A proposal for the integration of the circular economy as an objective of product portfolio management

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Abstract. Despite the circular economy (CE) being one of the most promising approaches for the operationalization of sustainable development, little is known about its links with product portfolio management (PPM). Adding to the objectives already established within the literature on PPM, this article, through a theoretical proposal, aims to contribute to the contemporary debate by proposing 'circularity' as one of the performance objectives for PPM. This new objective considers the resource cycle strategies of CE and proposes, in the early phases of new product development, portfolio evaluations that consider product project aspects such as: updating potential, emotional durability, the application of sensors and internet of things, and the use of renewable materials and energy.
Keywords: new product development; circular economy; product portfolio; innovation portfolio management; sustainable design.

1 Introduction

Over the last few years, the topic of the circular economy (CE) has received increasing attention throughout the world among researchers, business professionals and public policies [1]. This heightened attention has occurred due to the fact that in addition to being seen as a business model that combines sustainable development with economic development [2], [3], it is also an alternative to the linear economy model, which is based on the extraction, manufacture, use and disposal of products.

The transition from the linear economy to the circular depends on the adaption of business models directed towards the principles of CE, which aim in the value generation dimension [4] [5]: decelerate, close and strengthen loops to maintain the economic value of products for the longest time possible, while at the same time having the objective of delivering greater value to clients [6]. To achieve this, circular models demand that new product development (NPD) processes are aligned to the principles of CE [7-8], which demand product projects guided by principles such as recycling, recovery, and extended use [9], [10]. However, it should be pointed out that processes and practices related to the development of circular products are recognizably different from traditional NPD projects [11].

Indeed, there are various recent studies that have investigated and proposed ways that help companies to develop products aligned to CE principles [12]-[14]. These development models have also been referred to as circular product design (CPD) [7], [10], [15]. Yet, despite that fact that the greater part of environmental performance is defined in the early stages of NPD [16], there are relatively few studies looking at how CE might be integrated with the choices made in the initial stages of product projects [7]. In addition, it is at these stages that a large part of the environmental and cost aspects of products are determined [17].

Furthermore, in the same way that the literature has already presented a need for environmental sustainability integration with NPD [18], [19]; some studies have already indicated a need to expand works related to environmental management and project selection decisions [19], [20], as well as with product portfolio management (PPM) [16], [21], [22]. PPM is a process by which the portfolio of new product projects is continually examined and updated [23]. Effective PPM brings with it the expectation that the resources available exploit the best product opportunities identified and maximizing the value of such products once they have been developed and launched [23], [24]. PPM literature has recognized the importance of analyzing product portfolio outcomes based on four objectives: strategic alignment, balance, value maximization and preparation for the future [23], [25]-[28]

However, despite the recent importance given to CE and CPD themes, to the best of our knowledge, there have been no studies or theoretical proposals regarding how to direct product portfolios towards new product strategies that embrace CE principles. Notably, for the development of products aligned to CE principles, it is important that, in the early stages of the NPD process, CE principles be considered in decisions about which product projects should be developed, prioritized or discontinued. Although there are already proposals to integrate CE principles into the PPM [16], [21], [29] the literature does not yet present how CE can be considered a performance dimension to evaluate the PPM process.

Furthermore, as product portfolio management is a dynamic process [23], [30], an increase in investigations about, and an understanding of, its relationship with the principal approaches of environmental sustainability is relevant; CE is considered to be one of these approaches [2], [3]. Therefore, this article seeks to reduce this research gap and contribute to the contemporary debate on NPD, CE and innovation management by proposing the addition of circularity as one of the performance objectives for product portfolio management.

2 Product Portfolio Management

In the context of the NPD process, and especially in its early and planning stages, the PPM is considered a key success factor [31] as it determines the products and technologies a company uses to compete. Cooper and Sommer [32 p. 29] define PPM as “making resource investment decisions (go/kill and project prioritization) to maximize the value of the portfolio, create the right mix of projects, and balance resource needs with available resources.” Indeed, there are various studies which have

sought to emphasize that portfolio management is a dynamic process [33;34] that aims to translate company business and innovation strategy into new product project development decisions [23], [25], [32]. Additionally, PPM involves decisions about selecting, discontinuing, adding and replacing portfolio products [23], as well as killing, prioritizing, depreciating and allocating resources across different product projects [23], [24].

