GRAZIELA DARLA ARAUJO GALVÃO

Circular Business Model: An investigation of Value Stream, Barriers, and Competitive Criteria focusing on Technical Cycles

São Paulo

2021

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Revised version

Thesis presented at the Polytechnic School of University of São Paulo (USP) in candidacy for doctorate degree of Doctor of Science.

Research Area: Production Engineering

Supervisor: Full Professor Marly Monteiro de Carvalho

São Paulo

2021

GRAZIELA DARLA ARAUJO GALVÃO

Modelo circular de negócios: uma investigação de fluxo de valor, barreiras e critérios competitivos com foco em ciclos técnicos

Versão Corrigida

Tese apresentada à Escola Politécnica da Universidade de São Paulo (USP) para obtenção do título de Doutora em Ciências.

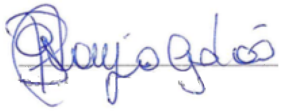
Área de Concentração: Engenharia de Produção.

Orientadora: Profª. Titular Marly Monteiro de Carvalho

São Paulo

2021

Este exemplar foi revisado e corrigido em relação à versão original, sob responsabilidade única do autor e com a anuência de seu orientador.
São Paulo, 11 de setembro de 2021
Assinatura do autor:



Ficha Catalográfica

Catalogação-na-publicação

Galvão, Graziela
Modelo circular de negócios: uma investigação de fluxo de valor, barreiras e critérios competitivos com foco em ciclos técnicos / G. Galvão -- versão corr. - São Paulo, 2021.
210 p.

Tese (Doutorado) - Escola Politécnica da Universidade de São Paulo. Departamento de Engenharia de Produção.

1.Economia Circular 2.Sustentabilidade 3.Fluxo de valor I.Universidade de São Paulo. Escola Politécnica. Departamento de Engenharia de Produção II.t.

ACKNOWLEDGEMENT

To Marly Monteiro de Carvalho for all advice, teaching, and patience during the last few years.

To professor Breno Nunes and Janaina Mascarenhas for valuable contributions.

To Steve Evans for welcoming me and advising me while I was doing my Sandwich PhD at Cambridge University. Thank you for understanding how difficult it is to be away from the family, in this way not only guided but also talked and made me feel part of your team.

To my husband, Paulo Ferrer, for our conversations about the circular economy and for his contributions.

To my mother and my godmother for always demonstrating the value of education and for their unconditional support.

To my children for their encouragement and for understanding my absence.

To colleagues and friends of post-graduation, in particular: Diego Clemente, Aline Homrich, Lorena Gamboa and Thayla Zomer (who helped me a lot during my time in Cambridge).

To the institutions: USP, CNPQ, Capes and FAPESP for the financial support so that this research could be carried out.

Thank you all so much

ABSTRACT

Galvão, G. D. A. (2021). *Circular business model: an investigation of value flow, barriers and competitive criteria with a focus on technical cycles* (Doctoral Thesis). Production engineering-Poli, University of São Paulo, São Paulo.

Circular economy implies the implementation of clean production and the use of renewable materials through technical cycles. For this, there must be clear and stable policies and tools. This research points out that, despite the growing prominence of Circular Business Models in research and practice, there is still considerable conceptual ambiguity about the drivers and barriers of the concept, the sustainability issues it addresses and the value streams it employs. The thesis is by article and was developed in three parts; Part 1 is an integrative thesis overview, and part 2 is presented the thesis' papers. The general objective of this thesis is to develop a research model that identifies the role of competitive criteria in technical cycles in the captured value and in the shared value in companies with operation strategies to overcome main barriers or CE obstacles. The thesis applies qualitative and quantitative approaches as this is multi and mixed-methods research. The results suggest that the implementation of technical cycles enhances the competitive criteria of organizations. This thesis contributes to the theory because academic literature on circular economy has expanded, and the discussion on competitive criteria has started, relating them to technical cycles. For practice, presents an algorithm for analysis and strategic conversion of barriers into obstacles, as well these interrelate with each other in the context of Circular Business Model.

Keywords: Circular economy. Sustainability. Circular Business Model. Value stream. Competitive Criteria. CE barriers

RESUMO

Galvão, G. D. A. (2021). *Modelo circular de negócios: uma investigação de fluxo de valor, barreiras e critérios competitivos com foco em ciclos técnicos* (Tese de Doutorado). Engenharia de produção-Poli, Universidade de São Paulo, São Paulo.

A economia circular implica na implantação de produção limpa e do uso de materiais renováveis por meio de ciclos técnicos. Portanto, deve haver políticas e ferramentas claras e estáveis. Esta pesquisa aponta que, apesar do crescente destaque dos Modelos Circulares de Negócios, tanto nas pesquisas quanto na prática, ainda existe uma considerável ambiguidade conceitual sobre: os direcionadores, as barreiras, as questões de sustentabilidade que eles abordam e os fluxos de valor que eles empregam. A tese é por artigo e foi desenvolvida em três partes, parte 1 é uma visão geral integrativa da tese e parte 2 apresenta os artigos da tese. O objetivo geral é desenvolver um modelo de pesquisa que identifique o papel dos critérios competitivos nos ciclos técnicos, no valor capturado, e no valor compartilhado em empresas com estratégias para superar as principais barreiras ou obstáculos da economia circular. Abordagens qualitativas e quantitativas, ou seja, pesquisa de métodos múltiplos e mista. Os resultados sugerem que a implementação de ciclos técnicos valoriza os critérios competitivos nas organizações. Esta tese contribui para a teoria expandindo a literatura acadêmica sobre economia circular e iniciando a discussão sobre critérios competitivos, relacionando-os aos ciclos técnicos. Para a prática, apresenta um algoritmo que ajuda a converter barreiras de economia circular em obstáculos, bem como analisar a inter-relação no contexto do Modelo Circular de Negócios.

Palavras-chave: Economia circular. Sustentabilidade. Modelo Circular de Negócio. Fluxo de valor. Critérios Competitivos. Barreiras de CE.

LIST OF PAPERS IN THIS PhD THESIS

Paper 1

Galvão, G. D. A., Homrich, A. S., Geissdoerfer, M., Evans, S., Ferrer, P. S. S., and Carvalho, M. M. (2020). Towards a value stream perspective of circular business models. Resources, Conservation and Recycling, 162, 105060.

Paper 2

Galvão, G. D. A., Evans, S. and Carvalho, M. M. (2021). Circular Business Model: Breaking Down Barriers in Transposable Obstacles. Under Review on Business Operation strategy and the Environment.

Paper 3

Galvão, G. D. A., Ferrer, P. S., S., Evans, S. and Carvalho, M. M. (2021). Unpacking the Value Conversion in Circular Business Model: exploring the moderating effect of competitive criteria. Under Review on International Journal of Production Economics.

LIST OF SUPPLEMENTARY PAPERS

Paper 4

Galvão, G. D. A., Nadae, J., Clemente, D. H., Chinen, G., & de Carvalho, M. M. (2018). Circular economy: overview of barriers. Procedia CIRP, 73, 79-85.

Paper 5

Galvão, G. D. A., Clemente, D. H. & de Carvalho, M. M. (2019). The Role of Policies and Regulations to foster the Circular Economy: lessons from the literature. Manuscript submitted for publication.

TABLES

ABBREVIATION

CBM	-	Circular Business Model
CC	-	Competitive Criteria
LBM		Linear Business Model
CE	-	Circular Economy
TCs	-	technical cycles
SBM	-	Sustainable business model
TBL	-	Triple bottom line
GO	-	General Objective
SO		Specific Objective
RQ	-	Research Question
PSS	-	Product Service System
SPSS	-	Statistical Package for the Social Sciences

SUMMARY

PART 1 - INTEGRATIVE THESIS OVERVIEW

1 INTRODUCTION

Circular Economy (CE) is a subject (vast, multidisciplinary and relatively new) still seeking theoretical and practical consolidation, which is reflected in literature with diversity of concepts and focal points (Blomsma & Brennan, 2017; Evans et al., 2017; Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Murray, Skene, & Haynes, 2015; Scheepens, Vogtlander, & Brezet, 2016; Witjes & Lozano, 2016). Despite the apparent immaturity, CE has gained particular attention because it is expected to be the most viable path to a robust sustainability scenario (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Homrich, Galvão, Abadia, & Carvalho, 2018) or, more specifically, consistent logic for achieving sustainable growth (Ranta, Aarikka-Stenroos, Saku, Mäkinen, & Saku, 2018).

The circular operation strategy can be reached through technical or biological cycles. Biological cycles refer to the consumption of bio-based materials, and they are designed to return to the system through processes such as composting and anaerobic digestion. In these cases, there are opportunities to extract more value from products and materials by taking advantage of them in a cascade (Macarthur, 2013). Biological cycles will not be researched in this work, but rather, it is emphasized in the technical cycle (TC).

Technical cycles are related to reverse logistics where there are the restoration and circularities of materials (Prieto-Sandoval, Jaca, & Ormazabal, 2018). More specifically, the technical cycle consists of controlling stocks with finite quantities of materials, advocating those products must be either shared, reused, remanufactured or recycled, restoring materials and closing the cycle. This cycle refers to inorganic or synthetic materials, which remain in continuous use without losing their properties or value (McDonough & Braungart, 2002).

Vezzoli and Manzini (2008) present two organizations strategies to implement a technical cycle. The first is 'cycle deceleration strategies' include decreasing material flows at each stage of the life cycle, cleaner materials, renewable materials, low-energy materials, and recyclable materials. The second is cycle closure strategies, including

recyclable materials, biodegradable materials, low energy materials, photodegradable materials, renewable materials, and cleaner materials. These resources would go through a “hierarchical process” to maximise the capture of value through TC (Reuter, van Schaik, & Gediga, 2015). However, companies need more studies to understand how value can be captured (Lacy et al., 2014). When companies are adopting some technical cycle in business models to operationalise CE, it can promote advances in the levels of maturity of the business models (Sehnem, Campos, Julkovski, & Cazella, 2019). CBM is composed of a group of circular practice aiming to create and capture value.

One of the reasons why CE is receiving more recognition is due to its focus on increasing the resources circularity (Genovese, Acquaye, Figueroa, & Koh, 2017) through TC, suggesting different ways to capture business value (Mizanur Rahman, Kim, Lerondel, Bouzidi, & Clerget, 2019). Therefore, the first question emerges whether the implementation of TC can even generate value for organizations, and whether this value is compatible.

RQ1: How does CBM influence the technical cycles to result in captured value and shared value?

Significant attention to the subject does not necessarily result in proportionate acceptance, as many aspects still require further development or refinement, including more quantitative research (Kirchherr & van Santen, 2019). Korhonen, Hpnkasalo and Seppala (2018), for example, criticizes how scientific development about the CE occurs, suggesting that it comes to the forefront of particular initiatives and interests of organizational segments: "(...) practitioners, i.e., policy-makers, businesses, business consultants, business associations, business foundations " which, according to the author, would lead to an academic demonstration that results in an artificial and confusing theoretical framework, a point of view that summarizes a large part of the criticisms made to the CE.

In fact, the construction of literature has come in many different directions, but not necessarily converging to a single concept or purpose. As an example, some authors sought theoretical support comparing CE to sustainability (Geissdoerfer, Savaget, Bocken, & Hultink, 2017, Macarthur, 2013; Zhang et al., 2009) or directly

addressing triple bottom line (TBL) issues (Lieder & Rashid, 2016; Witjes & Lozano, 2016). Others, however, construct their arguments about different strategic perspectives, such as product service system (PSS) (Annarelli, Battistella, & Nonino, 2016; Evans et al., 2017; Macarthur, 2013; Pialot, Millet, & Bisiaux, 2017; Scheepens, Vogtlander, & Brezet, 2016), sustainability (Homrich., Galvão, Abadia. & Carvalho, 2018), industrial ecology (Lewandowski, 2016), eco-design (MacArthur Foundation, 2015), cleaner production (Geng, Xinbei, Qinghua, & Hengxin, 2010), eco-innovation (Castellani, Sala, & Mirabella, 2015), closed economy (Geng & Doberstein, 2008), ecological loops (Haas, Krausmann, Wiedenhofer, & Heinz, 2015), green economy (Rizzi, Bartolozzi, Borghini, & Frey, 2013) and “cradle to cradle” paradigms (Bocken, Short, Rana, & Evans, 2014; Buxel, Esenduran, & Griffin, 2015; Glavič & Lukman, 2007; Preston, 2012). These strategies may be similar for some authors (cited above) or may co-operate with CE. Reigado, Fernandes, Saavedra, Ometto, & Costa (2017), for example, wrote that the adoption of PSS methodologies is a positive manner to support CE.

If this apparent dispersion brings discomfort, it also seems implicit to offer the potential motivator for the search for a conceptual normalization about the theme. This can be observed, for example, in Homrich., Galvão, Abadia, and Carvalho (2018), who conducted a semantic analysis and suggested a comprehensive concept from the meeting of the different views and interpretations outlined the literature: “CE is a operation strategy that emerges to oppose the traditional open-ended system, aiming to face the challenge of resource scarcity and waste disposal in a win-win approach with economic and value perspective”, or Geissdoerfer, Savaget, Bocken, and Hultink, (2017, p. 10), defining CE “as a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. It can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling”. Both views bring implicit insights about the value generated through the CE.

Additionally, when circular business model (CBM) ideals are arranged in terms of purpose, the value becomes an explicit element The objective of CE is “to maximize value at each point in a product's life (Stahel, 2016). “The circular system can be organized to create sustainable value by minimizing the environmental impact”,

meaning adding value to companies (van Buren, Demmers, van der Heijden, & Witlox, 2016, p. 2). The value in the broader debate around resource and waste is to create a set of strategies to extend resource life as a means to facilitate additional value extraction and reduce value loss and destruction (Blomsma & Brennan, 2017). One specific contribution of CE is its focus on the importance of high value and high quality in material cycles (Korhonen, Honkasalo, & Seppälä, 2018).

Companies that want to get value through TC demand to feat the remaining value of the products and suggest to the customer a new product accessible through remanufacturing, recycling, overhaul, or other life-extension strategies (Bocken, Bakker, & Pauw, 2016). It also implies the implementation of cleaner production patterns at a business level, a growth of manufacturers and consumers concern and awareness, the practice of renewable technologies and resources (Joshi, Seay, & Banadda, 2019). Thus, the second research question of the thesis is presented below.

RQ2: What are the main value streams within CBM?

In fact, technical cycles are important to save natural resources and money for consumers but not constantly be in the best interest of all manufacturers (Maitre-Ekern & Dalhammar, 2016).

As pointed out in chapter 1 and more explored in the articles, TC can add value to organizations. However, it needs more studies for companies to undusted value is generated (Lacy et al., 2014). The barriers presented here, and others indicated in articles1 and 2, need to be considered before elaborating a business model since some already exist and the companies do not adopt them.

Despite the expected benefits from the CE, criticisms of the model are recurrent (Korhonen, Honkasalo, & Seppälä, 2018). However, they emerge suggesting or revealing potential barriers to CE implementation and development, the scope and operationality of the CE. For example, increasing social and environmental value in a CE context could lead some businesses to economic instability in the early stages of transition (Xing & Luo, 2018) and constitute a major barrier, as the viability of the CE implies the need for mass adhesion.

The scope itself of social sustainability is subject to disbelief on the part of the

academic community, which perceives a concern centred on the environmental and economic dimensions, to the detriment of the social dimension (Geng, Fu, Sarkis, & Xue, 2012; Moreau, Sahakian, van Griethuysen, & Vuille, 2017). Such concern is explicit in other papers: “more attention should be paid to social barriers” (Ceglia et al., 2016, p. 382).

Scepticism is also revealed in the exposition of possible restrictions to the reality of a society ruled by the CE. Korhonen, Honkasalo, and Seppälä, (2018), for example, raised limits and challenges to the concept of circular economy: “(i) System boundary limits: Spatial: problems are shifted throughout the product life cycle, Temporal: short-term use of non-renewable resources can build long-term renewable infrastructure; (ii) Limits imposed by the physical scale of the economy; (iii) Limits imposed by trajectory dependence and incarceration, since the first technologies maintain their market position despite path dependency; (iv) Limits of social and cultural definitions, the concept of waste is always constructed in a cultural context, social and temporal context and this context is dynamic and changeable".

In fact, the barriers seem to gain special prominence in several works, such as the lack of incentives for CE implementation. Other significant barriers are presented to establish CE: (i) political, (ii) technological, (iii) legal areas (Mathews, Tang, & Tan, 2011), (iv) restrictive policies and regulations and (v) consumer acceptance (Zhang, Chu, Wang, Liu, & Cui, 2011). In addition to some authors have studied the main barriers of CE (Galvão et al., 2018; Riding et al., 2015; Zhang, Chu, Wang, Liu, & Cui, 2011), some organizations have also dedicated themselves to this study. For instance, the OECD studies market barriers such as regulatory and financial barriers, thus strengthening economic efficiency and competitive criteria (CC). Thus, the third and fourth research question of the thesis ir presented below.

RQ3: What are the main barriers or obstacles to implementing circular business models?

RQ4: Which operation strategies do companies use to overcome the barriers or obstacles?

Overcoming barriers can make business more competitive. In fact, there are

latent opportunities to increase the competitive criteria of organizations that face these challenges as transitory problems to be overcome (Schumpeter 1934).

Additionally, there is no confrontation between the mechanisms for generating potential gains declared in the CE research field with the classic and abundant literature on manufacturing operation strategy (competitive criteria). However, this relationship has already been mentioned (Lieder & Rashid, 2016).

Classical literature in this area has well-defined CC. For instance, quality, delivery performance, flexibility, innovativeness and cost (Garvin, 1987; Skinner, 1974). Although more recent studies add more items to this list, know-how (Phusavat & Kanchana, 2007), customer-service aspect (Lee, 2002), among others.

Although studies reveal that competitive criteria may vary depending on the sector and region(Lee, 2002), the most common criteria in the literature and organizations are used in this study (quality, delivery performance, flexibility, innovativeness and cost).

There are different nomenclatures for each CC, for instance: (i) flexibility can be operationalized as product mix flexibility or volume flexibility (Swamidass, 1987); (ii) quality is presented by eight different dimensions, performance, features, reliability, conformance, durability, serviceability, aesthetics and perceived quality (Garvin, 1987); (iii) delivery performance can be on-time delivery (Noble, 1995) or delivery reliability faster delivery times (Noble, 1995); (iv) innovativeness can be a frequency of new product introduction (Adam & Swamidass, 1989); and (v) cost efficiency. There are other nomenclatures; the competitive criteria name can also be found as a cumulative perspective (Murray, 1988; Noble, 1995). Competitive criteria aimed at sustainability are generally aimed at controlling material inventory, and value refers to the efficiency of these criteria (Pourhejazy, Sarkis, & Zhu, 2020). These CC are not related to the classic literature on strategic manufacturing. Above, points were raised about TC and the possibility of them influencing the captured value. At this point, we present the research's fifth research question.

RQ5: Competitive criteria have a moderating effect on the relationship between technical cycles and value capture?

The essence of CE involves a profound change in an organisation's operation and value creation (Ríos & Charnley, 2015). Some industries recognise the economic value inherent in the discarded products, incorporating them into the production chain. The larger the circular flow, the greater the revenue results. The more closed the loop, the more efficient and sustainable the circular system. According to Glavič and Lukman (2007), Linder and Williander (2017), and Preston (2012), value comes from maximizing the life of the material, therefore, according to new ways of capturing value (Yang, Evans, Vladimirova, & Rana, 2017).

Changing the linear business model to a circular model is considered difficult (Schulte, 2013), and the industries need to rethink their business models (Bocken, Short, Rana, & Evans, 2014; Buxel; Esenduran; Griffin, & 2015; Hart & Dowell, 2011). Moreover, this can provides new possibilities for creating and capturing value for companies (Moreno, Rios, Rowe, & Charnley, 2016). In contrast to the Linear Business Model (LBM) (Vargo & Lusch, 2004), CBM's (Evans et al., 2017; Glavič & Lukman, 2007; Linder & Williander, 2017; Preston, 2012); (Linder & Williander, 2017) the value creation logic is based on the value being retained in the products at the end of their useful life.

Value capture defines how value propositions are converted into revenues (Teece, 2010). Some previous studies advocate and create value capture mechanisms to increase in recycling capacity (Ranta, Aarikka-Stenroos, Saku, Mäkinen, & Saku, 2018). Also in how the CBM should focus the target audience to capture value (Roos, 2014) or management practices that companies implement to create, deliver and capture value (Lewandowski, 2016), or value capture of a single practice (Ríos & Charnley, 2015).

However, the basic premise of the circular economy is integrated with the dimensions of the value creation and capture business model (Ünal & Shao, 2019), so circular business models provide several new perspectives in terms of value creation and capture that need to be analysed. in depth (Ünal, Urbinati, Chiaroni, & Manzini, 2019).

One of the aspects that this work explores is after capturing value with whom the organizations share it. However, it is possible to find studies in the literature that set

goals for a shared economy (Diepenmaat, Kemp, & Velter, 2020). However, studies that show how this sharing is done (if it is done) may be a gap. The concept of shared value given by Porte is presented below.

> The concept of shared value recognizes that societal needs, not just conventional economic needs, define markets. It also recognizes that social harms or weaknesses frequently create internal costs for firms—such as wasted energy or raw materials, costly accidents, and the need for remedial training to compensate for inadequacies in education. And addressing societal harms and constraints does not necessarily raise costs for firms, because they can innovate through using new technologies, operating methods, and management approaches—and as a result, increase their productivity and expand their markets. Shared value, then, is not about personal values (Porter & Kramer, 2011).

To implement CE correctly, CBM must be one of the organization's strategies. At first is needed to point out that business model and operation strategy have different concepts (Casadesus-Masanell & Ricart, 2010; Teece, 2010). A operation strategy can be the plan that indicates the business model to be adopted (Casadesus-Masanell & Ricart, 2010). A business model describes the design by which a company creates, delivers, and captures value; that is, how the company operates the operation strategy (Teece, 2010). Consequently, a circular business model is a way to operationalize a circular economy operation strategy.

Not only companies have barriers to implement CBM. Most of the countries that have results with technical cycles are developed. In this way, technologies for recycling, for example, must be low-cost, economically practicable, socially adequate. Then, they are unlikely to succeed, especially in underdeveloped regions (Joshi, Seay, & Banadda, 2019). The adoption of CE globally still appears in the initial stages, mainly concentrated on recycling rather than reuse.

On the other hand, some more optimistic authors point out that CE can be seen as a disadvantage only by those who support permanent quantitative economic development without environmental and social concerns (Ghisellini, Cialani, & Ulgiati, 2016).

In any case, criticisms, concerns, and expectations of benefits, it is fundamental

to consolidate the aspects related to the expectations of value creation, barriers to operationalization that orbit the CE literature and practice as the only way to make a careful analysis of costs and benefits, and ultimately the very viability of the CBM.

1.1 Justification

Circular Business Model (CBM) are expected to contribute to allowing extended lifetimes of products and components through continuous cycles of reuse, repair, remanufacturing and closing material loops (Nussholz, 2017).

Although the move towards a CBM has been advocated and supported (Nußholz, 2017), there are limited researches on this topic (Fonseca, Domingues, Martins, & Zimon, 2018). The state of the art indicates that in-depth research on EC assessment is still needed, (Elia, Gnoni, & Tornese, 2016). The literature review by Mendoza, Sharmina, Gallego-schmid, and Heyes (2018) exposes that current models are flawed because they do not fill the gap between the strategic and operational levels or do not provide support on how CE requirements can be implemented.

Another point that still needs to be studied is that despite the growing popularity of CE, little is known about the obstacles of the industry that need to make the transition to a circular production system. Knowing how these concepts combine to facilitate or impede the transition of companies to circularity is scarce (Franco, 2017). According to the author, even when companies begin to operate sustainably from the outset, the question remains about shifting to a different production model for existing players with decades of market presence.

Besides value for the company itself, it is essential to note the company's value to society and the planet (Dyllick & Muff, 2015; Hall & Wagner, 2012). It means that it is essentially an aspiration for a sustainable society; the importance of sustainability for the future of the planet (Adams, Jeanrenaud, Bessant, Denyer, & Overy, 2016; Buxel; Esenduran; Griffin, & 2015; Gauthier & Gilomen, 2015; Marchi, Di Maria, & Micelli, 2013; Preston, 2012; Schaltegger, Lüdeke-Freund, & Hansen, 2012; Schoolman, Guest, Bush, & Bell, 2012).

Some modes to achieve CE are recycling, reducing and reusing, and CE can provide material cost reduction (Linder & Williander, 2017). Some authors point that a

significant share of the value-added in the original manufacturing process is saved or preserved in the remanufacturing process (Linder & Williander, 2017). Also, remanufacturing minimize consumption, decreasing the use of virgin materials and energy, and contributes to economic development and the creation of high-skilled jobs (Sze, Low, & Ng, 2018). However, the form of generating value and revenue in a business context is still not understood by academia and industries (Ranta, Aarikka-Stenroos, Saku, Mäkinen, & Saku, 2018). So, there are academic efforts to conceptually link circular business models and environmental value creation (Manninen et al., 2018).

Additionally, a circular business model is a growing trend of academic research (sustainability and circular economy) (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Glavič & Lukman, 2007; Moreno, Rios, Rowe, & Charnley, 2016; Schoolman, Guest, Bush, & Bell, 2012). Furthermore, interest in practical application is growing (Abdul-Aziz, 2012); and there is growing interest in sustainable business models (Bocken, Short, Rana, & Evans, 2014; Boons & Lüdeke-Freund, 2013; Roome & Louche, 2016).

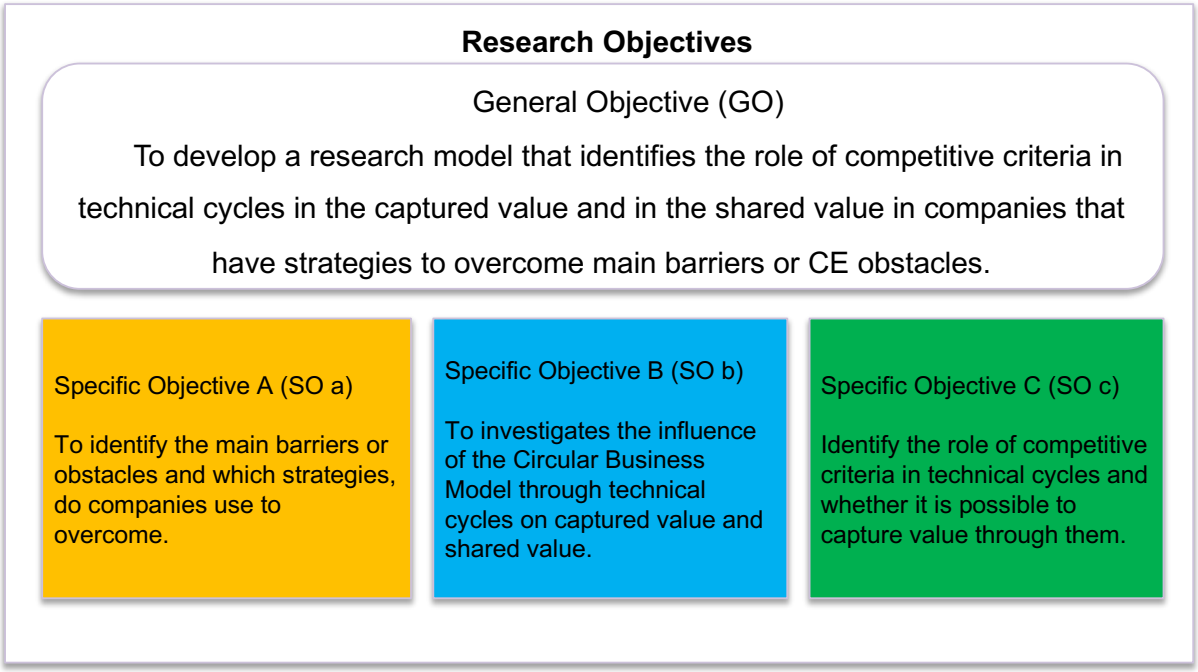
Another point to be discussed: to have value, the company needs to have a competitive advantage, so a good business model must have the logic of how to do business and meet the needs of customers (Teece, 2010). At this point, it is worth exploring how to be competitive through technical cycles. Studies reveal that organizations the most invest environmental and economic aspects. However, society increasingly demands that organizations also invest in the social part. The sustainable trade-offs must be managed well.

In short: “Studying business models in a CE is thus vital to determine the actual economic benefits that can result from embracing CE practices at the company” (Ranta, Aarikka-Stenroos, Saku, Mäkinen, & Saku, 2018, p. 989). The gaps identified in the literature indicate the need for complementary empirical research on the topic barriers (Farooque, Zhang, & Liu, 2019; Whalen, Milios, & Nussholz, 2017), value through CE (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Yang, Vladimirova, & Evans, 2017) related to CBM's technical cycles.

1.2 Research Objectives

For the context and the problem presented, the general objective (GO) of this thesis is to develop a research model that identifies the role of competitive criteria in technical cycles in the captured value and in the shared value in companies that passed operation strategies to overcome main barriers or CE obstacles. The specifics objectives (SO) are presented in figure 1.

Figure 1: General and Specific objectives



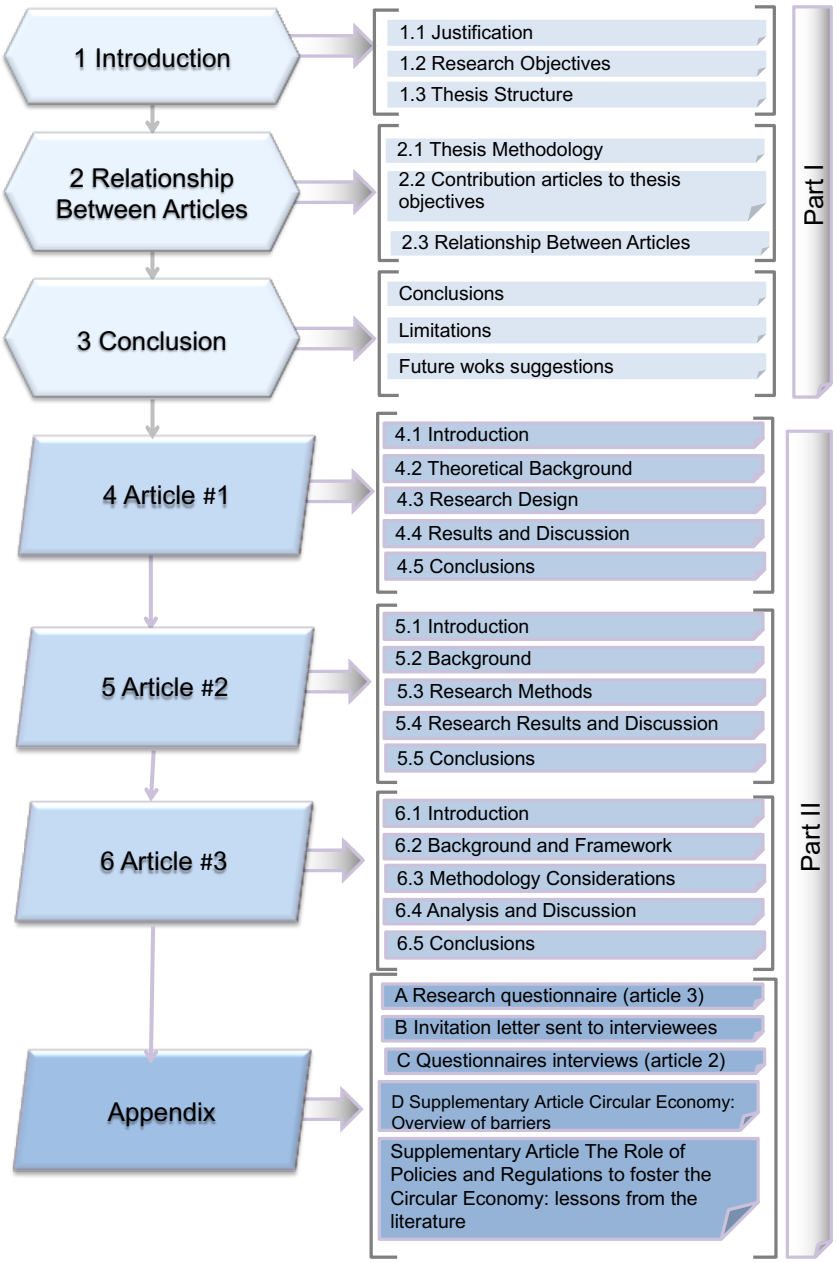
Regarding the first specific objective, many constructs and variables have been used over time in studies; for this reason, a literature review is adequate to the proposed objective. For the second and third specific objective, it will be necessary to relate them to the definition of the theoretical model. Besides the design of the model, it is necessary to identify the indicators to evaluate each construct. Finally, the fourth and fifth specific objective is related to the test and validation of the model through empirical research with a quantitative approach, using the survey method.

1.3 Thesis Structure

This thesis was designed as article-based, and it was separated into two parts. Part 1 is an integrative overview of the three articles, and it is composed of three sections.

Section1 is the Introduction, presenting a current panorama of research and concepts about circular economy and business model. Also, this section presents the main objective, specific objectives. Section 2, the relationship between the three articles is discussed and how each article answers the specific objectives of the thesis. The last section of Part 1 is the conclusion. Then, Part 2 is presented the thesis' papers. Figure 2 shows the structure of the thesis.

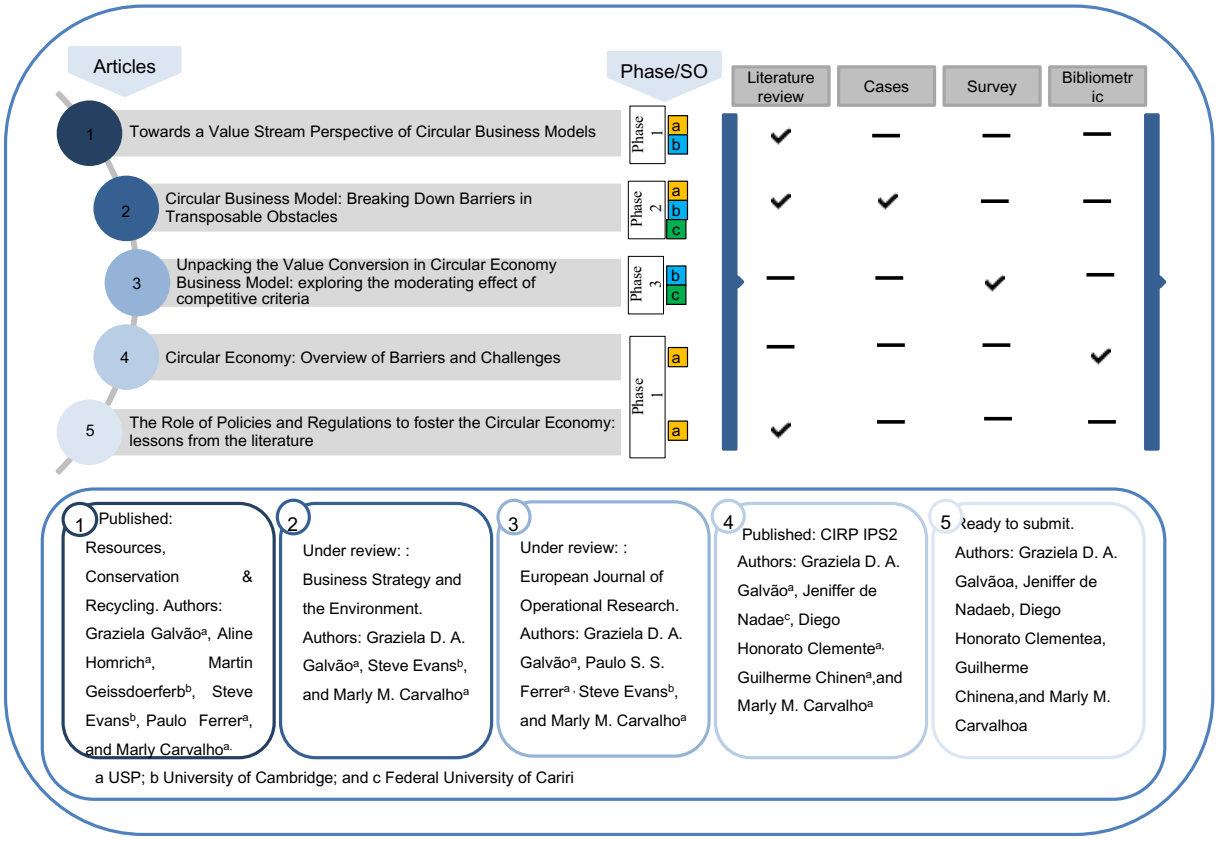
Figure 2: Thesis Structure



2 RELATIONSHIP BETWEEN ARTICLES

Before presenting the connections between the three articles, first is demonstrated more holistically the connection of the constructs of the articles for the thesis (figure 3). This research revolves around the scope of operations operation strategy.

Figure 3: Articles, phase, specific objectives, method, font and authors



An organization's MB must relate to how it operates and creates value for its stakeholders (Casadesus-Masanell & Ricart, 2010). According to the same author, this definition is similar to the definition of operation strategy.

However, a BM is more generic than a business operation strategy. A combination of the two (business operation strategy and BM) is necessary to safeguard any competitive advantage resulting from the recent design and implementation of BMs in the organization. In addition, choosing the appropriate operation strategy is something that must be done in more detail than developing a business model (connected with (i) and (ii) in Fig 4).

Another essential point, BM must demonstrate a more comprehensive approach

to explain how companies “do business” (Zott, Amit, & Massa, 2011) (this is connected with (i) and (ii) in Fig 4). Moreover, BMs show how value is created, not just how it is captured (Zott, Amit, & Massa, 2011) (this is connected with (v) and (vi) in Fig 4).

For example, technological innovation does not necessarily ensure that the business will be successful. It is necessary to develop products that are aligned with the business model and with the business operation strategy aimed at looking at the market and to capture value (Teece, 2010) (this is connected with (v) (vi) and (vii) in Fig 4).

There is also the possibility of a provisional BM, which needs to be evaluated concerning the current state of the business ecosystem and how it can evolve (Teece, 2010). Here can be associate with article 2 on barriers versus obstacles. A provisional vision may give an idea of a current barrier and evolve to an obstacle. That is, do not treat it as an absolute state, then adaptation is required.

To be competitive, the organization needs to have a BM that looks outside inwards, not the other way around. Competitive criteria are also related to having managers oriented to know and invest in 'essential competences', that is, "those activities in which their companies stand out and find market opportunities to implement them" (McGrath, 2010, p. 248). At this point, we can see the importance of having competitive criteria to guide the outside (viii in Fig 4).

