Sustainable Pharmaceutical Packaging: Integrating Eco-Service Design and Circular Economy for Patient-Centered Innovation

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Abstract. Traditional pharmaceutical packaging has focused on functionality but neglected sustainability, patient needs, and its potential values for individuals, society and the environment. This paper examines the connection between pharmaceutical packaging and its stakeholders, assessing current sustainable management practices. By analysing existing innovations and using the Eco-Service design evaluation method, this paper maps the pharmaceutical packaging production and service chain to identify key barriers and opportunities, aiming to propose systemic solutions for pharmaceutical packaging innovation in the context of service design and circular economy to demonstrate the feasibility. By drawing on the experience of the food industry, this paper explores how RFID-enabled reusable pillboxes can be integrated into existing pharmaceutical packaging service systems to reduce packaging waste at multiple levels, minimise the environmental footprint, and improve patient experience. It provides a novel way to inspire further pharmaceutical packaging researchers to promote more sustainable and focused patient well-being through multiple perspectives, including service systems.

Keywords: Pharmaceutical packaging, Sustainable innovation, Service system design, Eco-service design, Circular economy, Patient-centred, Well-being design

1 Introduction

Pharmaceutical packaging is crucial for patient-friendly medicines [1], but there is a gap between societal expectations and reality [2]. Packaging often fails to address patients' challenges, such as difficulty in identifying information, unclear expiration dates, and lack of disposal instructions [3,4]. Traditionally, packaging design prioritizes safety aspects like physical protection and information, with limited focus on social needs and user interaction [5,6].

Pharmaceutical contamination is a growing environmental and public health issue, with the industry generating over 300 million tons of plastic waste annually, half of which is single-use [7]. Packaging materials like PVC, HDPE, and polypropylene are

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commonly used, and even cardboard can affect recycling due to laminates and adhesives [8,9,10]. Pollution also stems indirectly from the healthcare supply chain [11]. While sustainability improvements in packaging can aid development [12], current research often overlooks the patient perspective, focusing instead on healthcare system solutions [13]. Patients, increasingly central to healthcare, face self-care challenges related to packaging information [14,15]. Integrating self-care with packaging, such as through medication calendars, could help [16], but few solutions combine patient experience, self-care, and sustainability. This essay proposes integrated sustainable packaging solutions by examining current and future value, innovation drivers, and stakeholder needs using an interdisciplinary eco-service design approach.

2 Literature review

2.1 Potential value and sustainable pathway of pharmaceutical packaging

Packaging is essential in a product's life cycle, protecting, preserving, and promoting its contents, but it often becomes an environmental burden once its function is fulfilled [17]. In the healthcare industry, packaging must prioritize protection, with materials such as high-density polyethylene used in cosmetic packaging for its resistance to abrasion and tearing, while polycarbonate in pharmaceuticals is not moisture-resistant, leading to potential oxidation and hydrolysis [18,19]. Extensive research into materials and functionality is necessary for pharmaceutical packaging.

However, demands for pharmaceutical packaging extend beyond safety, as it has the potential to address societal challenges and improve patient self-care [2]. Patient-friendly packaging is crucial, especially with the ageing population and increasing prevalence of chronic diseases. Such packaging can guide self-care, enhance medication adherence, and reduce errors, particularly for vulnerable individuals [20,21]. At the social level, it can reduce healthcare costs, improve efficiency, and minimize waste. Yet, pharmaceutical packaging, especially for prescription drugs, has long offered limited options to end-users, focusing on functionality and ignoring broader value and demands [2]. Food packaging faced a similar situation, prioritizing protection and shelf life, but has since evolved to address environmental impacts and consumer demands [22,23]. Consumers are now more aware of environmental issues and prefer bulk foods, prompting food companies to innovate with new materials and structures [24,25,26]. The pharmaceutical industry can learn from this shift [27], but researchers must consider how to adapt these lessons to innovate in pharmaceutical packaging.

2.2 The main actors driving sustainability in pharmaceutical packaging

The pharmaceutical supply chain involves manufacturers, distributors, pharmacists, and patients. Achieving sustainable pharmaceutical packaging requires focusing on these major stakeholders, as waste can occur throughout the chain, from packaging transportation emissions [28] to patient non-compliance [29]. Pharmaceutical packaging is categorized into primary (direct contact, e.g., capsules), secondary (protective and informational, e.g., medicine boxes), and tertiary (for storage and transportation,

e.g., wooden boxes) [11]. Promoting sustainability should consider the roles, needs, and driving forces of manufacturers, healthcare systems, and patients.