However, the literature has also recognized a number of challenges to effective PPM, of which the following may be highlighted: the possibility of a large number of new project ideas [32]; uncertainties in the initial stages of product planning [26]; NPD fuzzy front end complexity [35]; the influence of political decisions [36] and irrational decisions [37] in the choice of resource allocation in NPD projects; a focus on individual projects, in a way that is misaligned with other projects or the strategic planning of a company [24]; and the limitations of financial and human resources in relation to possible projects and products [23], [30]

To overcome these common PPM challenges, Cooper et al. [23], [24] identified three basic performance objectives for PPM: strategic alignment, balance and value maximization. These objectives have been broadly accepted by numerous other studies on the theme [23], [28], [33], [38]. More recently, researchers have also presented a further performance objective for PPM: preparation for the future [26], [28], [39], [40] To fulfill these objectives, a number of studies have suggested the adoption of models and methods specific to management which assist businesses in the process of the selection and prioritization of product projects, such as: financial, optimization and modeling, checklists, scoring and ranking, and products maps [23], [26], [41]. Table 1 synthetically presents each of these objectives, as well as the models and methods frequently recommended to be systematically applied, considering the scope of each objective.

Table 1. The synthesis of performance objectives in PPM.

Objective	Definition	Models and Methods which can be applied	References
Value maximization	Aims to optimize the relationship between resources used and forecast returns within product projects.	Financial, such as: net present value, internal return rate, Strategic Buckets and *payback*.	[23], [24], [25], [33], [38], [42].
Balance	Seeks balance in product development projects, especially between radical and incremental projects with short- and long-term deadlines, and with different levels of risk.	Diagrams (bubble and BCG, for example). Product and technology maps. Strategic Buckets	[23], [24], [25], [33], [38], [42].
Strategic alignment	Aims to align product portfolios with the strategic and business priorities of a company.	Product and technology maps. Scoring models and checklists. Diagrams. Strategic buckets. Market research and customer involvement in NPD.	[23], [24], [25], [33], [38], [42].
Preparation for the future	Evaluates if product projects prepare a company in terms of improving organization and infrastructure for greater long-term competitiveness, principally relating to the expansion of markets and the acquisition of new technological knowledge and competencies.	Product and Technology Maps. Scoring models and checklists.	[26], [27], [28], [39].

The systematization of PPM through the adoption of the models and methods presented in Table 1, are also aspects frequently recommended to improve the performance of product portfolio [23], [26], [34] and consequently of the NPD process [43]. Management skills, such as the agility with which product portfolios respond to technology and market changes [30], [33]; the adoption of modeling and optimization methods [39], [40]; and the use of cross functional teams [37], have also been suggested as management mechanisms for improving product portfolio performance.

3. Development of products for the circular economy

Kirchherr et al. [44] define CE as a business model that substitutes the "end of life" concept by reducing, reutilizing, recycling and recuperating products and materials in the processes of production, distribution and consumption. In addition to proposing production by means of closed-circuit material flows, involving practices for the reuse and recycling of products and components instead of the use of 'virgin' raw materials [45], CE is also guided by more sustainable consumption standards, which also demand consumer behavioral changes.

As a means of achieving CE principles, there are a number of studies that have suggested the adoption of circular business models, which predict the activities of slowing, closing and narrowing loops of materials and energy [9]. Therefore, the preservation of the economic and environmental values of products and materials for the longest time possible is inherent in these models [10]. For the adoption of circular business models, therefore, the adoption of the NPD process is fundamental, avoiding the extraction of raw materials from nature. This is intentionally regenerative, since it is the design that brings greater value to clients [6], [13].

Despite the relevance of NPD for the adoption of circular business models, Subramanian et al. [11] emphasize that, contrary to traditional NPD that tends to focus on product functionality, development cost and financial return; green NPD also considers the life cycle of products and a reduction in the prejudicial effect of the product on the environment. In this sense, CPD presents additional concerns, notably with respect to ecodesign [19], since in addition to incorporating design elements for the reuse, recycling, remanufacture and maintenance [8], it also uses design elements such as updating, multiple use cycles, emotional durability and biomimicry [10], [13]. In addition, the design strategy based on the sharing economy and the product service system (PSS) is also aligned with NPD for CE [46].

