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BEYOND THE 3R APPROACH: INSTITUTIONAL STRUCTURE AND OPERATIONAL DYNAMICS OF THE 9R CIRCULAR ECONOMY HIERARCHY

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Abstract. This article presents a comprehensive theoretical analysis of the structure and operational mechanisms of the circular economy. The study aims to identify the limitations of the conventional 3R approach (reduce, reuse, and recycle) and to substantiate an integrated operational model based on the extended 9R hierarchy. Employing content analysis, comparative analysis, and systems modeling, the study examines the five stages of the proposed mechanism, the hierarchy of 9R strategies, and three levels of feedback loops. The theoretical findings indicate that reducing the circular economy to recycling alone represents an incomplete methodological interpretation, as greater potential for economic value preservation exists at the higher levels of the hierarchy, particularly through reduced resource consumption and extended product lifespans. The proposed systems model comprises a five-stage core process, three levels of feedback loops, and an institutional framework. In addition, the article examines five principal types of circular business models and their underlying economic mechanisms. The central theoretical conclusion is that shorter circular loops generally enable a greater proportion of the value embedded in products to be retained.

Keywords: circular economy, 9R hierarchy, operational mechanism, closed-loop systems, eco-design, resource efficiency, value chain, life cycle assessment, circular business models.

Аннотация. В статье представлен комплексный теоретический анализ структуры и механизмов функционирования циркулярной экономики. Цель исследования заключается в выявлении ограничений традиционного подхода 3R (сокращение потребления ресурсов, повторное использование и переработка) и теоретическом обосновании интегрированной модели функционирования циркулярной экономики на основе расширенной иерархии стратегий 9R. С использованием контент-анализа, сравнительного анализа и системного моделирования рассматриваются пять этапов предложенного механизма, иерархия стратегий 9R и три уровня контуров обратной связи. Результаты теоретического исследования показывают, что сведение циркулярной экономики исключительно к переработке отходов представляет собой неполную методологическую интерпретацию, поскольку на более высоких уровнях иерархии, в частности при сокращении потребления ресурсов и продлении срока службы продукции, существуют более широкие возможности сохранения экономической ценности. Предложенная системная модель включает пятиэтапный основной процесс, три уровня контуров обратной связи и институциональную структуру. Кроме того, в статье рассматриваются пять основных типов циркулярных бизнес-моделей и лежащие в их основе экономические механизмы. Основной теоретический вывод заключается в том, что более короткие циклы циркулярного использования ресурсов, как правило, позволяют сохранить большую долю экономической ценности, воплощённой в продукции.

Ключевые слова: циркулярная экономика, иерархия 9R, механизм функционирования, замкнутые циклы, экодизайн, ресурсоэффективность, цепочка создания стоимости, оценка жизненного цикла, циркулярные бизнес-модели.

INTRODUCTION

In the contemporary global economy, the finite availability of natural resources and the continuous increase in waste generation have highlighted the need to reconsider conventional economic models. In recent decades, rising consumption levels and the intensive use of natural resources have increased pressure on ecosystems and resource availability. As resource demand continues to grow and waste accumulates,

the Earth's biological capacity faces increasing challenges in meeting human needs while maintaining environmental sustainability.

The linear economy, which has remained the dominant economic model for many decades, operates according to the principle of "take–make–use–dispose." Under this model, raw materials are extracted from the natural environment, transformed into products, and ultimately discarded as waste after use. Such a system often limits opportunities for resource recovery and value retention while placing considerable pressure on the environment (Murray, Skene, & Haynes, 2017). The annual generation of more than 2 billion tonnes of municipal solid waste worldwide and estimates of approximately 8 million metric tonnes of plastic entering the oceans illustrate the importance of transitioning towards more sustainable resource management practices.

The circular economy has emerged as an alternative economic approach aimed at addressing these challenges. Its central principle is to maintain resources, materials, and products within economic circulation for as long as possible, maximize their economic value, and facilitate their recovery, regeneration, or environmentally responsible reintegration into natural systems at the end of their useful lives. In this framework, materials traditionally classified as "waste" may become valuable inputs for subsequent production processes. Accordingly, the by-products of one activity can serve as raw materials for another, supporting more efficient resource utilization and reducing material losses (Ghisellini, Cialani, & Ulgiati, 2016). The circular economy therefore extends beyond recycling to encompass fundamental changes in product design, production, consumption, reuse, and resource recovery.