There is no way to predict the market to obtain a competitive advantage. For this. Thus, necessary to avoid the conventional measures of success of strategic planning success (McGrath, 2010). The competitive criteria can meet the purpose of business (viii in Fig 4).

2.1 Relationship between articles

In **article 1**, the main themes of circular economy are explored, coming from literature. Article 1 provides elements for the elaboration of the other two articles. CBM framework was elaborated to understand value flow better. The entire article highlights the need to be competitive in order to obtain value through a circular operation strategy.

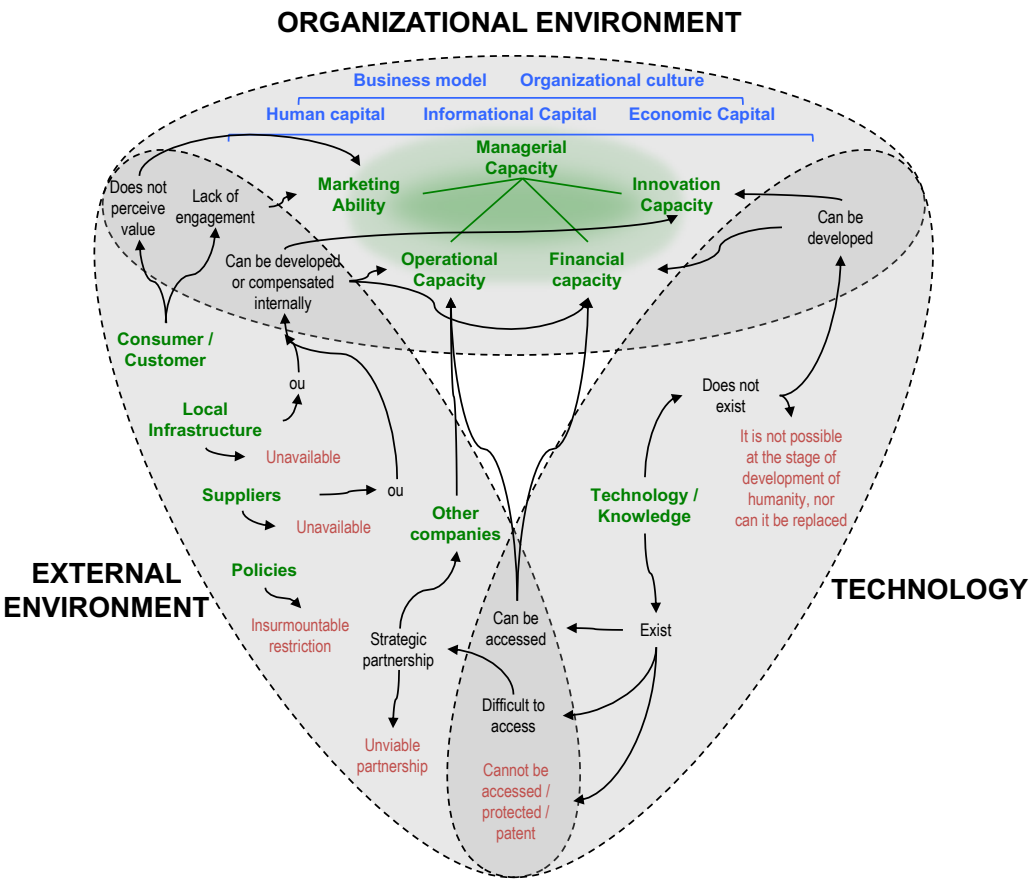
In addition, **article 1** provided elements for the elaboration of article 2 and 3.

These elements are represented in Figure 4 by the broad grey arrows identified by as i, ii and iii (article 1 for 2), or ii and iii (1 to 3).

Article 2 aims to explore the variables and constructs identified in articles 1, and identify others through the 40 interviews. In this sense, article 2 fulfils the exploratory role of the elements that make up the final model of the thesis. These relationships are represented in Figure 4 by the broad grey arrows identified as I, ii and iii.

Beyond receiving elements from article 1, **article 2** provides elements to article 3. Here comes a new element arising from the need to have a competitive operation strategy, the competitive criteria. These criteria were explored in the 40 interviews: in figure 2, these elements are represented as ii, iii and iv.

Figure 2 of article 2: Barriers and obstacles integrated in the CBM.

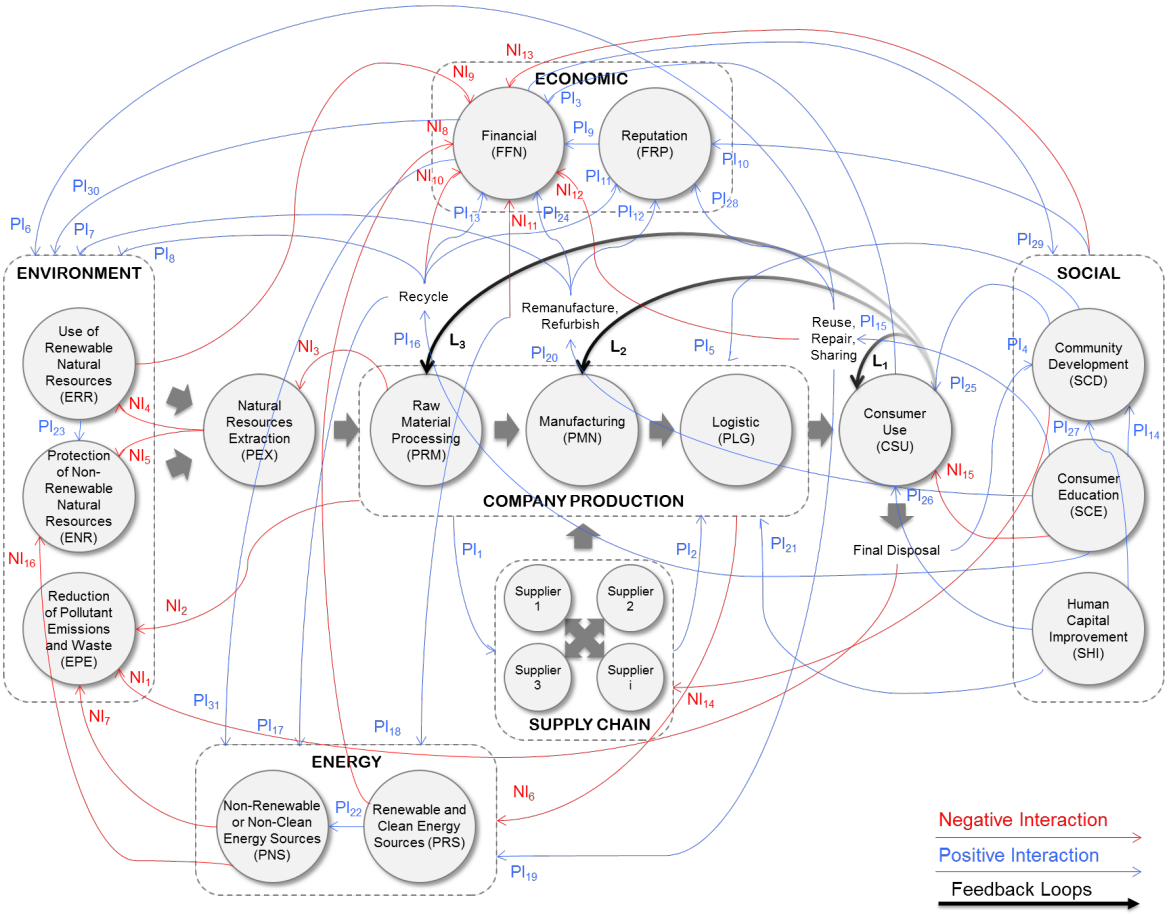


Article 3 presents the confirmatory theoretical model that receives elements from articles 1 and 2. Article 1 came the technical cycles and value of the circular business model (ii and iii). From article 2 came technical cycles, the value of the circular business

model and competitive criteria (ii, iii and iv).

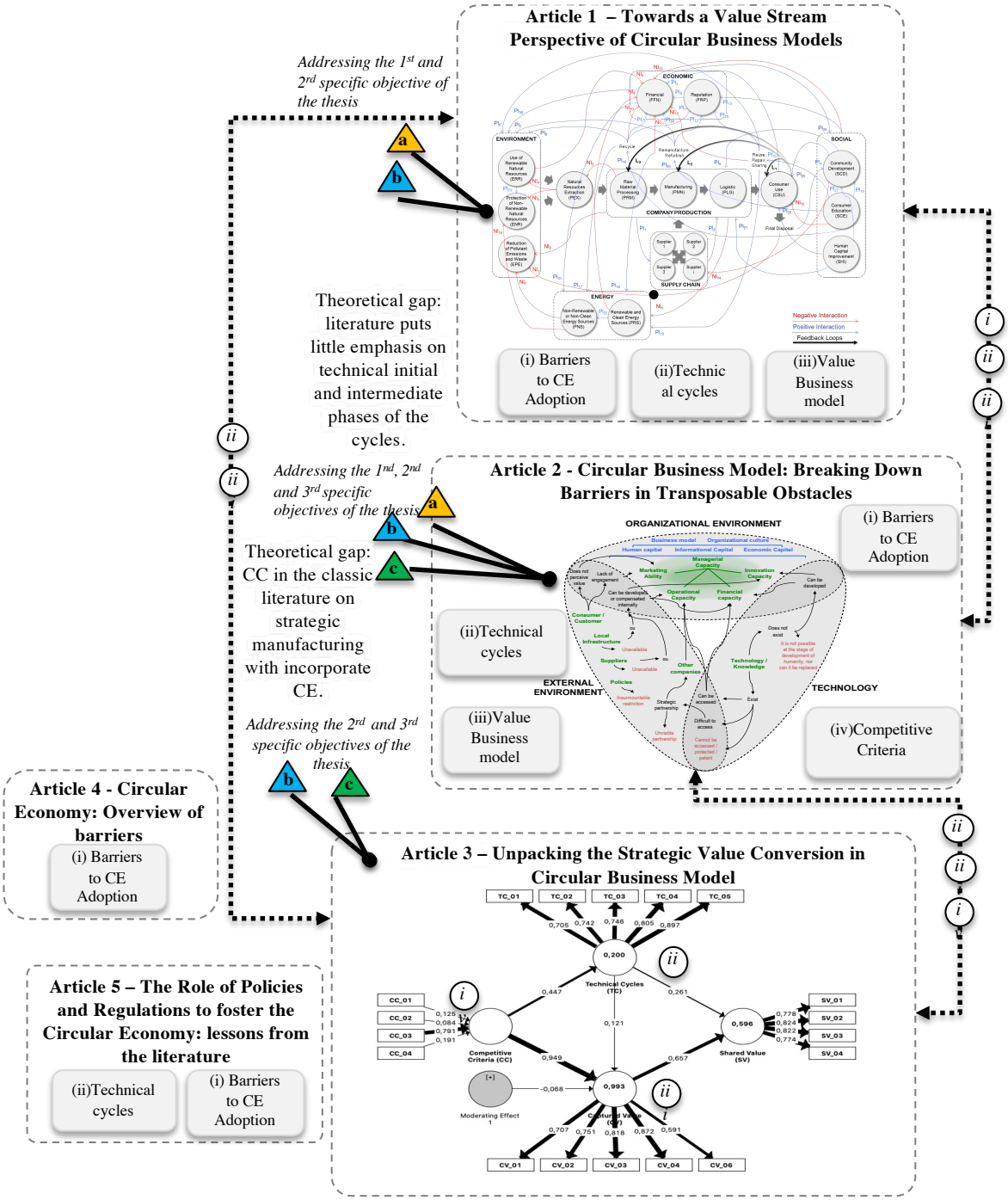
In summary, the theoretical model of the thesis aims to analyse the explanatory power of variables acting positively or negatively on the incorporation and operationalization of technical cycles as part of the corporate operation strategy and how these cycles are capable of generating economic, social and environmental value. The conceptual model developed in Article 1 (Figure 4) is the starting point for the final shape of the article 3 model.

Figure 4 of article 1 – Company Production in the Context of the Circular Business Model



Although the dialogue, the model of article 1 has more the simplicity of the flow of materials and its actors. Briefly, Figure 4 shows how the articles fit together. The arrows with dashed lines indicate how items i, ii and iii feed or contribute to developing the main thesis model.

Figure 4 - Representation of the logic of the concatenation of thesis articles



2.2 Contribution of articles to thesis objectives

To achieve **SO "a"** (Figure 5), article 1 initially begins with a literature review, where it was possible to identify constructs and variables related to the circular economy (table 1, article1).

Category	Addresses
(A) Conceptual basis (Concepts, terminology, paradigms)	A.1 Comparison between circular economy and sustainability A.2 The concept of sustainability A.3 Concept of the circular economy A.4 Addresses triple bottom-line issues and generation of value A.5 Concept of green economy A.6 Classic "supplier-business-customer" model A.7 Business model and operation strategy: concepts and differences A.8 Sustainable business model; linear business model; and circular business model A.9 Cradle to grave" and "cradle to cradle" paradigms A.10 Product service system (PSS)
(B) Objectives (What should be done)	B.1 A new economic model B.2 An integrative business model, incorporating the triple bottom line towards a true sustainability B.3 A collective effort among stakeholders; stakeholders' inclusiveness B.4 A profound change in the way of doing business B.5 To rethink business models B.6 The objective of CE is "to maximize value at each point in a product's life B.7 To eliminate the disparities between discourses addressed to the company and planet point of view B.8 New corporate strategies to support sustainability, adjust operation strategy to sustainability purpose B.9 Innovation in products, processes focusing on CE, with dynamic and intelligent solutions; radical and systemic innovation is needed to support CE B.10 Innovation fitting to the sustainable paradigm B.11 A proactive response from companies B.12 A need to address the social dimension properly B.13 To include "sharing" as part of CE model B.14 To adopt renewable technologies and materials B.15 To address consumer education B.16 To develop human capital
(C) Drives (Motivations, justifications, importance, benefits)	C.1 An aspiration for a sustainable society; the importance of sustainability for the future of the planet C.2 The circular economy can provide material cost reduction C.3 To assess the value that the company gives to society and the planet C.4 A significant share of the value added in the original manufacturing process is saved or preserved in the remanufacturing process C.5 Remanufacturing minimizes the consumption decreasing the use of virgin materials and energy, and contributes to economic development and creation of high-skilled jobs C.6 The value of CE in the broader debate around resource and waste is to create a set of "strategies to extend resource life as a means to facilitate additional value extraction and reduce value loss and destruction." C.7 One specific contribution of CE is its focus on the importance of high value and high quality in material cycles
(D) Barriers (Barriers, limitations, challenges)	D.1 Disruptive nature of today's sustainable initiatives D.2 No fostering dissemination of sustainable solutions D.3 Business models are difficult to observe D.4 "Decreased status" of the economic perspective when implementing sustainable business models, difficult to justify them as advantageous in a business vision

	D.5 Sustainability is commonly equated with eco-efficiency D.6 Organisations seem to try to shift the problem to others by focusing on process exchanges with suppliers, customers and competitors D.7 Sustainable innovations do not fit the logic of the dominant business models D.8 Lack of incentives to develop new sustainable materials D.9 International cooperation to implement CE D.10 Decisions addressing CE should be intercompany D.11 Lack of incentive to adopt CE D.12 Lack of support from public actors D.13 A long-term system changes or transition is required to implement CE D.14 The diffusion and adoption of sustainable solutions are minor compared to the overall needs D.15 Lack of financial resources and technical skills for small business in adopting CE D.16 Transformation of both production and consumption systems on a large scale D.17 CE development depends upon deeper understanding of consumers' attitudes and behaviours D.18 Difficult to change the linear business model to a circular model D.19 Research about innovation in sustainable business models is insufficient D.20 Little empirical research in developing the circular economy D.21 The supply chain is concerned only with delivering a product to a consumer without regard after end of its life
(E) Academic and practical implications (Knowledge status quo)	E.1 Growing trend of academic research E.2 Growing interest in practical application E.3 Growing interest in sustainable business models E.4 There are academic efforts to conceptually link circular business models and environmental value creation

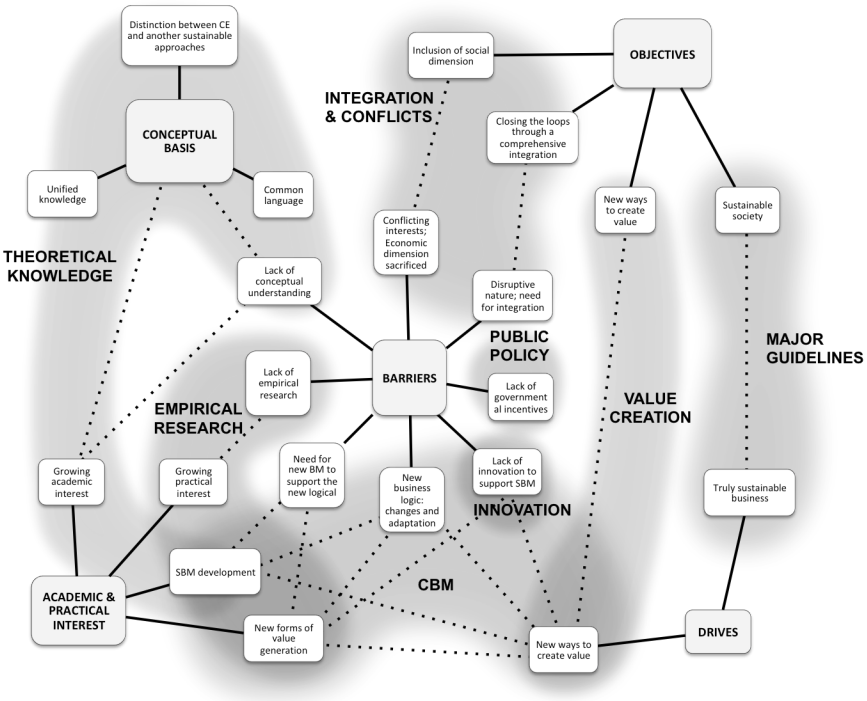
The constructs were categorized into: (i) Conceptual basis that includes concepts, terminology, paradigms; (ii) Objectives, that is, what should be done to be circular; (iii) Drives, characterized as Motivations, justifications, importance, and benefits; (iv) Barriers, including limitations, and challenges; and (v) academic and practical.

Figure 5: Specific Objective "a" with article 1,2,4 and 5

Specific objective achieved by Article 1
SO a- To identify the main barriers or obstacles and which operation strategies, do companies use to overcome.

Then provides the interconnections between the main aspects addressed in each category, revealing 8 clusters that allow a new way of synthesizing the status quo on the CE literature (fig 2, article 1): theoretical knowledge, empirical research, CBM, value creation, major guidelines, integration and conflicts, innovation; and public policy. Each construct of this is detailed in table 1 of the article.

Figure 2 of article 1 – Categorisation Framework and Clusters Identification



Article 1 also presents a representative framework that shows how all the constructs identified in literature interrelate positively and negatively until the last generation of value in a circular business model. In this framework (Figure 5 of article 1), the main contribution comes from clarifying how the value is generated through the CE technical cycles, considering vectors representing positive or negative interactions, respectively related to incentives and restrictions to the implementation and operationalization of the CE.

Besides, the literature review of article 1 enabled the elaboration of figure 3. The category barriers are diluted throughout the model, suggesting great diversity on the nature of the obstacles to be overcome, thus reinforcing the complexity of effective CE implementation. In this way, article 1 collaborates with elements for the elaboration of article 2.

Therefore, the most relevant category resulting from article 1 was barriers. The barriers were further explored in Article 4, which presented the CE barriers most discussed in the literature: (i) technological, (ii) political and regulatory, (iii) financial and economic, (iv) managerial, (v) performance indicators, (vi) customer and (vii) Social. The main barriers identified in the literature were: (i) technological, (ii)policy and regulatory, (iii) financial and economic, (iv) managerial, (v) performance indicators, (vi)

customer and (vii) Social. Article 5 focused on the most cited barrier in Article 4, publish policies. The articles are connected and collaborate to achieve **SO"a"**.

When analysing the results of the 40 interviews, the barriers to CBM were grouped into the organisational environment, external environment and technology. Within the organizational environment are the barriers related to organizational culture, managerial capabilities and business model. The external environment category features barriers related to circular supply chain (supply chain complexity and supply chain collaboration), infrastructure and consumption related barriers (lack of awareness, owner perception, rejection of remanufactured products), and technology, including lack of appropriate technology or lack of knowledge.

In figures 2, 3 and 4 of article 2, the possibilities of turning barriers into obstacles are summarized. A suitable example is technical knowledge because when it does not exist and cannot be developed, it becomes a barrier. On the other hand, if it does not exist, but it can be developed, it can be considered an obstacle. At this point, it will depend on the company's innovation capacity or capacity/availability to achieve partnerships. Analysing these results of article1,2,4 and 5 can be related to the **specific objective "a"** of the thesis.

The barriers reported in the literature seem to stem from the internal limitations experienced by organisations, as exemplified in article 2. It may be lack of managerial capacity, resources and corporate knowledge; on issues external to organizations, such as consumer behaviour (Paletta, Leal Filho, Balogun, Foschi, & Bonoli, 2019) and regulatory aspects (Galvão, Nadae, Clemente, Chinen, & Carvalho, 2018); or even in the absence of technologies. In common, these works seem to circumscribe these challenges within their limits, without pointing out an exit door or an opportunity to be explored. It was observed that some barriers pointed out by the studies could be temporary obstacles, some with more straightforward solutions to solve (partnership, for example). Article 2 thus suggests barrier that becomes an obstacle is a competitive advantage. The result generates discussions for the next **SO "b"** and **SO "c".**

To achieve **SO "b"** (Figure 6), it was first necessary to explain that value creation is based on a material flow in a linear business model. Where virgin material enters the upstream value chain and the entire value of the product, except the value of the

raw material, is added through the manufacturing and behaviour. They deal with different models, which occurs in most manufacturing industries (Vargo & Lusch, 2004) (article 1). In this model, products are usually downgraded after only one use, and their embedded value is lost (Velte & Steinhilper, 2016).

Figure 6: Relationship of research objective with articles 1,2, and 3

Specific objective achieved by Article 2
b- To investigates the influence of the Circular Business Model through technical cycles on captured value and shared value.

SO "b" is also answered by Article 2 as it presents a result concerning the interviewees answered about whether the company intended to continue investing in technical cycles or not. All respondents said the company would continue to reverse technical cycles, because the company captures value through TCs. There will be more investment in climate, renewable sources, post-consumption products, more water efficiency, energy efficiency and local development in relation to communities. Also, items that can improve the company's image with its customers and can generate more value.

Still, on SO b, article 3 contributes by researching whether technical cycles can influence value capture and the shared value in CBM. It deals with a survey with 233 respondents. This research has six hypotheses, three of which are directly linked to **SO "b":** H1b: Technical Cycles have a positive influence on captured value; H1e: Technical cycles have a positive influence on shared value; and H1f: The captured value is shared.

To achieve **SO "c"** (Figure 7) first, must be said that exploring the literature to elaborate article 1 read plenty about operations operation strategy articles. However, no clear criteria were found for obtaining a competitive advantage in CE. Thus, Article 2 brings the competitive criteria to be discussed. In this article, the companies invested in the technical cycles believe that it is worthwhile to continue investing because it is a competitive differential for the companies. It can be said that this point meets part of the specific objective c of the thesis. The figure below is presented the competitive criteria that improved the most after implementing CBM.

Figure 7: Relationship of research objective with article 2 and 3

Specific objective achieved by Article 3
c- To identify the role of competitive criteria in technical cycles and whether it is possible to capture value through them.

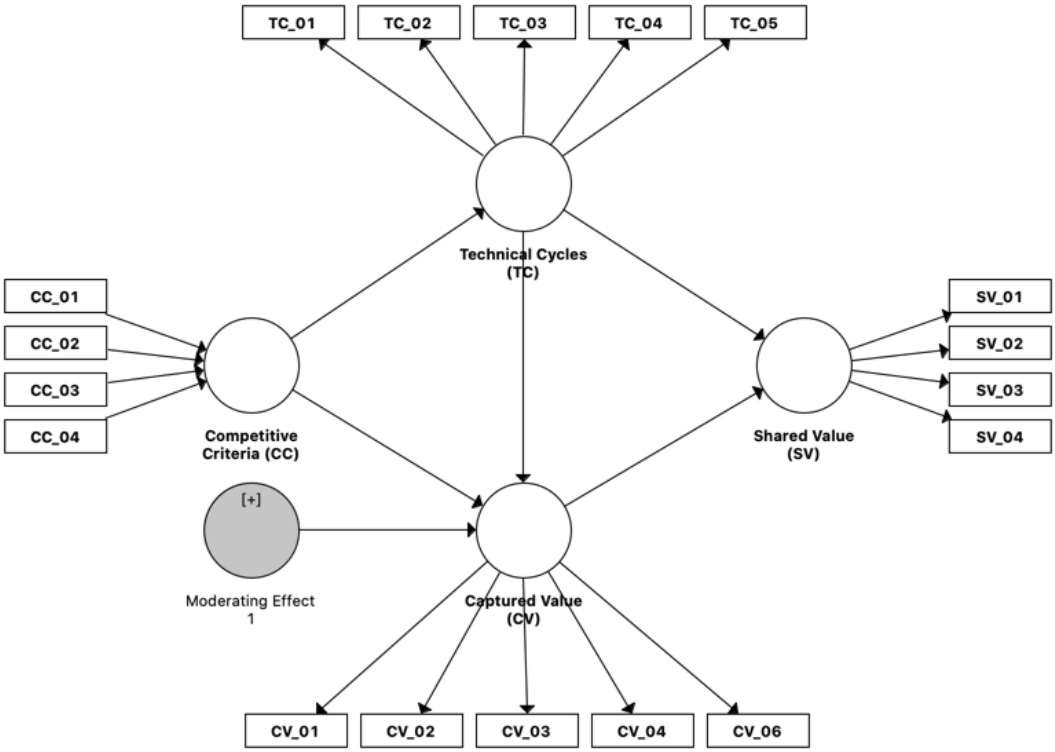
In addition to the 40 interviews, to contribute with **SO "c",** a questionnaire was sent to other company members to know which competitive criteria were improved in the company after CE implementation (article 2). The results show that quality, cost, innovation and delivery performance are significantly improved after CBM implementation. Flexibility was the competitive criterion that had a median improvement (table 1). Delivery performance provides how successful the supply chain is at providing products and services to the client (Bonner, Onofrei, Humphreys, Margey, & Cadden, 2021). Innovation, which was a late addition (Singh, Tripathi, Srivastava, & Iyer, 2015) can involve both the creation and development of product ideas (Oke, 2013). Table 2 presents some authors and the aspects studied by them.

Table 1: Improvement of competitive criteria

Dimension		Cases	Frequency
Quality	There was no improvement	3, 29, 34, 36	4
	The improvement was partial	1, 16, 17, 20, 24, 33, 38, 40	8
	Yes, there was improvement	2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 19, 21, 22, 23, 25, 26, 27, 28, 30, 31, 32, 35, 37, 39	27
		Total	39
Cost	There was no improvement	11, 29, 34	3
	The improvement was partial	3, 8, 20, 22, 26, 36, 39, 40	8
	Yes, there was improvement	1, 2, 4, 5, 6, 7, 9, 10, 13, 14, 15, 16, 17, 18, 19, 21, 23, 24, 25, 27, 28, 30, 31, 32, 33, 35, 37, 38	28
		Total	39
Flexibility	There was no improvement	26, 33, 34, 36	4
	The improvement was partial	1, 3, 5, 8, 16, 17, 20, 24, 38, 39, 40	11
	Yes, there was improvement	2, 4, 6, 7, 9, 10, 11, 12, 13, 14, 15, 19, 21, 22, 23, 25, 27, 28, 29, 30, 31, 32, 35, 37	24
		Total	39
Delivery Performance	There was no improvement	1, 33, 37	3
	The improvement was partial	2, 3, 5, 7, 8, 9, 11, 14, 16, 18, 20, 22, 24, 26, 28, 38, 38, 40	18
	Yes, there was improvement	4, 6, 10, 12, 13, 15, 17, 19, 21, 23, 25, 27, 29, 30, 31, 32, 34	17
		Total	38
Innovation	There was no improvement	1, 7, 29, 34, 36	5
	The improvement was partial	8, 21, 40	3
	Yes, there was improvement	2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33, 35, 37, 38, 39	32
		Total	40

Regarding contributions of article 3 to **SO "c**", a literature review was initially carried out with the objective of technical cycles within the scope of CBM. The review also included shared value and value captured by companies that adopted CBM. As the organizations' operation strategy aims to become competitive in the market, the criteria of competitive criteria were also inserted in the article. Also, a structural model (Figure 8) was elaborated and tested. Article 3 has six hypotheses, four of which are directly linked to **SO "c":** H1b: Technical cycles have a positive influence on captured value; H1c: The competitive criteria significantly affect the captured value; H1b: Technical cycles have a positive influence on captured value; and H1f: The captured value is shared.

Figure 8: Model Design



The article was carried out with companies from 50 different countries and sectors. The highlight is the consultancy services with matters related to the CE and sustainability (60 cases) and with waste management and recycling activities (37 cases) (Table 2).

Naturally, the sectors that work directly with direct sustainability issues are the ones most investors in the topic. However, large companies are making some investment, resulting in great results. For example, when a large packaging industry decides to recycle, the amount of material that does not waste is significant. That is, it

has a positive impact on the environment.

To ensure that the questions were well thought out, a pilot test was done. After the practitioners and researchers' feedback, slight improvements were made to the data collection instruments to eliminate possible misinterpretation. All the companies have circular actions, iso1400 and sustainability report. It was sent a message on LinkedIn with an interview information sheet to one hundred participants; that is a purposeful sampling process. The message was sent only to knowledgeable employees who had experience circular economy. During the companies' choice to be studied, it was verified whether the company intends to continue investing in CE. Before an interview, it was provided an information sheet which explained the concepts of CE. Also, the companies that invest in innovating to enhance circularity, also, the interviewees work in companies that invest in technology and disseminate the importance of circularity within the organization. Furthermore, the sustainability reports of the companies present a percentage of circular products.

In total, 40 respondents agreed to participate in the research. All these respondents were interviewed in March, April, or May 2020, either by a face-to-face meeting in their offices, or over Google meeting or Skype or WhatsApp. Each interview lasted about 20-48 minutes (discounting the time of the conversation before actually starting the interview.) e was conducted in English or Portuguese. The interviews were recorded and notes transcribed into a software NVivo.

The reason for following the path shown in figure 4 was to build the final theoretical model of the thesis. The objective of the thesis is represented in coloured triangles in the figure. For ease of understanding, the goals are always in the same colours, objective "a" in yellow, "b" in blue and "c" in green. First, it was necessary to explore the literature and understand the main drives, concepts, barriers and value stream; for this, article 1 was prepared. However, it was still not enough and exploring the barriers further in article 2. In this way, the competitive criteria were studied. Then qualitatively analysed the point of view of 40 interviews on these two themes (competitive criteria and barriers). This validity was essential to build the quantitative instrument. Below, in Figure 9 is a summary figure summarizing what purpose each article is aimed at.

Figure 9: Specific objective of the thesis achieved by Articles 1, 2 and 3

Specific objective of the thesis achieved by Article 1	SO “a” - article 1,2,4 and 5
Specific objective of the thesis achieved by Article 2	SO “b” - articles 1,2, and 3
Specific objective of the thesis achieved by Article 3	SO “c” - article 2 and 3

Table 2: Sample Distribution by Industry Sectors and Company Size (in number of employees).

Productive Sector	Number of Employees				
	<10	11 to 50	51 to 500	>500	Total
Apparel, Textil, Fashion	6	2	-	9	17
Automation, Manufacturing, Production (in general)	6	4	2	6	18
Chemical, Petrochemical, Oil & Gas, Plastic, Cosmetics	-	2	2	11	15
Construction, Construction Engineering	2	-	4	3	9
Consulting Services, Environmental Services, Circular Economy Consulting, Engineering,	28	13	5	14	60
Consumer Packaged Goods, Food & Beverage, Nutrition	5	2	-	4	11
Education, Research	6	1	3	5	15
Extraction of raw material; mining, fishing and agriculture	-	-	-	1	1
Financial Services, Bank, Investments	2	-	-	2	4
Government, State, County	-	2	1	2	5
Information Technology	1	-	-	4	5
Marketing, Media	2	2	1	-	5
Paper & Pulp	-	-	-	4	4
Renewable Energy, Energy	3	4	1	7	15
Technology, Materials & Product Development	6	2	1	3	12
Waste Management, Recycling	12	9	10	6	37
Total	79	43	30	81	233

2.3 Thesis methodology

Before listing the articles, it is necessary to talk about the methodology of this thesis. The qualitative and quantitative approaches were chosen. It is multi-method research (Singhal & Singhal, 2012) and mixed research (Baldassarre, Calabretta, Bocken, & Jaskiewicz, 2017). This research type helps develop rich insights into various phenomena of interest that cannot be fully understood using only a quantitative or qualitative method (Bryman, 2003). The thesis is developed as a set of three articles, one article was published and two submitted.

As mentioned above, Part 2 covers the three articles of the thesis, and the two

supplementary articles. The research was divided into three phases; the first planned phase was the literature review. The second phase was the exploratory part of the research with 40 interviews, and finally, the third confirmatory phase where the survey and the thesis theoretical model were developed and tested. Each phase resulted in an article, and the three articles help achieve the thesis objective (both: the specifics and general objective).

Detailing a little more, **SO "a":** "Identify the main barriers or obstacles and what operation strategies companies use to overcome" was achieved with articles 1. Articles 4 and 5 also provided subsidies to achieve this objective completely. Articles 1,4, and 5 were written in the first phase of the thesis. Figure 10 presents Specific Objective "a" and the articles that contributed to achieving this objective.

Figure 10: Specific Objective "a"

	Thesis Specific objective	Article and Methodology	Article Objective(s)
Phase1	SO a: To identify the main barriers or obstacles and which operation strategies, do companies use to overcome.	Article #1 Literature review and cross-reference snowballing and mind map modelling	To address the challenges of implementing new circular business models in existing global supply chains and creating value streams.
Phase 2		Article #2 Literature review and 40 interviews	To explore how barriers integrate solutions to face barriers or obstacles in the company and whether this brings a competitive advantage.
		*Article #4 Literature review and 40 interviews	To provide an overview on barriers and challenges for the implementation of the circular economy.
Phase 1		*Article #5 Literature review and 40 interviews	To investigate the policies, and regulations used to foster circular economy.

*Supplementary articles

The SO "b": "To investigates the influence of the Circular Business Model through technical cycles on captured value and shared value" was achieved with articles 2 with inputs of article 3. Article 2 is exploratory and qualitative; it was developed by applying 40 interviews. This article mainly discusses whether companies face barriers or obstacles in the implementation of the CE. It is also analysed whether the competitive criteria are barriers or obstacles and if overcoming them added some value to the organization. As article 3 deals with competitive criteria, it also contributes to objective b of the thesis. Figure 11 presents Specific Objective "b" and the articles that contributed to achieving this objective.

Figure 1: Specific Objective “b”

	Thesis Specific objective	Article and Methodology	Article Objective(s)
Phase 2	**b-** To investigates the influence of the Circular Business Model through technical cycles on captured value and shared value	Article #2 Literature review and 40 interviews	To explore how barriers integrate solutions to face barriers or obstacles in the company and whether this brings a competitive advantage.
Phase 3		Article #3 Literature review and 40 interviews	To investigate the influence of Technical Cycles in capturing and sharing value through the Circular Business Model, exploring the moderating effect played by Competitive Criteria in these relationships.

The **SO “c”:** “To identify the role of competitive criteria in technical cycles and whether it is possible to capture value through them was reached with articles 3 with contributions of article 2. The data were collected through a survey, whose final sample represented 233 different organisations from 50 countries and 16 productive sectors. Figure 12 presents Specific Objective “c” and the articles that contributed to achieving this objective.

Figure 12: Specific Objective “c”

	Thesis Specific objective	Article and Methodology	Article Objective(s)
Phase	**c-** To identify the role of competitive criteria in technical cycles and whether it is possible to capture value through them	Article #2 Literature review and 40 interviews	To explore how barriers integrate solutions to face barriers or obstacles in the company and whether this brings a competitive advantage.
Phase 3		Article #3 Literature review and 40 interviews	To investigate the influence of Technical Cycles in capturing and sharing value through the Circular Business Model, exploring the moderating effect played by Competitive Criteria in these relationships.

.

3 Conclusions

The general objective of the thesis is to develop a research model that identifies the role of competitive criteria in technical cycles in the captured value and in the shared value in companies that have operation strategies to overcome main barriers or CE obstacles. Moreover, this is due to gaps found in the literature on value flows related to technical cycles of the circular economy. More specifically, the literature puts little emphasis on the technical initial and intermediate phases of the cycles. The lack of quantitative article focused on the circular economy was another gap found in this research. The criteria for companies to become more competitive after the implementation of circular actions are also not well explored in theory. In this regard, the competitive criteria (cost, quality, flexibility, innovation and delivery performance) and their possible contributions are explored in this thesis.

This research thesis was designed as article-based; therefore, it was necessary to divide it into three phases: (i) systematic literature review, (ii) 40 interviews with sustainability officials from different companies, and (iii) survey and modelling. The content of articles 1, 2 and 3 solves the general research question and the objectives defined for this research. The main barriers or obstacles and which operation strategies, do companies use to overcome (articles1,2,4, and 5), the influence of the Circular Business Model through technical cycles on captured value and shared value (articles1,2, and 3), and the role of competitive criteria in technical cycles and whether it is possible to capture value through them (articles 2, and 3).

The research findings suggest that organizations face a considerable number of obstacles to implement the CE. However, few companies seem to face definitive barriers. This study suggests that if the barriers are appropriately treated, they can be converted into obstacles, which in turn result in opportunities that add strategic value to the business, increasing the competitive capacity of the organization. The best way to turn barriers into obstacles is through partnership and having a team with good technical skills.

The results also indicate that the implementation of technical cycles enhances the competitive criteria of organizations from the perspective of competitive criteria,

measured from a set of criteria previously highlighted in the general corporate operation strategy literature. Article 2 supports these findings.

With the preparation of these studies, it is also possible to conclude that cost reduction, increased quality and greater possibility to innovate appear as the main vectors for leveraging the competitive criteria of organizations inserted in the CE logic. As a competitive criterion, the innovation could not be evaluated in the model because it violated the normality assumptions in the data distribution. However, it was evaluated in the article. Productive flexibility and greater supply chain integration have also proved to be of significant importance for competitive criteria. Both Article 2 and Article 3 corroborate these findings.

With the confirmation of the hypotheses and validation of the theoretical model of article 3, we can suggest that competitive criteria contribute to technical cycles; Technical Cycles have a positive influence on captured value; Technical Cycles have a positive influence on shared value; the competitive criteria significantly affect the captured value; companies share the captured value.

