapter 1. Furthermore, existing studies over CE and waste management along with reverse logistics in the pharmaceutical industry are reviewed. Key concepts are explained separately and integrally. Under the CE background, to be more precise, the distinguishment between reverse supply chain and reverse logistics is firstly pointed out, then the structure of reverse logistics is presented in detail compared to forward logistics before the centralized returns center (CRC) is added in for optimization to gain a better understanding of the reverse logistics. The relationship between reverse logistic and CE is explained coherently. The scope is then narrowed into the pharmaceutical industry. Chapter 2 explores the role of innovation in pharmaceutical reverse logistics within the context of the Stakeholder-RBV. Since Chapter 3, qualitative case study methodology has been adopted to address the proposed research questions, illustrated by 18 recycling and disposal programs from 10 pharmaceutical companies. Concrete findings are presented based on a cross-case analysis using thematic analysis in Chapter 4. Referring to the interview material, discussions on identifying the drivers and barriers and proposing the innovative solutions are found in Chapter 5. The final conclusion, along with limitations and recommendations, is summarized in the concluding chapter.

Figure 1. Process of the study



Source: developed by author, 2024

2. Chapter 1: Theoretical framework

2.1 Theoretical foundation: Stakeholder theory and resource-based view (Stakeholder-RBV)

Every organization has actual and potential strengths and weaknesses, it is important to try to determine what they are and to distinguish one from the other for the good use of strengths to become competitive advantages (Ngowi et al., 2002; Teece et al., 1997). The resource-based view (RBV) describes how internal resources help a company develop and maintain a competitive advantage in the field of strategic management (Madhani, 2010). According to Barney (1991), “all assets, capabilities, organizational processes, company attributes, information, knowledge, etc. controlled by a company that enable the company to conceive of and implement strategies that improve its efficiency and effectiveness” are defined as organizational resources. Resources that are valuable, rare, imperfectly imitable, and non-substitutable can provide a sustainable competitive advantage and profit maximization for achieving success (Barney, 1991). Resources are considered valuable when they enable a company to implement strategies to improve efficiency and effectiveness. They are deemed rare if they are not possessed by many competing or potentially competing competitors. A company can imitate another's resources or acquire different resources as substitutes. If a resource is easily substitutable, it can't help in generating or sustaining a competitive advantage.

Despite its advanced development through studies, the RBV continues to be refined and improved. Stakeholder theory offers a new perspective for RBV that stakeholder relationships can also become ‘valuable, rare, imperfectly imitable and non-substitutable’ resources leading to competitive advantage (Barney, 2018; Harrison et al., 2007; Kull et al., 2016). As stakeholders can influence a firm by providing access to resources that enable the firm to achieve its objectives, they are affected by the compensation they receive for supplying these resources in return. Freeman et al. (2021) suggest there are four essential aspects that stakeholder theory can offer to inform RBV to become a more comprehensive theory: **normativity**, **sustainability**, **people**, and **cooperation**. For **normative** considerations, integrating values, norms, and ethics into the Stakeholder-RBV framework helps companies do the right thing and improves their ability to make better predictions. Under the **sustainable** development trend, the Stakeholder-RBV emphasizes that sustainable competitive advantage is intrinsically linked to sustainable stakeholder relationships. Thus, the Stakeholder-RBV is

fundamentally **human-centered**, viewing people as stakeholders who contribute resources, not as resources themselves, and recognizing them as ends rather than means. Stakeholder-RBV values both competition and **cooperation**, aiming to build sustainable cooperative advantage with other firms to achieve win-win success, beyond just focusing on its own financial performance (Freeman et al., 2021).

In the context of CE, to some extent, Stakeholder-RBV can help explore strategic resources via practices like reusing, recycling and eco-design considering the intertwined stakeholder relationships to form a socio-economic system (Desing et al., 2020). Therefore, efficient and effective reverse logistics is essential, requiring significant resources to ensure long-term competitiveness and survival of companies in the CE (Genchev et al., 2010).

The identification of **resources**, **capabilities** and **competencies** along with **stakeholders** are important in the application of Stakeholder-RBV in the reverse logistics. The RBV offers a strategic tool to classify **resources** in reverse logistics which help retrieve values from waste into tangible resources (e.g. warehouses and storage facilities, transportation, inspection and sorting equipment, recycling and remanufacturing machinery, inventory management system...) and intangible resources (e.g. skills and expertise, consumer relationships, supplier relationships, reputation...). The **capabilities** in reverse logistics are the unique abilities of a company to organize and manage the mentioned resources in a way that is valuable, rare, imperfectly imitable, and non-substitutable, thereby bringing competitive advantages to the company. Grounded in RBV, reverse logistics **competency** can be characterized as the mastery of essential processes for developing, combining, and deploying company-specific resources into reverse logistics capabilities, which further improve performance and boost social welfare (Genchev et al., 2010; Teece et al., 1997). To be more specific, according to Barney's (2018) Stakeholder-RBV, profits are generated when resources are co-specialized, meaning they are more productive when bundled together compared to when they are used separately. The **stakeholders** in reverse logistics encompass a wide range of parties involved in or affected by the processes of returning, recycling, remanufacturing, and disposing of products, including employees, suppliers, consumers, manufacturers, distributors, logistics providers and regulatory bodies (Guide & Van Wassenhove, 2009; Rogers & Tibben-Lembke, 1999). The network of these stakeholders can be deemed as a strategic resource for the company.

Using the resource-based perspective of the firm is a powerful framework to build sustainable stakeholder relationships and to help a firm succeed. Stakeholder-RBV supports the theoretical framework in this paper.

2.2 Literature review

2.2.1 Circular economy

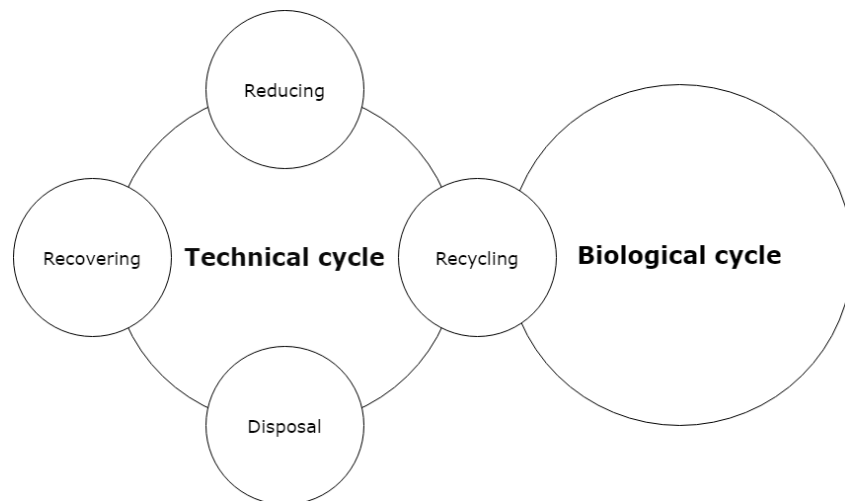
During the early days of industrialization, a linear model of resource consumption followed a 'take-make-dispose' pattern (Edirisinghe et al., 2024). Companies harvested and extracted materials, used them to manufacture products, and sold the products to consumers, who then discarded them when they no longer served their purpose. However, the unsustainable and conventional 'take-make-dispose' model results in significant resource losses. Recently, many companies have recognized that this linear system increases their exposure to risks, such as higher resource prices and supply disruptions (Ellen MacArthur Foundation, 2013). It is crucial to transition to a closed-loop economy model to address these problems.

The CE aims to achieve sustainability across environmental quality, economic prosperity, and social equity (Salmenperä et al., 2021). It involves a diverse range of stakeholders, including regulators, manufacturers, consumers, and the environment, all of whom are affected by the transition to sustainability (Julianelli et al., 2020). Geissdoerfer et al. (2017) and Salmenperä et al. (2021) define the CE as a regenerative system that reduces resource input, extends product lifecycles, minimizes waste generation, and ultimately closes the loop through high-value recycling. This closed loop is achieved through waste management strategies such as reducing, recovering and recycling from reusing and remanufacturing, and disposal based on sustainable design of **two cycles** (Grant et al., 2013), as illustrated in **Figure 2**.

The **technical cycle**'s goal is to recover non-biological materials without consumption. It aims to retain products, components and materials at their peak utility and value at all times. Reducing is the most environmentally friendly option because it reduces the usage of natural resources and energy. Recovering involves extracting value from waste by reusing and remanufacturing materials into products of similar quality and function, thereby preserving their value within the closed-loop cycle. Only unavoidable waste is disposed of at

the end of the lifecycle. The **biological cycle** is made up of flows of renewable materials, and the goal is to regenerate biological nutrients by returning them to the natural ecosystem. Recycling plays an important role in both cycles from a waste management perspective, as it involves collecting used products, components or materials and transforming them into other useful products, components or materials through processes like reusing and remanufacturing.