Sustainable Management by Manufacturers.

Manufacturers set the tone for sustainable packaging innovation [1,30]. However, they currently view packaging as an accessory, with limited innovation due to the industry's R&D focus and strict regulations [31]. Historically, green manufacturing innovations did not bring immediate profit [32]. But increasing consumer and policymaker attention to sustainability is shifting social and legal factors to support necessary changes [32].

Sustainable Management by Healthcare System.

Hospitals play a key role in promoting sustainable pharmaceutical packaging through waste management [13]. Sustainable supply chain management in healthcare includes ethical sourcing, environmental sustainability, and reducing carbon footprints [33]. This involves selecting pharmaceuticals from environmentally responsible companies and reducing packaging waste by adjusting prescription quantities and dispensing unpackaged medicines. Cultivating a waste reduction and recycling culture among stakeholders is also crucial [33].

Sustainable Management by Patients.

The role of patients in sustainable packaging management has been overlooked [34]. While the healthcare system manages most patient responsibilities, especially for hospitalized patients [35], independent purchasing of health products is increasing [36]. Patients often dispose of packaging and expired medicines with household waste, causing pollution and environmental impacts [37,38]. Reducing overmedication and developing waste collection systems are critical, with pharmacies taking on recycling responsibilities, but active patient involvement is still needed [37].

2.3 Medication adherence and self-care awareness

Medication adherence involves patients voluntarily taking medication as prescribed to achieve therapeutic effects [39]. Non-adherence is a global issue that can worsen patient conditions and lead to medication waste [29,40]. Patients may lack proper understanding of their medication regimens or adjust dosages based on their own interpretations [41], which is related to pharmaceutical packaging. Packaging is crucial for patient understanding of medication adherence and should be integrated into packaging innovation [42]. Adherence is linked to health literacy [43] and self-care awareness [14]. The key steps in medication adherence—initiation, implementation, and continuation—all involve self-care [20]. Packaging innovation should enhance self-care by focusing on individual self-care ability and its relationship with the healthcare system [44], though further research is needed on this.

Review summary.

Research on the environmental impact of pharmaceutical packaging and sustainable innovation is limited [17]. Some studies explore the relationship between sustainability and packaging's potential value, innovation factors, and supply chain stakeholders. Pharmaceutical packaging has been seen mainly as a safety accessory, with its role in sustainable development and patient care overlooked. Medication adherence and self-care are also neglected in promoting environmental sustainability and well-being. Stakeholders' responsibilities for sustainable management are not well defined. Few studies have integrated multiple perspectives to guide future packaging innovation and unify stakeholders' needs, including patient-friendly packaging.

3 Sustainable pharmaceutical packaging from an interdisciplinary perspective

3.1 Sustainable pharmaceutical packaging innovation based on assisted design theory

Service design is an emerging interdisciplinary field that includes product, system thinking and social sciences. It has proposed solutions to complex and systemic challenges and visualise the touchpoints of the service [45] to improve user experience and efficiency. In the life cycle of pharmaceutical packaging, the touchpoints of stakeholders can be defined as the behaviour of people interacting with pharmaceutical packaging. How the medical system receives packaging from transportation can be considered as a touchpoint, while patients opening packaging can be considered as another touchpoint. If want to improve people-centred products and healthcare services systematically, the service design processes and frameworks need to be modified in line with the expectations of key stakeholders. Patients, healthcare systems, and manufacturers are the main stakeholders, and their interests differ. What are their expectations in different touchpoints. How to provide patient-friendly while reducing the pressure of hospitals in pharmaceutical packaging and sustainability, as well as not harming the existing interests of pharmaceutical packaging manufacturers. This requires balancing the needs of stakeholders and integrating them with a single service design to meet and achieve the goal of sustainable development. Eco-design focuses on incorporating environmental criteria early in the design process to reduce the environmental impact of new products. Eco-SD (Eco-service design) (Figure 1) is a design approach combining eco-design with service design to address these challenges and conceptualise new services consistent with environmental sustainability and user experience. As a combined approach, Eco-SD can design new services that consider both ecological sustainability and user experience [46]. Yet design methods that enhance user experience are critical to achieving sustainable behaviour change [47]. Therefore, following the Eco-SD method allows people to innovate sustainably based on the product life cycle in the supply chain and system perspectives while considering user-friendliness. This is a comprehensive way of thinking about design innovation. And the barriers in existing

pharmaceutical packaging innovation and sustainable service design, such as user experience and environmental impact, can be analysed based on barrier classification for the ECO-SD method. (Figure 2)