Both the 40 companies studied and the 233 surveys analysed to show that when companies see value with technical circles, there is always the intention to increase investments in technical circles. During this study, it was possible to realize that the image before customers is the biggest motivation for these circular actions; it is the value that gives a return on investments. In addition, companies intend to invest in CE as they seek better production efficiency, thus reducing waste, resulting in less waste to be treated. The three articles, in common, pointed out the need for a good operation strategy for companies to be competitive, and yes, the circular economy is one of them.

Another essential point of Article 2 is that the EC is conceivably dependent on the regulatory sector. And that usually the company is motivated to do something towards sustainability when its competitor does it before, or when suppliers or customers price it.

Regarding contributions, this thesis presents some. The field of knowledge in the academic literature on circular economy has expanded, including the quantitative research gap in the CE area. Also, the discussion on competitive criteria has started,

relating them to technical cycles. In other words, Articles 2 and 3 relate to competitive criteria with the possibility of value in companies that have a CE implemented. Another point works already discussed value and barriers in CE. However, the thesis presents a different value cycle. The main contribution of article 1 is the proposal for a structure of the circular business model that contributes to the theory of circular economy, considering the dynamics of the value flow between different stakeholders, from positive loop interactions, negative feedback. The thesis includes work with companies in Europe and Brazil, which made it possible to point out some of the weaknesses that it expects if it is resolved in the future. For example, CE is still in the embryonic stage in most of the companies contacted in developing countries (which led to difficulty finding companies in Brazil for respondents to the questionnaire). The main contribution of articles 2 and 3 was to find a relationship between value and competitive criteria for companies that implemented CE, which may provide more interest in the area for future researchers. As a contribution to practice, article 2 presents an algorithm for the analysis and strategic conversion of barriers into obstacles (Figure 3) and they are interrelated in the context of the CBM (Figure 2).

The study also has some limitations, one of which is the qualitative research that may have a possible bias from the interviewees when answering the questions, seeking politically correct answers. Triangulations were made to avoid this effect. Due to COVID19, most of the interviews, mainly those made in Brazil, took place online, not observing on the spot and the interviewee in his environment. Another point, the companies that participated in the research needed to have CE implemented and an interest in investing in this operation strategy, which limited the number of companies analysed (article 2). New research that discusses the same themes may be interesting for a sectorial or country-by-country basis, seeking to understand the influence of operating in Brazil or other countries.

PART 2 - Articles

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4 Article 1: Towards a value stream perspective of circular business models

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Abstract

Circular business models could minimise material input into and leakage out of the economic system and play an essential role in utilising the resources and capabilities of the private sector for the transition to more sustainable economic development. Despite the growing prominence of the Circular Business Model concept in research and practice, there is still considerable uncertainty on how to implement these new circular business models in existing global supply chains. Equivalent haziness also lies on the value streams it creates. To address this gap, a comprehensive literature review on “circular economy” and “business models” was conducted by employing content analysis with detailed code trees. The results led to several findings. First, we identified the key conceptual dimensions of circular business models, their theoretical approaches, drives and barriers, sustainability trade-offs amongst triple bottom-line perspectives and types, and value streams within circular business models
and their ecosystems. Then, we designed conceptual mind maps to analyse the relationships between categories, illustrating the positive and negative interactions between key stakeholders. Finally, we proposed a circular business model framework that brings the novelty of connecting value streams within circular business models and their ecosystems. It allows the assessment of the positive and negative interactions between the circular business model building blocks in a systematic way.

Keywords – circular economy, business model, framework, value flow, sustainability.

Status: Published at Resources, Conservation & Recycling

4.1 Introduction

The European Commission's Horizons2020 Project suggests promising figures for the implementation of the Circular Economy (CE), leveraging the region's GDP by up to 0.5% by 2030, in addition to the creation of 700 thousand new jobs (European Commission, 2020).

Therefore, new sustainable business models (SBM) are required (Evans et al., 2017). Circular business models (CBM) stand out as a better adjusted SBM operation strategy (Geissdoerfer, Morioka, Carvalho, & Evans, 2018), with a significant increase in efficiency for organizations in the consumption of resources, primarily based on appropriate regulation, investment in innovation and the development of appropriate business models, capable of generating and flowing value in the supply chain (European Commission, 2020).

Nevertheless, circularity brings more than inspiration, but also new challenges for facing this paradigm shift (Homrich., Galvão, Abadia. & Carvalho, 2018), with a room for multidisciplinary research in the coming decades to overcome the current understanding (Dentchev et al., 2018).

The leverage CE approaches for sustainable development on na organisational level demands a new understanding of value (Yang, Evans, Vladimirova, & Rana, 2017). Thus, academia should keep "a watchful eye on the 'bigger picture' whole-systems research" (Velenturf, Purnell, Tregent, Ferguson, & Holmes, 2018), reinforcing the dependency between a single organisation, a specific CBM, and its value network in a circular supply chain (Geissdoerfer, Morioka, Carvalho, & Evans, 2018).

The complex value interaction in CBM implies trade-offs that ascend as obstacles to CE's promotion, whose understanding of structural dynamics of the business ecosystem is prerogative to leverage the skills and resources of members of the value chain (Ünal, Urbinati, Chiaroni, & Manzini, 2019). Thus, a sharing of language and understanding between the different perspectives of goals and interests is required (Morioka and Carvalho, 2016).

There is a broadly agreeing by experts about the need for expanding the types of values to include more diverse values and metrics besides economic (Velenturf and Jopson, 2019). Besides, the current CE phase stagnates on low-value resource retention options (Reike et al., 2018). In this context, this study aims to address the challenges of implementing new circular business models in existing global supply chains and creating value streams. Even though these themes are of great interest to academia and practitioners, no comprehensive and logical connections have been explicitly investigated.

As CE studies have a macro to micro-level orientation (from the "big picture"), it seems opportune to understand how those elements, value, and their consequent synergies and trade-offs arise in CBM and cascade down in the business ecosystem. Therefore, the first research question is formulated: (RQ1) How are CBMs positioned in the business ecosystem, from an organisational perspective? It is possible to understand the interactions that create the basis for the value stream map by placing the distinct elements from an ecosystem perspective. Finally, it is fundamental to understand how value flows in CBM from a broader perspective, highlighting the positive and negative interactions that arise amongst the different players. From this value stream mapping, it is possible to direct efforts to maximise the synergies and develop mechanisms to encourage the necessary trade-offs. Thus, a second research question emerged: (RQ2) What are the main value streams within CBM?

For answering these RQs, a comprehensive literature review on "circular economy" and "business models" was conducted by employing content analysis with detailed code trees. The first step was to curate the main concepts and ideas in the literature that have implications for the development of CE, as a base to identify synergies and trade-offs, thus modelling potential value streams to allow CBMs design and development. Thus, it is essential to revisit the acquis on the theoretical development of the CE, considering the implications to position the elements motivating positive and negative interactions amongst the different players in potential value streams in the CBM business ecosystem.

This article is organised in five sections. Section 2 presents the research context, briefly discussing the concepts of a circular economy, a sustainable business model, and a circular business model. Section 3 presents the research design, encompassing

literature review, merging content analysis, and mind maps to show the value streams and tradeoffs. After that, Section 4 presents the research results and discussion. Finally, in Section 5, a discussion about the main findings, theoretical and practical implications, conclusions, and future research paths are presented.

4.2 Theoretical Background

4.2.1 Circular Economy Overview

Concerns about the disparity between economic growth and social equity date back a considerable time (Dyllick & Hockerts, 2002). Despite advances in empirical approaches over the past 30 years addressing the relationship between business performance and sustainable development (Hall & Wagner, 2012), there is a consensus that there is still a long way to go before organisations can do business in a “truly sustainable” manner (Buxel; Esenduran; & Griffin, 2015). Three main reasons have been pointed out: first, in the corporate world, sustainability is commonly equated with eco-efficiency, disregarding several other relevant aspects (Dyllick &Hockerts, 2002); second, even organisations that do think about implementing a more comprehensive sustainable model seem to emphasise isolated actions, such as recycling, without considering other possibilities (Ghisellini; Cialani; & Ulgiati, 2016); and third, organisations seem to try to shift the problem to others by focusing on process exchanges with suppliers, customers and competitors, moving it between players without solving the issue from a global perspective (Buxel; Esenduran; & Griffin, 2015).

Also, there are some difficulties for companies to measure circularity. Moraga et al. (2019) created a framework for categorizing the indicators used in the CE, subdividing them into strategic (reasoning on what); and the scope of measurement (how). The scope of measurement shows how the indicators consider technology cycles, with or without a Life Cycle Thinking approach; as well as their effects on the environmental, social or economic dimensions. Sassanelli et al. (2019) confirmed that circularity can be measured from different perspectives. For example, through guidelines that used to support product design and development, providing strategic guidance for redirecting the linear life cycle towards a circular one.

In this context, CE emerges as a new and vital field in the school of sustainable thought (Moreno, Rios, Rowe, & Charnley, 2016; Mura et al., 2018), being defined as: “a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops” (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). According to Kirchherr, Reike, and Hekkert, (2017) that analysed 114 definitions of circular economy in a literature review, CE definitions are mostly related to the combination of reduce, reuse and recycle activities.

Despite being a very recent field, CE has already received significant attention worldwide, emerging as an approach that could transform the current model of production, as well as a new paradigm of sustainability. The traditional paradigm, “cradle to grave”, considers impacts at each stage of the product lifecycle in an isolated linear business model (LBM), from extraction to final disposal. However, the new paradigm of sustainability, “cradle to cradle”, contemplates how much “the loop can be closed” in a circular model of production, in which materials at the end of a cycle, can return as “inputs” in the beginning of a new lifecycle (Glavič; & Lukman, 2007; Preston, 2012), considers impacts at each stage of the product lifecycle in an isolated linear business model (LBM), from extraction to final disposal. However, the new paradigm of sustainability, “cradle to cradle”, contemplates how much “the loop can be closed” in a circular model of production, in which materials at the end of a cycle, ideally, can return as “inputs” in the beginning of a new lifecycle (Glavič & Lukman, 2007; Preston, 2012). Other schools of thought of CE and their definitions were studied by Homrich., Galvão, Abadia. and Carvalho, (2018), for instance: Industrial ecology, Biomimicry, Laws of ecology, Performance economy, Blue economy, Regenerative design, Permaculture, Natural capitalism, Industrial metabolism, Industrial symbiosis and Eco parks.

Yet, CE is one such operation strategy (Jabbour, 2018), which has been increasingly seen as a solution to the various challenges of sustainability and a way of enabling the integration of economic benefits (Lieder & Rashid, 2016; Nerurkar, 2017; Witjes & Lozano, 2016). Therefore, its concept is accepted as an essential enabler for companies moving to circular practices (Nußholz, 2018). In manufacturing, the raw material is transformed into valuable goods through a sequence of processes that

effectively add value, as well as others that end up not adding (Thanki &Thakkar, 2016). Waste is inherent in the production and consumption processes in linear logic, implying leaks in the value stream, which hold potential for increased system efficiency, thus the essence of value stream management. Following this reasoning, almost all types of waste produced, either as part of the production process or at the end of consumption, could have their potential value recovered after recycling (Niu & Zhao, 2014). These transformations are substantially valuable from a financial and environmental standpoint (Chong-ting et al., 2009).

The restorative and cyclical nature of a CE can be achieved through innovations in various corporate activities that enable maintenance, repair, reuse, remanufacturing, remodelling, recycling, and long-term design. These emphasize the non-purely closed-loops alternatives to implement circular economy ideas. The implied benefits of which are increased life and material recovery, resulting in longer lifecycles, as part of a more hermetic system (Lieder and Rashid, 2016). However, it also requires a complex interaction and adaptation in the flow of value between the parties (Homrich, Galvão, Abadia. & Carvalho, 2018). In short, CE principles go beyond traditional waste management practices, but incorporate superior design and manufacturing practices, breaking with traditional linear thinking that incurs waste. It also seeks to recover resources resulting at the end of the product life cycle, which, ideally, return as inputs to create new products, becoming a pathway for companies seeking to maximize value stream (Niu & Zhao, 2014; Romero- Hernández & Romero, 2018). In fact, within the CE context, there is an ongoing search for methods to assess waste and value gains from reuse cycles throughout the enterprise (Sunk et al., 2017).

The value of a resource from the CE perspective is, therefore, determined by the level at which its re-entry impacts in terms of use of the original resource (Romero-Hernández & Romero, 2018). Despite the earning potential of the operation strategies, companies that invest in recycling or other cycles do not always generate profit. This would be because implementation is often aimed at enhancing the corporate image. Regardless, there would not necessarily be a loss, but a trade-off that needs to be analysed in a comprehensive view of the organisational value stream.

4.2.2 Business Models for Circular Economy

The acceptance and integration of sustainability into an organisation will have a significant impact on its manufacture strategies, operations and the way it does business, and through dynamic and intelligent solutions (Ríos; & Charnley, 2015; Dyllick; & Muff, 2015).

A profound change may be necessary in order to enable management (Diaz-Lopez, Carpio, Martin-Morales, & Zamorano, 2019) to be consistently in line with the operation strategy, in a systematic, coherent and continuous manner; that is, the company's business model (BM) may require further development (Schaltegger; Lüdeke-Freund; & Hansen, 2012) to be capable of exploiting values still uncaptured in the system (Yang, Evans, Vladimirova, & Rana, 2017), while at the same time dealing with the eventual tensions that arise between sustainability commitments and performance goals (Morioka; & Carvalho, 2016).

When referring to BMs, the academic literature often attributes "the company's logic" meaning to it; that is, how the company operates to create value. This may cause there to be some misunderstanding with how the operation strategy concept is understood because in many situations there is a vertical relationship between the operation strategy and the BM. It can be said, though, that BM is "a reflection of the firm's realised operation strategy" (Casadesus-Masanell; & Ricart, 2010).

Thus, the BMs describes the design or architecture of the mechanisms for creating, delivering and capturing value; that is, how the company operates the operation strategy, organising operations to generate profit from meeting the needs of its customers (Teece, 2010). Procedure, in turn, can be described as the "planning of which BM to adopt"; while tactics are "the competitive choices enabled by each business model" (Casadesus-Masanell; & Ricart, 2010). A SBM, thus, must take a long-term perspective and create sustainable value for, and in collaboration with, a broad range of stakeholders (Geissdoerfer, Savaget, Bocken, & Hultink, 2017).

Therefore, a CBM is an SBM operation strategy or subcategory that allows closing, intensifying, dematerialising, and narrowing of resource loops (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). However, CBM still has many challenges to

overcome, mainly due to the intricated and necessary interaction among the various players, with their respective perceptions of value arising from potentially conflicting objectives (Homrich, Galvão, Abadia. & Carvalho, 2018), which results in a complex value stream, perspective studied in this work.

Rosa, Sassanelli, & Terzi (2019) analysed the CBM business and their archetypes in more detail: (i) share actions: Co-ownership, Use-orientated PSSs, Reuse, Repair; (ii) optimize actions: Industrial Symbiosis, Product-orientated PSSs; (iii) loop actions: Refurbish / Remanufacture, Recycling; (iv) virtualize actions: Result-orientated PSSs, De-materialize; (v) regenerate actions: Renewable energies, Bio- / Secondary materials. Which provides great material for analysis and reference. Important to note that the main aspect of CBM concept is to “help to prolong lifetimes of products and parts through successive cycles of reuse, repair, remanufacturing and closing material loops” (Nußholz, 2018, p. 185). Extending product lifetimes by reversing product obsolescence is known as the Product Value model (Whalen, Milios, & Nussholz, 2017). However, there are different types of CBM, such as sharing platforms (Lacy et al., 2014; Rosa, Sassanelli, & Terzi, 2019); product as a service ((Lacy et al., 2014; Yang et al., 2018); loops (Nußholz, 2018; Rosa, Sassanelli, & Terzi 2019); circular supply chains (Angelis et al., 2018; Geissdoerfer, Morioka, Carvalho, & Evans, 2018; Yang et al., 2018); resource recovery (Lacy et al., 2014; Velenturf & Jopson, 2019); and product life extension (Lacy et al., 2014). The next sections bring further discussion on some of these aspects.

4.3 Research Design

To answer the research questions, a systematic literature review was conducted, using a structured keyword string-based database search, cross-reference snowballing (Wohlin, 2014) and content analysis (Duriau, Reger, Pfarrer, & Sources, 2007).

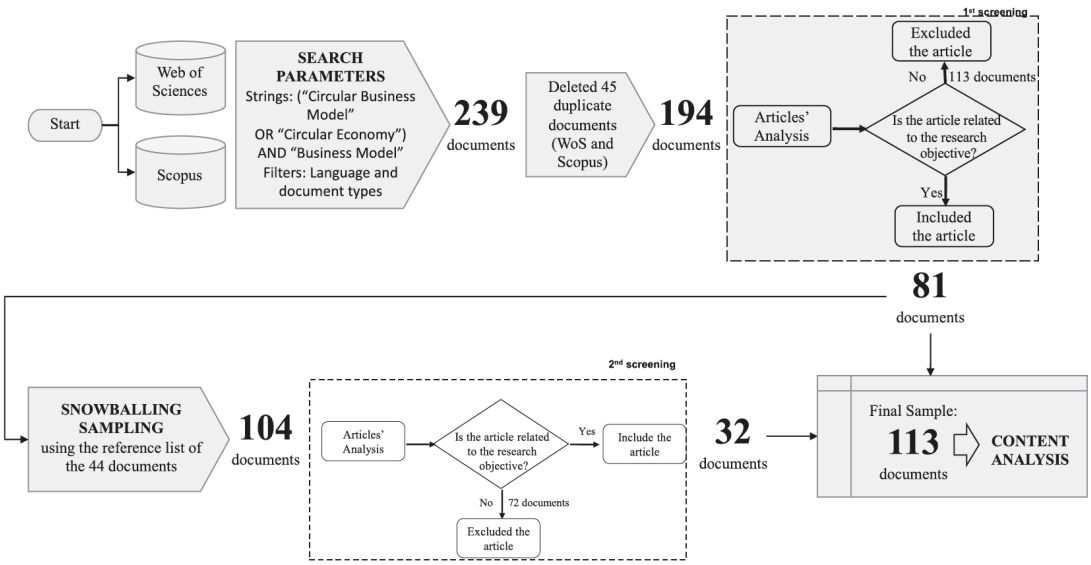
4.3.1 Sampling Procedures

Data were obtained from the scientific databases ISI Web of Science (WoS) and Elsevier Scopus, respectively due the search mechanism capable to reach all indexed journals with an impact factor in the Journal Citation Report (JCR) (Carvalho; Fleury; & Lopes, 2013) and do it is the most extensive database of peer-reviewed literature (Morioka & Carvalho, 2016).

Only two filters were applied: publications language (English) and document types, limited to “published articles”, “reviews” and “articles in press” in Scopus; and “articles” and “reviews” in WoS. Based on this search operation strategy, the initial sample was composed of 50 articles from the WoS database and 189 articles from Scopus. In the first screening, 45 duplicate documents were identified belonging to both database samples and eliminated. In the second screening, 113 other papers were also excluded by not being adequately related to the research subject, resulting in a sample of 44 documents.

Posteriorly, the snowballing technique was applied, which refers to using the reference list of a paper or the citations to the article to identify additional documents (Wohlin, 2014). Thus, an in-depth analysis was performed, resulting in other 104 documents for further investigation. After the screening of the snowballing sample, 72 papers were excluded, due to the lack of alignment with this research objective. Thus, the final sample was composed of 76 selected papers from high impact journals (Figure 1).

Figure 1 – Research Design



4.3.2 Data Analysis

The data analysis was qualitative and employed “narrative and more subjective methods to bring together the findings of the included studies and follow through questions” (Pare et al., 2015) aiming to outline significant approaches of the available

literature (Seuring; & Müller, 2008), including key concepts, identified barriers and constraints, needs, and practical and theoretical gaps.

The content analysis followed the guidelines suggested by Duriau, Reger, Pfarrer, and Sources (2007) and Mayring, (2014). The selected sample was organised, and the documents passed through the coding schema, first the analysis of content (frequency counts and cross-tabulations) and the interpretation of results (Duriau, Reger, Pfarrer, & Sources, 2007). The categories selected were “conceptual basis (concepts, terminology, paradigms)”, “objectives (what should be done)”, “drives (motivations, justifications, importance, benefits)”, “barriers (barriers, limitations, challenges)”, and “academic and practical implications (knowledge status quo)”.

A critical issue in applying content analysis is the identification of a set of relevant insights extracted from the studied sample (Mayring, 2014; Seuring; & Müller, 2008; Tranfield; Denyer; & Smart, 2003). For this purpose, qualitative visualisation methods were applied, combining two methods – a concept map and mind map, because reviewing is one of the typical application contexts and the combination of these “visualisation types can play to the strength of each one” (Eppler, 2006). The concept map shows the relationships between concepts, elucidating cross connections and their manifestations in a top-down reading direction (Novak; & Owin., 1984). The mind map has a centre-out perspective, with the primary domain in the centre and branches out to subtopics, in a creative manner that represents semantic or other connections in the comprised material (Buzan; & Buzan, 1995). While the conceptual diagram helps to introduce a new concept step by step iteratively and jointly, the mind map can be used for subsequent explanations and further elaborations (Eppler, 2006).

4.4 Results and Discussion

4.4.1 Identification, Classification, and Analysis of Principal Elements Found in Literature

After a scan and content analysis, a set of key ideas and approaches from the various documents was extracted. These highlights were then organised by topic similarity, resulting in a list of categories (basis for building the response to RQ1.

Table 1), basis for building the response to RQ1.

Table 1 – Categories Found in the Literature

Category	Addresses
(A) Conceptual basis (Concepts, terminology, paradigms)	A.11 A.1 Comparison between circular economy and sustainability (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Macarthur, 2013; Zhang et al., 2009); A.12 A.2 The concept of sustainability (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). A.13 A.3 Concept of the circular economy (Blomsma; & Brennan, 2017; Evans et al., 2017; (Geissdoerfer, Savaget, Bocken, & Hultink, 2017.; Murray; Skene; & Haynes, 2015; Scheepens; Vogtlander; Brezet, 2016; Witjes; Lozano, 2016); A.14 A.4 Addresses triple bottom-line issues and generation of value (Lieder and Rashid, 2016; Witjes and Lozano, 2016); A.15 A.5 Concept of green economy ((Rizzi, Bartolozzi, Borghini, & Frey, 2013); A.16 A.6 Classic “supplier-business-customer” model (Bocken, Short, Rana, & Evans, 2014; Buxel; Esenduran; & Griffin, 2015); A.17 A.7 Business model and operation strategy: concepts and differences (Casadesus-Masanell; Ricart, 2010; Teece, 2010); A.18 A.8 Sustainable business model; linear business model (Vargo; & Lusch, 2004); and circular business model (Evans et al., 2017; Glavič; Lukman, 2007; Linder & Williander, 2015; Preston, 2012); (Linder & Williander, 2015) A.19 A.9 “Cradle to grave” and “cradle to cradle” paradigms (Bocken, Short, Rana, & Evans, 2014., 2014; Buxel; Esenduran; & Griffin, 2015; Glavič; Lukman, 2007; Preston, 2012); A.20 A.10 Product service system (PSS) (Annarelli, Battistella, & Nonino, 2016; Evans et al., 2017; EMF, 2013a, b; Pialot, Millet, & Bisiaux, 2017; Scheepens, Vogtlander, & Brezet, 2016, Tukker, 2015).
(B) Objectives (What should be done)	B.17 B.1 A new economic model (EMF, 2013a; Gregson, Crang, Fuller, & Holmes, 2015); B.18 B.2 An integrative business model, incorporating the triple bottom line towards a true sustainability (Bocken, Short, Rana, & Evans, 2014; Buxel; Esenduran; Griffin, & 2015; Dyllick and Hockerts, 2002; Evans et al., 2017; Gauthier and Gilomen, 2015; Murray et al., 2017; Schaltegger; Lüdeke-Freund;

			& Hansen, 2012; Schoolman, Guest, Bush, & Bell, 2012; Schulte, 2013; Stubbs and Cocklin, 2008);
	B.19	B.3	A collective effort among stakeholders; stakeholders' inclusiveness (Bocken, Short, Rana, & Evans, 2014; Evans et al., 2017; Lieder; Rashid, 2016; Rizos et al., 2016; Schulte, 2013; van Buren, Demmers, van der Heijden, & Witlox, 2016; Witjes; Lozano, 2016);
	B.20	B.4	A profound change in the way of doing business (De Los Ríos; Charnley, 2015; Schaltegger; Lüdeke-Freund; Hansen, 2012; Schulte, 2013; Stubbs; Cocklin, 2008);
	B.21	B.5	To rethink business models (Bocken, Short, Rana, & Evans, 2014; Buxel; Esenduran; & Griffin, 2015; Hart; Dowell, 2011; Morris; Schindehutte; Allen, 2005; Schaltegger; Lüdeke-Freund; Hansen, 2012; Schulte, 2013; Stubbs; Cocklin, 2008);
	B.22	B.6	The objective of CE is "to maximize value at each point in a product's life (Stahel, 2016).
	B.23	B.7	To eliminate the disparities between discourses addressed to the company and planet point of view (Dyllick and Hockerts, 2002; Whiteman et al., 2013);
	B.24	B.8	New corporate strategies to support sustainability, adjust operation strategy to sustainability purpose (Hall; Wagner, 2012; Hart; Dowell, 2011; Olson, 2008; Schrader; Freimann; Seuring, 2012; Witjes; Lozano, 2016);
	B.25	B.9	Innovation in products, processes focusing on CE, with dynamic and intelligent solutions; radical and systemic innovation is needed to support CE (Antikainen; Valkokari, 2016; De Los Ríos; Charnley, 2015; Lieder; Rashid, 2016; Moreno, Rios, Rowe, & Charnley, 2016; Weissbrod; Bocken, 2016);
	B.26	B.10	Innovation fitting to the sustainable paradigm (Boons; Lüdeke-Freund, 2013);
	B.27	B.11	A proactive response from companies (Hart; Dowell, 2011);
	B.28	B.12	A need to address the social dimension properly (Christensen; Siemsen; Balasubramanian, 2014; De Los Ríos; Charnley, 2015; Gold; Hahn; Seuring, 2013; Lieder; Rashid, 2016; Murray; Skene; & Haynes, 2015; Tashman; Marano, 2009; Vachani; Smith, 2007);
	B.29	B.13	To include "sharing" as part of CE model (MONT, 2004);
	B.30	B.14	To adopt renewable technologies and materials (Ghisellini; Cialani; Ulgiati, 2016);
	B.31	B.15	To address consumer education (Ríos; Charnley, 2015);
	B.32	B.16	To develop human capital (Ríos; Charnley, 2015).
(C) Drives	C.8	C.1	An aspiration for a sustainable society; the importance of sustainability for the future of the planet (Adams, Jeanrenaud, Bessant, Denyer, & Overy, 2016;

(Motivations, justifications, importance, benefits)			Buxel; Esenduran; Griffin, & 2015; Dyllick and Hockerts, 2002; Gauthier and Gilomen, 2015; Marchi, Di Maria, & Micelli, 2013; Nations, 2016; Preston, 2012; Schaltegger et al., 2012; Schoolman, Guest, Bush, & Bell, 2012);
	C.9	C.2	The circular economy can provide material cost reduction (Linder & Williander, 2015);
	C.10	C.3	To assess the value that the company gives to society and the planet (Dyllick; Muff, 2015; Hall; Wagner, 2012).
	C.11	C.4	A significant share of the value added in the original manufacturing process is saved or preserved in the remanufacturing process (Linder & Williander, 2015);
	C.12	C.5	Remanufacturing minimizes the consumption decreasing the use of virgin materials and energy, and contributes to economic development and creation of high-skilled jobs (Sze; Low; NG, 2018);
	C.13	C.6	The value of CE in the broader debate around resource and waste is to create a set of “strategies to extend resource life as a means to facilitate additional value extraction and reduce value loss and destruction.” (Blomsma; & Brennan, 2017);
	C.14	C.7	One specific contribution of CE is its focus on the importance of high value and high quality in material cycles (Korhonen; Honkasalo; & Seppälä, 2018).
(D) Barriers (Barriers, limitations, challenges)	D.22	D.1	Disruptive nature of today’s sustainable initiatives (Gauthier; Gilomen, 2015); no fostering dissemination of sustainable solutions (Bocken, Short, Rana, & Evans, 2014; Boons; Lüdeke-Freund, 2013);
	D.23	D.2	Business models are difficult to observe (Gauthier; Gilomen, 2015);
	D.24	D.3	“Decreased status” of the economic perspective when implementing sustainable business models, difficult to justify them as advantageous in a business vision (Gauthier; Gilomen, 2015; Lieder; Rashid, 2016; Liu; Bai, 2014; Rizos et al., 2016);
	D.25	D.4	Sustainability is commonly equated with eco-efficiency (Dyllick and Hockerts, 2002; Ghisellini, Cialani, & Ulgiati, 2016);
	D.26	D.5	Organisations seem to try to shift the problem to others by focusing on process exchanges with suppliers, customers and competitors (Buxel; Esenduran; Griffin, & 2015);
	D.27	D.6	Sustainable innovations do not fit the logic of the dominant business models (Boons; Lüdeke-Freund, 2013; Hall; Wagner, 2012; Schaltegger; Lüdeke-Freund; Hansen, 2012);
	D.28	D.7	Lack of incentives to develop new sustainable materials (Preston, 2012);
	D.29	D.8	International cooperation to implement CE (Preston, 2012);

	D.30 D.9 Decisions addressing CE should be intercompany (Lieder; Rashid, 2016); D.31 D.10 Lack of incentive to adopt CE (Schulte, 2013); Lack of support from public actors (Zhang et al., 2009); D.32 D.11 A long-term system change or transition is required to implement CE (Schulte, 2013; van Buren, Demmers, van der Heijden, & Witlox, 2016,); D.33 D.12 The diffusion and adoption of sustainable solutions are minor compared to the overall needs (Gauthier; Gilomen, 2015); D.34 D.13 Lack of financial resources and technical skills for small business in adopting CE (Rizos et al., 2016; Zhu, Qu, Geng, & Fujita, 2017); D.35 D.14 Transformation of both production and consumption systems on a large scale (De Los Ríos; Charnley, 2015; Hazen; Mollenkopf; Wang, 2017; Vargo; & Lusch, 2004); CE development depends upon deeper understanding of consumers' attitudes and behaviours (Hazen; Mollenkopf; Wang, 2017); D.36 D.15 Difficult to change the linear business model to a circular model (Schulte, 2013); D.37 D.16 Research about innovation in sustainable business models is insufficient (Boons; Lüdeke-Freund, 2013; Linder & Williander, 2015); D.38 D.17 Little empirical research in developing the circular economy (Liu; Bai, 2014; Murray; Skene; & Haynes, 2015). D.39 D.18 The supply chain is concerned only with delivering a product to a consumer without regard after end of its life (Hazen; Mollenkopf; Wang, 2017).
(E) Academic and practical implications (Knowledge status quo)	E.5 E.1 Growing trend of academic research (sustainability and circular economy) (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Glavič; Lukman, 2007; Moreno, Rios, Rowe, & Charnley, 2016; Schoolman, Guest, Bush, & Bell, 2012); E.6 E.2 Growing interest in practical application (Rashid et al. 2013); E.7 E.3 Growing interest in sustainable business models (Bocken, Short, Rana, & Evans, 2014; Boons; Lüdeke-Freund, 2013; Roome; Louche, 2016). E.8 E.4 There are academic efforts to conceptually link circular business models and environmental value creation (Manninen et al., 2018).

In order to better understand the research results, Table 2 presents the research questions and the respective findings. Five categories were identified after reviewing the selected documents, and these are presented in basis for building the response to RQ1.

Table 1. The first category, “conceptual basis”, encompasses definitions and terminologies found in the selected sample of articles, providing the basis for the conceptual relationships developed in this work. The second category, "objectives", groups the development needs pointed out in the documents studied, which must be addressed by organisations, governments, and communities, to achieve a truly sustainable business model. The third category, “drives”, indicates the presence of contributing factors to the theme, which can offer opportunities if properly managed. The fourth category, “barriers”, contemplates the elements that represent negative forces for the development of sustainable business models, which must be managed to reduce the risks inherent to the implementation of sustainable business models. Finally, the fifth category, “academic and practical interest”, highlights the status quo of practical and theoretical knowledge, as suggested by the respective authors.

The analysis of the elements captured within the category “conceptual basis”, reveals the researchers' concern in distinguishing between the classic concepts and paradigms associated with sustainability and SBMs, confronting them with the conceptual framework that guides the CE ideals (Blomsma; & Brennan, 2017; Evans et al., 2017; Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Glavič; & Lukman, 2007; Linder; & Williander, 2015; Macarthur, 2013; Murray; Skene; & Haynes, 2015; Preston, 2012; Scheepens; Vogtlander; & Brezet, 2016; Witjes; & Lozano, 2016; Zhang et al., 2009). A holistic and integrative perspective of the elements identified in this category suggests, therefore, the search for the creation of a unified knowledge base and ordinary language, corroborating with part of the motivational theoretical gap of this work, also observed by Geissdoerfer, Savaget, Bocken, and Hultink, (2017). In addition, some schools of thought are addressed in this category, such as the concept of green economy ((Rizzi, Bartolozzi, Borghini, & Frey, 2013); cradle to cradle” paradigms (Bocken, Short, Rana, & Evans, 2014; Buxel; Esenduran; & Griffin, 2015; Glavič & Lukman, 2007; Preston, 2012) and; product service system (PSS) (Annarelli, Battistella, & Nonino, 2016; Evans et al., 2017; Pialot, Millet, & Bisiaux, 2017; Scheepens, Vogtlander, & Brezet, 2016; Tukker, 2015). Strategies for generating value through sustainable and circular actions are constant concerns in the articles (Evans et al., 2017; Glavič & Lukman, 2007; Linder & Williander, 2017; Preston, 2012). Also point out the conceptual differences between operation strategy and Business model (Casadesus- Masanell & Ricart, 2010; Teece, 2010), this is because it must be clarified

that the business model is a method for enterprises to achieve their strategic goals (Zhang et al., 2019).

The second category, “objectives”, seems centred on the need to integrate the various actors to allow the closure of the loops that support the CBM (Bocken, Short, Rana, & Evans, 2014; Evans et al., 2017; Lieder; & Rashid, 2016; Rizos et al., 2016; Schulte, 2013; van Buren, Demmers, van der Heijden, & Witlox, 2016; Witjes; & Lozano, 2016) and adequately implementing CE (Gregson, Crang, Fuller, & Holmes, 2015; Macarthur, 2015). Still, as an objective, the development of new business models, capable of creating value while being effectively sustainable, is highlighted (Korhonen; Honkasalo; & Seppälä, 2018; Linder & Williander, 2015). This category also reveals the insipidity of the integration of the social dimension, which seems to be the most backward to achieve CE objectives (Christensen; Siemsen; & Balasubramanian, 2014; Ríos; & Charnley, 2015; Gold; Hahn; & Seuring, 2013; Lieder; & Rashid, 2016; Murray; Skene; & Haynes, 2015; Tashman; & Marano, 2009; Vachani; & Smith, 2007). As a background, several elements begin to outline several challenges for the implementation of this model, as discussed below.

The category “drives” reinforces the importance of CE for the planet (Adams, Jeanrenaud, Bessant, Denyer, & Overy, 2016; Buxel; Esenduran; Griffin, & 2015; Dyllick & Hockerts, 2002; Gauthier & Gilomen, 2015; Marchi, Di Maria, & Micelli, 2013; Nations, 2016; Preston, 2012; Schaltegger; Lüdeke-Freund; & Hansen, 2012; Schoolman, Guest, Bush, & Bell, 2012). Concerns about how to provide material cost reduction are also present in this category (Linder & Williander, 2017). In these situations, some suggestions are provided, for example, remanufacturing that can decrease the use of virgin materials and energy (Sze, Low, & Ng, 2018). One specific contribution of CE is its focus on the importance of high value and high quality in material cycles (Korhonen, Honkasalo, & Seppälä, 2018). In addition, it suggests the concern of some studies in highlighting the benefits that can be extracted from CBM, by revealing values not perceived by traditional business models (Dyllick; & Muff, 2015; Hall; & Wagner, 2012; Korhonen; Honkasalo; & Seppälä, 2018; Linder & Williander, 2015; Sze; Low; & Ng, 2018).

In the fourth category, “barriers”, there are 8 types of problems that must be addressed in the implementation and diffusion of CE: (i) there is a disruptive nature in

sustainable initiatives (Gauthier; & Gilomen, 2015), where problems seem to be transferred from one player to another (Buxel; Esenduran; Griffin, & 2015; Hazen; Mollenkopf; & Wang, 2017), suggesting the need to integrate the various players (Lieder; & Rashid, 2016) on international basis (Preston, 2012); (ii) there is evident lack of conceptual understanding (Dyllick & Hockerts, 2002; Ghisellini, Cialani, & Ulgiati, 2016), corroborating with the findings discussed in the first category; (iii) conflicting interests (Gauthier; & Gilomen, 2015), whose service demands an apparent sacrifice of the economic dimension (Gauthier; & Gilomen, 2015; Lieder; & Rashid, 2016; Liu; & Bai, 2014; Rizos et al., 2016; Zhu, Qu, Geng, & Fujita, 2017); (iv) different business logic, demanding changes and adaptation of different players, such as consumers, production systems, etc. (Ríos; & Charnley, 2015; Hazen; Mollenkopf; & Wang, 2017; Schulte, 2013; van Buren, Demmers, van der Heijden, & Witlox, 2016; Vargo; & Lusch, 2004); (v) need for a business model capable of accommodating the distinct features of this new logic (Boons; & Lüdeke-Freund, 2013; Hall; & Wagner, 2012; Linder & Williander, 2015; Schaltegger; Lüdeke-Freund; & Hansen, 2012); (vi) lack empirical research, focusing on practical needs (Liu; & Bai, 2014; Murray; Skene; & Haynes, 2015); (vii) lack of sustainable innovation that fit the new business logic (Boons; Lüdeke-Freund, 2013; Hall; Wagner, 2012; Preston, 2012; Schaltegger; Lüdeke-Freund; & Hansen, 2012); and (viii) lack of governmental incentives and policies capable of accommodating losses during the adaptation process (Schulte, 2013; Zhang et al., 2009).

The fifth and last category identified, “academic and practical interest”, suggests a growing interest in sustainability and CE subjects, both theoretical (Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Glavič; & Lukman, 2007; Moreno, Rios, Rowe, & Charnley, 2016; Schoolman, Guest, Bush, & Bell, 2012) and practical (Rashid et al. 2013), as well as in SBM development (Bocken, Short, Rana, & Evans, 2014; Boons; L& üdeke-Freund, 2013; Roome; & Louche, 2016). Also, there is a growing interest in research that seeks ways of generating value through these business models (Manninen et al., 2018).