Figure 2. Closed-loop CE cycles



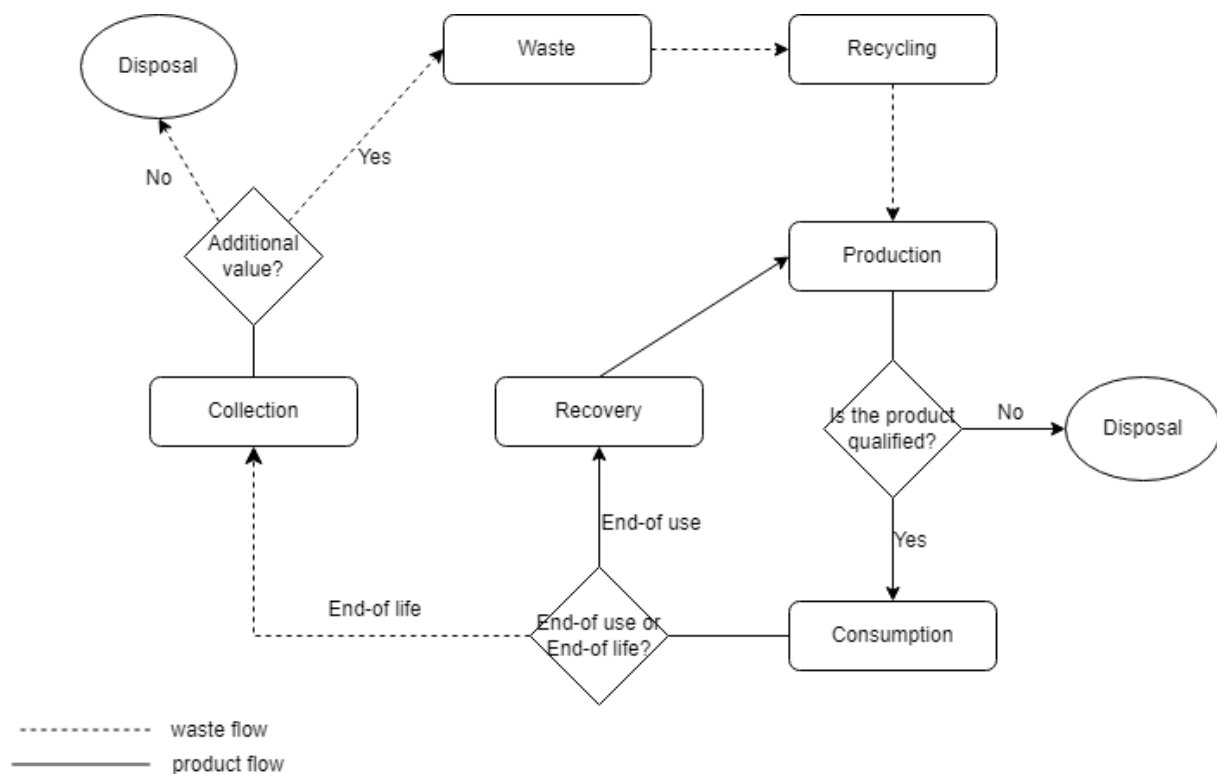
Source: developed by the author, based on [Grant et al., 2013](#); [Mallick et al., 2023](#)

In waste management, classifying used products is crucial. These products can be categorized into two types: ‘end-of-use (EoU)’ products and ‘end-of-life (EoL)’ products ([Mallick et al., 2023](#)). EoU products are items that have reached the end of their useful lifecycle and are no longer functional or desired by the consumer. These products are normally returned, and they can be recovered via remanufacturing for a technical upgrade, extending their lifecycle by reclaiming residual values. EoL products are often worn out and no longer useful to the current user ([Guide & Van Wassenhove, 2009](#)). They are often technologically obsolete and require proper waste management to ensure safe disposal in landfills.

The waste management process in the CE begins with the goal of waste prevention, as shown in **Figure 3**. When the waste materials are properly collected and sorted, they will be reprocessed into new materials under recycling for further production. During production, qualified products are distributed to consumers, while any unavoidable waste is generated and prepared for disposal. After consumption, some EoU products are sent to collection points to

begin the recycling process, whereas EoL products are disposed of due to lack of remaining value. If the additional value is technologically high, new products will be generated after recovery in the technical cycle. In the last stage of waste management, decisions are made regarding whether to dispose of or recycle the materials.

Figure 3. Waste management process



Source: developed by the author, based on [Salmenperä et al., 2021](#)

2.2.2 Reverse logistics in reverse supply chain

The term ‘**reverse logistics**’ is different from the term ‘**reverse supply chain**’. Before we dive in further, this paper distinguishes between these two terms.

According to [Guide & Van Wassenhove \(2002\)](#), key components of **reverse supply chain** are product acquisition, reverse logistics, inspection and disposition, reconditioning, distribution and sales. Product acquisition involves collecting used or returned products from end consumers. Reverse logistics is the process of transporting these products back to the company or a designated facility for further processing. During inspection and disposition, each product is assessed to determine whether it should be repaired, refurbished, recycled, or disposed of. Reconditioning includes activities like cleaning, repairing, and refurbishing to

recover the product to a usable condition. Finally, distribution and sales involve sending the reconditioned products back into the market, either through direct sales channels, secondary markets, or donation, ensuring that the reverse supply chain contributes to sustainability and value recovery. Thus, the reverse supply chain encompasses a much broader range of activities beyond reverse logistics alone. It emphasizes the integration of various functions and stakeholders throughout the entire supply chain.

Reverse logistics, a key component of the broader reverse supply chain, focuses on the return flow of products and materials from their destination back to the manufacturer or another designated location. Its primary purpose is to capture value through reusing, remanufacturing, recovering, recycling, or proper disposal via transportation, warehousing, distribution, and inventory management (Ko & Evans, 2007; Rogers & Tibben-Lembke, 1999). While economic motivations like enhanced revenue generation and cost reduction have historically driven reverse logistics, recent years have seen a shift towards addressing environmental concerns due to the growing emphasis on sustainability (Rogers & Tibben-Lembke, 1999). Typical reverse logistics activities include collecting used, damaged, unwanted, or outdated products, as well as packaging and shipping materials from the end user back to the producer or recycler (Kabir, 2013; Rogers & Tibben-Lembke, 1999). The reverse flow can involve products for reasons such as remanufacturing or refurbishment, and packaging due to its reusability or regulatory disposal requirements (Rogers & Tibben-Lembke, 2001). Effective reverse logistics for packaging can significantly reduce waste and improve sustainability, with companies potentially saving up to 30% on logistics costs and retaining up to 95% of material value through recycling and reusing operations (Ellen MacArthur Foundation, 2017; Rogers & Tibben-Lembke, 1999). The global market for recycled packaging is expected to grow significantly, reflecting the increasing emphasis on sustainable packaging solutions (MarketsandMarkets, 2021).

In summary, reverse logistics has shifted its focus from cost savings and revenue creation to sustainability, driven by environmental concerns. Key activities such as recovering, recycling, and proper disposal work together to manage product and material returns, aiming to extract economic and environmental value. This process benefits the community and environment by ensuring the recovery and recycling of used products and materials.

2.2.3 Forward and reverse logistics structure

To gain a better understanding of the reverse logistics process, a comparison between the **forward logistics structure** and **reverse logistics structure** is presented. Different stakeholders fulfill different roles (operation, coordination and regulation) in transportation, warehousing, distribution, and inventory management activities in both forward logistics and reverse logistics (Mallick et al., 2023).

In the **forward logistics structure**, as shown in **Figure 4**, the processes operated by the related stakeholders include: suppliers provide raw materials and components to manufactures who produce the finished products; the finished products are kept in the warehouses ready for distribution centers; logistics providers transport the products in a proper way and distribute to wholesalers and retailers who finally sell the products to end consumers.