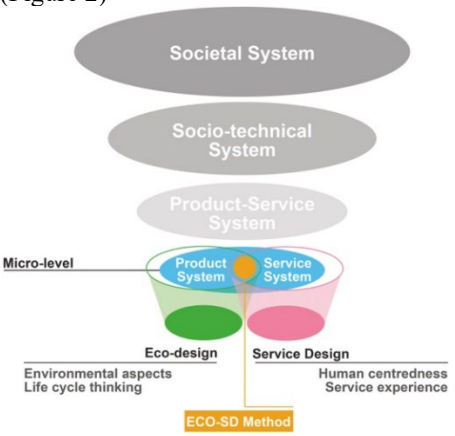

Fig. 1. (Sierra-Pérez et al., 2021) Positioning of ECO-SD method in Multilevel Design Model. [46]

Fig. 2. Eco-SD barrier plain explanation adapted from Sierra-Pérez et al., 2021

3.2 Relationship between Service design and other disciplines

Service design promotes innovation, but its full potential is hindered by limited understanding of its multiple perspectives [48]. Combining research from other disciplines is essential to broaden knowledge and solve problems. Sustainable innovation in pharmaceutical packaging should focus on eco-design integration and other aspects. Packaging design, as a factor influencing consumer purchases, affects attention, value understanding, and functionality perception, making it a crucial part of marketing and multi-sensory user experience [49]. Sustainability has become a key part of packaging functionality [50] and can be explored in the context of the circular economy (CE) [51]. The CE aims to reduce environmental impact and resource use through an expanded 9R framework, minimizing the discard link [10,52]. Reusable packaging, seen as a product-service system, can bring packaging into the CE but requires redefining stakeholders and their relationships through systematic service design, as it involves changes in the supply chain and logistics [53].

3.3 Healthcare system research and pharmaceutical packaging regulations

Design thinking systematically understands user needs and implements innovative ideas [54]. In pharmaceutical packaging innovation and service design, understanding stakeholder needs and experiences requires combining healthcare system studies with legal and regulatory insights. In healthcare, patient experience is paramount, and understanding patient needs enhances nursing efficiency and quality [55]. All touchpoints between patients and medical systems are critical for researchers and designers to optimize outcomes. Innovations in pharmaceutical packaging and service processes can improve user experience, enhance medication adherence, and improve treatment efficiency and effects. The medical system must respect patients and maintain their dignity by involving them in the care process and giving them self-care initiative [56]. Given that healthcare and pharmaceuticals are highly regulated industries, sustainable innovation and service design processes for pharmaceutical packaging must be conducted within the existing legal framework and practices.

4 Case study analyses

4.1 Successful case selection criteria

To comprehensively study the existing sustainable innovations in pharmaceutical packaging, this essay selects existing relevant cases for analysis. The chosen cases are based on classifications of the Eco-SD barrier model: situational barrier, service barrier, and sustainable behaviour barrier, corresponding to pharmaceutical packaging innovation in material, medication adherence, and sustainable management and recycling services.

4.2 Case Study

Case one.

On October 11, 2021, in Tokyo, Astellas Pharma started using biomass-based plastics made from plant-derived materials in blister packs as the primary pharmaceutical packaging. Fifty per cent of the raw material for blister packs is made from biomass-based plastics, such as sugar cane.

Case two.

Beebetter, developed by Cambridge Design Partnership, is a disposable pouch that ensures the correct medication dose for children. It combines multiple medications in one pouch. To take the medicine, the user squeezes the pouch and sucks on the nozzle, breaking an internal seal. As a reward, a spoonful of honey is released after the correct dose is taken.

Case three.

