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R-HIERARCHY REVISITED:
A MODIFIED MODULAR FRAMEWORK FOR CIRCULAR ECONOMY TRANSFORMATION

INTRODUCTION

The circular economy is one of the key concepts of sustainable development, focused on preserving the value of resources, materials and products in the economic system for as long as possible while minimizing waste generation and negative environmental impacts.

The R-hierarchy model is one of the most useful tools for explaining how the circular economy works - evolving from the original 3R concept (Reduce, Reuse, Recycle) into more complex frameworks encompassing up to 10 strategies.

Despite this widespread acceptance, there is no universally agreed categorization of R-strategies, which makes it difficult to compare results across studies and to set unified policy goals.

AIM OF THE PAPER

To present and justify a modified, extended R-hierarchy model, based on the EU's objectives regarding deposit-refund systems (for the collection of glass, PET and aluminum beverage containers) in the context of EU member states, particularly Slovakia (see Figure 1).

RESULTS

The paper proposes a modified modular R-hierarchy model that extends the existing 9R framework with two interconnected principles**: Return and Refund**

Return and Refund operationalize behavioural and economic incentive mechanisms that are absent from classical R-hierarchy models.

Return and Refund are positioned between Reuse and Repair; Return refers to sending a used product or its packaging back into the distribution system, while Refund acts as a financial and motivational mechanism.

This relationship is most pronounced in deposit-refund systems, where the consumer pays a deposit when purchasing a product and receives it back upon return, creating a direct economic motivation.

The synergistic effect of Return and Refund is a precondition for the functioning of other R-strategies, since without effective collection of products, subsequent repair, remanufacturing or recycling is not possible.

The model further introduces **Reclassification as a cross-cutting meta-principle** that systematically assesses materials and products across their life cycle and determines the most appropriate way of further use.

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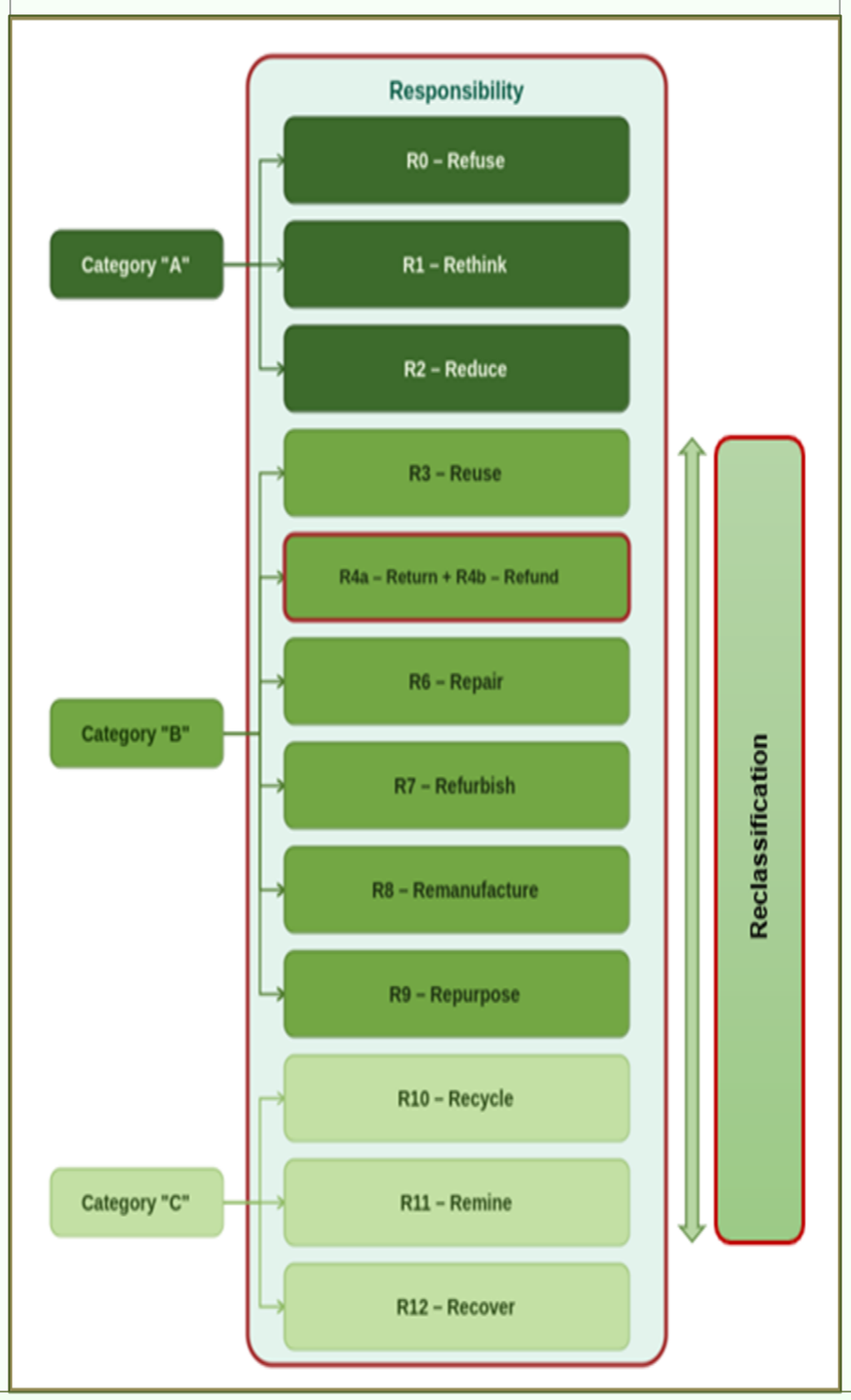
ABSTRACT