The fundamental distinction between linear and circular economic models is illustrated in Figure 1. In the linear model, resource flows are predominantly unidirectional, progressing from raw material extraction through production and consumption to final disposal. In contrast, the circular model incorporates interconnected material flows and feedback loops that enable products, components, and materials to be retained, recovered, and reintroduced into economic processes. These mechanisms support resource efficiency and contribute to the preservation of economic value throughout the product life cycle.

In the academic literature, the conventional 3R approach—reduce, reuse, and recycle—is widely employed to describe the fundamental principles of the circular economy. However, recent studies have emphasized the need for a more comprehensive classification that captures the diversity of circular strategies and their relationships. Kirchherr, Reike, and Hekkert (2017), who analyzed 114 definitions of the circular economy, identified considerable conceptual diversity and variations in the interpretation of its underlying principles. These findings highlight the importance of developing a systematic understanding of circular economy mechanisms and provide a theoretical basis for examining the extended 9R hierarchy (Figure 1).

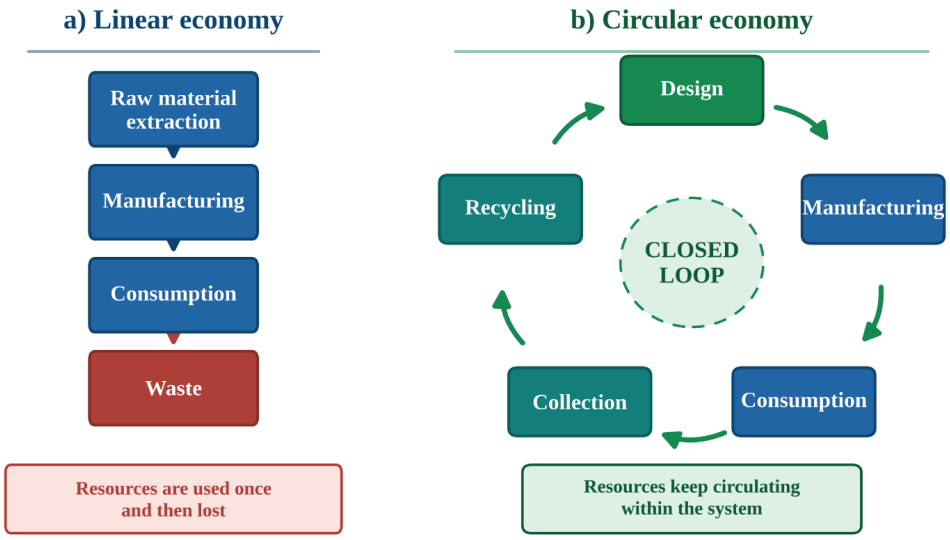


Figure 1. Comparative scheme of the linear and circular economy models[1]

Accordingly, the aim of this study is to identify the limitations of the conventional 3R approach and to provide a theoretical justification for an integrated operational model of the circular economy based on the extended 9R hierarchy.

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To achieve this aim, the study addresses four research questions:

1. What are the principal structural stages of the circular economy's operational mechanism?
2. How are the hierarchical relationships among the 9R strategies organized?
3. Why is recycling positioned among the lower-priority strategies rather than serving as the central mechanism of the circular economy?
4. How do circular business models facilitate the practical implementation of circular economy mechanisms?

The scientific contribution of the study lies in developing an integrated theoretical model that examines circular economy strategies not as isolated practices but as an interconnected hierarchical system. The proposed model combines the relationships among 9R strategies, resource circulation loops, and the structural stages of the circular economy's operational mechanism.

LITERATURE REVIEW

The conceptualization of the circular economy (CE) has evolved considerably over the past two decades, progressing from conventional waste management approaches toward comprehensive systemic frameworks encompassing sustainable product design, business model innovation, and value chain optimization.

The traditional linear economic model, characterized by the "take–make–use–dispose" pattern, has been widely examined in the literature in relation to resource inefficiency and environmental externalities (Murray et al., 2017). Early contributions to circular economy thinking emphasized the physical limitations of resource consumption and ecosystem capacity, thereby establishing a theoretical foundation for the development of closed-loop industrial systems (Ghisellini et al., 2016).