On February 20, 2024, UK brand Boots launched a blister pack recycling service. Since blister packs made of recyclable plastic and foil. Boots aims to keep them out of landfills. Users can upload photos of 15 used packs via the app and drop them off at Boots pharmacies for a discount. By partnering with MYGroup, Boots ensures the waste is fully recycled by separating and repurposing or turning it into a material called MYBoard™ for making items like tables, chairs, and flower pots.

4.3 Analysis of case strengths and weaknesses:

All cases solve their problems from their perspectives and achieve innovation in various areas of concern. Case 1 provides an example of how the future of pharmaceutical packaging is pushed towards sustainable development and a circular economy through material and process innovation. This is the first in the world to use biomass plastics for pharmaceutical blister packaging. In case 2, the patient's user experience and adherence are fully considered. Positive feedback is given to patients when taking medication, and a new way of metered dispensing is brought to vulnerable groups. Medication errors caused by cognitive ability are avoided. Case 3 demonstrates the feasibility of sustainable development and circular economy in pharmaceutical packaging by combining with service design. Through multiple touchpoints of interaction with people, the user experience is fully considered, and a reward mechanism is given. However, if wanting to design Eco-sd by synthesising and analysing existing cases, it is necessary to look at the previously mentioned barriers to defining existing pharmaceutical packaging innovations and sustainable service design through eco-sd. These still leave much to be desired. (Figure 3) This is because the fators include technology and markets, patient habits and perceptions, and laws and regulations.

Medical packaging innovation and sustainability lack a comprehensive, systemic approach, with few cases addressing this issue. The initiative, The Circularity in Primary Pharmaceutical Packaging Accelerator (CiPPPA), was launched in the UK. It aims to

connect stakeholders across the pharmaceutical supply chain to develop and implement primary pharmaceutical packaging recycling strategies. It calls for broad participation, including pharmaceutical manufacturers and patients, in collaboration with the NHS Healthcare system. It seeks to promote primary pharmaceutical packaging waste minimisation through a service design approach with touchpoints, such as developing end-of-life management strategies to divert waste from landfills, expanding recycling and collection campaigns, promoting sustainable materials and simplifying design, and improving current legal and regulatory restrictions through advocacy and action. This rare approach emphasises collective action and addressing current challenges to pharmaceutical packaging and social ecology by designing integrated service system processes. It values the social value of pharmaceutical packaging and the needs of stakeholders, recognising that one party alone cannot achieve sustainability but rather from multiple perspectives and touchpoints. However, the case is still in its infancy, and no more of their actions can be seen. At least, the trend of a systemic and comprehensive perspective in addressing sustainable recycling and innovative development in pharmaceutical packaging has been noticed. Therefore, it is even more important for future researchers and designers to see and understand the relevance of sustainable innovation and circular economy in pharmaceutical packaging from this lack of diversified perspectives. This paper is based on this and has the following discussion.

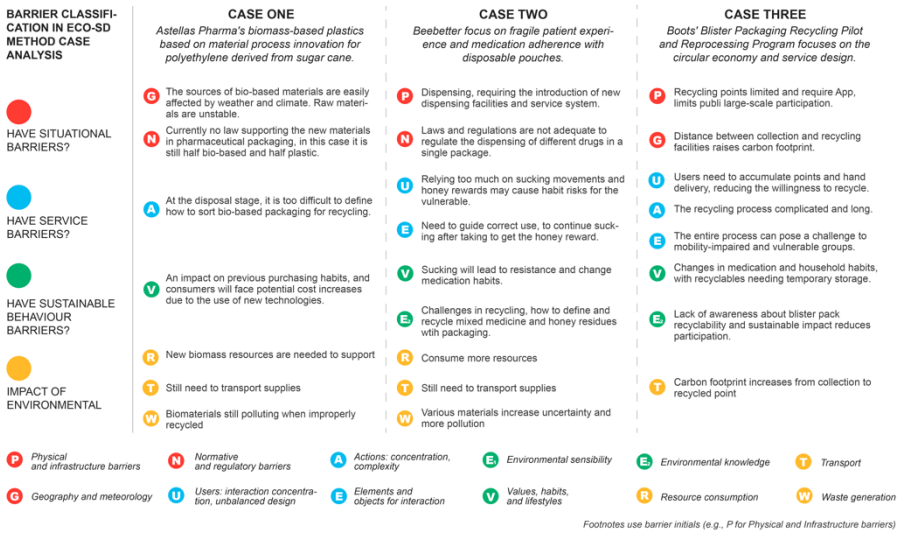

Fig. 3. Analysing the deficiency of the three cases through the eco-service design perspective