Figure 4. Forward logistics structure

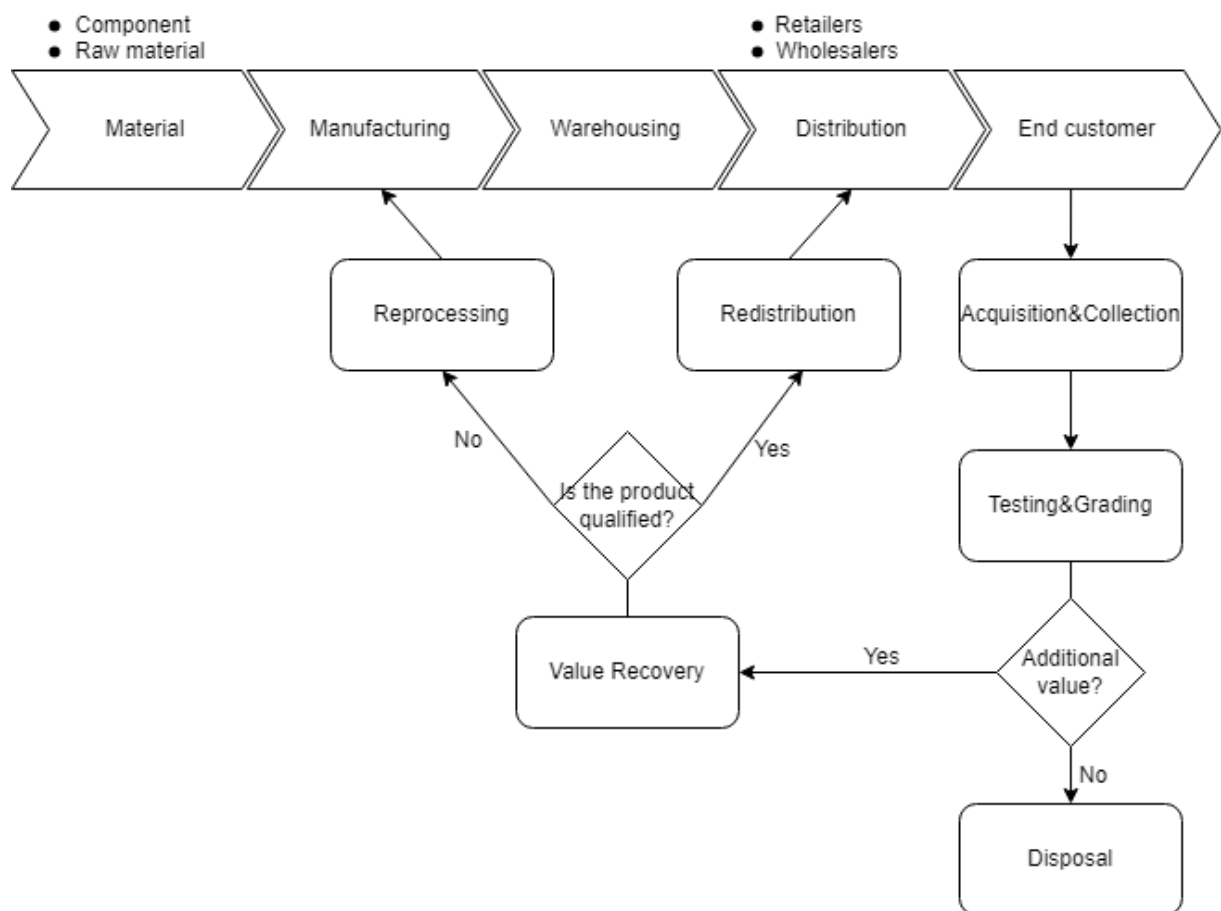


Source: developed by author, 2024

Both forward and reverse logistics manage the flow of goods and services, but they differ significantly in nature (Genchev et al., 2010). Stakeholders involved in forward logistics (suppliers, manufacturers, logistics providers, distributors, wholesalers, retailers, and consumers) must assume additional responsibilities to support reverse logistics, along with governmental regulators and environmental organizations (Mallick et al., 2023). Recent interest in supply chain management has expanded to include reverse logistics due to business competition and environmental concerns (Ko and Evans, 2007). To achieve these goals, companies need to make strategic decisions regarding materials planning, life cycle assessment (LCA), industrial sustainability, and information and communication technology to redesign the **reverse logistics structure** (Julianelli et al., 2020).

Specifically, companies need to initially consider where and how to collect recoverable products from previous users, whether to send the inspected collected products for value recovery or unqualified ones for disposal. In the value recovery stage, some collected products need reprocessing back into the supply chain to make them suitable for reuse, while some can be redistributed directly to future consumers after check and repackaging. In other words, four major stages are considered in reverse logistics which are acquisition and collection, testing and grading, reprocessing, and redistribution (Fleischmann, 2001), as shown in Figure 5.

Figure 5. Reverse logistics structure

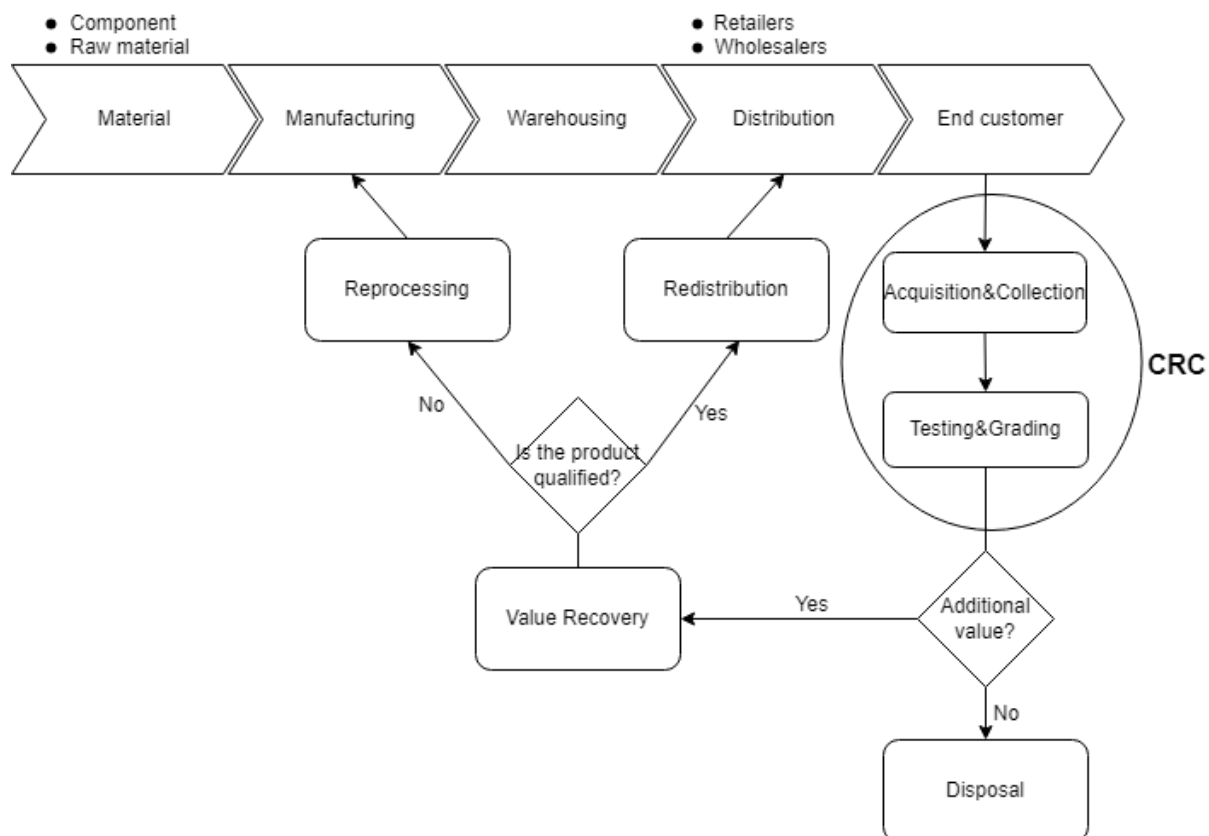


Source: developed by author, based on Fleischmann, 2001

One notable stakeholder in reverse logistics is the CRC, which acts as a specialized third-party intermediary between manufacturers and consumers for returns collection (Mallick et al., 2023). A CRC is a distribution center or a section of a distribution center where returns from various locations are collected and processed together (Rogers & Tibben-Lembke,

2001). This centralization allows for more efficient handling and faster processing times in acquisition & collection, and partially testing & grading, as shown in **Figure 6**.

Figure 6. Centralized returns center (CRC)



Source: developed by author, 2024

Centralizing the returns process offers several advantages. By sending returns to a CRC, companies can ensure more consistent decisions regarding product recovery or disposition, due to the standardized testing and grading processes, thereby facilitating error identification and avoidance (Kaynak et al., 2014). The quality of returns reprocessing typically improves with a centralized model, as it uses specialized equipment and trained staff skilled in handling returns and refurbishing products. Additionally, centralized returns operations allow companies to achieve economies of scale, reducing per-unit processing costs and minimizing administrative overhead (Min et al., 2006). Therefore, companies with significant returns volumes and specialized returns management needs may benefit from CRCs.

2.2.4 Reverse logistics and circular economy

A closed-loop supply chain (CLSC) is a comprehensive strategy that encompasses the design, control, and operation of systems aimed at maximizing value creation throughout a product's life cycle (Gaur et al., 2017). This approach addresses sustainability concerns by balancing environmental, social, and economic efficiency in modern supply chain management (Tavana et al., 2022). Achieving this involves the dynamic recovery of value from various types and volumes of returns over time (Geissdoerfer et al., 2017). Supported by the RBV, materials previously considered waste are now seen as valuable resources.

Forward logistics has been playing a key role in the traditional linear 'take-make-dispose' economy model of resource consumption. While under the sustainability trend, reverse logistics as an important counterparty of forward logistics can cooperate with forward logistics to close the loop in the CE transition. By incorporating reverse logistics into the entire supply chain framework, CLSC requires the establishment of an integrated system of forward and reverse logistics to manage both directions efficiently and sustainably, ensuring that products, materials, and components are recovered or recycled via reusing or remanufacturing rather than directly disposed of to achieve value extraction without new consumptions (Ding et al., 2023; Guide & Van Wassenhove, 2009).

Compared to forward logistics, the reverse logistics operations require more integration between supply chain stakeholders to close the loop for the CE due to its complexity and uncertainty. The conceptualization of logistics also evolves from 'the process of moving goods from the point of origin to consumers' to 'planning, executing, and controlling the efficient flow of products, services, and information through an economic system' by significantly involving reverse logistics for logistics network optimization (Ding et al., 2023; Rogers & Tibben-Lembke, 2001).

In summary, CLSC exemplifies the application of reverse logistics within the CE (Julianelli et al., 2020; Mallick et al., 2023). Reverse logistics supports the principles of the CE by addressing economic, environmental, and social objectives, and it catalyzes the development of CE as a strategic tool.