Ghisellini et al. (2016) provided a systematic review of the transition toward the circular economy, highlighting variations in implementation approaches across different regions and institutional contexts. Their analysis emphasized the importance of transforming linear resource flows into circular processes that support resource recovery, reuse, and the preservation of economic value.

Although the conventional 3R framework (reduce, reuse, and recycle) remains widely used, researchers have increasingly highlighted the need for a more detailed classification of circular economy strategies. Kirchherr et al. (2017) analyzed 114 definitions of the circular economy and identified substantial conceptual diversity in the interpretation of its principles and objectives.

Their findings indicate that many definitions place considerable emphasis on recycling and waste management, while upstream strategies, including refusing unnecessary products, reducing resource consumption, and redesigning products and production systems, receive comparatively less attention. Such an emphasis may limit the recognition of the circular economy's broader potential for resource efficiency, value retention, and systemic transformation.

To provide a more comprehensive classification, Potting et al. (2017) and Reike et al. (2018) examined extended frameworks of circular economy strategies. Potting et al. (2017) presented a hierarchy comprising ten strategies, ranging from R0 (Refuse) to R9 (Recover), and emphasized that strategies positioned higher in the hierarchy generally offer greater opportunities to reduce resource consumption and retain product and material value.

Reike et al. (2018) further examined value-retention strategies through the concept of resource circulation loops, distinguishing among shorter, intermediate, and longer loops. Their analysis suggests that shorter loops, particularly those involving direct reuse, repair, and refurbishment, generally provide greater opportunities to preserve the value embedded in products and components compared with strategies requiring more extensive material processing.

The practical implementation of the 9R hierarchy is closely associated with circular business model innovation. Bocken et al. (2016) identified three principal approaches to circular resource management: slowing, closing, and narrowing resource loops. These approaches provide a conceptual basis for developing business models that extend product lifespans, facilitate resource recovery, and improve material efficiency.

Product-as-a-Service (PaaS) arrangements and sharing platforms represent examples of business models that may align economic incentives with product durability, repairability, and more intensive asset utilization. By shifting the emphasis from product ownership toward access, performance, or service provision, such models can create opportunities for more efficient resource management.

Corvellec et al. (2022), in their critical examination of circular economy approaches, highlighted the importance of considering institutional arrangements, technological conditions, market structures, and broader socioeconomic relationships when assessing circular transitions. These considerations indicate that the successful implementation of higher-priority circular strategies depends not only on technological solutions but also on supportive institutional frameworks and appropriate business models.

Overall, the reviewed literature establishes a substantial theoretical foundation for understanding circular economy principles, resource circulation strategies, and circular business model innovation. Nevertheless, further conceptual integration is needed to explain how the hierarchical relationships among circular strategies interact with the stages of resource circulation, feedback loops, and institutional mechanisms.

The present study addresses this theoretical issue by developing an integrated operational model that combines a multi-stage resource flow, three levels of feedback loops, the extended 9R hierarchy, and supporting institutional arrangements.

RESEARCH METHODOLOGY

This study adopts a qualitative, theoretical-analytical research design based on the examination and synthesis of secondary sources. The methodological framework integrates content analysis, comparative analysis, and systems modeling. The research process is organized into three consecutive stages.

At the first stage, content analysis was employed as the principal research method. Key academic publications on the circular economy, including Kirchherr et al. (2017), Potting, Hekkert, Worrell, and Hanemaaijer (2017), Ghisellini et al. (2016), and Rizos, Tuokko, and Behrens (2017), were systematically examined. Methodological reports published by the Ellen MacArthur Foundation were also considered as supplementary sources.

The units of analysis comprised individual circular economy strategies (R0–R9) and the structural stages of the operational mechanism, from product design to resource recirculation. Particular attention was given to identifying the functions of each strategy, its position within the circular hierarchy, and its relationship with other stages of the resource circulation process.

At the second stage, comparative analysis was conducted to identify the conceptual and operational differences between linear and circular economic models and between the conventional 3R approach and the extended 9R hierarchy.