5 Discussion

From case studies, there is a lack of an approach that explores the potential of pharmaceutical packaging sustainability from an integrated system service design perspective

with stakeholder engagement and sustainable management as an entry point and combines this with the impact of patient self-care. This approach aims to achieve the sustainability of pharmaceutical packaging while enhancing user experience and adherence to meet patient needs. This study uses the ECO-SD barrier model to analyze stakeholders and touchpoints in the existing pharmaceutical packaging production chain and puts forward corresponding suggestions and solutions in combination with existing case studies. And put in the context of circular economy and system service design to explore the feasibility of realising.

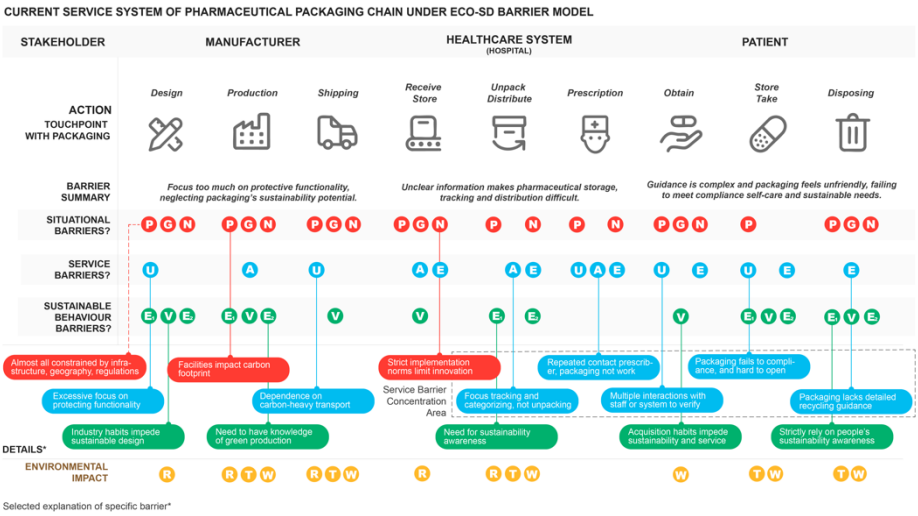

Fig. 4. Analysing the deficiency of the current package supply service chain through the eco-service design perspective

Situational barriers significantly impact the sustainability and patient experience of pharmaceutical packaging (Figure 4). These barriers, including facilities, geography, and regulatory influences, are hard to avoid in innovation. Currently, manufacturers face barriers due to an excessive focus on protection and neglect of sustainability [57]. This paper argues that material innovation and structural design can address these barriers. Before materials and regulations improve, reducing material and volume and focusing on end-of-life treatment can mitigate environmental impacts. Manufacturers can simplify packaging by using compact, biodegradable, or reusable materials or consolidating individual packages.

In the healthcare stage, the barriers focus on service, such as packaging that does not clearly show storage conditions, dates, effective tracking and the need for repeated communication with the prescriber to keep the patient informed and understood. Combining case 2 study, it is possible to reduce self-care difficulty by dispensing medication into the same container, which can be equipped with indication and tracking functions. By introducing RFID technology into current pharmaceutical packaging, it serves as tags that can be easily integrated into the packaging, supporting traceability throughout

the supply chain [58]. Patients can also be identified and bound by RFID, which can enable monitoring and tracking of medication, as well as combining RFID with other means of personalised and traceable medical advice, such as scanning the packaging to obtain e-medicine advice and instructions via smartphones, which can improve adherence and keep dignity.

At the patient stage, barriers centre on service and sustainable behaviour, including the complexity of obtaining, taking and disposing. Storage and recycling may be complex due to the lack of corresponding environmental knowledge and constrained habits. In conjunction with Case 3, the patient, as the vulnerable party involved in pharmaceutical packaging, and if sustainability and experience improvement are to be realised, systems and service design must be engaged. Considering the relationship between stakeholders in the pharmaceutical packaging and healthcare system and how the life cycle is passed, pharmaceutical packaging can unlock the potential for sustainability improvements by analysing the distribution chain that includes production, hospitals, and patients.