Specifically addressing product development for CE, den Hollander et al. [10] propose that CPD should combine design approaches for (i) product integrity, which aims to increase the use of the product and reverse obsolescence through extended use and recovery strategies; and (ii) design for recycling. Bocken et al. [9] highlight the importance of integrating CE concerns into the early stages of the NPD process, and for this purpose recommend three resource cycle strategies: (i) slowing resource loops: predict long-life product projects and the extension of the life-cycle of products and components; (ii) closing resource loops: aim to close the cycles between post-use and production, reusing the materials; (iii) narrowing resource flow: aim for efficiency in the use of resources, using less resources per product, whether that be the extraction raw materials, production or distribution. Some studies have also proposed the inform dimension, which seeks to use information technologies directed towards CE [7], [13], [47].

Table 2 presents these circular strategies, along with sample NPD design and practice approaches that add viability to each of these strategies.

Table 2. Synthesis of resource cycle strategies.

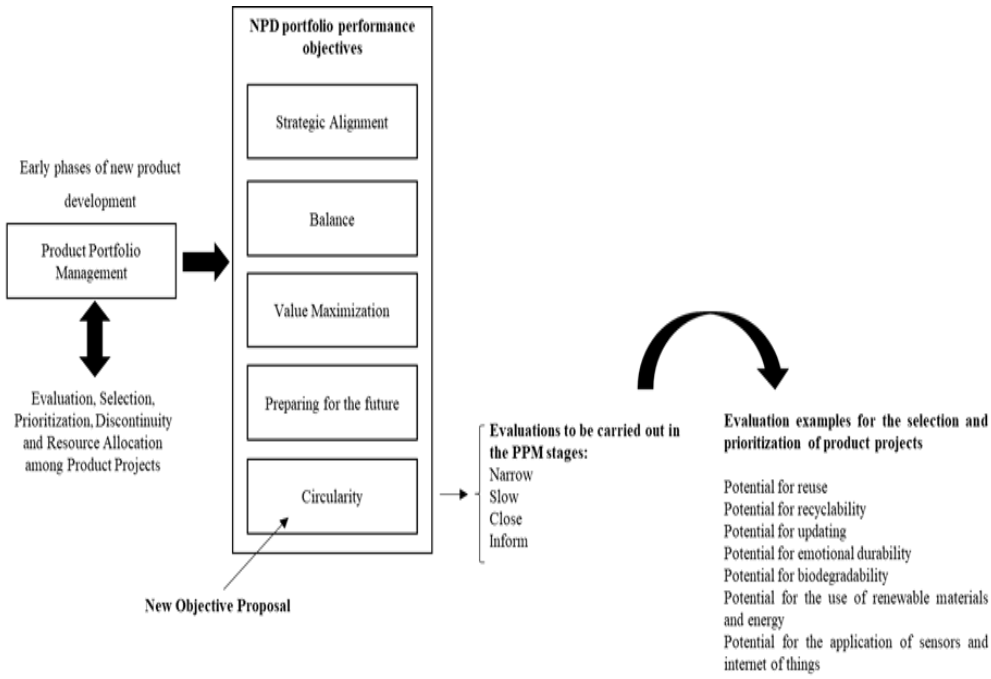
Circular Strategy	Examples of NPD design and practice approaches	References
Narrow	Design with low-impact inputs Design light-weight products Design for multiple function Maximize capacity use of product design for reduction of production steps	[13], [47]
Slow	Design for attachment and trust Design for reliability and durability Design for emotional durability Design for remanufacturing Design for refurbishing Design for repurpose Design for ease of maintenance and repair Design for upgradability and adaptability Design for standardization and compatibility Design for dis- and reassembly Design for product-service systems	[7], [9], [12], [13], [15]
Close	Design for recycling Design for dis- and reassembly Design for biological and technical cycles Design for biodegradability Design with renewable materials Design with non-toxic materials Design for biomimicry	[7], [9],[12], [13], [15]
Inform	Use artificial intelligence Design for virtualization Development of smart products (connectable products that are able to store data) Development of products that can be traced during use Development of products that can be sold through online platforms	[47]

4.Proposal for integrating the ‘circularity’ objective in product portfolio management

In light of these circular principles and strategies for CPD, and considering the planning steps of new products, this study proposes the insertion of the objective here referred to as ‘circularity’ and its evaluation by means of the four CE resource cycle strategies,

presented in section 3: narrow, slow, close, and inform; together with another four objectives traditionally recommended for PPM: value maximization, strategic alignment, balance and preparation for the future (Figure 1).