2.2.5 Reverse logistics in the pharmaceutical industry

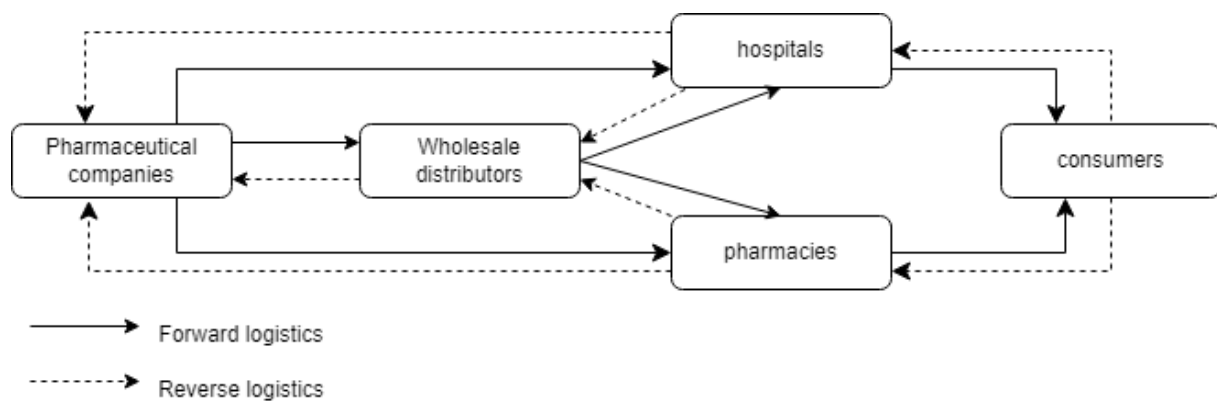
The pharmaceutical industry is known for its high research and development investments, stringent quality standards, long production times and shortening product cycles, which collectively contribute to substantial profit margins along the PSC (Narayana et al., 2014). For instance, the pharmaceutical sector in Europe significantly boosts the EU economy by creating highly skilled jobs and fostering investment in innovation. Since 2020, the European Commission has implemented and adopted 'a pharmaceutical strategy for Europe' to establish a modern regulatory framework involving all stakeholders. This strategy supports the pharmaceutical industry by promoting research and technologies that address patients' therapeutic needs and fill market gaps, especially those highlighted by the pandemic (*A Pharmaceutical Strategy for Europe*, 2024). However, the industry's high waste-to-product ratios, challenges in inventory management, and product recovery activities have raised considerable concerns regarding environmental impact and waste reduction (Ang et al., 2021).

Even though differentiated engagement happens based on different situations, the primary stakeholders in the PSC are regulators, pharmaceutical companies, logistics providers, wholesale distributors, hospitals/pharmacies and consumers (Mendoza, 2021). Pharmaceutical companies handle drug manufacturing and pricing before products are distributed by wholesalers. Specialized logistics providers ensure that vaccines and some fragile drugs are always kept in proper temperature and good conditions through transportation in the whole supply chain (*Cold Chain Packing & Logistics*, 2023). Most of the wholesalers have a direct relationship with hospitals and pharmacies where consumers can obtain the drugs they need. Compared to hospitals which can operate as an individual community, pharmacies can distribute via different channels which vary mostly from retail, specialty and online (Cohen et al., 2009; Letkiewicz & Górski, 2009). Moreover, due to the complexity and strict regulations in the pharmaceutical industry, government authorities play a crucial role in ensuring the safe manufacturing, distribution, and sale of medicines (Kull et al., 2016; Narayana et al., 2014). Stakeholder relationships in the pharmaceutical industry are more complex than in other industries and can become strategic resources if managed well.

The growing number of expired drugs and used medical devices or packaging in a rapidly expanding market highlights the need for measures to prevent environmental contamination and ensure public health safety (Narayana et al., 2014). Reverse logistics can

enable the recovery and reuse of valuable materials, reducing waste and minimizing disposal costs in the pharmaceutical industry. **Figure 7** illustrates the forward and reverse logistics flows among key stakeholders, with solid lines representing forward logistics and dotted lines representing reverse logistics. In the pharmaceutical industry, reverse logistics starts when consumers return EoL medicines and EoU medical devices or packaging to their point of purchase. The most appropriate resource recovery method is then decided based on the waste classification ([Mallick et al., 2023](#)). After being collected in hospitals or pharmacies, some products are returned to wholesalers, while others go back to manufacturers, depending on regulations and infrastructure.

Figure 7. Reverse logistics in the pharmaceutical industry



Source: developed by author, based on [Mendoza, 2021](#); [Narayana et al., 2014](#)

In general, the pharmaceutical industry is increasingly shifting towards sustainability for economic, social, and environmental considerations. Reverse logistics, through collaboration with key stakeholders, can help mitigate environmental impact and address safety issues within the industry.

3. Chapter 2: Role of innovation in reverse logistics within the pharmaceutical industry

According to [Kline & Rosenberg \(2009\)](#), innovation encompasses not only the generation of new ideas but also their implementation and adaptation within a system or organization to create value. Thus, innovation in the CE is not a linear pathway but rather a dynamic activity requiring collaborating of environmental, social and economic resources to achieve the common goal. Innovation can occur in product or process, with a significant focus

on process innovation in areas like reverse logistics (Ozdemir et al., 2023). Especially in the pharmaceutical industry, innovation on ‘how to mitigate environmental impact’ gains growing concerns (Munodawafa & Johl, 2019). In 2011, the European Commission launched the Eco-Innovation Action Plan (EcoAP) calling for partnerships between stakeholders and aiming to achieve environmental objectives through innovation (European Commission, 2011). Environmental innovation can help achieve resource efficiency, waste minimization, and the continuous use of material, without undermining economic performance, the organizations can realize greater competitive advantages (Díaz-García et al., 2015; Munodawafa & Johl, 2019). In the pharmaceutical industry, environmental innovation aims to save natural resources and reduce waste. It can be achieved technologically (engineering solutions) or non-technologically (such as policy and legislation) by different stakeholders. (Hojnik & Ruzzier, 2016).

Under the Stakeholder-RBV, collaborations with various stakeholders allow organizations to access valuable resources, which reduces their costs and risks and increases their opportunities to develop new competitive products or processes through innovative capabilities (Ozdemir et al., 2023). Stakeholders can be classified as ‘primary’ or ‘secondary’: primary stakeholders are crucial for an organization’s survival and operations, while secondary stakeholders are less essential (Hojnik & Ruzzier, 2016; Ozdemir et al., 2023). Primary stakeholders, such as pharmaceutical companies, logistics providers, wholesale distributors, hospitals/pharmacies, consumers, and regulators, play a more direct role in an organization than secondary stakeholders like universities and research centers, as they are actively involved in its ongoing operations. Reverse logistics innovation within the pharmaceutical industry aims to meet the needs of involved stakeholders and generate mutual benefits. It can originate from any primary stakeholder—regulators, pharmaceutical companies, logistics providers, wholesale distributors, hospitals/pharmacies, and consumers—through various activities such as transportation, warehousing, distribution, and inventory management (Hojnik & Ruzzier, 2016).

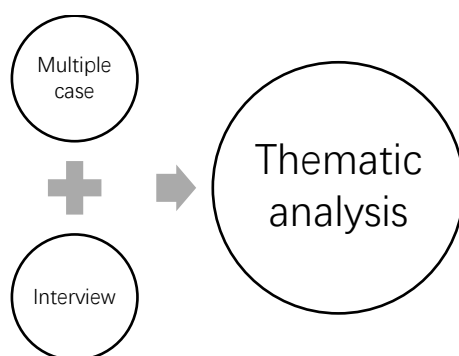
In summary, innovation is a valuable capability for utilizing resources effectively. In the pharmaceutical industry, innovation can be seen from both technological and non-technological perspectives, particularly as environmental innovation. Various stakeholders in reverse logistics within the pharmaceutical industry each contribute in different ways.

4. Chapter 3: Research methodology

4.1 Research design

This study aims to answer the following questions: ‘How are reverse logistics programs for recycling and disposal designed and implemented in leading pharmaceutical companies?’, ‘What are the key drivers and barriers influencing the effectiveness and efficiency of reverse logistics in pharmaceutical recycling and disposal programs?’ and ‘How can innovation promote the reverse logistics practices in the pharmaceutical industry?’ Given these objectives, the qualitative case study method is well-suited for this research. (Baxter & Jack, 2008). Furthermore, multiple case study provides stronger theoretical insights because they are based on extensive empirical evidence, allowing for a more comprehensive exploration of research questions and better theoretical development compared to a single case study (Eisenhardt & Graebner, 2007; Gustafsson, 2017). Therefore, this study used a descriptive research design, analyzing 18 case studies from 10 pharmaceutical companies with public recycling and disposal programs. This approach enabled a detailed investigation of the research questions through the cross-analysis of multiple cases. Additionally, two semi-structured interviews with pharmaceutical supply chain specialists were conducted to support the findings and provide future insights (Baxter & Jack, 2008). Thematic analysis was used to examine both firsthand and secondhand data, as illustrated in **Figure 8**.

Figure 8. Research method



Source: developed by author, 2024

4.2 Selecting cases

To avoid the problem of being too broad and lost in too many objectives, this paper selects the recycling and disposal programs from the pharmaceutical companies based on ‘reverse logistics’ definition and ‘circular economy’ context. Comprehensive keywords such

as ‘recycling’, ‘recovering’, ‘reusing’, ‘remanufacturing’, ‘disposal’, ‘waste management’, ‘closed-loop supply chain’ and ‘sustainable supply chain management’ in the pharmaceutical industry are identified based on our objectives. 18 real cases from 10 companies are described in detail, with the sources coming from academic papers, companies’ annual and sustainability reports, companies’ websites and magazine articles.

The general information of the companies and programs selected is listed in Table 1 below.