The codes in Table 1 were obtained through triangulation between bibliometrics, particularly the most cited keywords, and content analysis. The network of keywords (Appendix 2) represents the most discussed topics in the surveyed articles, where it is

possible to confirm the importance of the categories that emerged from the content analysis. A group of articles discuss strategies for the transition from linear to circular economy. Another group is more focused on barriers, opportunities and challenges for sustainability as example barriers to a bioeconomy (Reim et al., 2019). There are even articles that discuss more directly business models and frameworks to implement them and thus preserve resources for the future. Finally, another cluster deals more with increasing circularity / sustainability, in this group of articles words like waste, waste handling, recovery, recycling, LCA, consumption and energy, are central.

The framework represented in Figure 2 summarises the categorisation and ramifications of the main conceptual approaches, objectives, barriers, drives, and academic and practical interests identified in the sample studied. In addition, the suggested framework provides the interconnections between the main aspects addressed in each category, revealing 8 clusters that allow a new way of synthesising the status quo on CE literature: (i) Theoretical Knowledge; (ii) Empirical Research; (iii) CBM; (iv) Value Creation; (v) Major Guidelines; (vi) Integration & Conflicts; (vii) Innovation; and (viii) Public Policy.

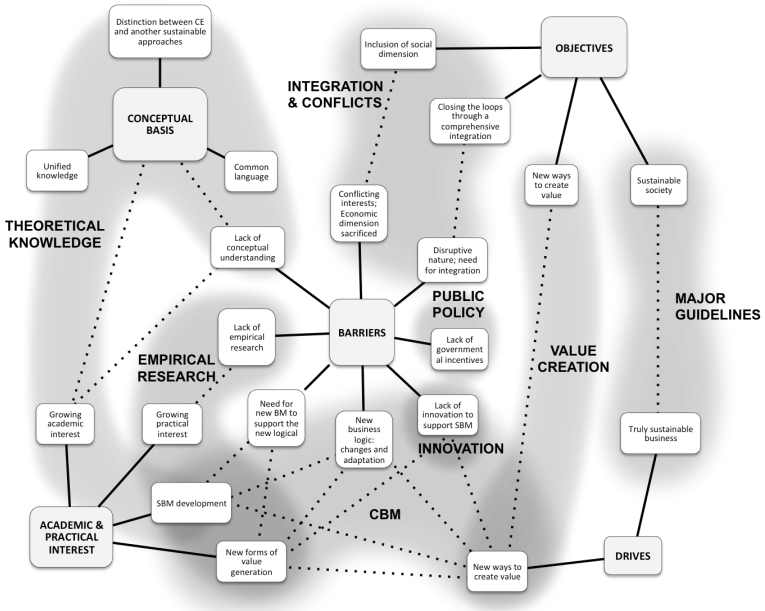
The clusters arise following the logic that transcribes the natural order of occurrences. The "Major Guidelines" cluster expresses the main need that motivates the development of CE, by the search for an effective sustainable society (Buxel; Esenduran; & Griffin, 2015). For this to happen, there is a need to integrate the various players (Lieder; Rashid, 2016), in order to close the loops that underpin CE (Bocken, Short, Rana, & Evans, 2014; Evans et al., 2017; Lieder; & Rashid, 2016; Rizos et al., 2016; Schulte, 2013; van Buren, Demmers, van der Heijden, & Witlox, 2016; Witjes; & Lozano, 2016). The integration, however, exposes conflicting interests, in many cases representing a compromise of the financial dimension (Gauthier; & Gilomen, 2015; Lieder; & Rashid, 2016; Liu; & Bai, 2014; Rizos et al., 2016; Zhu, Qu, Geng, & Fujita, 2017) (cluster "Integration and Conflicts"). There is, thus, a need to identify new ways of generating value (Korhonen; Honkasalo; & Seppälä, 2018; Linder & Williander, 2015), not only as an objective but as a drive (cluster "Value Creation"). The generation of value in this context demands the creation of new business models ("CBM" cluster) (Schaltegger; Lüdeke-Freund; Hansen, 2012), supported by sustainable technologies (cluster “Innovation”) (Boons; Lüdeke-Freund, 2013; Hall; Wagner, 2012; Preston,

2012; Schaltegger; Lüdeke-Freund; Hansen, 2012). However, this practical need requires empirical research (cluster "Empirical Research") (Liu; Bai, 2014; Murray; Skene; & Haynes, 2015) and theoretical support (cluster "Theoretical Knowledge") (Geissdoerfer, Savaget, Bocken, & Hultink, 2017).

A look at the intersections between clusters reveals that value generation depends on the development of CBMs (Schaltegger; Lüdeke-Freund; Hansen, 2012). The latter, in turn, reinforce the need for practice-oriented and theoretical research support (Liu; Bai, 2014; Murray; Skene; & Haynes, 2015), as well the development of new technologies for generate value in a sustainable way (Boons; Lüdeke-Freund, 2013; Hall; Wagner, 2012; Preston, 2012; Schaltegger; Lüdeke-Freund; Hansen, 2012). New forms of generating value in the circular context (supported by research and new technologies) becomes the crux of CE's launch (Manninen et al., 2018; Schaltegger; Lüdeke-Freund; Hansen, 2012; Yang, Evans, Vladimirova, & Rana, 2017). The proposed framework positions CBM development as a critical point to the implementation and diffusion of CE, corroborating with Evan et al. (2017) and Geissdoerfer, Savaget, Bocken, and Hultink, (2017)

In the sample studied, the participation of public actors appears in the framework only as a barrier, revealing precisely the lack of government support for CE, a problem already identified by Schulte (2013) and Zhang et al. (2009). In this way, the “Public Policy” cluster appears without connections to other clusters.

Figure 2 – Categorisation Framework and Clusters Identification



Indeed, government support in the form of incentives and regulations would act as a catalyst for CE development, fostering the necessary trade-offs and mediation required by many areas of conflict of interest, as the implementation of a CE requires a long-term transition, with deep and large-scale changes in existing production and consumption systems (Ríos; Charnley, 2015; Schulte, 2013; van Buren, Demmers, van der Heijden, & Witlox, 2016), a transformation that is hardly possible without the direct participation of governments. The challenges increase significantly as the issue of sustainability does not appear to be a priority (Gauthier; & Gilomen, 2015). For this purpose, it is essential that an international network of cooperation addresses the issues of the dissemination and implementation of a CE culture (“Integration & Conflict” cluster), going beyond a few isolated government initiatives, as seen today (Preston, 2012). To elaborate Fig. 2, a word / phrase tree was first created in NVivo software, together with the content analysis of the articles, this allowed to draw the figure with categorization and ramifications.

More than removing obstacles, it is necessary that public actors develop programmes to encourage the implementation of a CE, still currently the exception (Schulte, 2013; Ünal & Shao, 2019). In other words, "to deliver such a circular economy, the government needs to collaborate with partners across society" (Velenturf, Purnell, Tregent, Ferguson, & Holmes, 2018, p. 20). As the basis of a circular economy is the creation of a network of organisations recycling materials, is

also urgent to develop channels to foster relevant intercompany communication (Lieder; Rashid, 2016).

As the first step in building the response to RQ1, it was possible to identify, classify (basis for building the response to RQ1.

Table 1) and correlate (

Figure 2) the main elements in the literature, which represent conceptual basis, objectives, drives, barriers, as well as the theoretical and practical implications for CE development. The interrelation of the identified and categorised elements allowed the development of a framework, revealing clusters that highlights the importance of CBM, suggesting that it is the engine that would drive CE, which has the generation of value as fuel and government policies as a starter to overcome inertia caused by the resistance stemming from the complexity of integration and conflicting interests.

4.4.2 CBM in the Business Ecosystem

Linder and Williander (2017, p. 2) define CBM as “a business model in which the conceptual logic for value creation is based on using the economic value retained in products after use in the production of new offerings”, that is, products can be more valuable economic and environmental as they are preserved as long as possible (Hofmann, 2019). Irrespective of the isolated view of the aspects that concern the circular economy to CBMs, it is fundamental to understand the functioning of these mechanisms in a market context, as one of the central points is precisely the integration between the different players (Bocken, Short, Rana, & Evans, 2014; Buxel; Esenduran; Griffin, & 2015; Dyllick & Hockerts, 2002; Evans et al., 2017; Gauthier & Gilomen, 2015; Murray et al., 2017; Schaltegger; Lüdeke-Freund; & Hansen, 2012; Schoolman, Guest, Bush, & Bell, 2012; Schulte, 2013; Stubbs & Cocklin, 2008). While integration may reveal conflicts of interest, synergistic effects of collaboration may arise from interactions between the parties in the business ecosystem and can be exploited by new appropriate strategies (Kapoor, 2013). Moore (1993), for example, has long argued that gaining real benefits from sustainability is only possible through an innovative approach to how to compete.

However, the traditional model is still in vogue and organisations need to understand how to migrate securely to the business ecosystem context without feeling threatened. Besides, the success of a operation strategy depends on how healthy the ecosystem of which it is a part (Iansiti; Levien, 2004). An important step is to understand the operation of CBM as part of a business ecosystem. To do so, this topic is guided by RQ2: how are CBMs positioned in the business ecosystem, from an organisational perspective?

The semantic analysis reveals that the definition of CE suggests a means to the objective of sustainability; that is, by itself, alludes to the idea of operation strategy. However, a operation strategy is also the plan that indicates the business model to be adopted (Casadesus-Masanell; Ricart, 2010), while a business model describes the design through which the company creates, deliveries and captures value; that is, how the company operates the operation strategy (Teece, 2010). Consequently, a circular business model is the way to operationalize a circular economy operation strategy.

Although the literature indicates that sustainability can be considered as a strategic opportunity, its incorporation in a traditional business perspective still does not occur. Thus, organisations have to adjust their strategies and processes to achieve sustainable objectives (Schrader; Freimann; Seuring, 2012). It is essential that an organisation be structured in a way that is aligned with its strategic purposes (Mintzberg, 2007). Establishing a clear strategic vision, which includes the “green operation strategy”, is the way to coherently align corporate decisions to sustainable precepts (Olson, 2008). In the search for a sustainable society, it is expected that the organisation absorbs and incorporates the principles of sustainability into the drives of operation strategy, namely, vision, mission and values, and not only addresses isolated initiatives related to operational efficiency, which, though fundamental, are

not sufficient, as they do not necessarily support the long-term position of the company.

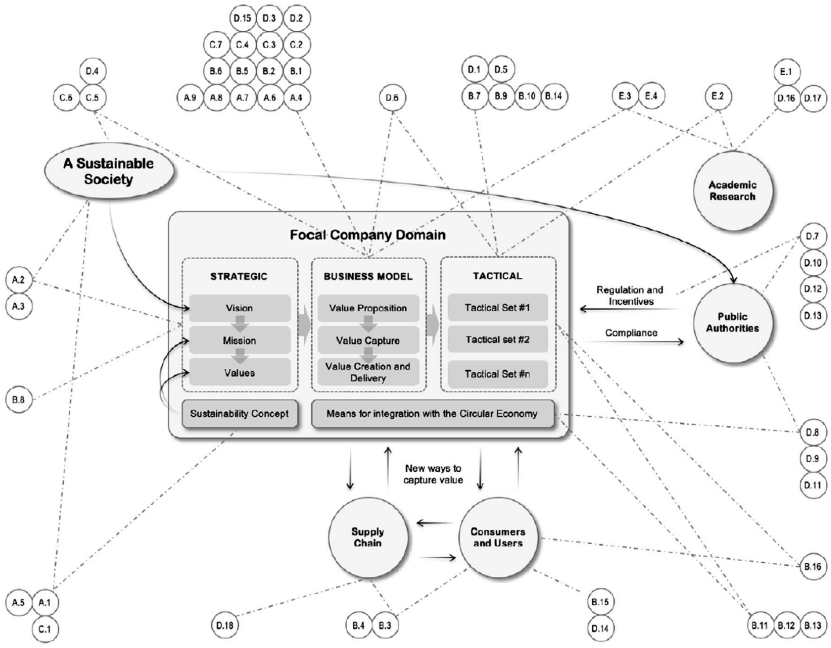


Figure 3 – CBM in a Business Ecosystem

Tactics are the competitive choices within the business model (Casadesus-Masanell; Ricart, 2010). In the circular business model, they should allow profit to be realised within the cyclical activities, considering that value is generated based on the efficiency of the material loops (Glavič; Lukman, 2007; Linder & Williander, 2015; Preston, 2012). Ultimately, tactics would be the strategic expressions for value capture in interaction with other players in the ecosystem. In the case of CBM, therefore, tactics must allow new forms of value capture, still unexplored (Yang, Evans, Vladimirova, & Rana, 2017). Still, in this context, the whole product and its service lifecycle and the material/energy loops must be analysed and properly oriented, by means of broadening the organisation's perception of its own field of activity.

The conceptual basis (Figure 3) shows the relationships between the "boxes" arranged in

3. Objectives, drives and barriers should be allocated in the appropriate area for proper treatment. Opportunities and risks must be managed, and needs must be addressed towards creating a truly sustainable business model. Besides, the elements intrinsic to an organisation should be separated from those which are external, such

as those related to public authorities, as discussed above. Consequently, companies should be prepared to commit to the regulation of public administration.

Based on these considerations, Figure 3 represents the deployment of the strategic vision, mission, and values to the necessary tactical deployment to promote the integration within a circular business model perspective.

The circles on the periphery of Fig. 3 incorporate circumscribed codes that establish the semantic relationship between the CBM model in Business Ecosystem represented with the items categorized in Table 1. As expected, category A and B items (Concepts and Drives) focus on the left half of the model, where the most abstract variables are represented, such as the society's vision and transcription of the organization's strategic package. Gradually, as you move to the right of the figure, barriers to realization emerge on a more material plane. Category B (objectives) appears more diffusely throughout the model. The schematic representation also reveals a significant concentration of items directly related to the structuring of the business model in the CE context, suggesting the relevance of CBM development, including with the support of the academy. The translation of value capture through tactical actions is also highlighted in the proposed model. This central part of the figure includes the elements for converting high level values into tangible results.

A semantic analysis of the concept of sustainability offers a clear picture about what is expected for now and for the future: “The balanced integration of economic performance, social inclusiveness, and environmental resilience, to the benefit of current and future generations” (Geissdoerfer, Savaget, Bocken, & Hultink, 2017).an idea that should be considered as part of the organisational mission.

Category D (Barriers) is diluted throughout the model, suggesting great diversity in the nature of the obstacles to be overcome, thus reinforcing the complexity of effective CE implementation. In this respect, the importance of public authorities for the CE is also emerging. Still in terms of importance, the academy presents a higher concentration of category E items (implications), suggesting that the applied theoretical development is the means to achieve the ends.

However, from a business ecosystem point of view, the organisation has an organic, environmentally adaptable feature (Kapoor, 2013). In this way, the corporate operation strategy and the various elements that structure it must allow the adequate flow of value with the medium. In this case, nominally with the supply network, with the consumption structure (customers) and with the political sphere.

The supply chain is expected to transcend the current status of the relationship with the organisations and to follow the life of its products to the end, as well as the consumers are expected to adapt to the new way of doing business, being able to value by a new perspective, which is not limited to the newly manufactured product. The integrative nature of the CE demands this adaptation on a large scale (Ríos; Charnley, 2015; Hazen; Mollenkopf; Wang, 2017; Vargo; & Lusch, 2004).

Innovation also has an essential role in a sustainable business ecosystem (Adams, Jeanrenaud, Bessant, Denyer, & Overy, 2016; Pieroni, McAloone,& Pigosso, 2019). In fact, of new technology must be in CBM (Rosa, Sassanelli, & Terzi., 2019), in addition to development of new technologies that give robustness to CE loops, innovative organisations also depend on the success of others innovating as part of the same ecosystem, reinforcing that the integrative nature promotes positive rather than negative interactions (Adner; & Kapoor, 2010).

On the other hand, there are several negative interactions, caused by conflicting interests as part of an integration of this magnitude. At this point lies the importance of the governmental structures discussed earlier, capable of stimulating change, which seems not to be feasible spontaneously, considering the complexity and diverse faces of the theme (Morioka; & Carvalho, 2016). Despite the evident importance of the role of government policies in resolving possible resistance, Cusumano, Kahl, & Suarez (2008) argue that many of the difficulties can be overcome by strategic alliances between players of a business ecosystem. In this sense, the discussion about how value flows in CBM becomes fundamental.

The positioning of these elements in Figure 3 responds to RQ1 as it presents the fundamental interactions between the various components, providing a strategic perspective. Also, the framework shown in Figure 4 provides the conditions to create the value stream map, to be addressed by RQ2.

4.4.3 4.Value Streams Across Circular Business Models

Once understood as the parts are positioned and interrelated, the next step is to identify how value flows through these relationships. To this end, this subsection aims to respond to RQ2: what are the main value streams within CBM?

In contrast to LBM, CBM's logic for value creation is based on the value being retained in products at the end of their useful life. The essence of CE involves a profound change in an organisation's operation and value creation (Ríos & Charnley, 2015). The company recognises the economic value inherent in the discarded products, incorporating them into the production chain. The higher the circular flow, the higher the income results (Cohen, 1996). According to Glavič and Lukman (2007), Linder and Williander (2017), and Preston (2012), the value comes from maximizing the life of the material, thus, as new forms of value capture (Yang, Evans, Vladimirova, & Rana, 2017).

The major challenge for sustainable business models in general, including the circular one, is economic viability. Research, so far, has been undertaken mainly in the search for solutions to the generation of residues, the use of natural resources and the environmental impact, to the detriment of economic and financial perspectives. Neglecting these aspects represents a significant barrier to the implementation of a CE since there is little in the way of discussion to show advantages from an organisational point of view (Lieder & Rashid, 2016), which at different points in the ecosystem emerges as negative interaction.

There are some definite ways of increasing productivity through a CBM (Linder & Williander, 2017). There is an expectation of significant reductions in the cost of acquiring materials through recycling and remanufacturing, for example (Linder & Williander, 2017). But the diagram representing the CBM (Fig. 4) suggests that there is a long way to go until it is possible for companies to achieve the same levels of financial performance achieved through the LBM. In the latter, the direct relationship between consumption and result is evident. In CBM, however, relationships are more complicated.

The first step towards adopting a genuinely sustainable model is to consider the three dimensions that are part of the concept, namely the triple bottom line (Hussain Rigoni, & Orij, 2018). Of the three dimensions that construct the idea of sustainability, environmental, economic and social, the last one still seems to receive less attention (Murray, Skene, & Haynes, 2017). On the other hand, when the social dimension receives right attention, the environmental aspect is neglected (Gold Hahn; & Seuring, 2013).

The decentralisation of the productive process and the empowerment of the local community certainly entail costs. In Figure 4, the cost of social development has a negative impact on the economic dimension, represented by vector NI13. The inclusion of the local community in the supply chain can also negatively impact the traditional suppliers, represented by vector NI14. But social development also brings benefits, such as reducing the cost of logistics (PI5) and consequently reducing emissions and environmental impact, as well as increasing productivity through the development of human capital (PI21) (D'Amato, Veijonaho, & Toppinen, 2018; Ríos & Charnley, 2015).

In addition, there is the economic gain inherent in image and reputation (PI10) (Dyllick & Muff, 2015). In fact, companies that invest voluntarily in social development gain a competitive advantage in the form of image appreciation (Hall & Wagner, 2012). Therefore, while these strategies increase costs, reinventing distribution channels can bring immediate benefits, as well as bringing long-term prospects (Vachani & Smith, 2007).

Conceptually, CE refers to a regenerative system that reduces emissions and losses by maximising materials, increasing the useful life of the products and reusing them at the end (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). In a first analysis, the focus seems to fall on the environmental dimension, including being an object of criticism of some authors. However, tacitly, there is the recognition of the economic value of the product at the end of its life (Glavič & Lukman, 2007; Linder & Williander, 2017; Preston, 2012). Therefore, somehow contemplating the economic dimension, just as it requires social engagement to close the cycle, specifically in the stages that follow after leaving the manufacturing company. The restorative and cyclical nature of CE can be achieved through loops of materials in different steps, such as recycling

(raw material), remanufacturing non-functional' products (or sub-products), and reusing those that are still functional (Jabbour, 2018; Lieder & Rashid, 2016).

Loops impact the dimensions of sustainability differently. The activity of recycling, for example, requires investments (NI_{10}) but allows the reduction of the cost of virgin raw material (PI_{13}). It also has a positive impact on the environment (PI_8) and the corporate image (PI_{11}). Remanufacturing or reforming competes with new products with higher added value. Therefore, these activities negatively impact the economic dimension (NI_{11}) but contribute to reputation (PI_{12}) and the environment (PI_7). Reuse or sharing reduces the demand for new products, therefore, positively impacting the environmental dimension (PI_6) and negatively impacting corporate results (NI_{12}). There is still no evidence to support an affirmation that there is value creation for the company, which is significant when there is reuse or the sharing of products, besides the recognition of the quality of a product itself. Sharing is an economic modality that has garnered considerable attention recently (Grinevich Huber, Karataş-Özkan, & Yavuz, 2019) but still has limited penetration in society (Mont, 2004).

However, for loops to occur efficiently, community participation is required. Consumer education becomes fundamental in all cycles: recycling (PI_{16}), remanufacturing (PI_{20}) and reuse (PI_{15}). Companies, therefore, should invest in education (NI13) to make CBM viable (Ríos and Charnley, 2015; Lüdeke-Freund, Gold, & Bocken, 2019). The paradox lies in the fact that companies invest in consumer education so that, at the end of the day, consumers buy fewer new products. If companies view this action from a LBM perspective, they will perceive it as a non-logic operation strategy, regarding the business endurance. That is why CBM has developed a new way of thinking about business. The challenge is to generate value in the loops, which demands investment and research in the innovation of products, processes and corporate strategies. From the CE perspective, emphasising success depends on an integrated and holistic vision and not just on innovation (Hall and Wagner, 2012). The action of government policies, as discussed above, should act precisely on these ambiguous or conflicting issues.

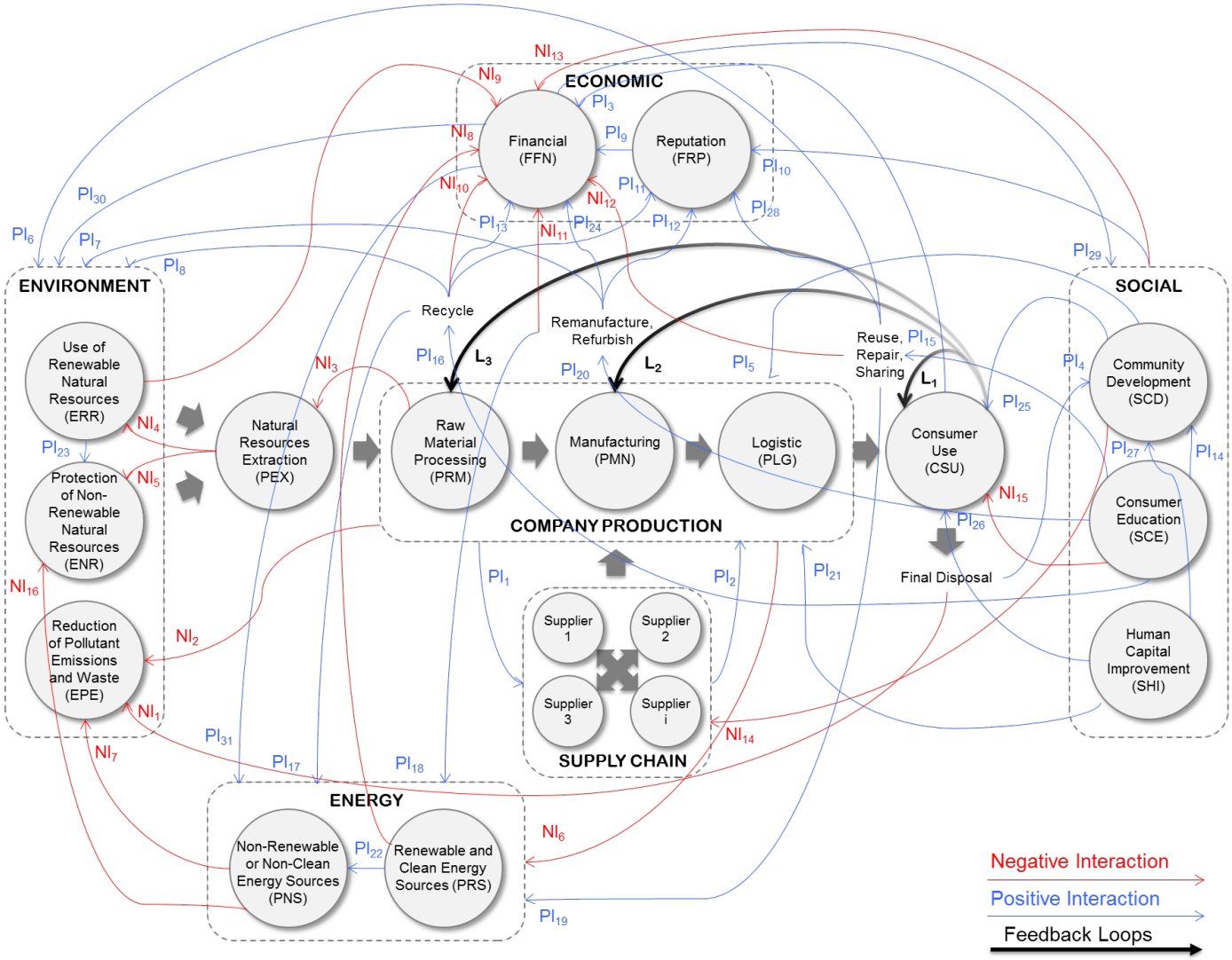
When innovating, the company must analyse the impact on the whole system and not only on isolated parts, as happens in the dominant model of business. On the contrary, innovations in the new sustainability paradigm should not fit the logic of the

LBM (Dentchev et al., 2018; Schaltegger; Lüdeke-Freund; & Hansen, 2012). Therefore, sustainable innovation must be radical and innovative to support the transformation of the business model (Antikainen & Valkokari, 2016; Diaz-Lopez, Carpio, Martin-Morales, & Zamorano, 2019; Witjes & Lozano, 2016). There is still a gap between sustainable business models and innovations, which merits researchers' attention. This is one of the main barriers to CBM implementation identified in this study (Boons & Lüdeke-Freund, 2013).

With the right incentives, sustainable materials will be developed to strengthen the loops in Figure 4, especially the L_3 (Preston, 2012). Innovation in design also becomes critical to resource optimisation (Ríos & Charnley, 2015; Vence & Pereira, 2019). Innovative designs, in addition to allowing the use of less material' (L_3), enable the reuse of parts (L_3) and higher efficiency in remanufacturing and repair (L_2), increasing the useful life of the products and the opportunity for reuse and sharing (L_1) (Moreno, Rios, Rowe, & Charnley, 2016). Consequently, all vectors are boosted favourably, after cyclic activities (L_1, L_2, and L_3), benefiting the environmental (fewer natural resources and less energy) and economic dimensions (financial and image value). The vectors PI_6, PI_7 and PI_8 are related to the lower impact on the natural raw material sources, the vectors PI_{17}, PI_{18} and PI_{19} are related to the lower energy consumption and, finally, PI_{11}, PI_{12} and PI_{13} contribute to the economic dimension.

The proposition of a circular business model framework (CBMF) responds to RQ2, presenting a flow map of value amongst the different players of the ecosystem. Positive and negative interactions are revealed, allowing identifying points of synergy and conflicting interests. Synergistic aspects should be explored as opportunities for value generation while conflicting interactions need to be managed appropriately. Strategic partnerships can bring significant contributions in dealing with these divergent points; however, the role of government policies is apparently instrumental in overcoming the inertia that precedes the CE. To facilitate the visualization of these positive and negative aspects, the matrix presented in Appendix 1 summarizes the vectors between the dimensions identified in this study.

Figure 4 – Company Production in the Context of the Circular Business Model



Indeed, there are some definite ways of increasing productivity through a CBM. There is an expectation of significant reductions in the cost of acquiring materials through recycling and remanufacturing, for example (Linder & Williander, 2015). But the diagram representing the CBM (Figure 4) suggests that there is a long way to go until it is possible for companies to achieve the same levels of financial performance achieved through the LBM. In the latter, the direct relationship between consumption and result is evident. In CBM, however, relationships are more complicated.

The first step towards adopting a genuinely sustainable model is to consider the three dimensions that are part of the concept, namely the triple bottom line. Of the three dimensions that construct the idea of sustainability, environmental, economic and social, the last one still seems to receive less attention (Murray; Skene; & Haynes, 2015). On the other hand, when the social dimension receives right attention, the environmental aspect is neglected (Gold; Hahn; & Seuring, 2013).

Social development implies a series of measures, usually attributed to the guardianship and responsibility of the public authority. However, the contemporary view of sustainability increases the scope of commercially oriented organisations. Gold Hahn; and Seuring (2013), for example, describe the involvement of poor communities in the productive processes of some multinational organisations, such as Danone, which developed micro-factories in poor regions of Bangladesh, decentralising their production process. Local small-scale cooperatives became raw material suppliers and a distribution network used several small and micro-entrepreneurs from the local community. Danone invested in the technological structure and managerial expertise. In this trade-off, the town became a supplier and also a consumer of Danone products, getting access to higher quality food without the logistics costs. In a traditional model, it would have been difficult to overcome due to the long distances of these communities to the producers. In a simple argument, in developing poor communities, organisations help themselves, by increasing their market (Tashman; & Marano, 2009). Market research reveals that those who pay a lower price are more likely to get and use a product than those who pay moderate prices, or even those who initially receive it for free (Christensen; Siemsen; & Balasubramanian, 2014).

The decentralisation of the productive process and the empowerment of the local community certainly entail costs. In Figure 5, the cost of social development has a negative impact on the economic dimension, represented by vector NI13. The inclusion of the local community in the supply chain can also negatively impact the traditional suppliers, represented by vector NI14. But social development also brings benefits, such as reducing the cost of logistics (PI5) and consequently reducing emissions and environmental impact, as well as increasing productivity through the development of human capital (PI21) (Ríos; & Charnley, 2015).

In addition, there is the economic gain inherent in image and reputation (PI10) (Dyllick; & Muff, 2015). In fact, companies that invest voluntarily in social development gain a competitive advantage in the form of image appreciation (Hall; & Wagner, 2012). Therefore, while these strategies increase costs, reinventing distribution channels can bring immediate benefits, as well as bringing long-term prospects (Vachani; & Smith, 2007).

Conceptually, CE refers to a regenerative system that reduces emissions and losses by maximising materials, increasing the useful life of the products and reusing them at the end (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). In a first analysis, the focus seems to fall on the environmental dimension, including being an object of criticism of some authors. However, tacitly, there is the recognition of the economic value of the product at the end of its life (Glavič; & Lukman, 2007; Linder & Williander, 2015; Preston, 2012). Therefore, somehow contemplating the economic dimension, just as it requires social engagement to close the cycle, specifically in the stages that follow after leaving the manufacturing company. The restorative and cyclical nature of CE can be achieved through loops of materials in different steps, such as recycling (raw material), remanufacturing non-functional' products (or sub-products), and reusing those that are still functional (Lieder; & Rashid, 2016).

However, for loops to occur efficiently, community participation is required. Consumer education becomes fundamental in all cycles: recycling (PI16), remanufacturing (PI20) and reuse (PI15). Companies, therefore, should invest in education (NI13) to make CBM viable (Ríos; & Charnley, 2015). The paradox lies in the fact that companies invest in consumer education so that, at the end of the day, consumers buy fewer new products. If companies view this action from a LBM

perspective, they will perceive it as a suicidal operation strategy. That is why CBM has developed a new way of thinking about business. The challenge is to generate value in the loops, which demands investment and research in the innovation of products, processes and corporate strategies. From the CE, emphasising success depends on an integrated and holistic vision and not just on innovation (Hall; & Wagner, 2012). The action of government policies, as discussed above, should act precisely on these ambiguous or conflicting issues.

When innovating, the company must analyse the impact on the whole system and not only on isolated parts, as happens in the dominant model of business. On the contrary, innovations in the new sustainability paradigm should not fit the logic of the LBM (Schaltegger; Lüdeke-Freund; & Hansen, 2012). Therefore, sustainable innovation must be radical and innovative to support the transformation of the business model (Antikainen; & Valkokari, 2016; Witjes; & Lozano, 2016). There is still a gap between sustainable business models and innovations, which merits researchers' attention. This is one of the main barriers to CBM implementation identified in this study (Boons; & Lüdeke-Freund, 2013).

With the right incentives, sustainable materials will be developed to strengthen the loops in Figure 5, especially the L3(Preston, 2012). Innovation in design also becomes critical to resource optimisation (Ríos; & Charnley, 2015). Innovative designs, in addition to allowing the use of less material' (L3), enable the reuse of parts (L3) and higher efficiency in remanufacturing and repair (L2), increasing the useful life of the products and the opportunity for reuse and sharing (L1) (Moreno, Rios, Rowe, & Charnley, 2016). Consequently, all vectors are boosted favourably, after cyclic activities (L1, L2, and L3), benefiting the environmental (fewer natural resources and less energy) and economic dimensions (financial and image value). The vectors PI6, PI7 and PI8 are related to the lower impact on the natural raw material sources, the vectors PI17, PI18 and PI19 are related to the lower energy consumption and, finally, PI11, PI12 and PI13contribute to the economic dimension.

The proposition of a circular business model framework (CBMF) responds to RQ3, presenting a flow map of value among the different players of the ecosystem. Positive and negative interactions are revealed, allowing identifying points of synergy and conflicting interests. Synergistic aspects should be explored as opportunities for

value generation while conflicting interactions need to be managed appropriately. Strategic partnerships can bring significant contributions in dealing with these divergent points; however, the role of government policies is apparently instrumental in overcoming the inertia that precedes the CE.

To facilitate the visualization of these positive and negative aspects, the matrix presented in figure 6 summarizes the vectors between the dimensions identified in this study.

4.5 Conclusions

This paper contributes to narrow the gap on the understanding of value streams through circular business models. By performing a literature review of the themes “circular economy” and “business model”, the circular business model concept is depicted through the linkage of themes of sustainability, closed-loop economy, drivers, barriers, and value streams.

By mapping the main high impact papers in the research fields of circular economy and business models, considering the business perspective as a background, five categories emerged: conceptual basis, objectives, drives, barriers, as well as the theoretical and practical implications for the development of CE. Based on this first step and searching to bridge the organisational operation strategy with the circular business model stock of knowledge, the internal deployment of steps towards a sustainable society is presented, by evidencing the dynamics within the organisational level by a business ecosystem perspective.

However, the main contribution of this paper is the proposal of a circular business model framework (CBMF) that contributes to the circular economy theory by considering the value stream dynamic among the different stakeholders, from the positive, negative and feedback loops interactions perspective. This allows the improvement of the assessment of positive and negative interactions in a systematic way, helping both researchers and practitioners to identify weaknesses and strengths from a value perspective. The matrix of value originated from these interactions and can be analytically used as a source to indicate “sustainable value” efforts to be incorporated in the operation strategy of the organisation. This evidence the necessary change of mindset from a linear to a circular value flow, which is needed to reach

sustainability. Once the value stream is identified, efforts to mitigate the negative interactions in a CBM can be targeted to circumvent the challenges. The role of government policies was evidenced in several stages of the study as the catalyst that acts by mediating the paradoxical and conflicting points.

Thus, some practical implications emerge from this research. First, the mapping of dynamics in the value stream in the CBM allows driving efforts to maximise positive aspects, as well as to develop mechanisms to minimise or eliminate negative impacts and tensions. Second, the CBMF can help organisations to understand the value stream in different levels of analysis, from the organisational perspective towards the business ecosystem. This research has some limitations related to the sampling process. The use of search engines and the content available in the ISI Web of Science and Scopus databases, the search string, the inclusion and quality criteria adopted, and the screening process can bring subjectivity and bias to the surveyed sample.

For future research, the matrix presenting the central interactions in a circular economy perspective is suggested as helping in modelling attempts towards CBM. Further research to understand the tensions and trade-off proposed in the CBMF are needed in field research. Finally, system dynamics simulation can be applied to formulate an in-depth understanding of the interaction in the value streams.

Acknowledgements

The authors wish to thank the National Council of Technological and Scientific Development (CNPq), the Coordination for the Improvement of Higher Education Personnel (CAPES) and the Foundation for Research Support of the State of São Paulo (FAPESP), for supporting this research.

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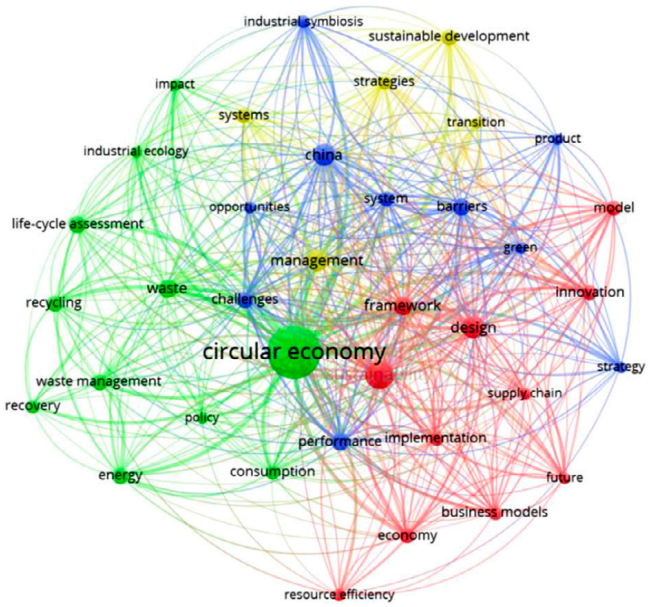
Appendix 1. Matrix of the Positive and Negative Interactions

From \ To		ECONOM		SOCIAL			ENVIRONMENT			ENERGY		PRODUCTION				SC	CS	LOOPS		
		FFN	FRP	SCD	SCE	SHI	ERR	ENR	EPE	PNS	PRS	PEX	PRM	PMN	PLG	SPP	CSU	L1	L2	L3
ECONON	FFN	-		PI_{29}	PI_{29}	PI_{29}	PI_{30}	PI_{30}	PI_{30}	PI_{31}	PI_{31}									
	FRP	PI_9	-																	
SOCIAL	SCD	NI_{13}	PI_{10}	-									PI_5	PI_5	PI_5	NI_{14}	PI_{25}			
	SCE	NI_{13}	PI_{10}	PI_{14}	-												NI_{15}	PI_{15}	PI_{20}	PI_{16}
	SHI	NI_{13}	PI_{10}	PI_{27}		-							PI_{21}	PI_{21}	PI_{21}		PI_{24}			
ENVIRONMENT	ERR	NI_9					-	PI_{23}												
	ENR							-												
	EPE								-											
ENERGY	PNS	NI_8						NI_{16}	NI_7	-										
	PRS									PI_{22}	-									
PRODUCTION	PEX						NI_4	NI_5				-								
	PRM								NI_2	NI_6	NI_6	NI_3	-			PI_1				
	PMN								NI_2	NI_6	NI_6			-		PI_1				
	PLG								NI_2	NI_6	NI_6				-	PI_1				
SC	SPP												PI_2	PI_2	PI_2	-				
CS	CSU	PI_3		PI_4					NI_1								-			
LOOPS	L1	NI_{12}	PI_{28}				PI_6	PI_6	PI_6	PI_{19}	PI_{19}							-		
	L2	*	PI_{12}				PI_7	PI_7	PI_7	PI_{18}	PI_{18}								-	
	L3	**	PI_{11}				PI_8	PI_8	PI_8	PI_{17}	PI_{17}									-

Appendix 2. Keywords network generated by the article base, using software VosViewe



5 Article 2 – Circular Business Model: Breaking Down Barriers in Transposable

Obstacles

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Abstract

Barriers to circular economy implementation are adversities that cannot be overcome by organizations in general. Other adversities, are relative, that is, true within a particular context of some organizations. In this sense, they would be - in fact - obstacles, which can emerge as a competitive differential for those organizations that have or develop internal capacity to overcome them. The aim of the article is to explore how barriers integrate solutions to face barriers or obstacles in the company and whether this brings a competitive advantage. In order to achieve the aim, 40 interviews were carried out in companies that already have implemented circular economy operation strategy. The results suggest that absolute barriers emerge as an extreme theoretical reference, of little occurrence in practice (outliers). Obstacles, however, are ordinary and frequent events, which can be converted into a competitive advantage, as appropriate manufacture strategies are incorporated into the circular business model.