The comparison was based on five principal criteria: resource utilization, product design, waste management, economic value creation, and environmental impact. This approach made it possible to distinguish the structural characteristics of the respective models and assess the relative roles of different circular strategies in preserving resources and economic value.

At the third stage, systems modeling was applied to develop an integrated representation of the circular economy's operational mechanism. The proposed model consists of a core resource flow comprising five interconnected stages, three levels of feedback loops, and a supporting institutional framework.

Each component was examined in relation to its functions and interactions within the broader system. Particular attention was paid to the relationships between resource flows, circular strategies, institutional conditions, and the mechanisms supporting value retention throughout the product life cycle.

To strengthen the reliability and conceptual consistency of the analysis, the study drew on peer-reviewed publications in international academic journals, including the *Journal of Cleaner Production*, *Resources, Conservation and Recycling*, and the *Journal of Business Ethics*, as well as official reports published by recognized international organizations.

The analysis was guided by the principle of source triangulation, whereby key theoretical conclusions were assessed against at least two independent sources. This approach was intended to improve the consistency of the conceptual interpretation and reduce reliance on individual theoretical perspectives.

Statement on the Use of Artificial Intelligence

Artificial intelligence tools were used to a limited extent (approximately 10%) to support language refinement, grammatical correction, proofreading, and technical editing of the manuscript. AI-assisted tools were not used to generate research findings, conduct the scientific analysis, or formulate the study's conclusions. The author retains full responsibility for the originality, accuracy, scientific integrity, and final content of the research.

ANALYSIS AND RESULTS

The theoretical analysis identifies five interconnected stages within the proposed operational mechanism of the circular economy. Together, these stages encompass the principal phases of the product life cycle, from initial design and resource utilization to the recovery and recirculation of products, components, and materials.

The proposed five-stage structure provides a systematic basis for examining the relationships between circular economy strategies, resource flows, and value-retention mechanisms (Figure 2).

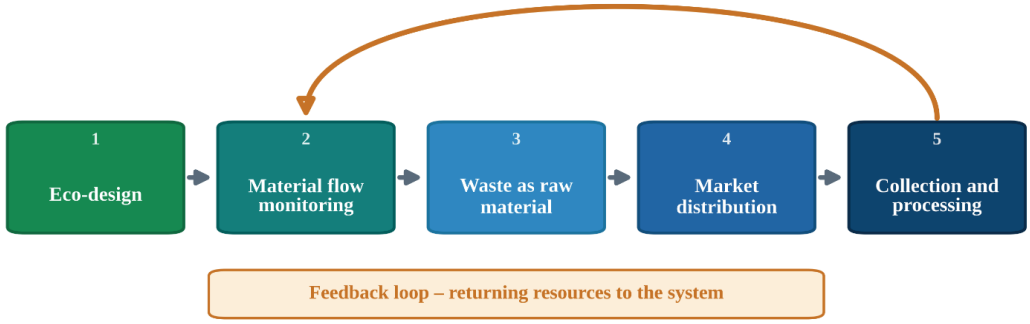


Figure 2. The operating mechanism of the circular economy: the five-stage core chain[2]

An important finding of the theoretical analysis is that the initial stage—eco-design—plays a fundamental role in determining the effectiveness of the entire circular economy mechanism. Within the circular economy framework, products are designed in accordance with closed-loop principles, emphasizing resource efficiency, material recovery, and the extension of product lifespans. Material selection prioritizes environmentally responsible, recyclable, or biodegradable materials, taking into account their suitability for the intended application and subsequent recovery processes.

Furthermore, products are designed with modular structures that facilitate the replacement, repair, and upgrading of individual components. Integrating modularity, repairability, and ease of disassembly into the initial design stage is particularly important, as the absence of these characteristics may reduce the technical feasibility and economic viability of returning products and components to circular processes at subsequent stages.

Consequently, eco-design establishes essential conditions for the effective implementation of circular strategies throughout the product life cycle. The characteristics of each stage and the corresponding implementation instruments are summarized in Table 1.