Table 1. General information of the companies and programs selected

	Pfizer	Johnson & Johnson	GlaxoSmithKline (GSK)	Sanofi	Eli Lilly	Novo Nordisk	Merck & Co	Bayer	Novartis	Amgen
Headquarter	New York City, U.S.	New Jersey, U.S.	London, UK	Paris, France	Indiana, U.S.	Bagsværd, Denmark	New Jersey, U.S.	North Rhine-Westphalia, Germany	Basel, Switzerland	California, U.S.
Products	Pharmaceutical drugs & vaccines	Medical technologies & Pharmaceutical therapies	Pharmaceutical drugs & vaccines	Pharmaceuticals Biotechnology Healthcare	Pharmaceutical drugs	Pharmaceuticals Healthcare	Pharmaceutical drugs & vaccines	Pharmaceuticals Chemicals Biotechnology Healthcare	Pharmaceuticals	Biotechnology
Program	1)Pfizer Responsible Disposal Advisor 2)Pfizer’s Safe Sharps Disposal Plan 3)Pfizer’s sustainable medicines program	1)Single-use medical device recycling program 2)Safe Returns program 3)Digital Health in a Circular Economy (DiCE)	1)Complete the Cycle Inhaler Recycling and Recovery Scheme 2)Safe Needle Disposal Plan	1)Injection Pen Recycling 2)Home Healthcare Free Recycling Program	1)Device Take-Back and Recycling 2)Recycling of Data Loggers	1)ReMed	1)Biopharma Recycling program 2)Ech2o Collection Recycling Program	1)Packaging and Shuttle Recycling	1)Safe Collection and Proper Disposal of Waste Sharps from Self-Injected Home Medications	1)Responsible Product Disposal

Source: compiled by author, 2024

4.2.1 Pfizer

1) Pfizer Responsible Disposal Advisor

In 2012, Pfizer and WM Healthcare Solutions, Inc., a subsidiary of Waste Management, Inc., jointly introduced a new and free online pharmaceutical disposal guide for healthcare providers called the “Pfizer Responsible Disposal Advisor (Waste Wizard)” (Pfizer, 2012). The Waste Wizard is an online search engine that offers waste categorization and disposal information, strictly following federal environmental regulations for hazardous wastes. Pfizer is the first pharmaceutical company to offer this resource to healthcare professionals, helping them navigate complex waste disposal requirements.

Additionally, WM Healthcare Solutions, Inc. offers cost-effective and sustainable environmental solutions for healthcare consumers. With extensive infrastructure and expertise in resource recovery, reuse, and recycling, they help Pfizer streamline operations, stay compliant with regulations, save resources, increase profits, and protect patients, communities, and the environment.

2) Pfizer's Safe Sharps Disposal Plan

In 2013, in compliance with state and local environmental regulations in the United States, Pfizer published a 'Safe Sharps Disposal Plan' aiming to provide a framework for managing various types of sharps either for safe collection or proper disposal of, to involve individuals in the recycling and disposal programs ([Pfizer, 2013](#)).

Pfizer provides comprehensive and up-to-date information and instructions for all its self-injected products across the nation online. Individual patients can access multiple resources to get their sharps disposal questions answered and find local disposal options with healthcare providers. In this way, Pfizer ensures that patients understand how to safely dispose of their injection devices in accordance with state and local requirements.

Pfizer also innovates by providing safer injection devices and supplementary take-back service. For example, Enbrel is one of the self-injection biopharmaceuticals provided by specialty pharmacies due to its refrigerated or frozen storage and shipment. It is offered in a single-use, SureClick auto-injector with the needle retracting into the device after use. The patients are automatically registered in a sharps mail back program. They will receive a pre-paid 1-gallon sharps container to collect the used injector. Additional containers are sent to patients before they mail back the filled container.

As a member within the Pharmaceutical Product Stewardship Work Group (PPSWG), a non-profit organization from U.S., Pfizer collaborated closely with industry peers to develop a consistent and appropriate approach to household pharmaceutical products and sharps disposal ([Helmer, n.d.](#)). The efforts include continuing to work with the whole supply chain stakeholders for consistency and partnering with pharmacy trade associations to advance a national strategy for self-injection medicines disposal.

3) Pfizer's sustainable medicines program

Pfizer is pursuing ways to reduce the environmental impact of their medicines throughout the product life cycle ([Pfizer, n.d.a](#)). Minimizing waste is a core focus of Pfizer's sustainable medicines program ([Pfizer, 2023](#)). The company consistently seeks waste minimization opportunities in its research and development, manufacturing operations and product packaging ([Pfizer, n.d.b](#)).

In 2022, at Pfizer's logistics center in Memphis, Tennessee, efforts were made to minimize the environmental impact of cold chain shipping operations. Initially, only about 3% of the single-use Styrofoam (manufactured from non-renewable petrochemicals and difficult to recycle) containers used for cold chain shipments were returned for recycling, while the majority ended up in landfills. To address this, Pfizer introduced reusable shipping containers that are easy to return and can be reused more than 70 times. This change to replace the Styrofoam shippers has reduced the amount of packaging waste sent to landfills by 90% ([Pfizer, 2022](#))

4.2.2 Johnson & Johnson

1) Single-use medical device recycling program

In hospitals, single-use medical instruments such as needles, surgical instruments, catheters, and endoscopes are used once per patient to prevent cross-contamination and reduce sterilization time. However, this practice generates significant waste, as these items are typically discarded after use. Johnson & Johnson aims to address this issue with its single-use medical device recycling program, which seeks to reduce the environmental impact by diverting these materials from landfills and incinerators ([Mannarino, 2023](#)). Johnson & Johnson helps every partner hospital with optimal bin locations and collection schedules, along with staff training to properly conduct the collections before they can be sent to reprocessing ([Johnson & Johnson MedTech, n.d.](#)). The program enables hospitals to recycle certain metal (steel, titanium, aluminum, copper and chrome steel) and plastic parts from Johnson & Johnson MedTech single-use medical devices and absorbable suture packaging. These materials are used to create new non-medical products, help creating a closed-loop process in the CE. In 2021 and 2022, components from over 25,000 single-use products were recycled through the program, and this number is expected to increase as more hospitals join the initiative ([Johnson & Johnson, 2021](#)).

2) Safe Returns program

The Safe Returns program, initiated over a decade ago in the U.S., aims to make it safe and convenient for patients to return Immunology self-injectable devices used at home. This program allows pharmaceutical patients to send back their devices in standard sustainable paper envelopes. In addition, Johnson & Johnson is enhancing its capability to disassemble these collected devices to reuse or recycle the materials and components, striving to achieve device circularity—an accomplishment not yet fully realized in the pharmaceutical industry ([Mannarino, 2023](#)).

Besides, Johnson & Johnson replaced the plastic trays in the secondary packaging of many Immunology self-injectable devices with fiber-based trays. These new trays can be recycled with regular cardboard in most countries. It hugely facilitates the recycling process and increases recycling rates ([Johnson & Johnson, 2021](#)).

3) Digital Health in a Circular Economy (DiCE)

As technology advances, digital health devices like wearable sensors, smart pillboxes, and electronic labels will become more common in healthcare ([Mannarino, 2023](#)). The growing consumption of these devices raises the issue of proper disposal at the end of their life cycle. Johnson & Johnson led the launch of the Digital Health in a Circular Economy (DiCE) collaborative initiative by the European Union which aims to extend product lifetime as far as possible ([Dice, 2023](#)). Johnson & Johnson is working with 20 organizations from 9 countries to examine every stage of the lifecycle of digital health devices, seeking opportunities to extend their use or ensure responsible disposal. However, these efforts are only effective if patients return the devices in the first place. Therefore, research on behavioral science is also included in Johnson & Johnson and DiCE.

4.2.3 *GlaxoSmithKline (GSK)*

1) Complete the Cycle Inhaler Recycling and Recovery Scheme

In 2011, GSK firstly launched the Complete the Cycle Inhaler Recycling and Recovery Scheme in the UK, encouraging patients to return all (not just those manufactured by GSK) empty respiratory inhalers to participating pharmacies for recycling ([GSK AU, 2013](#)). Participating pharmacies will have a Complete the Cycle collection container where consumers can drop off empty inhalers as they pick up new prescriptions. When the

containers are full, pharmacies send the inhalers to a specialized recycler (TerraCycle). Recovered plastics are used to create various household items, while non-recyclable components are utilized as fuel to generate energy. Since the program began in 2011, over 2 million inhalers have been recycled in the UK, reducing CO₂ emissions by an amount equivalent to removing approximately 8,600 cars from UK roads. In partnership with GSK, TerraCycle handles the recruitment of pharmacies and the distribution of program materials to participating stores ([TerraCycle, n.d.a](#)).

However, this program was stopped in 2020 because it could not achieve the required scale as a stand-alone service ([Janković, 2023](#)).

2) Safe Needle Disposal Plan

By law (Senate Bill 486) from the state of California, any pharmaceutical manufacturer that sells or distributes self-injected medications must implement a plan outlining how they support the safe collection and proper disposal of used devices. As a participating member of Pharmaceutical Product Stewardship Work Group (PPSWG), GSK submits the Safe Needle Disposal Plan subject to its self-injectable products. Addition to GSK's online Return Goods Policy with guidance on how, where, and when to return eligible products, GSK also sets a Response Center to provide specific instructions on disposal for free. Furthermore, to encourage returns, consumers can also return products for replacement if certain conditions are met ([GSK, 2024](#)).

4.2.4 Sanofi

1) Injection Pen Recycling

Sanofi is committed to eco-friendly design and has launched take-back programs in several countries to collect and recycle injection pens ([Sanofi, 2023](#)). In Germany, a program launched in April 2023, involving 35 pharmacies in Berlin, aims to collect 30% of Sanofi's SoloStars pens within a year. Based on the existing recycling infrastructure in Denmark, Sanofi has partnered with Novo Nordisk, Eli Lilly, and Merck KGaA to create the world's first cross-industry recycling solution for injection pens, targeting 25% recycling rate of distributed 6 million injection pens in Denmark, equivalent to 25 tons of plastic waste in one year.

2) Home Healthcare Free Recycling Program

Sanofi has partnered with US-based recycling initiative TerraCycle to make its product packaging recyclable ([TerraCycle, n.d.b](#)). Consumers can return some specific Sanofi hard-to-recycle packaging in any box for free through registration on TerraCycle website to join this program. Once collected by TerraCycle, the packaging is cleaned and separated by material type. The materials are then recycled into raw formats to make new products, such as park benches and picnic tables.