Fig. 1. Proposal for Integrating the Circularity Objective in Product Portfolio Management.



According to the proposal presented in Figure 1, these four CE resource cycle strategies can be variously deployed with the objective of guiding the work of managers and designers involved with PPM, and those who have the intention to also consider CE principles in their product portfolio decisions. In this way, as well as guiding portfolio management to maximize value, balance and alignment with a business strategy and the preparation for the future, the insertion of this new objective also adds guidance regarding how well the portfolio meets CE principles.

The adoption of this framework can, therefore, be useful in guiding businesses towards circular product portfolios, thereby driving the development of green products. There is a tendency for this action to improve innovative performance and, especially when the adoption of Green Technologies in NPD is considered, to offer better results in

terms of environmental sustainability. In addition, the proposal presented here is aligned to the results of Villamil and Hallstedt [29], which called attention to the importance of product portfolio that, as well as having environmental sustainability objectives, also meets those of balance, market attractiveness, profitability and long-term vision.

In accordance with other PPM proposals, the adoption of multifunctional teams is recommended throughout the product portfolio evaluation and selection process [33] and, in the case of the current proposal, the participation of team members from the environmental area [22] and those with the desired training and skills in CE. Table 3 shows a sample checklist application, one of the tools usually recommended for product portfolio management - although here focused on the evaluation of CE principles for the selection and prioritization of product projects.

Table 3. Sample checklist for the circular product portfolio - based on [48].

Circular Strategy	**Does the product design consider the potential for...?**	**Yes or No? not applicable**	**Comments**
Slow	Attachment and trust		
	Emotional durability		
	Remanufacture		
	Upgradability and adaptability		
	Easy Maintenance and Repair		
	Easy disassembly and reassembly		
	Product service system application		
Close	Reuse		
	Recycle		
	Dis- and reassembly		
	Use of renewable materials and energy		
	Use of non-toxic materials		
Narrow	Lower product weight		
	Multiple functions		
	Reduction of product production steps		
	The maximization of product capacity		

Inform	Development of smart products		
	Storage of data and use of artificial intelligence		
	Integration of sensors and the internet of things		
	Product traceability in all stages of the life cycle		
	Use of applications or online platforms for product sharing		

5. Conclusions

In proposing the integration of CE into the PPM, this work responded to the call for an increase in studies and proposals that integrate CE principles in the early phases of NPD. Although other studies demonstrate the importance of integrating PPM with environmental sustainability [29] and also with ecodesign [22] the results of this article contribute to the theme from a new perspective, proposing the integration of CE and PPM, and specifically adding a performance objective to portfolio management related to CE. In this way, it is understood that this work contributes to knowledge in the areas of innovation management, NPD, environmental sustainability, CE and project management.

The integration of concerns about CE, from the product portfolio stage, may prove useful in paving the way towards a green products development strategy, aligned to trends for greater environmental responsibility within companies. As well as proposing a new form of portfolio evaluation, this work reinforces the fundamentals of PPM: to integrate the other objectives that view the alignment of portfolio with business strategy, project value maximization, balance, and how the product portfolio prepares a business to be more competitive in the future. That is, the framework presented here simultaneously satisfies the elements of environment and governance.

Furthermore, it is important that the evaluation of circularity as an objective for product portfolio, as well as the criteria used, takes into account the specific needs and characteristics of each industry or business sector. For example, companies from the food or agribusiness sectors may have significantly different product portfolio objectives in relation to CE than those sectors acting in the automotive or electronics fields. Thus, contingency and dynamic capacity elements should be continually observed in the framework adoption efforts as proposed in this article.

Finally, it should be noted that the results of this work are based on theoretical reflections regarding the need to expand the debate on PPM, through the lens of environmental sustainability and, particularly, considering CE. However, the applicability of this proposal was not tested by means of evaluations carried out within businesses. The results presented here, then, initiate the discussion on circular strategies and criteria applied to PPM rather than conclude it. It is important, therefore, that future

studies take these discussions and results further, by investigating ways in which businesses can integrate PPM with CE. For example, the proposal presented in this article could be presented and improved upon by practitioners and experts on this topic. In addition, future studies that propose and evaluate new models, methods and tools for product portfolio management are also desirable.

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