The concept of R-hierarchy represents one of the key conceptual tools for the implementation of circular economy principles, evolving from the original 3R model (Reduce, Reuse, Recycle) to more complex frameworks encompassing up to ten strategies. This paper examines the development of R-strategy hierarchies and proposes a modified model that extends the established 9R framework. The proposed extension introduces two interconnected principles: Return and Refund, operationalizing behavioural and economic incentive mechanisms that are absent from classical models. The practical significance of these principles is demonstrated by an analysis of deposit refund schemes (DRS) implemented in EU member states, which reveals differences in the extent of their implementation and in collection efficiency. Furthermore, the paper introduces Reclassification as a cross-cutting meta-principle enabling adaptive material flow management, and Responsibility as an overarching normative framework guiding decision-making across all hierarchy levels. The proposed modular R-hierarchy offers a dynamic and context-sensitive instrument applicable at both enterprise and national levels, contributing to the systematic transition from linear to circular economic models.

KEY WORDS

R-hierarchy, circular economy, sustainability, waste, deposit refund system



Reclassification operates on two interconnected levels: material reclassification (transforming the perception of "waste" into "resource") and waste reclassification (identifying valuable fractions within waste streams).

Responsibility is incorporated as an **overarching normative framework** guiding decision-making by all actors across every level of the R-hierarchy.

The resulting model consists of three qualitatively different layers:

- an operational layer (classic R-strategies extended by Return and Refund),
- a decision layer (Reclassification),
- and a normative/management layer (Responsibility).

The proposed modular model is a dynamic, context-sensitive instrument applicable at both enterprise and national levels, contributing to the systematic transition to a circular economic model.

CONCLUSIONS

The paper presents a **multi-layered modified R-hierarchy model** that extends the classical 9R framework with the principles of:

- **Return,**
- **Refund,**
- **Reclassification**
- and **Responsibility**.

Return and Refund add the behavioural and economic dimension missing from the classic model — active return of products/packaging combined with financial incentives.

Reclassification functions as a cross-cutting decision-making mechanism that determines the optimal R-strategy for a given material based on technical, environmental and economic criteria.

Responsibility serves as the overarching normative framework, ensuring consistent application of all other principles across the entire hierarchy.

The practical relevance of the model is demonstrated through deposit-refund systems in Slovakia (and EU countries).

Successful implementation requires a coordinated approach spanning legislation, technological innovation and consumer awareness.

By embedding behavioural, decision-making and normative dimensions into one modular framework, the R-hierarchy becomes a practical decision-support tool for advancing circularity at both enterprise and policy level.

The proposed extension fills a long-standing gap in R-hierarchy models - the absence of mechanisms driving consumer participation and context-sensitive decision-making offering a more actionable framework for accelerating the transition to a circular economy.

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