4.2.5 *Eli Lilly*

1) Device Take-Back and Recycling

As a member of the Pharmaceutical Product Stewardship Work Group (PPSWG), Eli Lilly is committed to reducing emissions by exploring new options for minimizing EoL pharmaceutical product waste ([Eli Lilly and Company, 2023a](#)). Eli Lilly promotes policy decisions by educating patients and caregivers on proper disposal of its products. They also collaborate with local pharmaceutical associations and peer companies in the industry in several different countries at small scale. Additionally, Lilly is supporting partners financially and with resources to test new recycling technologies aimed at enabling the recycling and reuse of plastic from their used devices.

2) Recycling of Data Loggers

Each year, thousands of data loggers—small devices that measure temperature to ensure the quality of the pharmaceutical products—are discarded after use in logistics. In collaboration with these data loggers' manufacturers, Eli Lilly developed a recycling program to address this issue ([Eli Lilly and Company, 2023b](#)).

4.2.6 *Novo Nordisk*

1) ReMed

ReMed by Novo Nordisk is an innovative testament currently in 5 countries to take back the used injection pens to recycle the plastics for other uses ([Novo Nordisk, 2023](#)). Depending on the local laws, users can return their injection pens to their local pharmacy or freely mail them back directly. Once an injection pen is returned, it is sent to Novo Nordisk's recycling

partner. There, the pen is crushed and separated into different material types, which are processed to prepare them for new uses.

4.2.7 Merck & Co

1) Biopharma Recycling program

Merck & Co aims to reduce packaging materials for recycling, as the amount of material used determines the extent to which they can recycle ([Merck, 2018a](#)). This Biopharma Recycling Program is a US-based program partnered with Triumvirate Environmental that collects, cleans and recycles biohazardous single-use pharmaceutical product waste from Merck & Co's research labs and biopharmaceutical manufacturing operations into industrial-grade plastic lumber in construction, landscaping or transportation ([Merck, 2018a](#); [Merck, 2018b](#)).

Triumvirate Environmental is a US-based waste management and environmental services provider company in the Life Sciences, Healthcare, Education, and Industrial markets ([Triumvirate Environmental, n.d.](#)).

2) Ech2o Collection Recycling Program

Ech2o is the first collection and recycling program for EMD Millipore (the Life Science division of Merck KGaA of Germany) laboratory water purification consumables ([Labcompare, 2011](#)). In cooperation with Heritage Environmental Services, the Ech2o program allows U.S. users of EMD Millipore lab water purification systems to return used cartridges for disassembling. A unique feature of the Ech2o program is its traceable and certified process. It begins with user identification on the EMD Millipore website, followed by barcode tracking of the cartridge during transport, and ends at the audited Heritage waste management site where the cartridges are recycled. To ensure complete traceability, EMD Millipore also had a third-party specialist conduct a full life cycle assessment (LCA) of the cartridges, providing certifications.

Heritage Environmental Services, LLC is one of the largest full-service environmental firms in the U.S. They handle and treat both hazardous and non-hazardous wastes safely and according to regulations. Heritage Environmental Services works with companies across various industries, providing services like waste treatment and disposal, nationwide

transportation, lab testing, industrial maintenance, product recovery, and byproduct management.

4.2.8 Bayer

1) Packaging and Shuttle Recycling

The Packaging and Shuttle Recycling program aims to recycle Bayer crop protection containers in the United States ([Bayer Group, 2021](#)). Any Bayer empty drums that have exceeded their usable service life and contained Bayer-branded crop protection products are eligible for the program. Each year, Bayer will arrange for container pickup directly with retailers or consumers who have 10 or more drums. Through this program, Bayer aims to prevent plastics waste in the environment and avoid unsafe disposal of pesticides in the nature. With a focus on low- and middle-income countries, they train the farmers in-person or online how to safely use the pesticides when they sell the products ([Bayer, 2022](#)).

4.2.9 Novartis

1) Safe Collection and Proper Disposal of Waste Sharps from Self-Injected Home Medications

By laws from different states of the U.S., Novartis (as a member of Pharmaceutical Product Stewardship Work Group (PPSWG)) provides online education to patients how to properly dispose of waste sharps and gives instructions on how to mail-back sharps from its Cosentyx product in a 1.2-gallon FDA - cleared sharps collection container for free ([Novartis, n.d.](#)).

4.2.10 Amgen

1) Responsible Product Disposal

As a member of Pharmaceutical Product Stewardship Work Group (PPSWG), Amgen sets the Responsible Product Disposal program ([Amgen, n.d.](#)). Some of Amgen's home-used products (including sharps, autoinjectors and containers) can be mailed back to Amgen. These waste materials will be cleaned, sorted and then either recycled or sent to a waste-to-energy facility for incineration with energy recovery. Until 2023, the Amgen Rhode Island manufacturing facilities successfully divert 80% of landfill waste to the waste-to-energy facility, significantly reducing the amount of waste sent for disposal ([Kendall Square, 2023](#)).

4.3 Data collection

Data collection for this paper was carried out using a combination of firsthand and secondhand sources. 18 real company programs were reviewed from archival records to gain a comprehensive view from practice. Two semi-structured interviews were conducted with specialists from the pharmaceutical supply chain to supplement the findings. The combination of these two methods aims to ensure the reliability and validity of the data collected, providing a robust foundation for our analysis.

4.4 Data analysis

For qualitative analysis, each case was reviewed individually, followed by thematic analysis to identify patterns and themes across the cases. In this way, similarities and differences between the cases were identified. Combined with interview content, it also revealed the drivers and barriers to implementing recycling and disposal programs. Furthermore, innovation solutions were determined based on both practice and academic. And recommendations were made for different stakeholders. Finally, the limitations of the study were pointed out.

5. Chapter 4: Findings

The cross-case analysis begins with de-structuring the data into separate parts, such as words, phrases, or sentences. The 18 programs were filtered by common keywords, for example they all mentioned similar phrases: law, mail-back, online education, environmental associations, packaging innovation and third-party waste management companies. After the data is reduced through de-structuring, the refined data should be re-structured in the thematic analysis ([Aronson, 1995](#)). Thematic analysis in a qualitative study involves a close examination of the data to identify themes and patterns that are present in the data. Once themes have been identified, they can be grouped together into categories or codes that represent the underlying concepts or ideas expressed in the data. These categories can then be used to identify patterns and relationships within the data, which can be further explored and interpreted. In the 18 cases, 5 themes were identified, with some sub-themes to further explain the content.

5.1 Law and regulation

Due to the nature of pharmaceutical products, pharmaceutical waste cannot be disposed of in normal waste streams to avoid water and land pollution ([De Oliveira Souza et](#)

al., 2021; Kayode-Afolayan et al., 2022). As there are increasing amount of self-injection medicines consumed, government organizations have set mandatory regulations requiring pharmaceutical companies to safely collect or properly dispose of sharps from patients. For example, under law (Senate Bill 486) from the state of California, Pfizer (Safe Sharps Disposal Plan), GSK (Safe Needle Disposal Plan) and Novartis (Safe Collection and Proper Disposal of Waste Sharps from Self-Injected Home Medications) all have submitted their plans to the government agency - California Department of Resources Recycling and Recovery (CalRecycle). These plans will be strictly implemented to comply with local laws, maintain legal and operational standards within the companies, and foster community trust. Regular audits and assessments on these plans will be conducted to guarantee ongoing compliance and identify opportunities for further improvement.

5.2 Consultancy services

To facilitate the recycling process, pharmaceutical companies offer consultancy services through **online platforms** or **call centers**. Some pharmaceutical companies have developed professional **online platforms** with clear description and instructions for consumers to know how to deal with their used products. For example, Pfizer introduced the Pfizer Responsible Disposal Advisor (Waste Wizard), an advanced online platform that offers waste categorization and disposal information, strictly following federal environmental regulations for hazardous wastes. GSK published its online Return Goods Policy, providing guidance on how, where, and when to return eligible products, making it easy and convenient for patients. Additionally, some pharmaceutical companies have set up **call centers** to answer questions from patients or healthcare providers about recycling and disposal. For instance, GSK has a Response Center that offers specific disposal instructions for free. These timely call services, supplementary to the online platforms, provide clearer instructions and encourage more patients, especially the elderly, to participate in proper recycling and disposal practices.

5.3 Collaboration with stakeholders

In practice, the collaboration with different stakeholders includes **environmental associations, third-party specialists, pharmacies** and **peer companies**.

Many of the pharmaceutical companies from the cases are members of the **environmental association** - Pharmaceutical Product Stewardship Work Group (PPSWG),

for example Pfizer, GSK, Eli Lilly, Novartis and Amgen. PPSWG is an association dedicated to advancing sustainable practices within the pharmaceutical industry. It provides infrastructure and guidance to support member compliance on pharmaceutical disposal options. Besides, Johnson & Johnson works with 20 organizations from 9 countries under the Digital Health in a Circular Economy (DiCE) collaborative initiative by the European Union, aiming to extend the lifecycle of digital health devices. These environmental associations have a common goal and share resources among their members. By pooling their knowledge and expertise, members can benefit from shared research, innovative solutions, and a united voice in advancing environmental conservation efforts.