Therefore, in the context of service design. Transportation for inpatients, as the medication is provided directly by hospitals, the tertiary and secondary packaging in the distribution system can be combined and supplied in bulk packaging in the hospital's pill box. Then, it will be a better way for the hospital's service design innovation, such as a one-time display of all the details of the pharmaceutical packaging [59]. The pharmaceutical instructions in the boxes are on the same paper to enhance the patient's user experience and adherence. This could even be combined with a self-service printing station, allowing the instructions to disappear from the packaging to achieve more sustainable and practical packaging.

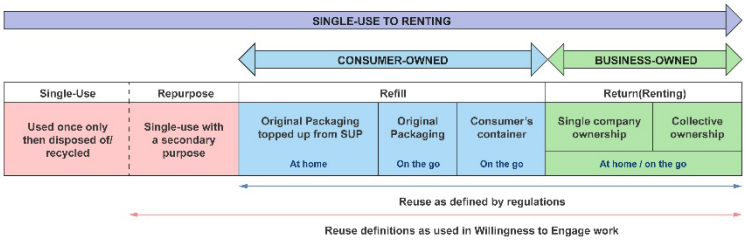

Fig. 5. Greenwood et al.'s (2021) Ordering of reuse from single-use to return. [27]

Put the above in a circular economy context. The attributes of environmentally friendly pharmaceutical packaging are reduced, recycled, reused, and repurposed [5]. And reusability, especially for secondary and distribution packaging, looks like a promising element of the circular economy. Discarding in a circular economy should be kept to a minimum. (Figure 5) As discussed, this paper proposes integrating reusable pill-boxes with RDIF into existing pharmaceutical packaging service systems as a solution for sustainability, packing innovation and circular economy. Combining the mentioned

suggestions can significantly influence pharmaceutical packaging stakeholders and sustainability processes to varying degrees. Drawing parallels from the food industry, hospitals and restaurants, healthcare providers can fill various medications directly into one reusable pillbox and sterilise, similar to how cutlery is managed. Patients interact with the reusable pillbox instead of traditional pharmaceutical packaging, enabling manufacturers to reduce produced packaging at all levels. Healthcare providers can develop more efficient recycling models, while patients have fewer recycling responsibilities. Reusable pillboxes can eliminate the need for printed instructions on the packaging, avoiding using non-recyclable inks. Medication instructions and dosages can be printed uniformly on one A4 paper via self-service printing with RFID, ensuring privacy and patient respect while promoting environmentally friendly practices. Meanwhile, as a tracking system, RDIF can prevent theft and be an identification mechanism for healthcare providers and patients to support self-care behaviours like self-printing, obtaining, and medication replenishment in the whole service system. By reinforcing patient engagement and letting them know they are part of treatment processes, thereby improving adherence. This uncommon perspective, as an example in pharmaceutical packaging innovation, can contribute to a sustainable future for the environment, the industry, and well-being.

6 Conclusion

This paper finds that sustainability in pharmaceutical packaging is a long-neglected issue, and current manufacturers are overly focused on protection and safety without sufficiently considering the real needs of patients, which particularly challenges ageing and vulnerable people. Traditional materials and designs struggle to meet these. Although there have been some attempts, such as introducing biodegradable materials and patient-friendly design, there is still a lack of system-integrated solutions from a service design perspective to consider stakeholders. By analysing existing cases that have achieved innovations in their respective fields and analysis within the eco-service design barrier model, this article proposes suggestions and possible improvements to the existing situation by combining service design from a circular economy perspective. This not only contributes to the construction of more environmentally friendly systems and pharmaceutical packaging but also offers the potential for sustainability in self-care and patient-orientated packaging innovations. For the reusable pillbox, there are some challenges, such as the need for high-cost infrastructure. However, this paper's value is through introducing service design and multiple stakeholder perspectives, especially patient benefits, into sustainable innovations in pharmaceutical packaging to provide different perspectives and interdisciplinary thinking for future researchers in sustainable pharmaceutical packaging.

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