Table 1
Stages of the operating mechanism of the circular economy[3]

№	Stage	**Core content**	**Instruments of implementation**
1	Starting from design (eco-design)	The possibility of recycling, disassembling and repairing the product is taken into account from the very start of its creation	Modularity, biodegradable materials, ease of disassembly
2	Monitoring the material flow	The process from raw material to waste is assessed on the basis of LCA (life cycle assessment)	IoT sensors, RFID/NFC tags, ERP systems
3	Using waste as raw material	Recycled materials are used instead of primary raw materials	Mechanical, chemical and biological recycling
4	Efficient distribution on the market	Products are leased, resold or gathered through collection points	PaaS model, secondary markets, platform economy
5	Collection, processing, recirculation	Waste is collected through dedicated systems and returned to production	Reverse logistics, remanufacturing, upcycling

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At the third stage of the mechanism, three different technologies are used for employing waste as raw material. In mechanical recycling, plastics, metals and glass are crushed, melted and reshaped. In chemical recycling, plastic or chemical waste is broken down at the molecular level and new substances are obtained. In biological recycling, organic waste is converted into compost or biogas.

A comparative analysis of the two models clearly reveals their fundamental differences across five criteria (Table 2).

Table 2
Comparative analysis of the linear and circular economy models[4]

Indicator	Linear economy	Circular economy
Resource use	Take – make – use – dispose	Repeated circulation of resources
Product design	Single use	Suited to repair and reuse
Waste	End product	Secondary resource
Value creation	Only in production	Throughout the entire life cycle
Environmental impact	High	Low

An illustrative conceptual comparison of these differences is presented in Figure 3. The circular model has a considerable advantage over the linear model across all the key criteria – resource efficiency, waste reduction, value retention, environmental benefit and innovation (Figure 3).

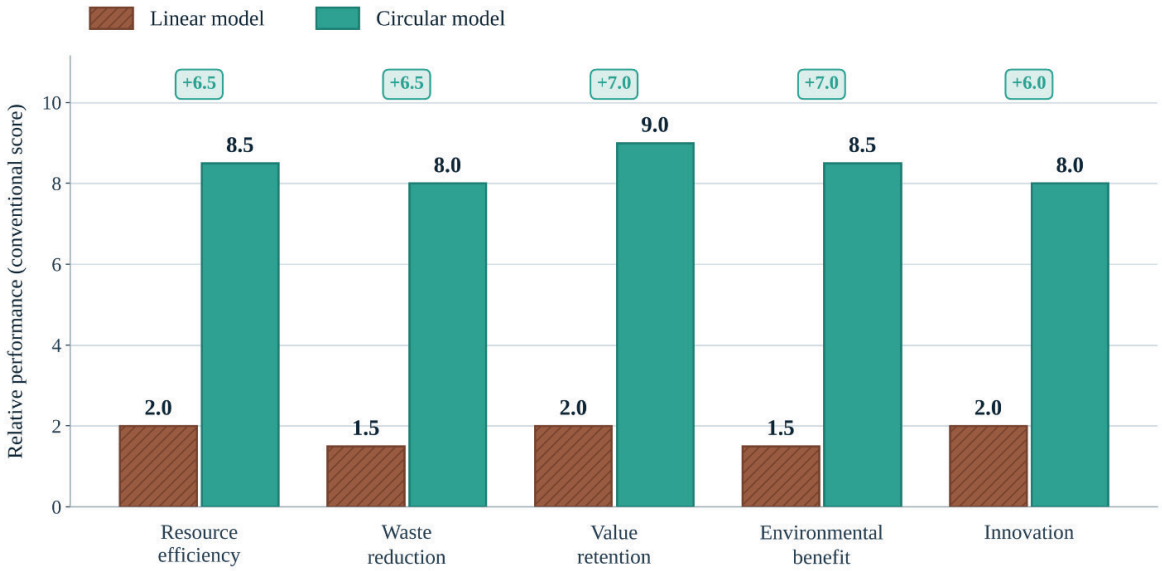


Figure 3. Comparative performance of the linear and circular models across the key criteria[5]

The conventional 3R principles of the circular economy are not isolated instruments but interconnected components of an integrated resource management system. Reducing resource consumption (Reduce) contributes to minimizing material inputs and waste generation, while reusing products and components (Reuse) extends their useful lives and reduces the demand for new resources. When products and components can no longer be effectively reused, recyclable materials may be recovered and reintroduced into production processes through recycling (Recycle). Together, these principles support the development of closed-loop resource circulation systems.