To save costs and increase efficiency, many pharmaceutical companies partner with **third-party specialists**, such as logistics service providers or waste management service providers to handle recycling and disposal. In most 'mail-back' cases, sharps can be returned in standard envelopes by local postal. For packaging return, such as in the Sanofi Home Healthcare Free Recycling Program, any packed box is accepted by local third-party logistics providers. This streamlined process accelerates both the return time and rate. As pharmaceutical waste management companies have extensive infrastructure and expertise in resource recovery, reuse, and recycling within the healthcare market, the waste management service of the pharmaceutical companies is outsourced to them. For example, WM Healthcare Solutions, Inc., a subsidiary of Waste Management, Inc. helps Pfizer introduce the “Pfizer Responsible Disposal Advisor (Waste Wizard)” platform to offer new and free online pharmaceutical disposal guide for healthcare providers. In the Complete the Cycle Inhaler Recycling and Recovery Scheme launched by GSK, pharmacies in the UK who receive the inhalers are required to send the inhalers to TerraCycle - a specialized recycler. Besides offering the recycling of inhalers service for GSK, TerraCycle also handles the recruitment of pharmacies and the distribution of recycling materials to them. TerraCycle also fully manages the packaging recycling of some home healthcare products from Sanofi in the Home Healthcare Free Recycling Program. Triumvirate Environmental collects, cleans and recycles biohazardous waste from Merck & Co’s research labs and biopharmaceutical manufacturing operations in the Biopharma Recycling Program. And Heritage Environmental Services offers cartridges recycling in the Ech2o Collection Recycling Program from Merck & Co. Moreover, Merck & Co even has a third-party specialist conduct a full life cycle assessment (LCA) of the cartridges to ensure complete traceability of their products. Outsourcing to third-

party specialists allows pharmaceutical companies to concentrate on their core expertise, while the third-party specialists help close the loop in the entire supply chain.

Pharmacies play as an important intermediate between pharmaceutical companies and consumers, as they have direct contact with patients in both flows: selling the medicines and receiving the returns. For instance, inhalers are collected in the participating pharmacies in the Complete the Cycle Inhaler Recycling and Recovery Scheme from GSK. The Injection Pen Recycling program from Sanofi, firstly launched in Berlin and involving 35 pharmacies, aims to collect one specific Sanofi product: SoloStars pens. In the ReMed by Novo Nordisk, users can return their injection pens to their local pharmacy depending on local regulations. When patients drop off their devices at pharmacies, pharmacists are responsible for collecting the used products in an orderly manner. Moreover, they can check if patients are using the devices correctly and provide instructions to help them improve their usage.

Working with **peer companies** allows for the sharing of information and infrastructure to reach a certain scale. For example, Sanofi has partnered with Novo Nordisk, Eli Lilly, and Merck KGaA to create the world's first cross-industry recycling solution for injection pens in Denmark. Such collaboration with peer companies can achieve much higher efficiency and effectiveness in recycling efforts.

5.4 Packaging innovation

To substantially change the situation, the packaging innovation focuses on adopting **reusable shipping containers** and **sustainable packaging materials**.

Many pharmaceutical products need to be kept cool during transportation. The insulated containers used by the pharmaceutical companies to ship them are changing from single-use to **reusable** material. For example, in Pfizer's sustainable medicines program, since Pfizer made this replacement at its logistics center in Memphis in 2022, the packaging waste sent to landfills decreased by 90%. Both [Pfizer \(n.d.b\)](#) and [Merck \(2018a\)](#) mentioned that they plan to reduce the amount of packaging, which aligns with the 'reduce' principle in the CE. To facilitate the recycling process and reduce risk, some pharmaceutical companies are replacing plastics packaging with **sustainable** fiber-based material, which can be easily recycled with regular cardboard in most countries. For example, Johnson & Johnson has replaced plastic packaging with fiber-based material in many of its Immunology self-

injectable devices. Compared to plastic, cardboard material generates much less greenhouse gas emissions.

5.5 Continuous education

Almost all pharmaceutical companies begin their recycling and disposal programs by educating consumers on 'why' and 'how' to return pharmaceutical products. As technology and regulations evolve, continuous education remains important. For example, Bayer places significant emphasis on regularly training farmers on the safe use of pesticides through various channels, especially in low- and middle-income countries.

In conclusion, the identified themes represent the current reverse logistics practice within the pharmaceutical industry. Law and regulation stand out as the first theme, as compliance with regulations ensures legal and operational standards are maintained in the companies. Consultancy services via online platform or call center facilitate consumer participation in these programs. Collaboration with various stakeholders, including environmental associations, third-party specialists, pharmacies, and peer companies, enables the sharing of information and resources to enhance the effectiveness of waste management strategies. Pharmaceutical companies are also increasingly prioritizing sustainable packaging innovations, such as reusable shipping containers and fiber-based materials, to reduce environmental impact. Lastly, continuous education for consumers is crucial to keep the public engaged and informed about the importance of proper pharmaceutical disposal, thereby fostering a more sustainable and effective reverse logistics process.

6. Chapter 5: Discussions

The findings from the multiple cases show that the current recycling and disposal programs address several specific aspects, but recycling options in the pharmaceutical industry are limited and challenging to implement. After investigating the cases in detail to answer the first research question: 'How are reverse logistics programs for recycling and disposal designed and implemented in leading pharmaceutical companies?', this paper identifies drivers and barriers using interview material to address the second research question: 'What are the key drivers and barriers influencing the effectiveness and efficiency of reverse logistics in pharmaceutical recycling and disposal programs?'. Then innovative

solutions are proposed from a stakeholder perspective to answer the last research question: ‘How can innovation promote the reverse logistics practices in the pharmaceutical industry?’

6.1 Drivers

The key drivers for advancing recycling and disposal programs can be categorized as external or internal, namely **law and legislation**, and **market pull**, respectively.

For external drivers, **law and legislation** are the most important trigger, which is emphasized in both multiple case studies and interviews with specialists from the pharmaceutical supply chain. As EPR continues to expand globally within the pharmaceutical industry, companies are increasingly required to manage the entire lifecycle of their products—from design and manufacturing to post-consumer disposal. Due to stringent quality standard in the pharmaceutical industry, law and legislation play a crucial role in ensuring public safety, regulating the reverse logistics process, and improving reverse logistics infrastructure (De Angelis et al., 2018; Khan & Ali, 2022). To meet higher standards of environmental protection and public health, these companies must legally collaborate with various stakeholders (Fasken, 2022).

For internal drivers, **market pull** encompasses various considerations aimed at capturing and maintaining market share. According to interview content, the production cost of drugs is relatively low compared to their selling price, which does not provide sufficient financial incentive to recover and recycle these products. However, due to social and environmental sustainability pressures, pharmaceutical companies have to enhance their corporate image by taking actions to meet consumer expectations. Failing to do so could result in losing market share in the CE (Hojnik & Ruzzier, 2016; Mallick et al., 2023).

6.2 Barriers

The barriers emerged from the practice include **unbalanced regional development**, **insufficient knowledge on consumer behavior** and **lack of coordination and collaboration within the supply chain network**.

The government plays a crucial role in implementing CE practices (Khan & Ali, 2022). However, due to **unbalanced regional development**, the laws and infrastructure for pharmaceutical returns vary significantly between countries and even within different regions

of the same country, affecting the degree of implementation of recycling and disposal programs. Developing countries face much more difficulties in implementing these programs compared to developed countries due to their lack of financial resources and funding, and limited expertise and technology (Veleva et al., 2018; Veleva & Cue, 2019). Currently, recycling practices are often limited to pilot programs in specific developed countries with comprehensive laws and infrastructure. However, as evidenced by the closure of GSK's Complete the Cycle Inhaler Recycling and Recovery Scheme, if the implementation does not reach a certain scale, recycling is not economically feasible as a stand-alone service. The success of CE requires greater participation from all regions worldwide.

All recycling and disposal program implementations rely on consumers returning used products in the first place. Ensuring that consumers return products for recycling requires continuous education through various channels. However, **insufficient knowledge on consumer behavior** could be another barrier. Research in behavioral science can help understand what motivates or prevents consumers from recycling. Factors like convenience, perceived benefits, and social norms influence their willingness to return products (Claudy & Peterson, 2022; Gomes et al., 2022). By addressing these factors, companies can develop better strategies to encourage participation.

The complexity of the PSC makes it challenging for the supply chain actors to monitor the entire supply chain, particularly during reverse logistics operations. Reverse logistics demands extensive infrastructure and expertise, which can be costly for pharmaceutical companies to manage independently. The **lack of coordination and collaboration within the supply chain network**, especially in terms of information communication and technology cooperation among pharmaceutical companies, distributors, pharmacies, and consumers, further complicates the practice of reverse logistics (Ding, 2018).

6.3 Innovative solutions

Innovative solutions are proposed to address the identified barriers. To tackle issues such as unbalanced regional development and insufficient knowledge on consumer behavior, **collaborative platforms** can be effective. Specifically, these platforms can facilitate communication among different stakeholders involved in the reverse logistics process. Additionally, sharing successful experiences and resources with developing regions on the collaborative platforms can further expand reverse logistics practice into a bigger scale.

Outsourcing and **product-specific innovations** can deal with the lack of coordination and collaboration within the supply chain network. Outsourcing improves professional through specialization, while product-specific innovations can revolutionize subsequent reverse logistics activities from the point of origin. It is notable that advancements in technology can significantly contribute to innovations in **traceability**.

Establishing **collaborative platforms** that involves regulators, pharmaceutical companies, third-party specialist, pharmacies and consumers can achieve transparency and open communication. Regulators from different regions can exchange knowledge and experiences regarding the adoption of CE principles to facilitate the reverse logistics practices at a bigger scale (De Angelis et al., 2018). Once a legislative framework is built, pharmaceutical companies play a key role in disseminating regulations and educating pharmacies and consumers through various programs. They are also responsible for investigating consumer behavior to tailor specific medical education initiatives. Third-party specialists, as requested by pharmaceutical companies, can publish relevant information regarding the specialized services they offer. Pharmacies, serving as the direct link between pharmaceutical companies and consumers, are provided with advanced training to raise their awareness of environmental impacts and to influence consumer behavior through professional therapy and consultation services (Kümmerer, 2009). On the collaborative platform, all information is publicly shared, allowing stakeholders to communicate their current needs and gain insights into future requirements (Ozdemir et al., 2023).