Keywords: Circular Economy; Barriers; Business model; Organizational Environmental; Competitive criteria.

5.1 Introduction

While the coronavirus pandemic threatens many lives throughout, in the first half of 2020, there was a decline of about 8.8% less carbon dioxide emitted compared to the same period in 2019 (Liu et al., 2020). It is due to changes in behaviour initiated in Europe, such as working from home, providing online education, reducing travel, limiting visits to stores, among other activities (Sarkis, 2021). In 2022, with the resumption of activity, some actions are being implemented to stimulate the post-COVID-19 economic recovery. However, now with transformations towards a more sustainable supply and production (Sarkis, 2021). In this way, with the commitment of people and organizations and public policies, the results of recovery in economic

growth while strengthening the resilience against future climatic shocks and mitigating climate change itself can be promising. These actions and packages are called Building Back Better (BBB) (Di Serio, Fragetta, & Melina, 2021). These actions are presented in Europe; however, there is no discussion about BBB in countries like Brazil.

The implementation of sustainable or circular actions may face obstacles or barriers. Barriers companies face to implement a circular business model (Jaeger & Upadhyay, 2020) and change the way they operate (Bocken & Short, 2016) can delay the transition to a sustainable future. Therefore, it is necessary to identify what is preventing or delaying the implementation of circular actions in organizations.

There are several studies that highlight the barriers found by organizations to implement a circular business model (Galvão, Ferrer, Chinen, & Carvalho, 2018; Jaeger & Upadhyay, 2020; Tura et al., 2019; Vermunt, Negro, Verweij, Kuppens, & Hekkert, 2019), as well as migrate to new operating systems aligned to the circular paradigm (Bocken & Short, 2016; Jesus & Mendonça, 2018; Genovese, Acquaye, Figueroa, & Koh, 2017).

The reported barriers seem to originate from the internal limitations experienced by organizations, such as lack of managerial capacity, resources and corporate knowledge; on issues external to organizations, such as consumer behaviour (Paletta, Leal Filho, Balogun, Foschi, & Bonoli, 2019) and regulatory aspects (Galvão, Nadae, Clemente, Chinen, & Carvalho, 2018); or even in the absence of technologies or general knowledge to overcome some challenges in the journey of change. In common, these works seem to circumscribe these challenges within their own limits, without pointing out an exit door or an opportunity to be explored.

This study, however, argues that there may be an exacerbated simplification in this identification and analysis of the so-called barriers to the circular economy. The authors understand that there is no panacea to deal with all these challenges, but that - yes - there are latent opportunities to increase the competitive criteria of organizations that face these challenges as transitory problems to be overcome.

At this point, researchers have been looking for answers on how the circular model could increase economic growth while reducing negative effects on the natural environment and society (Bocken, Short, Rana, & Evans, 2014; Boons & Lüdeke-Freund, 2013; Schaltegger, Lüdeke-Freund, & Hansen, 2012; Stubbs & Cocklin, 2008). In other words, economic growth is almost a desired side effect, which goes in the wake of the greater objective of environmental and social preservation, a point of view that naturally results in highlighting problems for achieving this balance advocated by the Elkington's Triple Bottom Line (Elkington, 1997).

Although there are many barriers or obstacles, some companies strive to be circular. At this point, researchers have been looking for answers on how the circular model could increase economic growth while reducing negative effects on the natural environment and society (Bocken, Short, Rana, & Evans, 2014; Boons & Lüdeke-Freund, 2013; Schaltegger; Lüdeke-Freund; & Hansen, 2012; Stubbs & Cocklin, 2008), thus becoming a more competitive company.

However, after analysing the literature on barriers to CE, it was noticed that there is no deepening in the discussion of how barriers are integrated into plans. Circular business models must establish tactical options to provide value generation in the context. Furthermore, the discussion of what a barrier is must be deepened. This is because, barriers should be seen as a transient "dead end street", that is, while the solution is exclusively outside the organization. Obstacles, however, must have a counterpart within the business model in this case, Circular Business Model (CBM).

A barrier that becomes an obstacle is a competitive advantage, for example, companies could advance in the competitive criteria namely quality, delivery performance, flexibility, innovation and cost. The competitive criterion cost is defined as the ability to manufacture products at a lower cost than competitors (Slack & Lewis, 2002). The innovation criterion within organizations with CBM can help to significantly reduce the uncertainties inherent to the topic for the entrepreneurs and stakeholders (Linder & Williander, 2017).

Therefore, the main objective of our study is to identify how organizations deal with critical barriers and to discern the conditions in which CBMs face these barriers and how they act to overcome them, turning them into obstacles and gaining

competitive capacity. It is necessary to identify the barriers to the implementation of the circular model, in this way, its contribution will generate positive results (Inghels, Dullaert, Aghezzaf, & Heijungs, 2019). In addition, it is important to explore what practices are being implemented and how they can be improved (Bragança & Regina, 2020). In consequence, the article will answer the 3 research questions presented below.

RQ1. How are organizations dealing with barriers and turning them into obstacles when possible?

RQ2. How operation strategies that deal with barriers and obstacles foster and influence the competitive criteria?

To answer the 3 research questions, 40 semi-structured interviews were carried out, in addition, it was sent a questionnaire with the criteria of competition to analyse whether they have improved after the implementation of the circular economy in the respective company.

In the next section, we build the conceptual framework for the paper, section 3 will present methods, section 4 presents the main findings from the research, which are discussed in the chapter 5. The paper closes with conclusions.

5.2 Background

5.2.1 Circular Business Model

Business model (BM) “simplifies representations of the value proposition, value creation and delivery and value capture elements and the interactions between these elements within an organizational unit” (Geissdoerfer, Vladimirova, & Evans, 2018, p. 401).In addition, BM must reflect aspects of the organization’s management, the customers’ wishes, and how the company will draw a plan to meet the needs and obtain value (Teece, 2010).

For these points to be met or implemented, the BM may need some changes. For example, new internal or external policies or other external demands (Saebi, Lien, & Foss, 2017) create value for the organization (Ünal, Urbinati, Chiaroni, & Manzini, 2019).

According to Lacy et al. (2014) and Stahel (2016), a BM with clear and well-defined objectives can bring some benefits, such security of resources, flexibility and different business models to create value. In addition, for the company to become even more competitive, it is advisable to invest in competitive criteria, for example: (i) Quality is defined as consistent compliance with consumer expectations expectations (Hazen, Mollenkopf, & Wang, 2017), (ii) Delivery reliability can be defined as the delivery of products within the time promised to the customer (Teixeira & Paiva, 2008), and (iii) Flexibility, which is the ability to supply a wide variety of products (Araújo & Castro, 2011).

Thinking more specifically about promoting sustainability, many companies are committing to CBM (Jaeger & Upadhyay, 2020). Consequently, these organizations strive to produce minimal adverse effects on the environment, seeking to increase the product's life cycle "from the initial phase of material extraction to the product's disposal" (Zhijun & Nailing, 2007).

Unlike the linear production model (PL), CBM can bring new benefits to the market and society. In addition to the need for some changes, companies may need to invest in new organizational capabilities, resources and technical skills. In this way, they can also serve future markets and obtain new opportunities (Hofmann & Jaeger-Erben, 2020). Some studies point to the circular economy as vital for the future of business. Its positive results in the environment and a sustainable economy can be translated into a financial gain for the organizations' shareholders (Aboulamer, 2018).

Some places that already have more mature CBMs show promising results, for example, some countries in Europe. These sites have invested in technological infrastructure for CBM and have already obtained, resulting in improved resource productivity and reduced costs in the mobility, food and built environment sectors by almost €1 trillion by 2030 (Ellen MacArthur Foundation, 2015). Stocks and investments related to circularity, the greater the flow, and the income results (Cohen, 1996).

To increase the flow, CE needs buy-in, but it is still a decidedly new topic. Even so, after more than two decades of CE logic, its actions have increased in popularity among corporate representatives, decision-makers, politicians and scientists (Kirchherr, Reike, & Hekkert, 2017; Korhonen, Honkasalo, & Seppälä, 2018). Thus,

“the concept of CBMs was identified as an important facilitator for companies moving towards circular practices” (Nußholz, 2018, p. 185).

5.2.2 Circular Economy Barriers

The importance of the transition from linear to circular production is already presented in the literature (Frishammar & Parida, 2019; Hofmann, 2019; Velenturf, Purnell, Tregent, Ferguson, & Holmes, 2018). However, this transition faces a considerable degree of uncertainty for organisations and the scientific community (Hofmann & Jaeger-Erben, 2020). These uncertainties can result in a series of barriers/obstacles to CE implementation (Álvarez Jaramillo, Zartha Sossa, & Orozco Mendoza, 2019). Therefore, studying them can be the first step for companies to implement CBM successfully (Inghels et al., 2019).

Notably, most companies rarely face CE barriers (Jaeger & Upadhyay, 2020). The literature itself has already pointed out a few. Jaeger and Upadhyay (2020), for example, identified some: high upfront costs, complex supply chains, poor business-to-business (B2B) cooperation, lack of product and design information production, lack of technical skills, commitment to quality, and product disassembly is time-consuming and expensive. As for the CBM, challenges were categorised by Ritzén and Sandström (2017) as structural, operational, financial, attitudinal and technological. Pheifer (2017) also identified barriers to CBM, including no sense of urgency and company culture, lack of data, funding of circular business proposals, current government legislation and regulation, and current linear system in place.

It can also find other specific barriers, such as transitioning from the linear to the circular model. At these points, Dieckmann, Sheldrick, Tennant, Myers, & Cheeseman (2020), divided them into nine categories, namely: (i) characteristics of materials, (ii) processing technologies, (iii) environmental impact, (iv) issues industry and supply chain, (v) organisational context, (vi) external motivators, (vii) public perception, (viii) regulatory structure and (ix) economic viability.

Other authors have also published articles with more specific barriers, for example, Haupt, Vadenho and Hellweget (2017), who concluded in their research that company CE indicators are often not reported for the entire organisation. In addition,

they also indicated that teams are generally not informed about the final destination of the materials they helped to circulate, generating frustration in the team, decreasing their collaboration in the future. For the authors, this aspect is a barrier to the implementation of BCV.

Another point to be considered, according to (Ghisellini & Ulgiati, 2020), is that companies must change their vision, no longer focusing mainly on short-term goals. In this way, they may miss potential future economic opportunities derived from introducing innovations and technologies aimed at CE. At the company's managerial level, studies indicate that there is a lack of consolidated guidelines. In other words, studies point to several benefits of CBM. However, in practice, companies are not yet guided on how to implement the model. This failure in practical sets of proceeding from the linear to the circular model is a barrier for managers in organisations (Geng & Doberstein, 2008; Su, Heshmati, Geng, & Yu, 2013). Indeed, management levels need guidance as the transition from linear to circular is the biggest challenge for organisations (Ellen MacArthur Foundation, 2015). CBM implementation is hampered by managers' lack of knowledge (in CBM) (Adams, Osmani, Thorpe, & Thornback, 2017). Naturally, companies of different sizes may have different barriers (Álvarez Jaramillo et al., 2019; García-Quevedo et al., 2020). It is worth remembering that although barriers can be challenging to overcome, the company becomes more competitive (Galvão et al., 2020).

Other points that make decision-makers continue to invest in CBM are the five potential benefits pointed out by Mont et al. 2017, economic and environmental benefits, more significant supply and resilience, new and improved relationships with customers and the company's values and aspirations. Also, "market pressure" is another essential external factor needed for CBM implementation. The barriers presented above can be divided into three main categories: organisational environment, outdoor environment, and Technology. Table 2 shows the categories of barriers explored in this study.

Table1: Barriers to CBMs

Barrier category	**Description**	**References**
Organisational Environment	*Organisational culture*	de Jesus & Mendonça, 2018; Dieckmann et al., 2020; Franco, 2017; Geng & Doberstein, 2008; Govindan & Hasanagic, 2018; Kirchherr et al., 2018; Mangla et al., 2018; Masi, Kumar, Garza-Reyes, & Godsell, 2018; Ormazabal, Prieto-Sandoval, Puga-Leal, & Jaca, 2018; Rizos et al., 2016; Sousa-zomer, Magalhães, Zancul, & Cauchick-miguel, 2018; Tura et al., 2019

	Managerial capabilities	Adams et al., 2017; Dieckmann et al., 2020; Geng & Doberstein, 2008; Gontard et al., 2018; Haupt, Vadenbo, and Stefanie,2017; Hofmann & Jaeger-Erben, 2020; Jaeger & Upadhyay, 2020; MacArthur, 2015; Mangla et al., 2018; Ormazabal et al., 2018; Ranta, Aarikka-Stenroos, Ritala, & Mäkinen, 2018; Ritzén & Ölundh, 2017; Rizos et al., 2016; Sousa-zomer et al., 2018; Su, Heshmati, Geng, & Yu, 2013; Tura et al., 2019
	Business model	Franco, 2017; Geng & Doberstein, 2008; Ghisellini & Ulgiati, 2020; Gontard et al., 2018; Hopkinson, Zils, Hawkins, & Roper, 2018; Jaeger & Upadhyay, 2020; Mangla et al., 2018; Oliveira, França, & Rangel, 2018; Sousa-zomer et al., 2018; Su, Heshmati, Geng, & Yu, 2013
External Environment	*Barriers related to circular supply chain (supply chain complexity and supply chain collaboration)*	de Jesus & Mendonça, 2018; Franco, 2017; Geissdoerfer, Morioka, de Carvalho, & Evans, 2018; Gontard et al., 2018; Govindan & Hasanagic, 2018; Jaeger & Upadhyay, 2020; Kirchherr et al., 2018; Mangla et al., 2018; Masi et al., 2017; Rizos et al., 2016; Sousa-zomer et al., 2018; Tura et al., 2019
	Infrastructure	de Jesus & Mendonça, 2018; Dieckmann et al., 2020; Govindan & Hasanagic, 2018; Oliveira et al., 2018; Ranta, Aarikka-Stenroos, Mäkinen, & Saku, 2018; Ritzén & Ölundh, 2017; Rizos et al., 2016; Sousa-zomer et al., 2018; Tura et al., 2019
	Consumption related barriers (Lack of awareness, owner perception, rejection of remanufactured products)	Baxter, Aurisicchio, & Childs, 2017; de Jesus & Mendonça, 2018; Dieckmann et al., 2020; Franco, 2017; Geng & Doberstein, 2008; Gontard et al., 2018; Govindan & Hasanagic, 2018; Hopkinson et al., 2018; Kirchherr, Reike, and Hekkert, 2017; Mangla et al., 2018; Masi et al., 2017; Ormazabal et al., 2018; Ranta, Aarikka-Stenroos, Mäkinen, & Saku, 2018; Ritzén & Ölundh, 2017; Rizos et al., 2016; Sousa-zomer et al., 2018; Tura et al., 2019
Technology	*Lack of appropriate technology*	de Jesus & Mendonça, 2018; Franco, 2017; Gontard et al., 2018; Kirchherr, Reike, and Hekkert, 2017; Mangla et al., 2018; Ormazabal et al., 2018; Rizos et al., 2016; Sousa-zomer et al., 2018
	Lack of knowledge	de Jesus & Mendonça, 2018; Dieckmann et al., 2020; Geng & Doberstein, 2008; Mangla et al., 2018; Ritzén & Ölundh, 2017; Sousa-zomer et al., 2018

5.2.3 The influence on Competitive criteria

Competitive priorities can help operations managers decide production, capacity, technology, planning, and control. By making decisions about these aspects properly, the company can be in a good market position (Skinner, 1969). Such decisions are normally seen from the demands of the client and the market, within two organizations we cannot make a clear indication of alignment between the competitive priorities and the result of improvement(Carpinetti & Martins, 2001).Studies on these aspects are considered mature. However, the debate on which competitive priorities should receive more attention continue and follow three different lines: trade off, cumulative and integrative models (Flynn & Flynn, 2004).

The trade-off model was proposed by Skinner (1974), for the author, cost, flexibility, quality, and delivery resources must receive different priorities. That is, each of these aspects must be studied. However, what is chosen as a tactical objective should receive more investment. although Sarmiento (2011, p. 4174). has a different view "opposed to widely-accepted views, trade-offs and compatibilities can be complementary, and not necessarily mutually exclusive, when explaining relationships between various competitive criteria"

The cumulative perspective, on the other hand, was proposed by Murray(1988) and Noble (1995), whose author calls the same question by the name of capabilities competences. Other nomenclatures for the same aspects are found in the literature, which is criticized by Corbett and Wassenhove (1993). In this model, the resources of delivery, cost, flexibility, quality must have high performance simultaneously (Boyer & Lewis, 2002). The authors of this line of thought criticize the trade-off model, as they believe that a capability should not have priority but that it must have a relationship between them (Flynn & Flynn, 2004).

The integrative model, presented by Corbett and Wassenhove (1993), suggests that to improve production performance, capabilities should be organized in the best possible way, that is, one capability should not replace the other. In this case, it is not necessary to invest in 1 capital equally. There may be combinations (with a defined life cycle) to achieve the organization's plan. In addition, some criteria may influence others (Bolwijn and Kumpe, 1990). For example, the interaction of flexibility positively in product innovation in factories (Oke, 2013).

In addition to the different nomenclatures, some authors are dedicated to studying specific capabilities. For example, flexibility, defined by Swamidass (1988), can be operationalized as product mix flexibility or volume flexibility. Alternatively, even the quality, which is presented by eight different dimensions (Garvin, 1987). Delivery performance provides how successful the supply chain is at providing products and services to the client (Bonner, Onofrei, Humphreys, Margey, & Cadden, 2021). Innovation, which was a late addition (Singh, Tripathi, Srivastava, & Iyer, 2015) can involve both the creation and development of product ideas (Oke, 2013). Table 2 presents some authors and the aspects studied by them.

Table 2: Operations performance objectives

Criteria	References
Quality	(Bonner et al., 2021; Boyer & Lewis, 2002; Corbett & van Wassenhove, 1993; Flynn & Flynn, 2004; Garvin, 1987; Singh et al., 2015; W Skinner, 1974)
Cost	(Bonner et al., 2021; Boyer & Lewis, 2002; Corbett & van Wassenhove, 1993; Flynn & Flynn, 2004; Garvin, 1987; Singh et al., 2015; W Skinner, 1974)
Flexibility	1993; Flynn & Flynn, 2004; Garvin, 1987; Oke, 2013; Singh et al., 2015; W Skinner, 1974; Swamidass, 1988)

Delivery performance	993; Flynn & Flynn, 2004; Singh et al., 2015; W Skinner, 1974)
Innovation	(Bonner et al., 2021; Corbett & van Wassenhove, 1993; Flynn & Flynn, 2004; Oke, 2013; Singh et al., 2015; W Skinner, 1974)

5.3 Research methods

This section presents the methodology used to answer the 3 research questions. It is a qualitative research (Merriam, 2009) with 40 semi-structured interviews, archival materials, and documents sent by the interviewed companies. According to Bell, Bryman, & Harley. (2018) this type of questioner allows interviewees to share their comprehension on the topic more spontaneously, it also facilitated the interviewers to keep the attention on the discussion by following pre-defined questions.

5.3.1 Sampling and data collection

The data were collected in different countries, however most of the companies interviewed are based in Brazil or in the UK. in addition to the interviews, all companies provide secondary data (see Table 3).

To ensure that the questions were well thought out, a pilot test was done, and after the feedback from practitioners and researchers, slight improvements were made to the data collection instruments to eliminate possible misinterpretation (for example, rewriting phrases making it easier to understand and excluding two questions that seemed redundant).

The authors looked companies with circular actions, iso1400 and sustainability report. The authors sent a message on LinkedIn with an interview information sheet to one hundred participants. that is, purposeful sampling process (Gentles, Charles, Ploeg, & McKibbon, 2015). The message was sent only to knowledgeable employees who had experience circular economy. During the choice of the companies to be studied, it was verified whether the company has the intention to continue investing in CE. Before an interview, it was provided an information sheet which explained the concepts of CE. Also, the companies that invest in innovating to enhance circularity, also, the interviewees work in companies that invest in technology and disseminate

the importance of circularity within the organization. Furthermore, the sustainability reports of the companies present a percentage of circular products.

In total, 40 respondents agreed to participate in the research. All these respondents were interviewed in March, April, or May 2020, either by a face-to-face meeting in their offices, or over Google meeting or Skype or WhatsApp. Each interview lasted about 20-48 minutes (discounting the time of the conversation before actually starting the interview.) e was conducted in English or Portuguese. The interviews were recorded and notes transcribed into a software NVivo.

Their industry types included government, property development, manufacturing, and in order to understand all of the cycle, we also interviewed waste management companies, these companies were indicated by some of the companies in the industry. In other words, we seek responsible hair for the sustainability and circularity of companies that disseminate circular letters, the country for the consequence. The profile of the research companies/participants is provided in Table 3.

Table3 - Profile of the interviewed companies **Multinational, interview held at the headquarters above*

Interviewed	B2B B2C	Sector/ Size	Interviewees' roles	Country	Platform and duration	Material provided by the company	Circular actions
C1	B2B/ BSC	Wind energy/L	Global Head of Lean Manufacturing and Operational Excellence	*Spain	27' face-to-face	News Articles, Company Releases, Research Articles, and sustainability report	recycling and energy efficiency
C2	B2B	Wind energy/L	Head of Wind Advisory	*Denmark	24' Skype	News Articles, Company Releases, and sustainability report	recycling and energy efficiency
C3	B2B/ B2C	Energy/L	Sustainability Manager	*Brazil	28' face-to-face	News Articles, Company Releases, Other Company Material and sustainability report	recycle and reuse
C4	B2B	Energy/L	Head of Sustainable Projects	*UK	44' Skype	News Articles, Research Articles, and sustainability report	recycling and energy efficiency
C5	B2B/ B2C	Manufacturing/ Service/S	New Product team	Brazil	32' face-to-face	News Articles, Research Articles, and sustainability report	recycle
C6	B2C	Manufacturing/Service/L	Strategic Project management in Circular Economy	*Brazil	41' Skype	News Articles, Research Articles, and sustainability report	Recycle, reuse, remanufacture, reduce waste
C7	B2B/ B2C	Manufacturing/ Service/L	Sustainability and Circular Economy Strategy & Leadership	*Netherlands	34' face-to-face	News Articles, Research Articles, and sustainability report	recycle
C8	B2C	Manufacturing/Service/L	Director	UK	21' Skype	News Articles, Research Articles, and sustainability report	Recycle, reuse, remanufacture, reduce waste
C9	B2B	Sustainable Service	Sustainable Development Director	Netherlands	43' Google Meet	News Articles, Research Articles, and sustainability report	recycling and reuse
C10	B2B/ B2C	Manufacturing/L	Sustainability and Innovation Manager	UK	42' Face to face	News Articles, Research Articles, Other Company Material and sustainability report	Recycle and recovering resources

C11	B2B/ B2C	Manufacturing/M	Corporate Sustainability Manager	Spain	35' Skype	News Articles, Research Articles, and sustainability report	Recycle
C12	B2B/ B2C	Construction /L	Director of Sustainability	*Brazil	24' Google meet	News Articles, Company Releases, Research Articles, and sustainability report	recycle
C13	B2B/ B2C	Sustainable construction/ S	Expansion and New Business Director	Brazil	37' Skype Busines	News Articles and sustainability report	Recycle, reuse and reduce waste
C14	B2C	Environmental Service/S	Circular Economy Consultant	*Brazil	29' Google meet	News Articles and sustainability report	
C15	B2B	Environmental Service/S	Vice President	Brazil	22' Microsoft Teams	News Articles, and sustainability report	Recycle, reuse and reduce waste
C16	B2B/ B2C	Governmental/L	Head of Sustainable	UK	21'	News Articles	Recycle, reuse and reduce waste
C17	B2B	CE Certification /S	Head of Sustainable projects	Brazil	28' conference call	News Articles, Other Company Material and sustainability report	recycle
C18	B2B/ B2C	Financial/L	Corporate Sustainability Manager	*Brazil	25' Skype	News Articles, Research Articles, Other Company Material and sustainability report	recycle and reuse
C19	B2B/ B2C	Water supply/L	Superintendence of Research, Development Technological and Innovation	Brazil	26' Google meet	News Articles, Company Releases, Other Company Material and sustainability report	recycle and reuse
C20	B2C	Waste Management /S	CEO	Brazil	37' WhatsApp	News Articles, Company Releases, and sustainability report	Recycle, reuse, remanufacture, reduce waste
C21	B2B/ B2C	Waste Management /M	Sustainability Director	Brazil	27' Skype	Sustainability report	recycle and reuse
C22	B2B/ B2C	NGO	Director	UK	29' Skype	News Articles and sustainability report	Recycle, reuse and reduce waste
C23	B2B/ B2C	Plastic resins/ biopolymers/ L	Sustainable Development Director	*Brazil	26' Skype	News Articles, Company Releases, Research Articles, Other Company Material and sustainability report	recycling and reuse
C24	B2B	Packing/L	Market Sustainability Manager	*Brazil	25' Skype	News Articles, Research Articles, and sustainability report	recycling and reuse
C25	B2B/ B2C	Sustainable Service/S	Head of Sustainable	UK	57' Google Meet	News Articles, Company and sustainability report	Recycle, reuse and reduce waste
C26	B2B	Sustainable Service/L	Senior Sustainability Consultant	UK	20' Skype	News Articles, and sustainability report	Recycle, reuse and reduce waste
C27	B2B	Technology/ Service/L	Circular Economy Solutions Strategist	USA	29' Skype	News Articles, Research Articles, Other Company Material and sustainability report	Recycle and reuse
C28	B2B/ B2C	Automotive/ S	Innovation sector	Germany	30' Google Meet	News Articles, Company Releases, Research Articles, Other Company Material and sustainability report	Recycle, reuse and reduce waste
C29	B2B	Automotive/ L	Circular Economy expert	*Italy	48' Google Meet	News Articles, Company Releases, Research Articles, and sustainability report	Recycle, reuse and reduce waste
C30	B2B	Automotive/ L	Chief Communications Officer	*UK	26' Google Meet	News Articles and sustainability report	Recycle and reduce waste
C31	B2C	Waste Management	S	CEO	Sweden	Recycle, reuse, remanufacture, reduce waste	
C32	B2B/ B2C	Upcycling/L	CEO	UK	27' Skype	News Articles and sustainability report	Recycle
C33	B2B/ B2C	CE Consultant/S	Environmental Manager	Brazil	43' Skype	News Articles and sustainability report	recycle
C34	B2B	Textile Upcycling/S	Director	UK	20' Google meet	News Articles, Other Company Material and sustainability report	recycling and reuse
C35	B2B	Textile/L	Head of Sustainable projects	*UK	28' Skype	News Articles, Research Articles, Other Company Material and sustainability report	Recycle, reuse, remanufacture, reduce waste

C36	B2B/ B2C	Food/L	Sustainability Director	Brazil	26' Skype	News Articles, Company Releases, and sustainability report	Recycle, reuse and reduce waste
C37	B2B/ B2C	Food/L	Environmental Manager	*Brazil	41' WhatsApp	News Articles, Research Articles, and sustainability report	recycle and reuse, reduce waste
C38	B2B/ B2C	Food/L	Head of Value Chain Sustainability	*UK	38' Google meet	News Articles, Research Articles, and sustainability report	Recycle, reuse and reduce waste
C39	B2B/ B2C	Food/L	CEO	*Brazil	32' face-to-face	News Articles, Other Company Material and sustainability report	Recycle and reduce waste
C40	B2B/ B2C	Food/L	Sustainability Manager	*UK	32' Google Meet	News Articles, and sustainability report	Recycle and reduce waste

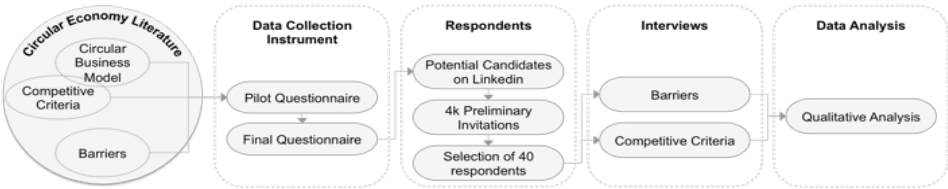
5.3.2 Data Analysis

This study builds on a combination of primary and secondary data gathered from the interviews. The primary data analysed were the 40 interviews, the secondary data other company material and sustainability report. Using an extensive set of data gathered from multiple sources increased data triangulation (Yin, 2015).

The content analysis took place by all transcripts of the interviews that were inserted into the NVIVO software (Bazeley & Jackson, 2013). It was used to generate a series of categories arranged in a tree words structure connecting text segments grouped into separate categories of codes or ''nodes'' to further the process of axial or pattern coding to examine the association between different a priori and emergent categories (including table 1). The codes emerged from the interviews, and only after coding, the second data was inserted and analysed by the software.

Same studies focused on circular economy looking for barriers or obstacle were made, they played the same methodology and obtained significant results (Agyemang et al., 2019; Shao, Huang, Lemus-Aguilar, & Ünal, 2019; Tura et al., 2019). The research design is summarized in figure 1 shown below.

Figure 1: research design



5.4 Research Results and Discussion

This chapter presents the results and analyses of the research, in order to answer the three research questions. Item 4.1 intends to answer RQ1. " How are organizations

dealing with barriers and turning them into obstacles when possible?” and finally, item 4.3 to answer QR2 “How operation strategies that deal with barriers and obstacles foster and influence the competitive criteria?”. Analysing the interviews, we separated the barriers into three categories: barriers in the organizational environment, barriers in the external environment and technological barriers (see fig 2).

5.4.1 Barriers and obstacles to implement CBM or increase CE

As for the terms in this topic, “barriers” or “obstacles”, the definitions are already provided in the introduction. However, the difference was more noticeable during the interviews. Many interviewees pointed out that the problems they faced during the CBM implementation were simple to be resolved with little investment (time, money and others). Furthermore, during the interviews, some used the term “barrier”, and others used “obstacle”. In this way, we realized the difference for them, and then we were blurring the definitions for barriers and obstacles. From the interviewees' point of view, when issues of barriers were addressed, they thought more about something that would hinder their ability to progress with the implementation of the model, however, what happened during the implementation of CBM was something that only slowed their progress, that is, an obstacle. It is important to emphasize that not everything is a barrier, many can be converted into an obstacle, an operation strategy is prescribed for this (fig 2).

5.4.1.1 Organisational Environment

Organizations invest mostly on recycling and waste reduction (see table 1). However, they continue to invest in more circular actions. However, it was pointed out that companies with partnerships have difficulty converting partners that CE is not limited to recycling materials. This can be a problem, as according to Jaeger and Upadhyay (2020), it prevents a more circular system.

In some countries, such as Brazil, that recycling is not yet a culture, biggest challenge is to get consumers (not just partners) to recycle (C14, C6, C21). The company need have to be creativity to find solutions to these obstacles. For this, it is necessary that the company marketing ability, that is, the ability to present value, different from generating -, generating connections, engaging, changing the perception of value. For example, the company 21, managed to increase the level of recycling in

developing countries, appealing to the sentimental side of people, it makes donations to charities, for each ton recycled by the customers. According to interviewee C23, “In CE, nothing is possible to do alone, right, so we have to talk to the chain”.

Another obstacle reported by companies with circular products is the difficulty in having their products back at the end of their lives. It is a culture that is not widely practiced by consumers, especially in developing countries, a fact confirmed by companies that have headquarters in different continents. Some companies that manage to make their consumers aware entertain another type of problem, the reverse logistics. How to bring recycled products back to the company. For this, the solution was to partner with waste collection and management companies, some companies invested in training for proper separation of their residues. C6 was one of the companies benefiting from this type of partnership, "we were very encouraging by one of our clients, who already had a very strong policy in this sense, they said that if we really manage to structure an operation, they would buy more than us and help us to implement the reverse logistics ".

Operational Capacity is another aspect in which respondents are concerned. This is because in order to work with rigor it is necessary to rethink internal structure and processes. For this it is necessary to have financial capacity, this is a point that can be a barrier or obstacles, according to the interviewees. To make decisions about structure and processes, it is need well-prepared managers with knowledge of CE, and it is also needed a person in charge, otherwise the team will not advance. This aspect was explored by Ritzén and Olundh (2017), according to the authors without a CE leader in the company, the management and operational levels are waiting for the other to take responsibility for an CE transition. In this post we are dealing with managerial Capacity, where managers must have the ability to integrate and develop the marketing ability, operational, financial capacity and innovation capacity within the company.

Within the organization's internal environment, the issue of team resistance was also presented. Again, it needs internal work to make the team more aware of the importance of circularity and show that it can bring value to the organization. “Unfortunately, few professionals still do not understand the need for this change and treat waste as garbage”, according to C32. It is important to have disseminators of CE principles within organizations. This will increase the involvement of the entire team.

Still talking about the internal environment, innovation is also something that can leverage CBM. According to the interviewees, after the implementation of CE new opportunities appeared, they also said that companies should be aware of the opportunities and, innovation capacity is something that companies should invest. Innovation capacity must also be under continuous evolution, and this can leave the environment uncertain (obstacle pointed out in the interviews). According to Bourgeois, (1980), this type of environment makes some managers more proactive and they tend to take a greater degree of risk. Ritzén and Olundh (2017) had already expressed that a CBM requires disruptive changes and radical innovation and that it needs managers with specific skills to do so. The lack of support for innovations aimed at CE was also reported during the interviews. This aspect is in line with the studies by Hofmann & Jaeger-Erben (2020), according to the authors, the lack of theoretical and practical knowledge about CBM innovation processes leaves the organizational environment rigid.

5.4.1.2 External Environment

A common obstacle among the companies studied is the need for consumers to perceive value and engagement. This can be an obstacle because “recycled raw material, in the market there is still a lot of prejudice from people in relation to this” C16.

In order for consumers to value circular products, some companies reported that before starting the journey they decided to inform customers in advance about their new attitude towards the CE, “explaining or educating them about the paths in the production process, because if customers don ' t see that process, obviously "C32. Some companies, Brazilians mainly, need to explain what CE is. The main ways to reach the customer was through the website or explaining on the packaging of the products. The company C23 added that in addition to the environmental area, customers see a lot of value when investing in the social area, another way to engage customers.

Companies do invest so that the customer (B2B or B2C) perceives value in their product. Company 6, for example, has a specific budget to inform the client of its actions aimed at sustainability and circularity. Naturally, this communication is done

differently between B2B and B2C. For the b2b client the focus is to show how it can add value to the company if it is circular and its suppliers are also.

Another common obstacle for the organizations studied is policies. Among them, we can mention that some companies stay in countries that charge fees for recycling products, that is, they buy recyclable inputs with high taxes, this makes it very expensive for companies to become circular. Consequently, products arrive more expensive for customers and in developing countries, such as Brazil, consumers need to opt for the cheapest. Some companies that have tax incentives are able to make products with competitive prices (C3). Some companies have even added that correct regulations may allow them to invest more in social projects, "I'm sure I can get much more" C32. This was most often cited by small companies, who claim that current rates make it even difficult to achieve economic sustainability. The country of company C3 has implemented a solid waste law in 2020, so, although very late, companies will be forced to think about recycling products. But this law does not encourage circularity "it does not encourage you to be a circular operation" C6, as it forces companies to correctly dispose of some waste however it has not prepared the population on the importance of recycling, and many companies depend on the final consumer to have your product return after its use. Manage waste in countries where there is no law for this, and people are not aware of the importance of sustainability making the circularity of companies difficult. "So, all this complexity of human interrelationships, associated with the life cycle of products is a challenge. C23" Some policies generate positive results, for example C23 is working to reduce CO2, not only in companies that are located in Europe, but also in countries that do not have legislation or authority to do so.

Local Infrastructure was a commented point, even the multi nationals face obstacles related to transport, communication, among others. Companies that produce in smaller cities (mainly in developing countries) may find it difficult to transport their products to the consumer. The C1 interviewee reported that he has already partnered with companies that were in the same region to improve roads. Some companies, mainly those of wind energy, which can establish production in almost isolated points, face communication obstacles.

There are also obstacles related to the supply chain, that is, the supply and flow of products or by-products. The barrier was one of most mentioned by the interviewees (26 of them), this is because it is the need for involvement of all actors within the value chains (suppliers, manufacturers, retailers, consumers). The result points out that when one company decides to implement CE, resistance can come from some partners. C3 stated that "Exchange the mindset, so we work hard on this issue of circularity, communicating and training our employees, our suppliers for this dialogue, this win-win". The need for a joint effort between suppliers and manufacturers is important for the supply chain, but it is difficult to achieve, according to respondents. This obstacle (in some cases barriers) can delay CBM in organizations (Masi, Day, Godsell, 2017). Sheff (2018) said that globalization brought bigger market and greater competition for companies, but it also made supply chains more complex and difficult to manage. Some companies have an intelligent sector to track inputs and waste, some companies hire others that do this service. Most of the companies interviewed are already preparing or are ready to receive their products back "we have this responsibility; we are structuring our ecosystem to receive these products in post-consumption" C6. Larger companies, with more resources, seek to intervene in the entire product chain, with the aim of increasing the entire value chain. According to C25 "This way we can divide the value generated by the implementation of CE".