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In practice, the three principles complement and reinforce one another. For example, a company may design a product that requires fewer raw materials (Reduce), incorporate features that facilitate its continued use and repair (Reuse), and ensure that its constituent materials can be efficiently recovered and recycled at the end of its useful life (Recycle). However, although the conventional 3R framework provides a fundamental basis for circular resource management, it encompasses only three broad strategies and does not fully capture the hierarchical relationships among different circular practices or their relative priorities in preserving economic value.

The hierarchical structure of these strategies is illustrated as a pyramid in Figure 4, while their characteristics and corresponding implementation mechanisms are presented in detail in Table 3.

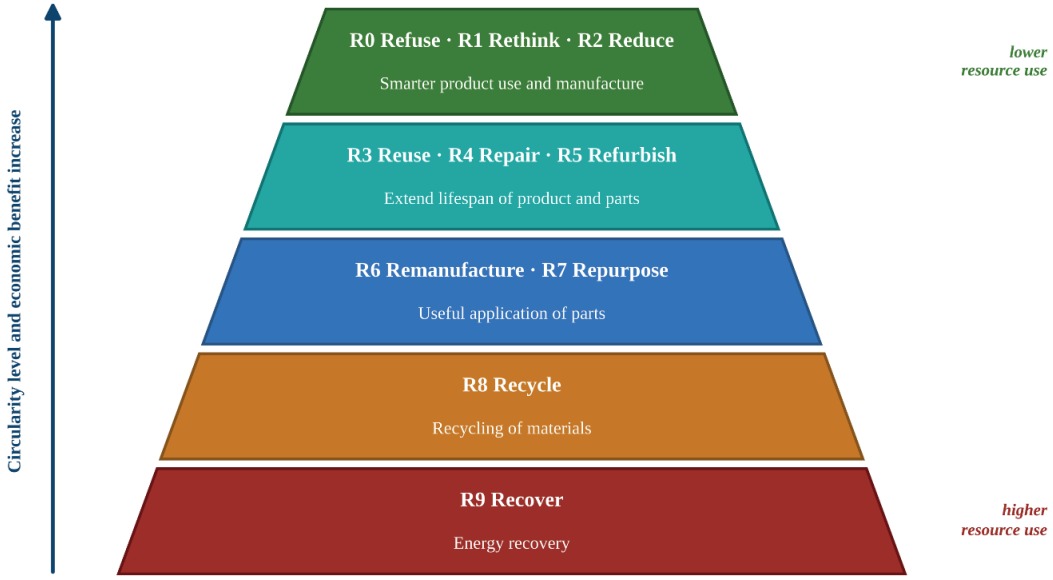


Figure 4. The 9R hierarchy of circular economy strategies[6]

The Hierarchy of 9R Strategies

To address the limitations of the conventional 3R framework, an extended hierarchy of circular economy strategies, commonly referred to as the 9R hierarchy, is considered. This framework organizes circular strategies according to their relative levels of circularity and potential for resource conservation and value retention. Strategies positioned higher in the hierarchy generally require less additional material processing and offer greater opportunities to preserve the economic value embedded in products and components (Potting et al., 2017) (Table 3).

Table 3

The 9R classification of circular economy strategies and their place in the mechanism[7]

Code	Strategy	Content	Stage
R0	Refuse	Abandoning the product entirely or replacing its function with a fundamentally different solution	1–2
R1	Rethink	More intensive use of the product: sharing, leasing, service model	3
R2	Reduce	Cutting material and energy consumption in production and consumption	2–3

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R3	Reuse	Use of a still-serviceable product by another consumer for its original purpose	3–4
R4	Repair	Restoring a faulty product and retaining it in its original function	3
R5	Refurbish	Modernising an old product and raising its quality level	4
R6	Remanufacture	Assembling a new product from used components	4–5
R7	Repurpose	Applying the product or its parts in an entirely new function	5
R8	Recycle	Converting materials into secondary raw material	5
R9	Recover	Incinerating waste for the purpose of energy recovery	5

The hierarchy is divided into three logical groups. The upper levels (R0-R2) are aimed at reducing resource consumption at the initial stage – this is the group of “smarter product use and manufacture”. The middle levels (R3-R7) are aimed at extending the lifespan of the product and its parts. The lower levels (R8-R9), in turn, are aimed at recovering the material or the energy and require the greatest amount of resources.