Outsourcing certain activities in pharmaceutical reverse logistics to third-party specialists can create a win-win situation by fostering cross-industry collaboration and allowing each party to focus on their specialization, thereby enhancing resource productivity (Maranesi & De Giovanni, 2020). However, according to the interview, outsourcing within the PSC is challenging due to quality concerns. For example, outsourcing reverse logistics to third-party logistics service providers requires finding personnel with the right qualifications and the necessary infrastructure. To address this issue, pharmaceutical companies can outsource the same activity to multiple third-party specialists simultaneously, allowing them to switch providers easily if any problem arises.

To extend the lifecycle of their products, pharmaceutical companies are focusing on **product-specific innovations**, including green chemistry and eco-friendly packaging (Merck, 2018a; Pfizer, n.d.b). Green chemistry aims to reduce or eliminate the use and generation of hazardous substance by seeking replacement and changing chemical synthesis (Tucker, 2006). For example, through advancements in green engineering technologies, scientists can now extract APIs from non-expired or EoL medicines. This recovery process is over 90% effective, making the extracted APIs suitable for further formulation development and helping to avoid potential pollution from landfilling (Hsieh et al., 2017). Meanwhile, it sets even a higher requirement for reverse logistics to manage the returned medicines. The shift to eco-friendly packaging can transform the activities of various stakeholders along the PSC. Biodegradable packaging offers user-friendly and non-toxic advantages, while smart packaging enhances the detectability and usability of medicines (Hui et al., 2020; Meherishi et al., 2019). It facilitates the return process and increases the return rate. Thus, product innovation significantly influences process innovation in reverse logistics.

As mentioned in the interview, **traceability** as one capability is of high importance in the pharmaceutical industry because it ensures product quality. Fast-developing technologies such as Radio Frequency Identification (RFID) and Internet of Things (IoT) can help pharmaceutical companies become more agile by improving traceability and lifecycle information management (Julianelli et al., 2020; Mallick et al., 2023). Real-time tracking at each stage of the product lifecycle enables pharmaceutical companies to maintain accurate records of their products, monitor their status, and address any issues swiftly (Ding, 2018). This capability allows for accurate predictions of recycling and disposal volumes and facilitates compliance with regulatory requirements by providing detailed documentation from production to disposal (Taylor & Senac, 2014).

The identified themes and findings represent the current reverse logistics practices within the pharmaceutical industry. Law and regulation stand out as a primary driver, supporting the pharmaceutical industry in maintaining compliance with environmental and safety standards. Market pull is driven by the need to gain market share under social and environmental pressures, which motivates companies to enhance their corporate image. The barriers can be summarized as information asymmetry and technology gaps at the levels of country, industry, and individuals. Innovations can be categorized as either technological

(such as product-specific innovations and traceability) or non-technological (such as collaborative platforms and outsourcing) to address the barriers. These insights highlight the importance of stakeholder collaboration, green manufacturing, and continuous education in enhancing reverse logistics practices within the pharmaceutical industry. Through this qualitative case study method, this study provides valuable perspectives on reverse logistics practices, aiding stakeholders in better understanding and improving these processes for both environmental and social benefits.

7. Conclusion

7.1 Limitations and recommendations

Implementing reverse logistics is challenging due to the high standards required for traceability and quality in real life. Currently, most common reverse logistics practices focus on the return of medical devices and packaging rather than the pharmaceuticals themselves. This is largely because, from an economic standpoint, the cost-benefit analysis often shows that recycling drugs is not financially viable. Nevertheless, under increasing social and environmental pressures, recycling and recovering APIs are becoming more prominent trends. Properly managing pharmaceutical waste and ensuring safe disposal are essential to prevent environmental contamination and protect public health. Although recycling drugs may not always be economically advantageous, the broader social and environmental benefits underscore its significance. Addressing this issue will require cross-industry collaboration to identify the most cost-effective solutions in future studies.

It is recommended that future research can quantitatively measure the effectiveness of these programs to provide more concrete evidence of their impact. Currently, in the pharmaceutical industry, the availability of reverse logistics data is limited because reporting such information is not mandatory in most countries. This lack of standardized data poses a significant challenge for researchers. Future studies should focus on developing methods to collect and analyze relevant data to accurately evaluate the success of reverse logistics and sustainability initiatives. Collaboration with regulatory bodies and industry stakeholders to establish mandatory reporting standards and create comprehensive databases would be instrumental in addressing this issue. Enhanced data collection and transparency will not only support more robust research but also drive improvements in sustainability practices across the pharmaceutical industry.

7.2 Summary

This thesis is unique in exploring innovation possibilities in reverse logistics and the CE within the pharmaceutical industry, focusing on recycling and disposal programs. The pharmaceutical industry, known for its high consumption of natural resources and significant emissions, can greatly influence public safety. In response to sustainability trends, pharmaceutical companies are adopting CE principles to enhance resource efficiency, minimize waste, and ensure the continuous use of materials by incorporating reverse logistics as a strategic tool.

Through a multiple case study approach, thematic analysis identified key strategies that drive sustainability and efficiency in managing pharmaceutical waste, examining 18 real cases from 10 outstanding companies. Governments play a crucial role in establishing a legislative framework that supports the implementation of reverse logistics processes. In compliance with these laws, pharmaceutical companies, acting as intermediaries, bear the responsibility of offering consultancy services and continuous education to consumers. Due to the stringent quality standards and complex nature of the PSC, collaboration with stakeholders across the entire supply chain is essential to achieve sustainable development goals. Additionally, innovations in packaging that reduce emissions can substantially increase return rates. Interviews provided evidence for the findings and offered valuable insights into identifying opportunities and challenges. The combination of public case studies and interview sources comprehensively illustrates the landscape.

The identified drivers and barriers highlight that the integration of reverse logistics in the PSC not only mitigates environmental impacts but also enhances economic and social benefits. Despite progress in mandatory legislation and the industry's shift towards a sustainability mindset, challenges remain, particularly due to unbalanced development and lack of coordination. Humans, while affected by the pharmaceutical industry, also play a primary role in the implementation of reverse logistics. It is interesting to conduct research on consumer behavior to identify the enablers and obstacles to implementing recycling and disposal programs. Grounded in Stakeholder-RBV, relationships among key stakeholders, including regulatory bodies, manufacturers, distributors, healthcare providers, and consumers, are crucial for the successful implementation of reverse logistics programs. Collaborative efforts among these stakeholders lead to more effective and sustainable waste management

practices. Specific innovative solutions are proposed to address barriers from the stakeholder perspective. By incorporating stakeholders on the collaborative platform, they can communicate transparently and share resources. Beyond governmental legislative efforts, pharmaceutical companies must take the lead in overcoming barriers. Technological innovations can enhance tracking and managing returns, and product-specific innovations in green chemistry and sustainable packaging can revolutionize reverse logistics activities. Moreover, as a type of process innovation, outsourcing some specific activities to third-party specialists can improve resource integration and efficiency, leading to economic benefits. However, ensuring quality remains a primary focus in this specialization. In practice, pharmaceutical companies have backup solutions to ensure quality standards are met.

However, current recycling and disposal practices are limited in the returns of medical devices and packaging. Further technological advancements should focus on recycling pharmaceuticals after a cost-benefit analysis to meet higher ethical and environmental standards. As this research only uses a qualitative research method, future quantitative research method could offer evidence on the program's impact from another perspective.

In conclusion, the pharmaceutical industry stands to benefit significantly from embracing reverse logistics and CE principles. By continuing to innovate and collaborate, the industry can achieve greater sustainability, reduce environmental impact, and improve overall public health and safety.

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Appendix

Interview question list

1. Can you please introduce yourself and your role within the pharmaceutical supply chain industry?
2. How do you think resource scarcity and safety issues impact the environment in the pharmaceutical industry, and how can the pharmaceutical supply chain help mitigate this negative impact?
3. From your experience, what are the critical resources and capabilities required for successful implementation of reverse logistics in pharmaceutical companies?
4. What are the key challenges you observe in implementing recycling and disposal programs in pharmaceutical companies today?
5. In your opinion, how would you define innovation in the context of reverse logistics and circular economy within the pharmaceutical industry?
6. What kind of innovations do you think can happen in the supply chain (especially in the reverse logistics sector) in the pharmaceutical industry?
7. Is there any additional information or perspective you think would be valuable to include in a study focusing on innovation in reverse logistics and circular economy within the pharmaceutical industry?
8. Finally, are there any other experts or resources you would recommend that I can reach out to regarding this topic?

Abstract:

The aim of this paper is to explore innovations in pharmaceutical reverse logistics within the context of the circular economy (CE). The pharmaceutical industry is highly regulated due to its impact on the environment and public safety. By investigating 18 real public recycling and disposal cases from 10 prominent pharmaceutical companies, thematic analysis summarizes the concrete implementation processes of these programs. Combined with interviews with pharmaceutical supply chain (PSC) specialists, this qualitative research identifies drivers and barriers to success. The findings highlight innovative solutions, including technology such as big data and product-specific innovation, as well as non-technology approaches like stakeholder collaboration based on the stakeholder resource-based view (Stakeholder-RBV). This paper evaluates the real-life programs through both academic and practical evidence and provides potential solutions to promote sustainable development.

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