Other plyers or companies is something that can be an obstacle to the implementation of CBM. Related to this, the main obstacles cited by the interviewees were: public-private partnerships, partnership with waste collection companies (for not being able to deal with the specific type of waste); recycling companies e, technology companies to make recycling better. To overcome these obstacles, some companies have trained other small companies to recycle or remanufacture their waste or products at the end of the road. Companies (for instance C32, C40 and C4) seek partnerships with customers and suppliers to achieve circularity. Some companies, mainly B2B, already have a code of conduct to increase circularity. Some companies invest in educating their consumers, the objective is to increase the level of awareness regarding the importance of recycling or returning the product at the end-of-life C23.

A company that invested in this type of partnership said it was worth it. Some companies, such as C10 and C6, have partnerships with universities to find better

solutions for their production line / circularity. Naturally, companies seek this partnership to have a competitive advantage. With the interviews, it was possible to realize that the main way to overcome any barrier, is with partnership, a problem of a company, with a large amount of certain waste, can be the solution for another company that needs the same material to continue producing with circular materials. As respondent 5 said, "no individual organization can deliver circularity in isolation." Partnership can come when other companies realize that it is possible to have value with CE, you can improve production efficiency, buy products that last longer in factories, sell your waste, recycle your waste, among other ways. "The ideal is that companies and society need to work together". C10 recycles more than 1.2 million tonnes of steel scrap each year.

5.4.1.3 Technology

Inexistent technology, few interviewees claimed that technologies does not exist were barriers to be circulated. As an example, the C31 company that would like to recycle plastic more often, however it is not possible because the fibbers are no longer functional after a few cycles, in this case, they are looking for technology to be able to solve this barrier. The food companies said that many solutions aimed at their area did not exist on the market, this problem had already been pointed out by Lüdeke-Freund, Gold, & Bocken (2019), where they concluded that technologies “were developed mainly in the context of widely focused services. in electronics, clothing, furniture and durable food instead of food products. Some companies have said that the main problem after implementing CE and producing with recyclable materials, is the quality of the material they receive. It takes a long time to separate and see what they can really use, then give the correct destination for the material with a different quality than what they need, and the quantity of remains is sometimes not enough.

Protected technologies, in this case, these are technologies / innovations protected by patent. For example, plastic packaging companies are investing in reducing the amount of material per product and bio-friendly plastics or reduce the known as secondary or tertiary packaging. All the companies interviewed, who work with plastic, showed concern about it. The companies that invested and managed to overcome this barrier, patented technology. Now it is an obstacle for companies that have not yet obtained it, either they wait for the patent to be opened, or continue to

invest in it. The companies C37, C23 and C39 succeeded, and this was profitable because, plastic was approximately 80% of their waste.

Expensive technologies, companies that do not have the money to invest in new technologies, obstacles faced in different proportions by some companies. Even large companies, sometimes not convinced, that are worth investing to improve some processes, or do not believe that technology will make the company more efficient, in this case, can be seen as an expensive investment for decision makers. Dinâmicas de inovação CBM tendem a exceder as capacidades organizacionais de complexidade gestão em comparação com esforços recorrentes de eficiência ou ajustes às rotinas operacionais (Hofmann & Jaeger-Erben, 2020).

Regarding the recycling of plastic, companies said that the recycling process is very expensive. "And we were costing a lot of money to take care of the plastic packaging, as they are mixed materials" C5. Some have invested in research to change the type of plastic C5, other companies have transferred responsibility to suppliers and only buy packaging that can be recycled.

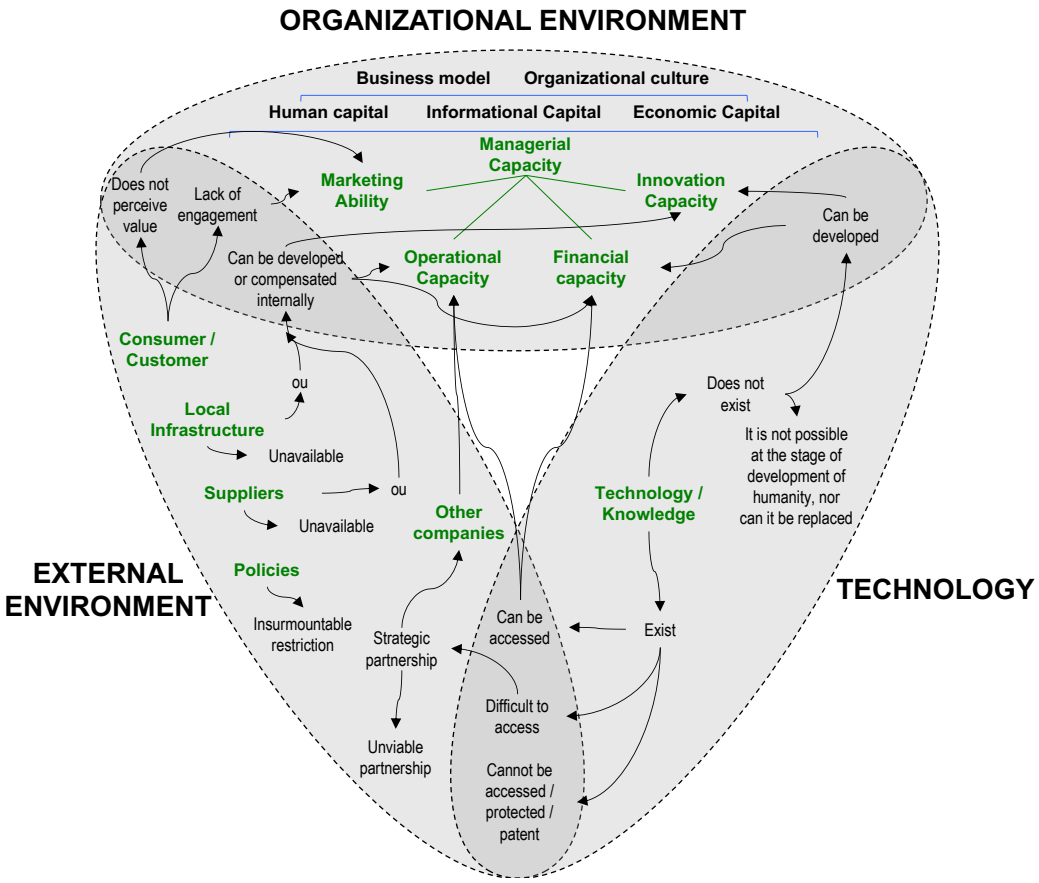
4.1 Breaking Down Barriers in Transposable Obstacles

This topic presents how companies insert barriers and obstacles in the manufacture strategies to implement CBM. Analysing the 40 interviews, more than 30 hours of content, it was noticed that the organization does not create barriers, but can demonstrate inability to deal with adversity. It is necessary to draw up plans to overcome barriers and make it just an obstacle to be overcome with the right operation strategy. Although there are many articles dealing with barriers to implementing CE, in the interviews it was possible to see if these are obstacles to be integrated into the business model operation. Few companies presented barriers; barriers are insurmountable, obstacles are not.

Organizational Environment: Everything discussed so far for the implementation of the CBM must be accompanied along with a good team capitation, the company must have up-to-date information about what is happening and have financial capacity for the implementation. In addition, having managers with the ability to make decisions on the time to certify about marketing, operations, finance and innovation. These points were pointed out, by the interviewees, as something that should be developed and

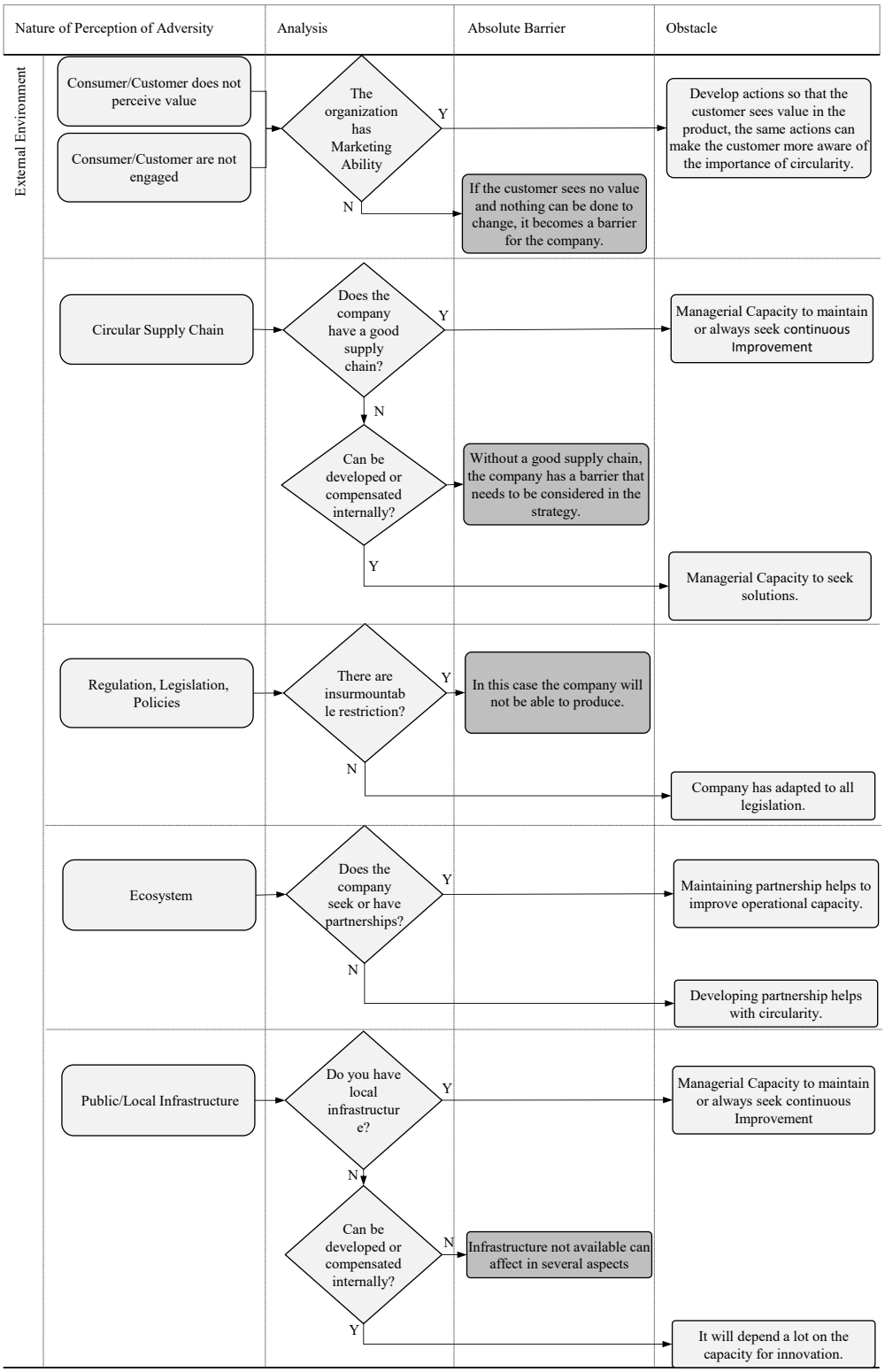
developed continuously. Failure to take decisions at the right time can result in lost business opportunities (Saebi, Lien, & Foss, 2017).

Figure2: Barriers and obstacles integrated in the CBM.



External Environment: Analysing the results, it was possible to understand that consumer /costumer need perceive value and must be engaged with circular practices (or sustainable actions), in both situations the company needs to have marketing ability to count on new consumers or keep those it already has. Local infrastructure and suppliers are other important points for the company's operation strategy to be developed, otherwise it can be compensated internally, depending on the organization's ability to innovate. As for external policies, not much that the company can do, just adapt to meet them and avoid fines or other penalties. Another aspect much discussed in the interviews. it was “other companies”. Larger companies already have partnership strategies, and others are still studying how I got partnerships to leverage CE. It was possible to observe that Operational capacity is necessary to get new partnerships.

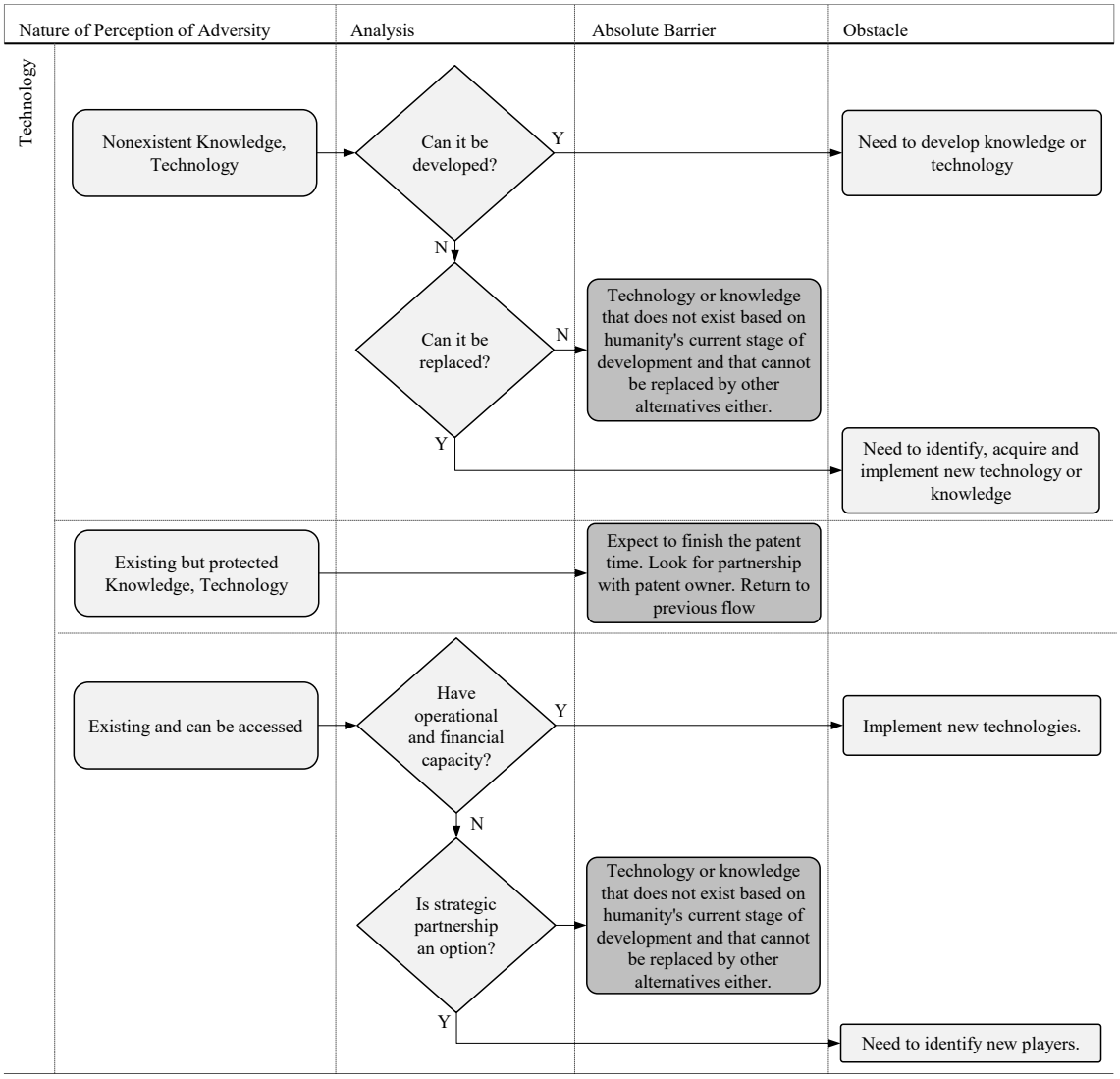
Figure3: Manufacture strategies to overpass barriers related to external environment.



Technology: If the technology does not exist, and cannot be developed, it becomes a barrier. If it doesn't exist, but it can be developed, it will depend on the company's ability to innovate. If the technology exists but cannot be accessed (patent

/ protected), this is a temporary obstacle. Whether it exists and can be accessed will only depend on the financial capacity and operational capacity. In Figure 3 we present the algorithm for the analysis and strategic conversion of barriers. You can see with the interviews that training them to overcome barriers / obstacles must be inserted in the manufacture strategies of companies. According to the interviewees, only in this way can the circular model be successfully implemented and obtain value from this implementation. All suggestions were the result of the interviews.

Figure4: Manufacture strategies to overpass barriers related to technology



Organisational environment: Decision makers must have a group of skills to meet the demands received from within the company, as well as from the external environment. Correct decisions must be made in order to make the company's business model generate internal value, but also for consumers. The importance of taking care of human capital was pointed out, in the case of companies in developing

countries, they need to invest so that the team becomes engaged with the principles of CE. Respondents pondered when each point should receive more attention (investment) in the company. Organizations with a more mature culture of sustainability / CE, understand that investments must be made in all areas, and they invest in CE in the most appropriate way (according to the organization's internal policies).

5.4.2 Competitive criteria

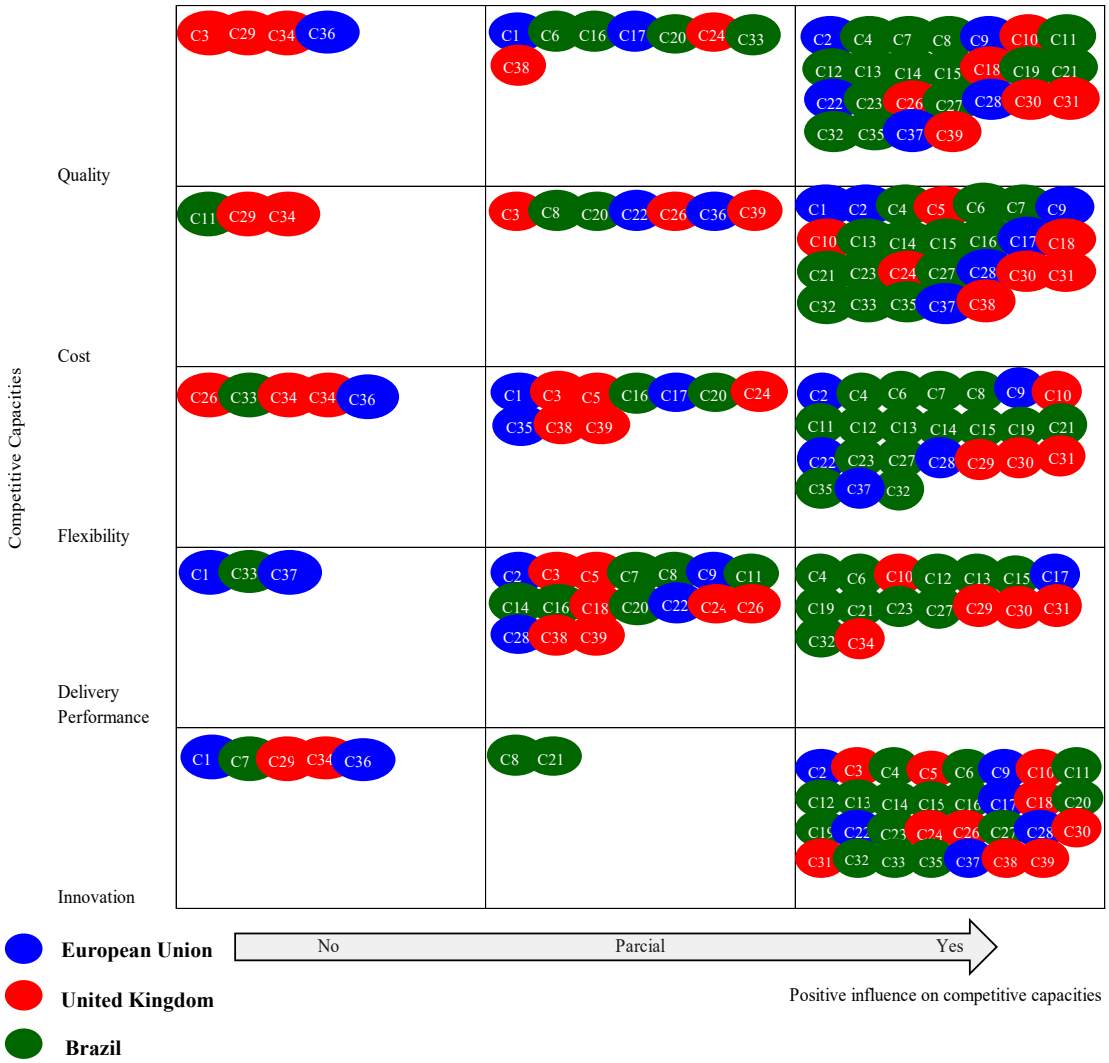
Having the customers revealed that they overcame the obstacles to be more competitive with other plyers in the market, the researchers sent a questionnaire to other members of the company. The intention was to know which competitive criteria really improved in the company, after overcoming obstacles to implement CE. These themes were discussed above, but the questionnaires also helped to triangulate the information given by the interviewees. The results are shown in table 4 and analysed below.

As shown in the figure 5, delivery performance stands out as the only criterion that has improved more partially. Interviewee C37 justified that this is something that depends more on the preparation of the team, the organization should already have this attribute even before the implementation of the CE.

Another criterion that stands out is innovation, 32 interviewees claimed that there was an increase in the company's innovation, because either it increased this sector, or there was more investment or made new products / businesses possible.

When investing in CE, quality and productivity (cost reduction) also showed significant improvements for 27 and 28 (respectively). 8 respondents replied that there was a partial improvement, as they claimed that these improvements were made together with the implementation of CE, that is, it was not a result of the implementation of CE. In the figure, it is possible to see the responses on the scale: "no" when there was no improvement in the criteria, "partial" when there was a partial improvement or "yes" when there was a significant improvement in the competitive criteria.

Figure 5: Competitive Criteria



The items totalling less than 40, the respondents were unable to say whether there was an improvement or not.

As for flexibility, the results show that 24 people believe that there was an improvement in product flexibility, some claim that there was new business model opportunity (C2 and C5, for example). In general, it can be said that, when implementing CE, the 5 criteria make the company more competitive.

In developing a business model, it should be considered “factors affecting the organization, both external (industry-related) and internal (firm-specific)” (Pateli & Giaglis, 2005, p. 11).

The last question asked to the interviewees and in the questionnaires was because, despite the barriers, companies intend to continue investing to increase

circularity within organizations. The response was unanimous, all intend to continue their circular actions. The competitive criteria in figure 4 were mentioned during the responses, in addition to other aspects that we will present below. The positive answer is always associated with the value that CE brings to the company. This point was widely discussed by the interviewees, as shown below. "CE differ us of a lot of other competitors in this area, so that certainly brings new business, that certainly makes new business feasible, reinforces the brand's commitment" C6.

All 40 companies intend to continue investing in circular products. Companies staying in the European added that by 2030 they aim to be carbon neutral (police). "The company will continue this investment, this has already been shown in our unfolding of our strategic planning for the leaders, we need do more with less resources and this will extend to our suppliers, to our business partners" C3. C23, for an example said that the result with the CE implementation was so good that the company made a public commitment to recycle 100% of its manufacturing waste.

The investments most mentioned by companies abroad: climate, renewable sources, taking care of post-consumption products, more water efficiency, more energy efficiency and local development in relation to communities. Some short-term goals and some long-term goals. Other companies are still investing as they are still adjusting and researching how to generate revenue through CE cycles. For example, manufacturing companies, whose process steel has different by-products, like dust steel on a large scale. The companies that solved this point, packed this waste and sold it to other industries. These companies track what is done that this material sells until closing the cycle.

One of the companies made a public declaration of responsibility with the circularity in 2020. In addition, some companies present "a black list of materials in which some she has stopped using and others she intends to stop using in the future" C37. The most common product on this black list is PVC. The companies that invested in reducing waste or reaching zero-waste goal say they have already returned the value of investment.

Still companies reported that after implemented the circular economy in the company, this generated product flexibility. Many companies invest in eco-design (C1,

C10, C7, C37, C6, C37, C28, 24, C32), because they believe that this way there will be less waste at the end of production. Cleaner and more efficient production generate savings for companies, that is, one more perception of the value pointed out by the interviewees. A common point answered by the interviews was that the greater the challenges / barriers overcome, the more competitive the business becomes.

5.5 Conclusion

This article concludes that organizations face many obstacles to implementing CE, however, few companies seem to face definitive barriers. Through proper treatment, the challenges encountered can be converted into opportunities that add strategic value to the business, increasing the organization's competitive capacity. As one of the theoretical contributions, it is proposed to extract these challenges into 3 categories as to their origin: internal to organizations, environmental and technological. In this sense, it is expected to give fluidity to the connection with the research on operation strategy.

The data obtained also suggest that companies that have already implemented CBM have seen significant improvements in innovation, product flexibility (some of which have achieved a new business model with CE), greater efficiency in production with reduced costs and increased product quality. These have usually been seen almost as by-products, but which, it is argued here, could be inserted in the primary objectives of the organizations. Thus, the conversion to CBM should not be a burden, but an end whose gains should be pursued, which is expected to result in motivations for the implementation of the Circular Economy.

As a contribution to practice, this article presents an algorithm for analysis and strategic conversion of barriers into obstacles (Figure 3), as well as these interrelate with each other in the context of CBM (Figure 2).

Other findings were that there are efforts on the part of interviewing companies to become more circular and more responsible for their waste. During the conversations, you can see that the image before the customers is the biggest motivation for these sustainable actions. Tax incentives are needed to help companies invest more in circularity, which is a consensus in all 40 companies. All companies understand that circularity must continue, they must overcome barriers with partnerships.

Companies are betting on innovation to seek better efficiency in the production, so there will be less waste to be treated. Increase production efficiency, decrease waste, leftovers (water and other natural resources) and waste. The intention of all companies is to increase circularity, and to share the value with partner companies. Companies that see more value with the implementation of CE are working in partnership and companies that are still starting to perceive value, are still working individually.

The theoretical research contribution is to deepen the understanding of barriers and connections with CBM. The practical contribution is the understanding of barriers and obstacles in the organizational perspective, allowing the elaboration of more robust business models, with more realistic and effective strategic options.

A limitation of the study is the number of people interviewed by company, if we had access to more respondents, more barriers could appear. Another point, it was not possible to visit the companies, this could be an interesting triangulation for the study.

Acknowledgments: The authors would like to thank CAPES, CNPq and FAPESP, for supporting this research. The authors thank all respondents for their contribution.

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6 Article 3: Unpacking the Value Conversion in Circular Business Model: Exploring the Effect of Competitive Criteria

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Abstract

Purpose: This article investigates the influence of Technical Cycles in capturing and sharing value through the Circular Business Model, exploring the moderating effect played by Competitive Criteria in these relationships.

Design/methodology/approach: The research design applies the Partial Least Squares Structural Equation Modelling technique in the strict rigour of the Confirmatory Composite Analysis protocol, aiming at the necessary robustness for confirmatory purposes. We gathered data through a survey whose final sample represented 233 different organisations from 50 countries and 16 productive sectors. From a representation of the value flow, from the Technical Cycles to the sharing, the study shows the moderating effect played by the Competitive Criteria.

Findings: The results also suggest that cost reduction, higher quality, operational flexibility and delivery capacity influence the relationship between the Technical Cycles and the Captured Value and indirectly affect the Shared Value.

Originality: This study innovates as it tests the impact of classic Competitive Criteria in the Circular Economy context and statistically analyses how strategic value flows in the logic of the circular business model based on empirical data. Conversely, a revision to the Competitive Criteria in the classic literature on strategic manufacturing is also proposed to incorporate circular logic characteristics.

Keywords: Circular Economy; Technical Cycles; Competitive Criteria; Circular. Business Model.

Article classification: Research Paper

6.1 Introduction

Circular Economy (CE) is receiving more recognition due to its focus on increasing the resources circularity (Koh et al., 2017) through Technical Cycles (TC), suggesting different ways to capture business value (Mizanur Rahman, Kim, Lerondel, Bouzidi, & Clerget, 2019). These resources would go through a “hierarchical process” to maximise the capture of value through TC (Reuter, van Schaik, & Gediga, 2015). In other words, special attention to changing an economy based on increased consumption and obsolescence by an economy based on sharing and capturing value (Reike et al., 2018).

Therefore, effective management of the circular business model (CBM) in line with the operation strategy is necessary. The company's business model (BM) would require further development to explore values not yet captured in the previous system (Yang, Evans, Vladimirova, & Rana, 2017), creating value retained in the whole life cycle. Therefore, the CE's essence involves a profound change in the operation and the creation of value for an organisation (Ríos & Charnley, 2015). The greater this circular flow is, the greater the revenue results can be (Cohen, 1998). According to these conditions, value flow management would be associated with a strategic and operational approach to business, aiming to analyse, capture value throughout the organisation, maximizing efficiency (Hines et al., 1998).

This paradigmatic change has led to the warning of the need to develop CBMs, circumscribing TCs as operational enablers for the generation, capture, and sharing of strategic value as part of the circular ecosystem (Yang, Evans, Vladimirova, & Rana, 2017). There is already considerable literature that mentions potential organisational benefits associated with the TCs implementation (Morioka & Carvalho, 2016). Such as cost reduction, quality increase, enhancement of the corporate image, innovative capacity (Adner & Kapoor, 2010; Linder & Williander, 2017). However, no study integrates these expressions of value, from the perspective of Competitive Criteria (CC) and operation strategy, as fundamental inputs in the design of a BM (Zott et al., 2011).

Decisions regarding operational, competitive, and sustainability criteria need to be planned in the short and long term to obtain value in a BM (Pourhejazy, Sarkis, &

Zhu, 2020). This, because some companies are impelled to make long-term operation strategy due to “the increasing complexity of the global business environment together with changes in technology and customer expectations has led to a shift in the nature of competition” (Soosay et al., 2016). Furthermore, to be truly competitive, the organisation needs to have clear CC within the business (Porter, 1985). The classic literature on manufacturing operation strategy presents the following CC: Quality, Cost, Flexibility, Delivery performance, and innovation (Flynn & Flynn, 2004; Garvin, 1987; Skinner, 1974).

Additionally, there is no confrontation between the mechanisms for generating potential gains declared in the CE research field with the classic and abundant literature on manufacturing operation strategy. However, this relationship has already been mentioned (Lieder & Rashid, 2016). Thus, to obtain value through TCs, it is necessary to know if the CC have any moderating effect on them. Thus, below we present the research questions.

RQ1: How does CBM influence the TCs to result in captured value (CV) and shared value (SV)? RQ2: Do the competitive criteria have a moderating effect on this relationship?

The missing link between these two fields of academic research can lead to unrealistic assumptions about the strategic sustenance of these mechanisms, therefore, compromising the effectiveness of CBMs and, consequently, the organisational success itself (Demil & Lecocq, 2010; Diepenmaat, Kemp, & Velter, 2020). Besides, recent BM research focuses on innovation, there is a gap in related quantitative research on the CE field (Kirchherr & van Santen, 2019).

Hereupon, it is essential to shed light on the causal relationships in the circular logic of generating and converting strategic value – epistemological basis. The main objectives of this work emerge: (i) investigates the influence of the CBM through TCs on CV and SV; (ii) to explore the moderating effect play by the CC on this relationship.

Structural Equation Modelling (SEM) was used to achieve these confirmatory objectives, specifically with the Partial Least Squares (PLS) technique), supported by

the rigour of the Confirmatory Composite Analysis (CCA) protocol (Hair, Howard, & Nitzl, 2020).

The study contributes to the literature in three folds. First, the validated research model demonstrates the value flow through TCs and both the organisation's CV and SV network with other players. Second, it shows the crucial role of the CC on the value stream through direct, moderate, and indirect effects. Third, the study contributes to filling the gap for quantitative studies in the CE field. From a practical perspective, by shedding light on the influence of CC and the conversion of operation operation strategy in the CE context.

6.2 Theoretical Grounding and Conceptual Framework

6.2.1 Technical Cycles in the Circular Business Models Context

CBMs represent a new strategic business structure, in line with the CE logic, inserting the particularities of a new dynamic in the value flow (Galvão et al., 2020). The broad and integrative proposal that builds the CE requires incorporating TCs for closing restorative loops of potential value already in circulation (Bocken, Short, Rana, & Evans, 2014; Evans et al., 2017; Geissdoerfer, Savaget, Bocken, & Hultink, 2017). Hereupon, the CBMs importance is emphasized as conductors between the operation of the TCs and the generation of value in the circular logic (Yang, Evans, Vladimirova, & Rana, 2017).

TCs comprise the operational processes that enable the formation of closed loops, through which value is generated, captured, and shared in the CE context (Macarthur, 2019). They can be considered a solution for generating waste, scarcity of resources and sustaining economic growth (Lieder and Rashid, 2016). Through the TCs implementation, conversion to clean production occurs, with the rational use of material and energetic inputs, and reducing wastes (Lewandowski, 2016). Ultimately, they represent the operational portion results in generating strategic value by increasing the useful life of products, components and inputs to production, enabling the reuse, repair, technological update.

The sharing cycle is an alternative to the current property-based consumption system, resulting in more sustainable consumption patterns, such as car or tools

sharing (Moreno, Rios, Rowe, & Charnley, 2016). The remanufacturing cycle allows organisations to significantly save the original manufacturing process, recovering the maximum parts and components of products already used (Linder & Williander, 2017). The recycling cycle allows the recovery and reprocessing of raw material from products that have reached the end of their useful life, already recognized as an important strategic efficiency vector (Macarthur, 2019). Through the reuse cycle, recover the maximum parts and components of products already used to be incorporated into new products (MacArthur, 2019; Moreno, Rios, Rowe, & Charnley, 2016) added to these cycles, the idea is new products have their life cycles extended, enabling a positive return for companies (Stahel, 2016). For the conversion of value that ends this loop, it is necessary to involve several other players in the circular ecosystem, such as consumers, associations and other organisations (Bocken, Short, Rana, & Evans, 2014; Schulte, 2013; Yang, Evans, Vladimirova, & Rana, 2017).

6.2.2 Competitive Criteria in Manufacturing Operation strategy Literature

CC help to make decisions regarding production, capacity, technology, planning and control, leave organisations in a good position in the market, involving value trade-offs decisions (Corbett & van Wassenhove, 1993; Flynn & Flynn, 2004). Hereupon, the classic manufacturing operation strategy literature has consolidated some CC over time.

Each CC encompasses different definitions. The cost reduction is a relevant aspect to the CC gain due to efficiency gain (1993; Flynn & Flynn, 2004; Garvin, 1987; Skinner, 1974; Slack,1994).

Quality, as a competitive differential not only leverages the valorisation of the product, as when applied to the production processes, it allows the reduction of waste. Eight dimensions can measure quality: performance, features, reliability, conformance, durability, serviceability, aesthetics and perceived quality (Garvin, 1987).

Delivery resources represented by a more integrated and effective operational chain (Flynn & Flynn, 2004; Garvin, 1987; Skinner, 1974; Slack, 1994) is essential to emphasize that, in the CE context, the type of integration mentioned in the supply chain

has greater breadth, capable of making effective value sharing (as discussed above). This concept was not part of the manufacturing operation strategy classic literature.

Flexibility refers to generating value on several production fronts, including the basket and volume of products offered by Swamidass (1987). Innovation concerns the development of new processes, new products and technologies, bringing competitive advantage (Corbett & van Wassenhove, 1993). Furthermore, marketing as resource-intensive functions is still reported as a specific criterion, emphasizing that this function is not a natural part of manufacturing activity (Junkunc, 2007; Sethi & Sethi, 2009).

CE needs innovation to be implemented in organisations, or even, CE can lay down the most innovative organisation (Pieroni, McAloone, &Pigosso 2019). Studies show CE search also results in a product (Kapsalis, Kyriakopoulos, & Aravossis, 2019) and environmental quality CC and positive contributions in TCs. In other words, we want to investigate whether the five CC can positively contribute to the TCs, according to the following hypothesis.

H1a: Competitive criteria contribute to technical cycles.

6.2.3 Capturing Value

CBMs aims to create, deliver and capture value in circular logic through the elements of costs and revenue streams of the BM (Galvão et al., 2020). Therefore, circular manufacture strategies must be implemented (Nußholz, 2018; Shahbazi, Wiktorsson, Kurdve, Jonsson, & Bjelkemyr, 2016).

To capture value, the literature points out some actions that can be taken by companies, the main ones are: (i) investing in consumer education to recognize the value of products in line with CE principles brings positive results (Ríos and Charnley, 2015); (ii) increasing the product's useful life generates a positive return when analysed in the long term (the consumer recognizes added value as quality) (Nußholz, 2018; Shahbazi, Wiktorsson, Kurdve, Jonsson, & Bjelkemyr, 2016; Stahel, 2016); (iii) investing in social development, within the scope of the CE, valuing the image and the brand organisation (Murray, Skene, & Haynes, 2015; Wolf, 2014); (iv) invest in environmental protection, valuing the organisation's image and brand (Hart & Dowell, 2011; Olson, 2008); (v) reduce costs with a more rational use of material and energy

(Borrello, Caracciolo, Lombardi, Pascucci, & Cembalo, 2017; D'Amato, Veijonaho, & Toppinen, 2018); (vi) invest in sales of refurbished or remanufactured products, resulting in a positive economic impact for the company (Stahel, 2016); (vii) maximizes results by reducing the environmental impact (for example, saving water or reducing waste) (MacArthur, 2019; Hart & Dowell, 2011; Olson, 2008); and (viii) invest in technologies and processes capable of converting value into circular logic (Adner & Kapoor, 2010; Linder & Williander, 2017; Moreno, Rios, Rowe, & Charnley, 2016).

Despite considerable literature on CBM, it rarely discusses the real achievement of circular value in real-world configurations. Therefore, it is essential to explain how businesses capture the value of their CE practices through TCs (Hopkinson, Angelis, & Zils, 2020). Therefore, the research hypothesis that emerges from the literature on this topic relates TCs and positive results in the CV:

H1b: Technical Cycles have a positive influence on captured value.

Sustainable development practices and CE conditions improve organisational performance, leaving the company more competitive (Sarfraz, Ivascu, Belu, & Artene, 2021). It is also known it is possible to capture value from CE (Hopkinson, Angelis, & Zils, 2020). However, we want to investigate whether the criteria of commitment (operational literature) can increase organisations' chance of capturing value. Thus, we present the following hypothesis:

H1c: The competitive criteria significantly affect the captured value.

In the H1b hypothesis, we will test whether the TCs positively influence CV. We also tested whether CC has a moderating effect on the relationship between TCs and CV, according to H1d.

H1d: Competitive criteria have a moderating effect on the relationship between technical cycles and value capture.