Systems modelling established that the fundamental distinctiveness of the mechanism is manifested in its feedback loops. The core chain outwardly resembles the chain of the linear economy, yet the essence of the model lies precisely in these feedback loops (Figure 5).

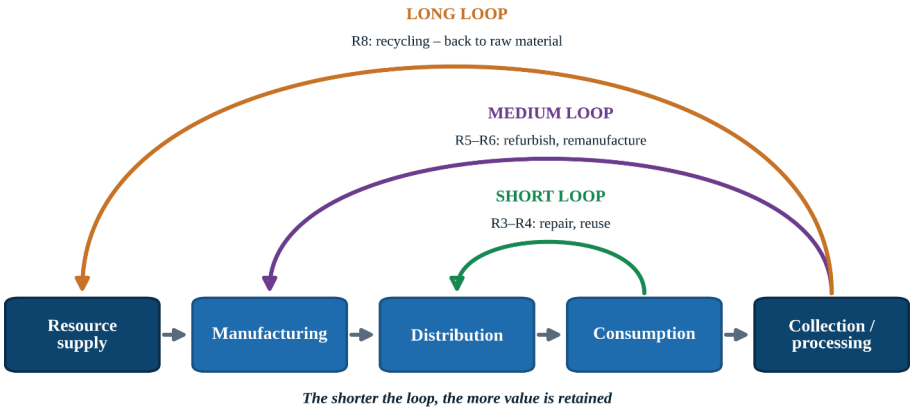


Figure 5. The three levels of feedback loops of the circular mechanism[8]

The short loop (R3–R4: reuse and repair) closes within the consumption stage and requires the fewest resources, because the product is preserved in its entirety. The medium loop (R5-R6: refurbishment and remanufacturing) disassembles the product into components and returns them to the production stage. The long loop (R8: recycling), in turn, reduces the material to its original raw state and directs it to the resource supply stage. In the long loop the original structure of the material and the value added to it are lost entirely. It is precisely from this that the central proposition of circular economy theory follows: the shorter the loop, the more of the value added to the product is retained.

The force that sets the operating mechanism in motion in practice is the circular business model. The analysis identified five principal types of model (Table 4).

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Table 4
The principal types of circular business model and their economic mechanism[9]

Type of business model	Operating mechanism	Economic effect and practical example
Circular supply chain	Use of renewable or secondary materials instead of primary raw materials	Protection against raw material price volatility; packaging and textiles
Resource recovery	Extraction of valuable components from waste streams, and industrial symbiosis	Disposal costs turned into revenue; metallurgy
Product life extension	Keeping the product on the market through repair, refurbishment and remanufacturing	Secondary market revenue; electronics and the automotive industry
Sharing platform	Distributing under-used assets among many users	Higher utilisation rate; car sharing, office rental
Product-as-a-Service (PaaS)	Ownership remains with the manufacturer; the consumer buys the outcome	The manufacturer has an interest in a durable product; lighting equipment

The Product-as-a-Service (PaaS) model is of particular importance. Under this model, products are provided through leasing, subscription-based arrangements, or other service-oriented mechanisms rather than being sold outright. This approach creates economic incentives for companies to extend product lifespans, as manufacturers' financial returns become increasingly associated with the long-term reliability, durability, and performance of their products.

The findings of the study provide an important theoretical clarification of the prevailing understanding of the circular economy's structure. In practice, the R8 (Recycle) and R9 (Recover) strategies are frequently emphasized as central components of circular economy implementation. However, these strategies generally involve more extensive material processing and energy inputs than higher-priority value-retention strategies, as they may result in the loss of product structure and a substantial proportion of the economic value embedded in products and components. By contrast, the R0–R2 strategies place greater emphasis on preventing unnecessary resource consumption, improving product design, and optimizing resource utilization. Their implementation may be supported by organizational and institutional improvements, although technological adaptations may also be necessary depending on the specific application.

This conclusion is consistent with previous research. Ghisellini et al. (2016) emphasized the interconnected nature of circular economy principles and the importance of integrating resource reduction, reuse, and recycling within a broader systemic framework. The present study extends this perspective to the 9R hierarchy by examining the relationships among circular strategies and resource circulation loops. The proposed theoretical interpretation suggests that shorter loops generally provide greater opportunities to preserve the economic value embedded in products and components. This perspective is also consistent with the importance of systemic approaches to circular economy implementation discussed by Rizos et al. (2017).

The analysis also provides a basis for clarifying several common interpretations of the circular economy. The first concerns the perception that the circular economy is primarily associated with recycling. Although recycling remains an important component, circular economy principles encompass a broader range of strategies, including resource consumption reduction, product life extension, reuse, repair, and refurbishment.

The second concerns the perception that adopting circular economy practices necessarily increases business costs. While implementation may require initial investment and organizational adjustments, circular business models can also generate cost savings, improve resource productivity, and create new business opportunities.

The third concerns the assumption that circular economy practices can completely eliminate the need for primary raw materials. Although circular strategies can substantially reduce demand for virgin resources, some primary material extraction may remain necessary because of material losses, technological limitations, and changes in economic demand.

The practical implications of the study are particularly relevant to policymakers and institutional decision-makers. Circular economy policies may achieve greater resource efficiency and value retention by prioritizing higher-level strategies within the 9R hierarchy, particularly eco-design, repair infrastructure, and sharing-

9 Author's development.

based business models. Expanding recycling capacity remains important; however, a comprehensive circular transition also requires measures that prevent waste generation and extend product and component lifespans. These findings may provide a conceptual foundation for developing national circular economy strategies and supporting institutional frameworks.

Several limitations of the study should be acknowledged. First, the research is theoretical and conceptual in nature, and the proposed model requires empirical validation through subsequent studies. Second, the practical applicability and relative effectiveness of individual 9R strategies depend on sector-specific characteristics, technological capabilities, institutional conditions, and national economic contexts. Consequently, the proposed hierarchy should be interpreted as a general analytical framework rather than a universally applicable prescription.

Promising directions for future research include quantitatively assessing the economic effects of individual strategies within the 9R hierarchy, comparing their performance across economic sectors, and evaluating the financial sustainability of circular business models.

CONCLUSION AND RECOMMENDATIONS

The study provides a theoretical justification for understanding the operational mechanism of the circular economy as an integrated system comprising a five-stage core process, three levels of feedback loops, and a supporting institutional framework. The principal conclusions are summarized as follows.

First, the conventional 3R framework provides a fundamental understanding of circular economy principles but does not fully capture the detailed structure and hierarchical relationships of circular strategies. The extended 9R hierarchy offers a more comprehensive analytical framework for identifying strategic priorities and supporting practical decision-making.

Second, interpreting the circular economy primarily through recycling represents an incomplete methodological perspective. Higher-priority strategies aimed at reducing resource consumption (R0–R2) and extending product lifespans (R3–R7) generally provide greater opportunities for resource conservation and the preservation of economic value. Recycling remains an essential component of circular resource management, particularly when higher-value retention strategies are no longer technically or economically feasible.

Third, eco-design plays a fundamental role in determining the effectiveness of the circular economy's operational mechanism. Decisions made during the initial design stage influence product durability, repairability, modularity, and disassembly potential, thereby affecting the feasibility and economic efficiency of subsequent circular processes. Design-related limitations may be difficult or costly to address at later stages of the product life cycle.

Fourth, the theoretical analysis of resource circulation loops supports the general principle that shorter loops tend to retain a greater proportion of the economic value embedded in products and components. Accordingly, strategies such as direct reuse, repair, and refurbishment may offer greater value-retention potential than recycling, depending on product characteristics and implementation conditions.

Fifth, circular business models, particularly Product-as-a-Service arrangements, serve as important economic mechanisms supporting the practical implementation of circular strategies. By linking manufacturers' financial incentives to product durability, reliability, and long-term performance, these models can encourage product life extension and more efficient resource utilization.

Overall, the proposed theoretical model contributes to a more systematic understanding of the structural, operational, and institutional dimensions of the circular economy. It may serve as a conceptual foundation for developing national circular economy policies, improving organizational resource management strategies, and conducting future empirical research on the economic and environmental performance of circular systems.

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