6.2.4 Sharing Value

Porter and Kramer (2011) wrote companies could create SV in three ways: (i) Receiving products and markets; (ii) redefining productivity in the value chain; and (iii) creating support industry groups at company locations. Within the umbrella of CE) the

sharing value can also come through these actions, among others (Galvão et al., 2020). However, it is essential to note that trust is a critical variable in developing effective collaboration and communication (Ünal, Urbinati, Chiaroni, & Manzini, 2019).

Thus, companies can share value with actors in a comprehensive and integrated supply chain. For example, a supplier can see more value in becoming part of CE by sharing waste (Stahel, 2016; Ünal, Urbinati, Chiaroni, & Manzini, 2019; Vermeulen, 2015). Industries can share value with partners through industrial symbiosis initiatives by connecting industries at different scales in an ample space sharing to obtain environmental and economic benefits through the exchange of resources, as material, water, energy, and by-products (Chertow & Ehrenfeld, 2012).

Sharing value with consumers, users, and the community has also proved to be worthwhile for companies. Customers who participate in something more significant has value, and CE can be the option for many of them (Ünal & Shao, 2019). To share value, companies also need to innovate in their circular based business including the involvement of a network of stakeholders (Tunn, Bocken,van den Hende, 2019). The prospect of a CE can be attractive to companies of all sizes. Through their TCs, companies can collaborate and share best practices in CE implementation (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). It is unknown whether this sharing also results in SV (Hopkinson, Angelis, & Zils, 2020). It leads to the research hypothesis emerges H1e.

H1e: Technical Cycles have a positive influence on shared value.

As presented in this chapter, the literature presents how to create, capture, share value, or even measure SV. However, we do not find a parallel in the classic strategic manufacturing literature, if after capturing the value, there is an intensification of sharing this value. Consequently, we also investigated whether this occurs and with whom organisations prefer to share the CV. Thus, we present the H1f:

H1f: The captured value is shared.

6.2.5 Value Conversion in CE: Nomological Network

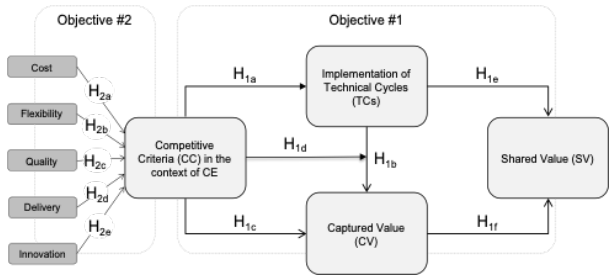
The set of concepts about generating, capturing, and sharing value in the CE context, further the CC reported in the classic strategic manufacturing literature, were listed i (Figure 1). The relational associations between these constructs generated the hypotheses to be tested in this research. Construct validation is not restricted to measurements of its predictive capacity – it is necessary, initially, to represent the nomological network, which starts the process of defining the construct, based on its relations with the other variables involved, structured through a logic of theoretical foundation (Cronbach & Meehl, 1955). The nomological representation (Figure 1) consists of the relationships between the theoretical concepts discussed above, whose measurement of the strength of relationships is reflected in hypotheses to be tested, in observance of the objectives of this research.

Figure 1 - Nomological Representation, Research Model and Hypotheses

Correlation of Constructs and Formulation of Hypotheses

CBM Domain	Structural Relationship Hypotheses	Potential Value Reported in CE Literature	Theoretical Association Hypotheses	Competitive Criteria (Classic Manufacture Strategy Reference)	
From value generation to value capture	CC → TC H_{1a}: Competitiveness contribute to Technical cycles. TC → CV H_{1b}: The value is captured through the technical cycles. CC → CV H_{1c}: Competitiveness implies capturing value. H1d : Competitive criteria has a moderating effect on the relationship between TC → CV	Cost reduction, productivity (Borrello *et al.*, 2017; Amato *et al*., 2020; Schrader *et al*., 2012; Schulte, 2013; Zhang *et al*., 2009)	H_{2a} ➔	Cost	(Boyer and Lewis, 2002; Corbett and van Wassenhove, 1993; Flynn and Flynn, 2004; Garvin, 1987; Skinner, 1974)
		New product lines, as refurbished or remanufactured products (Stahel, 2016)	H_{2b} ➔	Flexibility	(Boyer and Lewis, 2002; Corbett and van Wassenhove, 1993; Flynn and Flynn, 2004; Garvin, 1987; Skinner, 1974; Swamidass, 1988)
		Superior quality products with extended service life (Nußholz, 2018; Shahbazi *et al.,* 2016; Stahel, 2016)	H_{2e} ➔	Quality	(Boyer and Lewis, 2002; Corbett and van Wassenhove, 1993; Flynn and Flynn, 2004; Garvin, 1987; Skinner, 1974)
		Greater supply chain integration (however, with a larger scope than that observed in linear logic) (Seuring and Müller, 2008; Stahel, 2016; Ünal *et al*., 2019; Vermeulen, 2015)	H_{2c} ➔	Delivery	(Boyer and Lewis, 2002; Corbett and van Wassenhove, 1993; Flynn and Flynn, 2004; Skinner, 1974)
		Technologies and processes capable of converting value into circular logic (Adner and Kapoor, 2010; Linder and Williander, 2017; Moreno *et al*., 2016)	H_{2f} ➔	Innovation	(Corbett and van Wassenhove, 1993; Flynn and Flynn, 2004; Skinner, 1974)
		Improved image and brand enhancement (Wolf, 2014)	-	There is no parallel in the classic strategic manufacturing literature	
From value generation to value sharing	TC → SV H_{1e}: The value is shared through technical cycles.	TCs provide value sharing (Gold et al., 2013; Seuring & Müller, 2008; Stahel, 2016; Ünal et al., 2019; Vermeulen, 2015)	-	There is no parallel in the classic strategic manufacturing literature	
From value capture to value sharing	CV → SV H_{1f}: The captured value is shared.	The captured value is shared (Chertow and Ehrenfeld, 2012; Ünal and Shao, 2019; Antikainen and Valkokari, 2016; Tunn *et al*., 2019)	-	There is no parallel in the classic strategic manufacturing literature	

Nomological Representation and Hypotheses



6.3 Methodological Considerations

The sample surveys of this research are based on a systematic and standardized data collection and analysis (Marsden & Wright, 2010). The transition from manifest to latent variables implicit in the objectives of this research led to the choice of the PLS-SEM (Wold, 1980), more specifically, Consistent PLS (PLSc) (Dijkstra & Henseler, 2015). The confirmatory procedure followed the rigour established by Hair, Howard, and Nitzl (2020). Therefore, contemplating the use of CCA (Schuberth, Henseler, & Dijkstra 2018) due report of the critical variables (Hair, Risher,Sarstedt, & Ringle 2019).

6.3.1 Sampling Approach and Data Collection

Over two months, 2.200 professionals involved in activities related to CE, were invited to participate in the survey, resulting a final sample of 233 respondents representing distinct companies-previous treatment of the data excluded those questionnaires that did not present satisfactory consistency. As a repetitive pattern of answers, incoherence or incompleteness in the information presented, or respondents who have not confirmed having the profile sought (Hair et al., 2018). G*Power software was adopted to establish a sample size target, indicating 103 cases as the minimum sample size. The data were collected through a survey, using a 7-point Likert scale (Likert,1932)," respecting the criterion of symmetry (Hair, Hult, Ringle, & Sarstedt, 2016) and ordinal semantics (Nunnally & Bernstein, 1994).

To avoid Common Method Bias (CMB) (Podsakoff, MacKenzie, Lee, & Podsakoff 2003) the semantics adopted in preparing the collection instrument sought guidance mainly for indicators of a judgmental nature (Fischer, 1998). Also a preventive procedure: (i) randomness in the order of the questions (Chang, Van Witteloostuijn, & Eden 2010); (ii) open questions, used for content verification and confirmation, additionally the merging of formative and reflective measurement variables (Jordan & Troth, 2020); (iii) a pilot questionnaire was previously submitted to a selected group of practitioners, and academic researchers to identify possible points with divergent interpretation or misunderstanding), and (iv) suggestions were incorporated into the final version of the questionnaire. As ex-post approaches, Harman`s single factor was initially made using IBM-SPSS), presenting a satisfactory result, precisely, below 50% (44.7%). However, other statistical analyses of collinearity of the modelling were

performed as part of CCA, and the results are available in section 4. Anyhow, some distortion degree must be considered an ontological study limitation (Fischer, 1998).

6.3.2 Operationalization of Variables

The indicators consisted of 22 items, coded and related to latent variables based on the theoretical review (Table 1). It indicates the nature of the measurement inherent in the relationship between the latent variables and the respective indicators, nominally being formative or reflective (Hair, Hult, Ringle, & Sarstedt, 2016).

Table 1 – Operationalization of Variables

Construct (Y_i)	Measurement Model	Indicators (x_j)		References
Implementation of Technical Cycles (TC)	Reflective	(TC_01)	Development of products that can be shared during use (sharing).	(Nußholz, 2018; Shahbazi et al., 2016; Stahel, 2016)
	Reflective	(TC_02)	Development of products that can be refurbished or remanufactured.	(Stahel, 2016)
	Reflective	(TC_03)	Development of products that can be reused or transferred between consumers after use.	(Nußholz, 2018; Shahbazi et al., 2016; Stahel, 2016)
	Reflective	(TC_04)	Development of products with extended service life.	(Nußholz, 2018; Shahbazi et al., 2016; Stahel, 2016)
	Reflective	(TC_05)	Development of products that use recycled material for their production / commercialization.	(Hart & Dowell, 2011; Schrader et al., 2012)
Competitive Criteria (CC)	Reflective	(CC_00)	The implementation of circular techniques and principles positively impact corporate competitiveness.	(Bocken et al., 2014; Donner et al., 2020; Evans et al., 2017; Geissdoerfer et al., 2017)
	Formative	(CC_01)	More flexible production system (greater breadth in the generation of value).	(Corbett & van Wassenhove, 1993; Flynn & Flynn, 2004; Garvin, 1987; W. Skinner, 1974; Swamidass, 1988)
	Formative	(CC_02)	More integrated and effective operational chain (effective integration of suppliers, buyers of industrial leftovers, production, logistics, etc.).	(Corbett & van Wassenhove, 1993; Flynn & Flynn, 2004; Garvin, 1987; W. Skinner, 1974)
	Formative	(CC_03)	More efficient use of resources (raw materials, energy, etc.).	(Corbett & van Wassenhove, 1993; Flynn & Flynn, 2004; Garvin, 1987; W. Skinner, 1974)
	Formative	(CC_04)	Superior quality standards (products with higher added value).	(Corbett & van Wassenhove, 1993; Flynn & Flynn, 2004; Garvin, 1987; W. Skinner, 1974)
	Formative	(CC_05)	Increased innovation potential (development of new processes, new products and technologies, etc.).	(Corbett & van Wassenhove, 1993; Flynn & Flynn, 2004; W. Skinner, 1974)
Value Captured by the Company (CV)	Reflective	(CV_01)	The company maximises results by reducing environmental impact (for example, saving water or	(Borrello et al., 2017; D'Amato et al., 2020; Schrader et al., 2012; Schulte, 2013; H. Zhang et
	Reflective	(CV_02)	Investing in consumer education to recognise the value of products in line with CE principles brings positive results.	(De los Ríos & Charnley, 2015)
	Reflective	(CV_03)	The increase in the product's service life generates a positive return when analysed in the long term (consumer	(Nußholz, 2018; Shahbazi et al., 2016; Stahel, 2016)
	Reflective	(CV_04)	Investment in social development, as part of the CE, has enhanced the organisation's image and brand.	(Murray et al., 2015; Wolf, 2014)
	Reflective	(CV_05)	Investment in environmental protection, as part of the CE, has enhanced the organisation's image and brand.	(Hart & Dowell, 2011; Olson, 2008; Schrader et al., 2012)
	Reflective	(CV_06)	The company reduced costs with a more rational use of material and energy resources.	(Borrello et al., 2017; D'Amato et al., 2020; Schrader et al., 2012; Schulte, 2013; H. Zhang et al., 2009)
Value Shared by the Company (SV)	Reflective	(SV_01)	The company has succeeded in sharing value with actors in the supply chain.	(Chertow & Ehrenfeld, 2012; Seuring & Müller, 2008; Stahel, 2016; Ünal et al., 2019; Vermeulen,
	Reflective	(SV_02)	The company has succeeded in sharing value with consumers and users.	(Antikainen & Valkokari, 2016; Tunn et al., 2019; Ünal & Shao, 2019)
	Reflective	(SV_03)	The company has succeeded in sharing value with the surrounding community.	(Antikainen & Valkokari, 2016; Tunn et al., 2019; Ünal & Shao, 2019)
	Reflective	(SV_04)	The company has succeeded in sharing value with different associations (associations of informal workers, such as recyclable waste collectors, etc.).	(Antikainen & Valkokari, 2016; Tunn et al., 2019; Ünal & Shao, 2019)

The only formative measurement is the composite type and refers to the latent variable “Competitive Criteria” (CC), whose composition was discussed in subsection 2.2. As an exception, the CC_00 indicator has reflective measurement, having been designed to meet the purpose of redundancy analysis to validate the convergence of the formative model (Chin, 2010). Formative training related to operation strategy is justified as there is a robust theory on the subject (Podsakoff, Shen, & Podsakoff, 2006). The other variables have reflective measurements (Table 1).

6.3.3 Structural Model Design

The structural model was elaborated from the representation of the nomological network (Cronbach & Meehl, 1955) in section 2. In general, it aims to verify how the conversion of the strategic value occurs in the CE context (objective #1) by testing the relationship between (i) Competitive Criteria (CC) with the Technical Cycles implementation (TC); (ii) Competitive Criteria (CC) with the Captured Value (CV); (iii) Technical Cycles (TC) with the Captured Value (CV); (iv) Technical Cycles (TC) with the Shared Value (SV); and (v) Captured Value (CV) with the Shared Value (SV). Additionally, a variable (grey colour) was included to measure the moderating effect of the CC variable in the TC->CV ratio. Specifically, on how CC moderates the relationship TC->CV.

Simultaneously, the formative measurement of the CC latent variable is checked for its components (composite). This analysis aims to confirm whether the CC in the corporate operation strategy general literature is replicated in the CE context (objective #2).

Besides these, this characterisation of the formative and reflective measurement models makes up the relationships between latent variables and is fundamental to sustain the results obtained. The model of this study has a formative-reflective characteristic, whose formative construct (CC) imposes a cause-effect relationship with the latent variables of a lower order (TC and CV). This type of structure implies particular attention to the collinearity analysis of the formative measurement model (Ringle et al., 2012).

6.3.4 Procedures and Parameters for Data Analysis

The preliminary treatment and analysis of the data were carried out using some support software, such as IBM SPSS software and R software environment for statistical computing and graphics (Core Team, 2020). The PLS modelling was carried out using SmartPLSPlus with the additional algorithms support, as PLSc, Bootstrapping (Hair, Hult, Ringle, & Sarstedt, 2016) and PLSPredict (Shmueli et al., 2019).

The study of normality receives particular attention in this research (Hair, Risher, Sarstedt, & Ringle 2019). Considering the robustness of the PLS-SEM even when there is minus normality, it is recommended the researcher analyse how far the data deviate from the normal distribution by assessing skewness and kurtosis. Not just the mere rejection of the hypothesis through tests such as Kolmogorov-Smirnov and Shapiro-Wilk tests (Hair, Hult, Ringle, & Sarstedt, 2016).

6.3.4.1 Confirmatory Composite Analysis with PLS-SEM

Reflective indicators are empirical manifestations that lead to the latent variable, therefore, and should be tested in favour of the statistical robustness of the model as a whole (Sarstedt et al., 2016). Conversely, formative measurement starts from theory and seeks to validate indicators, therefore, meeting the purpose of the first objective established for this research. Finally, the validation of the structural model aims to establish the significance of the relationships between the constructs of the tested model, therefore, directed to the second objective of this research (Hair, Howard, & Nitzl, 2020).

6.3.4.2 Reflective Measurement

The first step for validating the reflective measurement model is estimating loadings and significance, using PLSc and Bootstrapping (Hair, Hult, Ringle, & Sarstedt, 2016). Both indicators and constructs analysis were performed. Composite reliability or the reliability of the construct can be measured by both Cronbach's alpha (α) and composite reliability (CR) (Hair, Howard, & Nitzl, 2020; Hair, Hult, Ringle, & Sarstedt, 2016). Both measurements must be above 0.7 in confirmatory research but below 0.95, a threshold beyond which it could indicate measurement redundancy (Hair, Risher, Sarstedt, & Ringle 2019). Hair, Howard, and Nitzl (2020) still propose the nomological

analysis to validate the consistency of the findings with the theoretical basis, added to the predictive validity analysis of the reflective model. The latter, however, used in a longitudinal study, therefore not applicable to this particular research.

6.3.4.3 Formative Measurement and Competitive Criteria in CE

Formative measurement is the basis for validating the hypothesis that the CC in the corporate operation strategy general literature is replicable in the CE context. If the formative measurement model is considered valid, it will be assumed that CC apply to CBMs.

The formative measurement model assumes the cause of the indicators or constitutes the construct. Thus, unlike the reflective model, there is no covariance in formative measurement, whose assessment must consider particular aspects, including implying different interpretations of the parameters, compared to reflective measurement (Hair, Howard, & Nitzl, 2020). Convergent validity for the latent variable with formative measurement requires redundancy analysis (Chin, 1998, 2010). This reference can be obtained from a single indicator that summarizes the concept of the formative construct (Hair, Howard, & Nitzl, 2020). In the present research, the indicator CC_00 (CE has a positive strategic impact on the company, increasing the competitive differential) was included to serve as the alternative basis for reflective measurement to support the redundancy analysis. For convergent validity, it is expected that the path coefficient with the referential variable of reflective measurement is above 0.700 and R2>0.640.

6.3.5 Structural Model

The evaluation of the structural model includes some specific steps for the rigour of the CCA. Initially, the collinearity analysis is made as described above (including the same basis for assessing VIF), however now for the structural model. Then, the strength of the relationships between the constructs is analysed and validated by t-statistic (two-tailed test at the 5% level; t-value above ± 1.96) (Hair, Howard, & Nitzl, 2020).

The predictive validity of the structural model must be done through a series of validation steps to meet the confirmatory purpose (Chin et al., 2020; Hair, Howard, &

Nitzl, 2020). Initially, the analysis of the determination coefficient (R2) of the endogenous variables is made, which interpretation follows the parameters: R2<0.25 (weak effect); 0.25≤R2<0.5 (moderate effect); R2≥0.5 (substantial effect); and R2≥0.9 (overfit) (Henseler & Fassott, 2010). An alternative view of the model's predictive capacity is obtained by the effect size (f2), which impacts exogenous constructs on endogenous constructs. The f2 interpretation uses the following criteria: 0.02<f2≤0.15 (small effect); 0.15≤f2<0.35 (medium effect); and f2≥0.35 (large effect) (Cohen, 1988). Additionally, the Blindfolding-Based Cross-Validated Redundancy Measure (Q2) (Chin et al., 2020; Hair, Hult, Ringle, & Sarstedt, 2016) provides a predictability measurement parameter outside the sample. The interpretation of Q2 is made using the following parameters: 0<Q2<0.25: small predictive accuracy; 0.25≤Q2<0.50: medium predictive accuracy; and Q2≥0.50: significant predictive accuracy (Hair, Howard, & Nitzl, 2020).

The last step uses the PLSPredict method, which simulates prediction based on holdout-based samples generated randomly (Shmueli et al., 2019). If all indicators have major errors, the predictive power is considered inadequate. If most indicators have higher errors, then the predictive power is low. If the minority of indicators show major errors, the predictive power is average and, if no indicator has significant errors, then the predictive power will be high (Hair, Howard, & Nitzl, 2020).

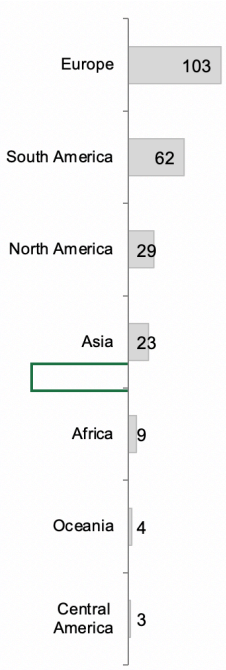
6.4 Analysis and Discussion of Results

6.4.1 Sample Demographics

The selection criterion was based exclusively on previous experience in implementing some aspects of the CE, as the respondents evaluated results already obtained. Thus, the analysis included 233 different organisations, distributed in 50 countries, with representation on all continents, nonetheless with a significant difference in frequency (Table 2). European companies make up the majority of the sample (44%), distributed in 21 countries. Despite representing 10% of the sample, the Asian continent was represented by 13 different countries. South America represents the second largest portion of the sample. North America also had a significant concentration of respondents from the U.S.A.

Table 2 – Sample Distribution by Country and Region

Europe (103 cases)	Austria	1
	Belgium	8
	Czech	1
	Denmark	1
	Finland	2
	France	5
	Germany	13
	Greece	1
	Ireland	1
	Italy	4
	Latvia	1
	Netherlands	11
	Norway	2
	Polska	1
	Portugal	1
	Romania	2
	Serbia	1
	Spain	14
	Sweden	5
	Switzerland	1
	United Kingdom	27
North America (29 cases)	Canada	5
	United States of America	24
Central America (3 cases)	Costa Rica	2
	Mexico	1
South America (62 cases)	Argentina	1
	Brazil	58
	Chile	1
	Colombia	1
	Paraguay	1
Asia (23 cases)	Bangladesh	1
	China	1
	Hong Kong	1
	India	8
	Indonesia	2
	Japan	1
	Jordan	1
	Malaysia	1
	Pakistan	1
	Qatar	2
	Singapore	2
	Thailand	1
	Vietnam	1
Africa (9 cases)	Egypt	2
	Kenya	1
	Nigeria	2
	Senegal	1
	South Africa	1
	United Arab Emirates	2
Oceania (4 cases)	Australia	4



It was essential to reach the largest possible number of companies that raise CE from a strategic perspective aligned with the research aims. Thus, the sample has several companies (208 cases; 89.2%) totally or partially incorporate CE as part of their operation strategy, and companies operating in various productive sectors (16). The highlight is the consultancy services related to the CE and sustainability (60 cases) and waste management and recycling activities (37 cases).

The research purposes are fundamentally related to the conversion of value, in theory, supported by literature of operation strategy and universally widespread, additional noise resulting from specific public incentive policies (Zhu, Qu, Geng, & Fujita, 2017) and cultural differences that can alter the consumption patterns of a society (Borrello, Caracciolo, Lombardi, Pascucci, & Cembalo, 2017) should be considered a methodological limitation.

6.4.2 Normality and Multivariate Normality

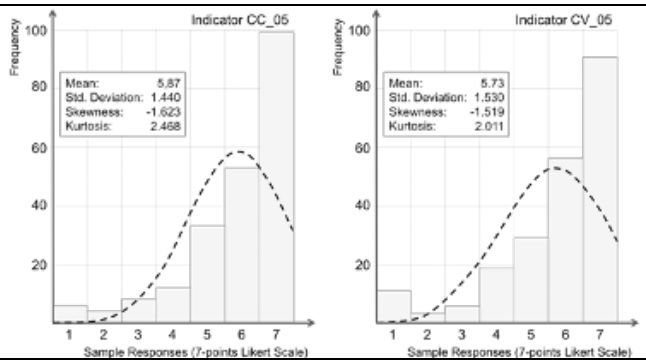
The Q-Q curve of normality of the collected sample reveals satisfactory adherence to the referential line, including the survey data follows a normal distribution. This considering the expected behavioural variation of the Social Sciences (Cohen, 1988). The analysis revealed two variables with severe non-normal distribution: CC_05

(increased innovation potential, as the development of new processes, new products and technologies) and CV_05 (investment in environmental protection of CE, has enhanced the corporate image and brand). Consequently, the indicators CC_05 and CV_05 were discarded from the model. The graphical analysis reveals both variables show similar behaviour, with significantly negative skewness and significantly positive kurtosis (Table 3). These results catch almost 80% of the responses collected are concentrated in points 5, 6 and 7 on the Likert scale.

Table 3 – Normality of Indicators

Normality of Indicators											
Indicator	**Missing**		**Dispersion**			**Skewness**	**Kurtosis**	**Test of Normality**			
Code	#	%	Mode	Mean	Std Dev.	Statistic	Statistic	Kolmogorov-Smirnov	Signif.	Shapiro-Wilk	Signif.
CC_00	6	2,58%	6	5,32	1,642	-0,855	0,173	0,182	0,00	0,873	0,00
CC_01	10	4,29%	7	5,34	1,548	-0,881	0,230	0,165	0,00	0,880	0,00
CC_02	10	4,29%	7	5,31	1,670	-0,940	0,028	0,209	0,00	0,861	0,00
CC_03	10	4,29%	6	5,33	1,368	-0,813	0,595	0,170	0,00	0,901	0,00
CC_04	11	4,72%	7	5,35	1,608	-0,858	0,025	0,180	0,00	0,873	0,00
CC_05	9	3,86%	7	5,87	1,440	-1,623	2,468	0,226	0,00	0,764	0,00
CC_06	2	0,86%	4	4,59	1,936	-0,465	-0,872	0,160	0,00	0,902	0,00
CV_01	2	0,86%	7	5,32	1,611	-0,748	-0,215	0,180	0,00	0,876	0,00
CV_02	2	0,86%	7	5,45	1,540	-1,062	0,743	0,184	0,00	0,856	0,00
CV_03	3	1,29%	5	5,50	1,294	-0,983	1,204	0,182	0,00	0,877	0,00
CV_04	9	3,86%	7	5,48	1,601	-1,096	0,660	0,182	0,00	0,844	0,00
CV_05	10	4,29%	7	5,73	1,530	-1,519	2,011	0,221	0,00	0,783	0,00
CV_06	3	1,29%	7	5,19	1,603	-0,790	-0,030	0,192	0,00	0,890	0,00
SV_01	8	3,43%	7	5,03	1,712	-0,736	-0,251	0,179	0,00	0,895	0,00
SV_02	8	3,43%	7	5,41	1,633	-1,093	0,593	0,199	0,00	0,848	0,00
SV_03	8	3,43%	7	5,07	1,769	-0,798	-0,207	0,185	0,00	0,880	0,00
SV_04	8	3,43%	4	4,80	1,672	-0,492	-0,320	0,147	0,00	0,916	0,00
TC_01	2	0,86%	7	4,45	1,924	-0,295	-0,990	0,125	0,00	0,915	0,00
TC_02	2	0,86%	7	4,91	1,912	-0,649	-0,645	0,167	0,00	0,881	0,00
TC_03	2	0,86%	7	4,77	1,947	-0,485	-0,896	0,151	0,00	0,893	0,00
TC_04	3	1,29%	7	5,12	1,960	-0,822	-0,482	0,189	0,00	0,841	0,00
TC_05	2	0,86%	7	5,29	1,977	-0,923	-0,454	0,230	0,00	0,806	0,00

Normality of Indicators CC_05 and CV_05



The elimination of these variables from the model does not mean this finding is not relevant. On the contrary, the high concentration of responses in the positive range of the scale suggests regardless of other indicators (high degree of independence). Despite the concepts behind the variables having robust theoretical support, they do not meet the conditions tested by the multivariate analysis technique used.

6.4.3 Measurement Model Validation

4.3.1 Reflective Measurement Model

The standardized loading analysis of the reflective model showed only the CV_06 indicator with a load below 0.708 (0.591). As the standardized loading is more significant than 0.400, the simulation was repeated without the CV_06 variable, which proved not to inflate the model's reliability above the 0.7 thresholds, both for CR and Cronbach's Alpha (with CV_06: CR=0.866 and α=0.859; without CV_06: CR=0.885 and α=0.882). Thus, the CV_06 indicator was maintained in the model. The CV_01 and TC_01 indicators presented outer loadings very close to the limit and without prejudice to the analysis. All outer loadings showed significance at the 5% level (Hair, Howard, & Nitzl, 2020).

The SV construct was evenly explained by its indicators. In contrast, the variance of the TC construct was higher explained by the TC_05 indicator (development of products that use recycled material for their production/commercialization) and less explained by the TC_01 construct (development of products that can be shared during use). TC_01 had the lowest average of all variables in the model (4.45), revealing less popularity.

The reliability and validity analysis of the constructs were satisfactory, as the convergent validity, indicating the indicators share significant portions of the construct's variance to which they belong, as expected in reflective measurement (AVE≥0.5)(Table 4).

Table 4 – Reflective Measurement: Convergent and discriminant validity

Reflective Measurement: Outer Loading, Reliability and Convergent Validity										Reflective Measurement: Discriminant Analysis											
	Outer Loading			**Indicator Reliability**		**Construct Reliability**		**Convergent Validity**		**Discriminant Analysis**											
Indicator	Standardized								**Indicator**	Cross Loading				Fornell-Larcker			HTMT			Bootstrapping 95%		
Code	Loading	t-stat.	ρ-value		Code	α	CR	AVE	Code	CV	SV	TC		CV	SV	TC	CV	SV	TC	CV	SV	TC
CV_01	0,707	8,078	0,000	0,500					CV_01	**0,707**	0,550	0,499										
CV_02	0,751	7,061	0,000	0,564					CV_02	**0,751**	0,609	0,368										
CV_03	0,818	38,023	0,000	0,669	CV	0,859	0,866	0,568	CV_03	**0,818**	0,606	0,483	CV	0,754								
CV_04	0,872	7,401	0,000	0,760					CV_04	**0,872**	0,647	0,392										
CV_06	0,591	14,541	0,000	0,349					CV_06	**0,591**	0,414	0,312										
SV_01	0,778	16,919	0,000	0,605					SV_01	0,573	**0,778**	0,439										
SV_02	0,824	23,685	0,000	0,679	SV	0,876	0,877	0,640	SV_02	0,649	**0,824**	0,408	SV	**0,757**	0,800		0,763			0,846		
SV_03	0,822	24,873	0,000	0,676					SV_03	0,627	**0,822**	0,437										
SV_04	0,774	7,543	0,000	0,599					SV_04	0,569	**0,774**	0,447										
TC_01	0,705	15,146	0,000	0,497					TC_01	0,376	0,414	**0,705**										
TC_02	0,742	19,192	0,000	0,551					TC_02	0,418	0,385	**0,742**										
TC_03	0,746	20,183	0,000	0,557	TC	0,889	0,886	0,611	TC_03	0,407	0,416	**0,746**	TC	0,546	0,541	0,782	0,552	0,538		0,675	0,679	
TC_04	0,805	16,389	0,000	0,648					TC_04	0,466	0,374	**0,805**										
TC_05	0,897	8,665	0,000	0,805					TC_05	0,461	0,516	**0,897**										

The discriminant analysis results revealed a deviation of CV-SV is superior to CV-CV (0.757>0.754), which is not a problem since loads of the indicators of the SV construct vary little between themselves (0.774~0.884) (Henseler et al., 2015). The HTMT procedure rejects the hypothesis that there are problems of a discriminant nature in the 95% confidence interval (all constructs have HTMT<0.85). The nomological analysis also did not reveal any inconsistency (Cronbach & Meehl, 1955).

4.3.2 Formative Measurement Model

The measurement model of the CC is formative that has precedents in academic research on corporate operation strategy, pointed out as more appropriate than reflective measurement (Podsakoff, Shen, & Podsakoff, 2006). However, it is necessary to verify the convergent validity of the formative measurement model (Hair, Howard, & Nitzl, 2020).

Figure 2 – Formative Measurement Redundancy Analysis

Formative Measurement Redundancy Analysis: Competitive Criteria

Formative Measurement Model

Convergent Validity		**Indicator**	**Multicollinearity**	**Outer Weight**		**Outer Loading**	
Coefficient	R^2	Code	VIF	Value	ρ	Value	ρ
0,838	0,701	CC_01	2,186	0,125	0,202	0,673	0,000
		CC_02	2,129	0,084	0,397	0,619	0,000
		CC_03	1,320	0,791	0,000	0,950	0,000
		CC_04	1,905	0,191	0,024	0,591	0,000

Following the assessment of the formative measurement model (Figure 2), the multicollinearity analysis of the indicators was performed, suggesting the formative model has no multicollinearity issues (VIF<3) (Hair, Risher,Sarstedt, & Ringle 2019).

The variables CC_01 and CC_02 did not show statistical significance for the Outer Weight parameter. Considering the outer loading parameter revealed all indicators have values above 0.5 and retain statistical significance, moreover, the theoretical consistency in a vast literature, the indicators were maintained in the model (Cenedella & Bassellier, 2009).

The cost reduction also emerges with the most expressive outer loading (0.950; ρ=0.00). The variable CC_04 (quality increase) confirming its relative and absolute contribution to the construct CC. The production flexibility system (CC_01) and the greater integration of the supply chain (CC_02) emerge with great absolute importance as CC, despite not having obtained statistical significance in the outer weight parameter: “when an indicator’s outer weight is non-significant but its outer loading is high (i.e., above 0.50), the indicator should be interpreted as absolutely important” (Hair, Hult, Ringle, & Sarstedt, 2016, p. 148). With outer loadings 0.673 and 0.619, the empirical evidence finds a parallel in the literature, confirming flexibility and integration as formative indicators of the CC in CE context.

4.3.3 Structural Model Validation

The analysis of the structural model that represents the value conversion process through CBMs was validated by the criteria established by the CCA (Hair, Howard, & Nitzl, 2020), not revealing any multicollinearity problems in the constructs (all VIF<3) or severe problems at the level of the indicators (CV_03, CV_04 and TC_03 with small variations above 3) (Table 5).

The analysis of the individual predictive capacity of the constructs proved to be strong for SV, moderate for CV, and modest for TC (both for R2 and Q2). However, from a Social Science perspective, Cohen (1988) suggests a much more significant interpretation (SV and CV with a strong impact and TC being moderate). The analysis of predictive capacity by PLSPredict reproduce the set of individual indicators thoughtfully, suggesting having a general medium predictive power (the minority of the

indicators reveals problems, both by the RMSE and MAE criteria). However, none of the deviations found was significant (the highest value is 0.027, in absolute terms).

Table 5– Structural Model Assessment

Structural Model Assessment: Construct and Indicators										
Construct	**Data Fit (R^2)**					**Construct Crossvalidated Redundancy**	**Indicator**	**VIF**	**PLSPredict**	
Code	Original Sample	Sample Mean	Standard Deviation	T Statistics	P Values	Q^2	Code	(indic.)	RMSE	MAE
CC	-	-	-	-	-	-	CC_01	2,186	-	-
							CC_02	2,129	-	-
							CC_03	1,320	-	-
							CC_04	1,905	-	-
CV	0,993	0,988	0,018	55,236	0,000	0,545	CV_01	1,606	0,013	-0,013
							CV_02	2,716	0,015	0,005
							CV_03	3,032	-0,005	-0,010
							CV_04	3,273	0,012	0,007
							CV_06	1,285	0,031	0,020
SV	0,596	0,602	0,069	8,607	0,000	0,332	SV_01	1,861	0,020	0,005
							SV_02	2,454	0,016	0,012
							SV_03	2,715	0,005	0,004
							SV_04	2,088	-0,014	-0,027
TC	0,200	0,212	0,062	3,233	0,001	0,114	TC_01	1,942	-0,002	0,001
							TC_02	2,974	0,013	0,007
							TC_03	3,176	0,009	0,018
							TC_04	2,033	0,027	0,001
							TC_05	1,869	-0,005	-0,022

Structural Model Assessment: Relations and Effects								
Hypothesis	**Total Effect**					**Colinearity**	**Size Effect**	**Structural Relations**
Reference	Original Sample	Sample Mean	Standard Deviation	T Statistics	P Values	VIF	f^2	Path Description
H_{1a}	0,447	0,455	0,069	6,503	0,000	1,000	0,000	CC -> TC
H_{1b}	0,121	0,115	0,037	3,258	0,001	1,239	0,000	TC -> CV
H_{1c}	0,949	0,948	0,018	53,678	0,000	1,239	0,000	CC -> CV
H_{1e}	0,261	0,257	0,081	3,223	0,001	1,396	0,000	TC -> SV
H_{1f}	0,657	0,657	0,075	8,743	0,000	1,396	0,000	CV -> SV
$H1_d$	-0,068	-0,065	0,023	2,924	0,003	1,218	0,000	Moderating Effect 1 -> CV
$H1_d$	-0,045	-0,043	0,017	2,664	0,008	-	-	Moderating Effect 1 -> SV

The analysis of structural coefficients was satisfactory in all relations of the model, showing significance measured by t-statistic ($t>1.96$; p-value≤ 0.05) (Table 5).

Figure 3 summarises the representation of the force of the effects between the constructs listed in the model. The research model shows the value flow through TCs that emerges from the direct and indirect effects in a complex correlation cascade.

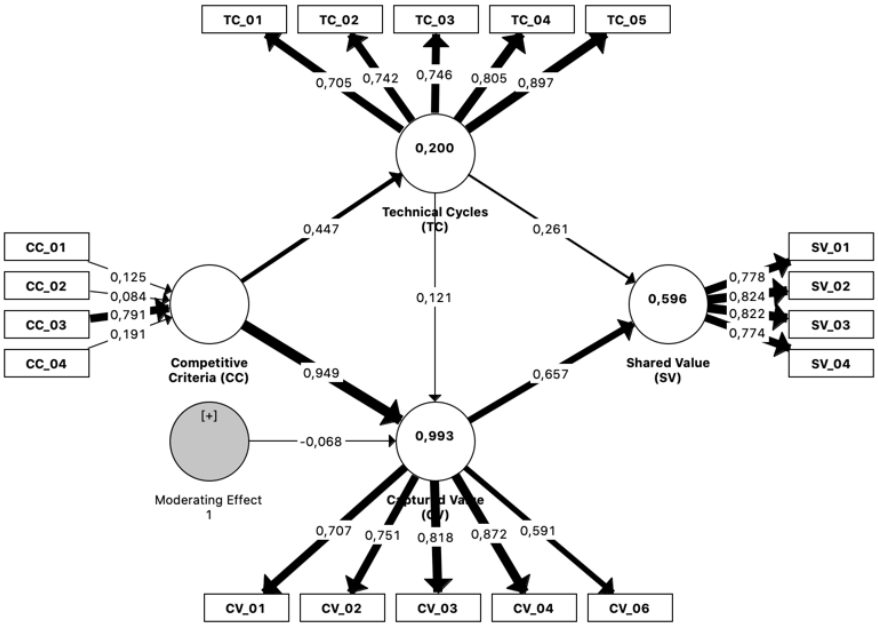
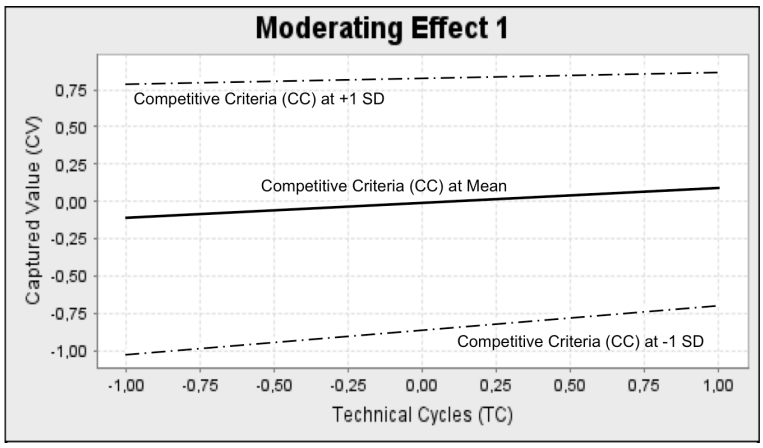


Figure 3 – Value Conversion in CBM: Consistent PLS Algorithm output

Finally, the moderating effect of Competitive Criteria (CC) on Technical Cycles (TC) and Captured Value (CV) relationship is also significant at a 1% level. However, the size of the effect is small. The upper line represents the relationship between CV->TCs when CC has high values (standard deviation above average). For highly CC values, the CV->TC ratio is weaker. According to Gardner et al.), Weakening: Z moderates the positive (negative) relationship between X and Y, so the relationship becomes weaker as Z increases. The bottom line represents the relationship between CV->TC when the CC has low values (standard deviation below the mean). For low values of CC, the relation TC->CV ratio is more substantial (figure 4).

Figure 4 – Moderate Effect of CC: Smart PLS Output



6.4.4 4.4 Exploring indirect Effects

Besides the direct and moderate effects analysed in the structural model, the indirect effects also play an essential role in this complex structural model for both dependent value constructs (CV and SV). Also, TC has one statically significant indirect effect at 1% level latent variable on SV through CV (TC->CV->SV), enhancing SV's total effect (Table 6a).

The CC play an essential role in the value stream. Beyond the direct and moderate effects explored in the structural model discussion (Table 5), CC fostering the effects on CV and SV from different ways, through direct and indirect effects.

CC have a significant direct effect on the CV as expected, while moderate the relationship between TC and CV (Table 5). Moreover, there is a small but statically significant indirect effect at a 1% level on CV through TC (CC->TC->CV) (Table 6b).

The traditional literature on CC did not address the SV construct; thus, a direct link between CC and the SV variables is not represented in the model, which implied the absence of a direct effect. Surprisingly, the CC shows several ways to influence SV indirectly. SV is essential in CBM what explains the CC perspective of operation operation strategy influence also SV. The existing literature does not indicate that CC influence the sharing capacity, a loop that constitutes the logic of CE.

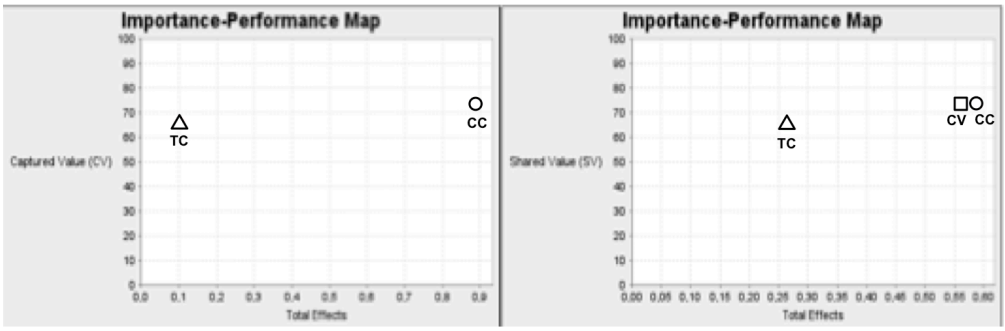
Through the research model, we identified three paths of the indirect effect of CC on SV (Table 6c). First, there is a substantial and statically significant indirect effect at a 1% level on SV through CV, i.e., CC->CV->SV). Second, there is a small but statically significant indirect effect at a 1% level on SV through TC, i.e., CC->TC->SV. The third and smallest but still significant indirect effect at a 1% level crosses a long pathway from CC through TC and CV until it reaches SV (CC->TC->CV->SV).

Table 6: Effects analysis of TCs and CC

Table 6a Effect analysis between Technical Cycles and Share Value: TC -> SV						
Effect	**From Technical Cycles (TC) to Shared Value (SV) (Streams)**	**Original Sample**	**Sample Mean**	**Standard Deviation**	**T Statistics**	**P Values**
Direct	Technical Cycles (TC) -> Shared Value (SV)	0,182	0,182	0,085	2,151	0,032
Indirect	Technical Cycles (TC) -> Captured Value (CV) -> Shared Value (SV)	0,080	0,075	0,026	3,094	0,002
Total	Technical Cycles (TC) -> Shared Value (SV)	0,261	0,257	0,081	3,223	0,001
Table 6b: Effect analysis between Competitive Criteria and Captured Value: CC -> CV						
Effect	**From Competitive Criteria (CC) to Captured Value (CV) (Streams)**	**Original Sample**	**Sample Mean**	**Standard Deviation**	**T Statistics**	**P Values**
Direct	Competitive Criteria (CC) -> Captured Value (CV)	0,895	0,895	0,030	30,226	0,000
Indirect	Competitive Criteria (CC) -> Technical Cycles (TC) -> Captured Value (CV)	0,054	0,053	0,020	2,739	0,006
Total	Competitive Criteria (CC) -> Captured Value (CV)	0,949	0,948	0,018	53,678	0,000
Table 6c: Effect analysis between Competitive Criteria and Shared Value: CC -> SV						
Effect	**From Competitive Criteria (CC) to Shared Value (SV) (Streams)**	**Original Sample**	**Sample Mean**	**Standard Deviation**	**T Statistics**	**P Values**
Direct	Competitive Criteria (CC) -> Shared Value (SV)	0,000	0,000			
Indirect	Competitive Criteria (CC) -> Technical Cycles (TC) -> Captured Value (CV) -> Shared Value (S	0,036	0,035	0,014	2,620	0,009
	Competitive Criteria (CC) -> Technical Cycles (TC) -> Shared Value (SV)	0,081	0,083	0,042	1,923	**0,055**
	Competitive Criteria (CC) -> Captured Value (CV) -> Shared Value (SV)	0,588	0,588	0,068	8,595	0,000
Total	Competitive Criteria (CC) -> Shared Value (SV)	0,705	0,705	0,048	14,840	0,000

Synthesizing the Importance-Performance Maps shows the crucial role of CC in the structural model (Figure 5). Although both TC and CC appear to be very relevant for CV, the effect from CC is much stronger than TC. Regarding SV, both TC and CC present themselves as necessary and with very expressive effects. Both findings reinforce the role of CC regarding the effect on the CV and SV.

Figure 5– Importance-Performance Map: Consistent PLS Algorithm output



6.4.5 Discussion

The analysis of the model confirms the structural relationship between the TCs implementation and the capture and sharing of value (H1a;b;c;d;e;f). The results reflect the CC of strategic manufacturing structure in CBMs (H2a;b;c;d;e;), suggesting the need to complement this set of criteria associated with the perspective of traditional linear manufacturing.

CV could be explained by both TC (H1b) and CC (H1c), with moderate and strong effect. Even with a moderate effect, CV explained by TCs is an aspect that deserves

particular attention, as the literature rarely discusses this cause-and-effect relationship (Hopkinson, Angelis, & Zils, 2020). Instead, considering TC is a means of building value, CV can be better perceived if guided by criteria (CC). The effect of CC on CT is strong (0.447), also confirming H1a. In analogy to classic literature, manufacturing is the medium whose strategic structuring uses traditional CCs (Brumme et al., 2015), reinforcing the importance of a set of CCs capable of translating the operation into the CBMs. Despite the validation of hypothesis H1a, the literature does not link CC with TC. Thus, the CBMs importance is emphasized as conductors between the operation of the TCs and the generation of value in the circular logic (Yang, Evans, Vladimirova, & Rana, 2017).

The CC importance is evidenced by the results obtained, as it affects all other constructs, either directly (on TC and CV) or indirectly (on CV and SV). Indeed, the results suggest more directly the relation of CC and relation to CV (H1c). However, it may be worth a superior discussion regarding sharing, as it is through TCs that sharing value occurs. The analysis using the value coefficients together with f2 was more enlightening to understand this flow. The results show a substantial effect from CC to CV (0.949) and CV to SV (0.657). Particularly, the sharing of value is explained more from CC and through CV than TC.

The analysis of the value flow in the light of the CC proves even more interesting when one observes the moderating effect of CC in the relationship between TC and CV (H1d). Consequently, organizations intensify the capture of value from the TCs, by increasing the CCs. Although this phenomenon was expected, it had not yet been measured.

The value captured by organisations is shared with other players in the ecosystem, therefore, characterizing the descriptive CBM context, validating H1f. However, part of the total effect of this relationship flows indirectly through the CV. Asked about the sharing of value in an open question, many respondents pointed out that it is necessary to capture it beforehand, suggesting this is the natural order - which contradicts the observed direct effect. Understanding how sharing flows directly or indirectly may be explained by another open question, in which respondents related the players with whom they share value. Consumers, surrounding community, suppliers and waste pickers association were the most cited. A characteristic found in

circularity is the trade-off between forms of value (Galvão et al., 2020); therefore, an industrial waste may represent a value to be shared with the waste picker, for example, although it was not necessarily a value already captured by the organisation.

By delving deeply into the open questions, the complexity of the perception of value becomes evident, as Galvão et al. (2020), had already suggested. One of the respondents reported that he had many difficulties in closing the recycling cycle for plastic packaging due to the low adhesion of consumers. By changing the appeal previously based on environmental protection (CV_05) to a proposal to promise the conversion of recycled packaging into food to be donated to needy families (social development; CV_04), the adhesion was so great that the company had difficulty in dealing with the large volume of packaging returned by customers. This finding suggests more recognition of social value in proportion to the environment, raising important questions for future research. Furthermore, it reinforces the importance of consumer awareness to leverage CBMs (Nußholz, 2018;), and the development of instruments to measure this complex value trade-off. In this example, the economic and environmental value created through TC (recycling) was only leveraged by creating social value. Nevertheless, the data suggest that recycling still leading role as TC, SV would be one of the main obstacles to converting the value to the social dimension (Murray et al., 2015).

Despite the total effect measured in the path coefficients (0.261), f2 analysis points to a lesser effect in the direct relationships between TC and SV (H1e), but still significant. However, the sharing loop is a link established both in practice and literature (Homrich, Galvão, Abadia. & Carvalho, 2018).

Nevertheless, the research carried out in the literature does not directly link the variables CC and the SV, which implied a gap between these constructs in the model. However, SV is in the domain of CBM; therefore, it is expected that there is a way of measuring CC associated with this construct from the perspective of strategic manufacturing.

Considering the traditional criteria, cost reduction has the most significant importance among the CC, supported by numerous researches on CE (Borrello, Caracciolo, Lombardi, Pascucci, & Cembalo, 2017), and the corporate operation

strategy general literature (Skinner, 1974). The cost reduction, obtained by the more conscious use of material and energy resources, is confirmed as the main CC leveraging the TC implementation. The results suggest that CBM has brought a broader cost reduction for companies, and the reductions already expected with more rational use of material and energy resources (Borrello, Caracciolo, Lombardi, Pascucci, & Cembalo, 2017; Schrader et al., 2012).

Quality is also confirmed for its relative and absolute contribution to the construct CC. The increase in product quality, which is reflected in reliability and extended service life (1993; Flynn & Flynn, 2004; Skinner, 1974) and brand enhancement (Junkunc, 2007; Sethi and Sethi, 2009), stands out with a relevant competitive differential resulting from the implementation of circular logic. The higher quality would still imply catalysing the reuse and sharing cycles (Seuring and Müller, 2008; Stahel, 2016; Ünal, Urbinati, Chiaroni, & Manzini, 2019; Vermeulen, 2015). Some results were more than expected; for example, the flexibility of the production system and the greater integration of the supply chain emerges with absolute importance as CC.

As CC, innovation could not be evaluated in the model for violating the premises of normality in the data distribution. However, data distribution with a markedly leptokurtic and asymmetric profile to the right suggests a trend towards unanimity. Suppose for multivariate analysis; the variable could not be used. In that case, the individual and complete assessment of the data indicates great relevance of innovation in the CC context, which would find support both in the corporate operation strategy general literature and in the CE. On the other hand, if they do not contribute to modelling purpose, this finding corroborates previous research, suggesting that the CE positively impacts the organisational image (Wolf, 2014) and acts as a catalyst for innovation in processes and technologies.

In conclusion, safeguarding methodological limitations, the analysis of the empirical evidence suggests accepting the hypothesis H2(a;b;c;d;e). Therefore, it is recommended that these criteria be considered strategically in the logic of CBMs.

6.5 Conclusions

The researchers investigated the influence of the CBM through TCs on CV and SV. Besides, we explore the moderating effect play by the CC on this relationship.

The validation of the model and the other results obtained suggest the acceptance of H1 (a, b, c, d, and e). Specifically, the TCs implementation leverages CC in the CE context. Those CC result in CV, which can finally be shared in the logic of the circular ecosystem.

The results obtained from empirical observations suggest that the companies that implement the TCs of the CE have their competitive capacity increased, measured from a set of criteria previously highlighted in the corporate operation strategy general literature. The costs reduction and the increase of quality appear as the main vectors leveraging the CC inserted in the logic of the CE. Productive flexibility and greater integration of the supply chain also proved significant absolute importance for CC, thus confirming the hypotheses H2 (a, b, c, d, and e). Besides, CC has a direct influence on how companies capture heat and their cycles. However, the relationship of CC with CV is always indirect or weak. Besides, CC has a direct influence on how companies capture the value and on their TCs. However, the relationship between Cc and CV is always indirect or weak.

The analysis of the model also indicates that CC influence the TCs implementation. More outstanding CC are effectively reflected in the capture value, which is subsequently shared with other players in the ecosystem, following the logic of CBMs.

The study contributes to the literature in three folds. First, the validated research model demonstrates the value flow through TCs, gathered for both the CBM and the SV network with other players. Second, it shows the crucial role of the CC on the value stream through direct, moderate, and indirect effects by influencing the relationship between TCs and CV and indirectly affecting SV. CC have a moderating effect on the relationship between the TCs and CV. Third, the study contributes to filling the gap for quantitative studies in the CE field. From a practical perspective, by shedding light on the influence of CC and the conversion of operation operation strategy in the CE context, this article contributes to the structuring of CBMs on a more robust basis. As a reflex, it also contributes to the CE's propagation and consolidation. As innovation could not be evaluated in the model, we suggest a theme for future research, assessing the impact of innovation on the company's competitive differential, as a result of adherence to the principles of the CE. The current literature has not supported a

theoretical relationship between CC and SV, even though the CBMs in the domain comprehend the latter. The analysis of indirect effects suggests consistency in the relationship between these constructs. We suggest creating sharing capacity, as a category of CC, in evaluating the manufacturing operation strategy, in this case, the manufacturing inserted in the circular context.

The same limitations challenged this research. As a background of the Social Sciences, the bias resulting from the subjectivity inherent to the human condition implies a limitation of an ontological nature. Methodological limitations were also observed. Countries with different CE public policies and distinct consumption habits resulting from cultural differences can influence organisations' value capture dynamics. Analytically, indicators eliminated for violating assumptions favouring reliability can alter the load balance among the other variables of the model.

Acknowledgement: This work was supported by the National Council of Technological and Scientific Development (CNPq); the Coordination for the Improvement of Higher Education Personnel (CAPES); and the Foundation for Research Support of the State of São Paulo (FAPESP).

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APPENDIX A: Research questionnaire (article 3)

BLOCK I - Company and the respondent characterizations

Name of respondent:

E-mail of the interviewee:

Interviewee's area:

Company Name:

Industry Sector:

Number of employees:

- Less than 10
- Between 10 and 50
- Between 51 and 500
- More than 500

For all questions in blocks II, III, IV, V, VI and VII use the following scale:

- 1 Fully Disagree
- 2 Strongly Disagree
- 3 Partially Disagree
- 4 Indifferent
- 5 Partially Agree
- 6 Agree Almost Totally
- 7 Agree

Is Circular economy part of the company's operation strategy?

Implementation of Technical Cycles:

The organization develops products that can be shared during use (sharing).

The organization develops products that can be refurbished or remanufactured.

The organization develops products that can be reused or transferred between consumers after use.

The organization develops products with extended service life.

The organization develops products that use recycled material for their production / commercialization.

Competitive Criteria:

The implementation of circular techniques and principles positively impact. The implementation of circular techniques and principles have become more flexible production system (greater breadth in the generation of value).

The implementation of circular techniques and principles have become more integrated and effective operational chain (effective integration of suppliers, buyers of industrial leftovers, production, logistics, etc.).
The implementation of circular techniques and principles have become use of resources (raw materials, energy, etc.) more efficient.
The implementation of circular techniques and principles have become more superior quality standards (products with higher added value).
The implementation of circular techniques and principles have become increased innovation potential (development of new processes, new products and technologies, etc.).

Value Captured by the Company
The company maximises results by reducing environmental impact (for example, saving water or reducing waste).
Investing in consumer education to recognise the value of products in line with CE principles brings positive results.
The increase in the product's service life generates a positive return when analysed in the long term (consumer recognises added value).
Investment in social development, as part of the CE, has enhanced the organisation's image and brand.
Investment in environmental protection, as part of the CE, has enhanced the organisation's image and brand.
The company reduced costs with a more rational use of material and energy resources.

Value Shared by the Company
The company has succeeded in sharing value with actors in the supply chain.
The company has succeeded in sharing value with consumers and users.
The company has succeeded in sharing value with the surrounding community.
The company has succeeded in sharing value with different associations (associations of informal workers, such as recyclable waste collectors, etc.).

Does the company intend to share value with another sector? Which?
Does Circular Economy / Sustainability collaborate with Operations Management in any other way? which?
How can the circular economy / Sustainability impact your business?

APPENDIX B: Invitation letter sent to interviewees

I am Graziela working with Steve (University of Cambridge), and I am writing to ask for 30 minutes of your valuable time. We believe you are leading, or interested in Circular Economy/Sustainability and can help our research into barriers, motivations and value generation in the implementation of Circular Economies in organisations. We will send you, after analysing the results, an executive summary, with the perception of the overall scenario ("What about others? better or worse than us?"). It is important to mention that all data will be presented anonymously.

Research Abstract Our goal is to identify patterns that may delay or accelerate circular actions. We will send you an executive summary that shows all interviewees, with a private addition comparing your results to the whole set. This will compare you in the areas of: the main opportunities, the views across stakeholders, the level of interaction with other organisations, the challenges and drivers felt by each company, suggestions and future business driven possibilities; The insights come from interviews conducted with senior staff from companies either leading or progressing in Circular Economy/Sustainability (either at the strategic or operational).

We are collecting data in Brazil, UK and Spain to begin, expanding to Europe, Asia and North America. We are trying to answer two main questions: • What are the value opportunities from circular business models? • How does CE influence strategic value generation for the organisations Email me back if you have any questions, or if you prefer, we can already set a date for the interview (via Skype or other software of your choice). A entrevista pode ser em português ou inglês.

Best Regards

Graziela Galvão

Institutions involved in the project doctoral researcher (Graziela Galvão)

University of Cambridge (Prof. Steve Evans)

University of São Paulo (Prof. Marly Monteiro de Carvalho)

APPENDIX C: Questionnaires interviews (article 2)

1. Your company has been taking actions that are aligned with circular economy/sustainability principles – for example recycling, remanufacturing, reuse, conscious use of raw materials. How did it start?
2. What was the main motivation behind the decision to adopt a more sustainable approach?
3. Have the expectations been met? Has your organisation realised the value of transitioning to a more sustainable approach? Could you explain what are the main benefits? What was the best results achieved so far? If value has not been realised, could you explain the main reasons for that?
4. Regarding the challenges, could you provide an overview of the main barriers/challenges faced and the implications of those? Have you faced any barrier to implement new circular processes? And after the implementation?
5. Did the implementation of a circular approach lead to other process/product innovations?
6. How has the flexibility of production changed after implementing a circular approach? If has there been any productivity gains, what percentage? Which are the improvements in terms of quality (both in terms of product and processes)? How many production costs have been reduced?
7. In your opinion, does circular economy lead to efficiency and/or effectiveness improvements?
8. How does your company invest in educating/increasing awareness of your customers? Do you think that your customers understand/recognise the value of products aligned with circular economy principles? If so, has it brought positive results to the company? Consider both B2B and B2C.
9. Do you believe that if there were tax incentives or other adoption supporting policies, more companies would be motivated to invest more in circular economy-driven actions? Why?
10. What are the company plans to continue investing or even expand investments in circular economy?
11. Do you believe that a more collaborative, efficient and intelligent use of limited resources available can be a motivation for the adoption of a circular economy approach? Could you explain that?

12. Do you believe that investing in consumer education / awareness to recognise value in products aligned with circular economy principles has brought positive results? Why?

Questionnaires on competitive criteria.

13. After the implementation of the circular economy model in the company, do you believe that the criteria below show any improvement?
14. Quality, if there has been improvement, please comment.
15. Delivery performance, if there has been improvement, please comment.
16. Flexibility, if there has been improvement, please comment.
17. Innovativeness, if there has been improvement, please comment.
18. Cost, if there has been improvement, please comment.

APPENDIX D: Supplementary Article Circular Economy: Overview of barriers

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Abstract

Circular economy has emerged as a way to achieve sustainability. Although interest in the subject is growing rapidly, barriers to its implementation are still in place. In this study, a number of barriers are identified and grouped through a content analysis. The present article adopted bibliometric research as a methodological approach. The research method combined bibliometric, networks and content analysis. The sample is composed of 195 articles extracted from the Web of Science Core Collection and Scopus databases. The main barriers identified in the literature were: (i) technological, (ii)policy and regulatory, (iii) financial and economic, (iv) managerial, (v) performance indicators, (vi) customer and (vii) Social.

Keywords: circular economy; barriers; challenges; qualitativy content analysis; bibliometrics

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Introduction

The terms Circular Economy and sustainability are increasingly gaining traction within the academia, industry, and policymakers (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). Many barriers to the implementation of sustainable strategies are still in place (Bey; Hauschild; & Mcaloone, 2013). Circular Economy (CE) is a operation strategy whose goal is to address the challenges of resource scarcity and waste disposal, in a win-win approach from an economic and value perspective (Homrich, Galvão, Abadia, & Carvalho, 2018). In 1990, CE was conceptualized for the first time in the Economics of Natural Resources and the Environment, a book by British environmental economists, David W. Pearce and R. Kerry Turner. The authors drew attention to how society at the time that work was published did not direct relevant efforts to properly address the waste generated from the consumption of the most diverse products (Su, Heshmati, Geng, & Yu, 2013). Policy makers have to address the public concerns prior to promulgating and implementing related regulations (Pan et al., 2014).

CE is related to different topics. For example, it can offer a new perspective on waste and resource management (Blomsma; & Brennan, 2017), and the concept brings up diverse themes, like sustainability (Homrich, Galvão, Abadia. & Carvalho, 2018), industrial ecology (Lewandowski,2016), eco-design (Ellen Macarthur Foundation, 2015), cleaner production (Geng, Xinbei, Qinghua, & Hengxin, 2010)), eco- innovation Castellani; Mirellani, 2015), closed economy (Geng; & Doberstein, 2008), ecological loops (Haas, Krausmann, Wiedenhofer, & Heinz, 2015) and product service systems (Tukker, 2015). Circular Economy can also be understood as a political goal, aiming to replace the linear economic model, summarized in a "take, make, use, dispose" system that places raw materials at one end and exteriorized residues at the other (Gregson, Crang, Fuller, & Holmes, 2015), with the circular model (Geng et al., 2016).

To establish CE, significant barriers in the political, economic, technological and legal areas exist. A country requires strong political support to promote CE (Mathews; Tang; & Tan, 2011). However, lack of incentives to adopt CE still prevails in some (Schulte, 2013).

This article aims provide an overview on barriers and challenges for the implementation of the circular economy. To this end, a bibliometric analysis was performed, merging a content analysis of the 195 papers in the final sample. The lack of information regarding the benefits of circular economy is a barrier and a challenge to the implementation of circular economy models in the literature, due to the unfamiliarity of the term "circular economy" (Rizos et al., 2016). As such, this research can pave the way for a better academic understanding of the mechanisms underlying the barriers and resistance to the acceptance and propagation of the circular economy, as well as of better ways to address and reduce these barriers (Rizos et al., 2016). In addition, this literature review of the literature published in 2018 points out CE revisions until 2017. The table presented in the appendix does not present any revision or bibliometric related to the CE implementation barrier (Homrich, Galvão, Abadia. & Carvalho, 2018).

There are significant reports from international organizations that point barriers to CE. For example, the OECD, studies markets barriers, as regulatory and financial barriers thus strengthening economic efficiency and competition. The European Commission also deals with markets barriers (European Commission) lack of

knowledge as barriers to solving problems such as food waste, Landfill and lack of investment in circular economy innovation (European Commission, 2011). This study looks for more general barriers, not only of a specific area.

Methodology

The research design combined quantitative and qualitative strategies, merging bibliometric and content analysis, since these methods are complementary (Carvalho; Fleury; & Lopes, 2013). Bibliometric research can be used in several areas of knowledge, collaborating to improve trend research and analysis, while content analysis allows an understanding of the research constructs and their relationships (Duriau, Reger, Pfarrer, & Sources, 2007). Finally, this approach allows us to identify the stage in which a research front is found (Spinak, 1988). In addition to the bibliometric, the 22 articles with the greatest impact factors, in order to obtain the results.

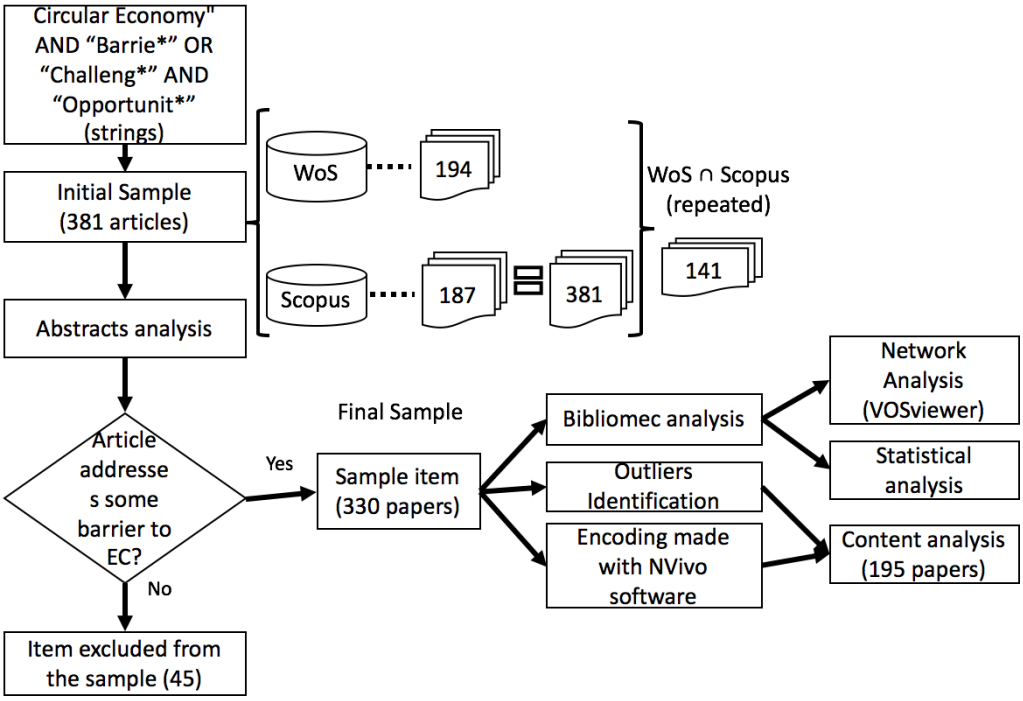
According to Carvalho; Fleury; and Lopes (2013), an article impact factor can be calculated as follows: (i) extract the average citation per year (taken from the ISI); (ii) Find the impact factor of the sources of publications (obtained in Journal Citation Reports, JCR); (iii) perform the following operation: IF = Average citation X (1 + JCRFI). "It is important to note that, considering this impact index, the article can change the position in the citation ranking" (Carvalho; Fleury; & Lopes, 2013). The 25 highlighted publications were selected by their IF values reached, by means of a boxplot graph to observe the outliers, or points outside the curve. The graph obtained was plotted using the Minitab software (fig. 3.).

Sample definition and steps for the data collection

The Web of Science Core Collection and Scopus databases were searched to produce this article. The first article identified in these databases was published in 2005, and the most recent was published in 2017. The following data were analysed: total publications, year of publication, sources, impact factor, countries, network of citations and keywords and hot topics, followed by an analysis of the 25 articles with the highest impact factor.

The first stage of the data collection consisted of searching for the keywords "Circular Economy" AND “Barrie*” OR “Challeng*” AND “Opportunit*” at the Web of Science Core Collection and Scopus databases. A total of 381 publications were found, 141 of which were excluded because they were repeated in both databases. After reading the abstracts, another 45 were excluded because they were not aligned with the purpose of this research. Thus, the blibliometric study was performed considering 195 papers.

Fig. 1. presents the methodological flow for the sample collection.



Source: authors

Results

Evolution and main sources of publications

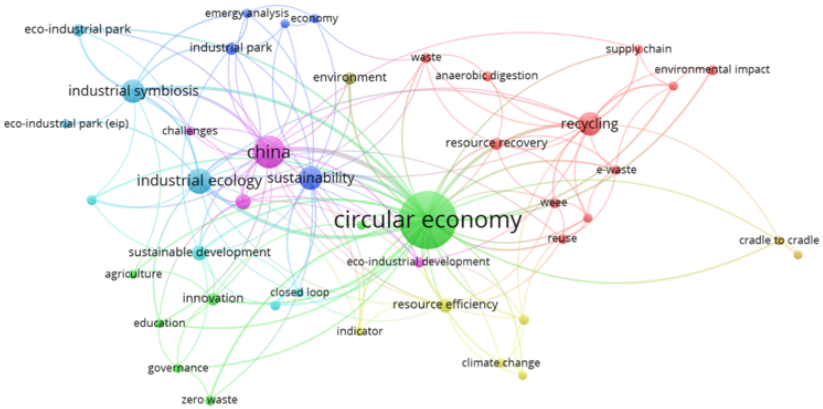
The first article in the sample was published in 2005. However, the theme began to spark academic interest after 2014 (12 papers). The years of 2016 and 2017 accumulated 127 articles on the evaluated subject, suggesting that interest in barriers and opportunity is growing. Concerning the publication sources, Journal of Cleaner Production published 38 papers on the subject, Resources Conservation and Recycling, 10 and Sustainability, 9. The other 138 papers were published in 106 different sources, suggesting the multidisciplinary of the theme. This information was taken from the databases (ISI and Scopus). About 40% of the sample were shown to

be case studies, i.e. articles that evaluate the barriers in practice in order to implant CE.

Keywords

To complement the overview on the selected sample (195 articles), the circular economy keywords network was prepared using the VosViewer software (Eck et al., 2010), presented in Fig. 2. These words were categorized into 6 main groups: (1) strategic variables, corresponding to the main drives for circular economy (sustainable development, closed loop); (2) inputs, that are the independent variables within the circular economy research theme (China, challenges, environment and ecology), (3 and 4) outputs, that are the result of the circular economy implementation (recycling, reuse, environmental impact, sustainability, e-waste, waste, resource efficiency and climate change) and (5) cluster of industries investing in CE (industrial ecology, industrial symbiosis, eco-industrial park). This categorization was possible after reading the articles.

Figure1 - Keywords

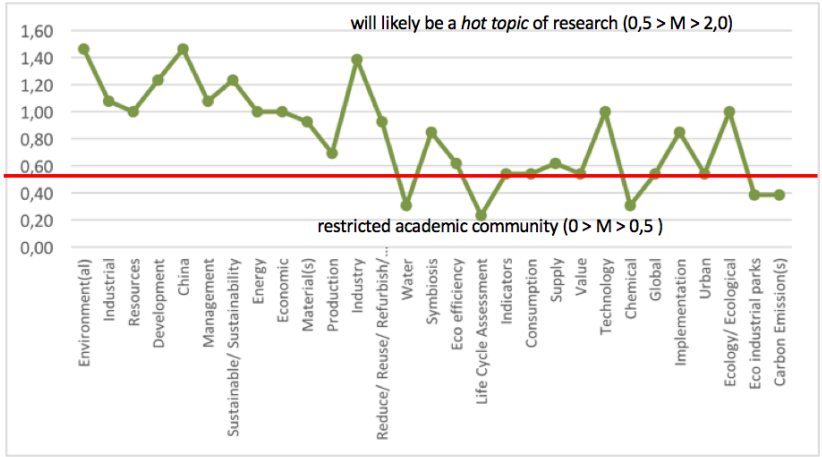


Hot Topics

By scanning the frequency of the words in the article titles, abstracts, author keywords, and keywords for more promising research topics that are more likely to appear in the future, it was possible to trace the hot topics related to the study of barriers and opportunities within the theme "Circular Economy", by using NVivo software (Bazeley; & Jackson, 2013). An analysis of the hot topics was performed to generate the HB index (Hirsch, 2005) through the relationship of the most recurrent topics, identified in Fig. 3. Finally, the M index was calculated as the linear relation between HB and the

number elapsed years (n = 12 years) since the first publication. Hot topics thus, were calculated as: HB-M * n, in accordance to criterion in (Banks, 2006).

Figure 3 - Hot topics



The “h index,” is a useful way to characterize the scientific output of a researcher (Hirsch, 2005), while HB is a quick method to aid new-comers to identify how much interest and work has already been achieved in their chosen area of research (Banks, 2006). The criteria for the interpretation of the M index are presented in Fig. 3. In this sample, the “Chemical” issue is not yet a hot topic within circular economy; however, themes of “Symbiosis” and “Technology” are considered hot topics.

Impact factor and Outliers

The 25 articles with the highest impact factor were read, allowing for understanding on the main points discussed and which method was applied to this end.

A total of 30% of the papers in the sample were related to CE studies in China, as China exhibits more CE policies than other countries (Manara; & Zabaniotou, 2016). The central government of China guaranteed to stimulate the sustainable development of economy and society in 2002 (Yuan; Bi; & Moriguichi, 2006).

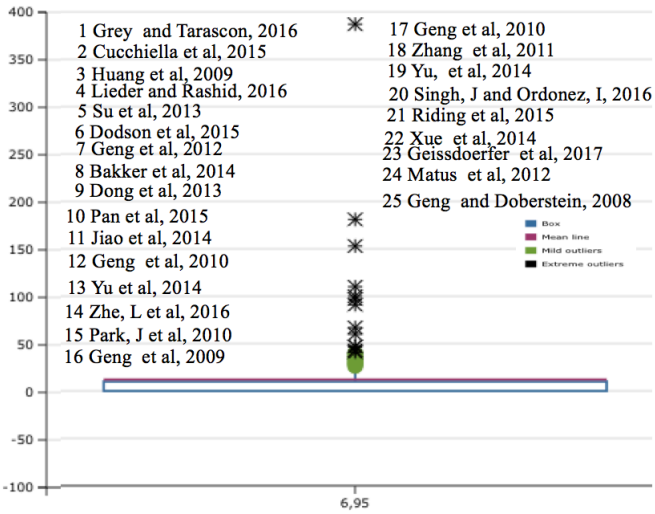


Figure 4 - Outliers

An initial content analysis for outliers is presented below, in order from highest to lowest impact factors:

a) Literature Review. The development of improved rechargeable batteries represents a major technological challenge. Sustainability and cost concerns to minimize the ecological implications associated with their wider use are discussed in this article (Grey; & Tarascon, 2016).
b) Literature Review. A discussion of the economic assessment results as the main challenges in the recycling sector and streamlines some concrete solutions (Cucchiella, D'Adamo, Koh, & Rosa, 2015).
c) Literature Review. This article gives a comprehensive review of state-of-the-art research, carried out to understand different ideas relevant to CE as well as motivation for the research and their recurrence context (Lieder; & Rashid, 2016).
d) Case study. Barriers and opportunities in the deployment of CE China are addressed in this article (Su, Heshmati, Geng, & Yu, 2013).
e) Literature Review. This article provides an overview of the current research in the area of critical and precious metals recovery using bio sorption, its application to real-life wastes and the potential uses for these metal-loaded materials for catalysis or functional materials. Challenges of elemental sustainability are discussed (Dodson et al., 2015).
f) The article studies the system of indicators for CE in China. These national indicators can help to achieve CE goals and outcomes (Geng, Fu, Sarkis, & Xue, 2012).

g) Case study. This article maps the environmental impacts of refrigerators and laptops against their increasing energy efficiency over time. One of the main research challenges is to determine when to apply which product life extension operation strategy (Bakker et al., 2014).
h) Case Study. The article evaluates and compares the number, scale and the related environmental/ economic gains of IS activities in iron/steel- centred industrial areas in Liuzhou and Jinan in China, and Kawasaki in Japan (Dong et al., 2013).
i) Literature Review. Authors discussed the dilemma of energy demand, waste management, and greenhouse gas emission for communities globally, the waste-to-energy supply chain as a district energy system should be a viable method towards circular industrial economy (Pan et al., 2014).
j) Literature Review. This article proposes a research agenda to clarify the mechanisms of policy intervention and facilitation of industrial symbiosis based on a comprehensive review of industrial symbiosis literature. For the authors, policies may be major barriers to the deployment of industrial symbiosis (Jiao; & Boons, 2014).
k) Case study. This paper first introduces the main initiatives for the promotion of cleaner production in Liaoning and then identifies the key barriers (Geng, Xinbei, Qinghua, & Hengxin, 2010)).
l) Case study. The authors study the reasons for a number of successful and unsuccessful eco-industrial parks (Yu; Jong; & Dijkema, 2014).
m) Case study. The main barriers to the industrial symbiosis of industrial parks are central themes in this article (Zhe et al., 2016).
n) This paper explores the challenges and opportunities of how firms and organizations can strike a better balance between economic progress and environmental stewardship in the context of China's emerging 'circular economy' policy paradigm and based on ecological transformation theoretic approaches (Park; Sarkis; & Wu, 2010).
o) Case study. This paper outlines some of the regional CE initiatives that have been successful to date in Dalian, China. The authors identified several challenges that have held back complete implementation (Geng et al., 2009).
p) Literature Review. This article presents some problems about remanufacturing, and then it points out several barriers, such as restrictive

policies and regulations, consumer acceptance, scarcity of technologies, among others (Zhang, Chu, Wang, Liu, & Cui, 2011).

q) Bibliometric and Network Analysis. This study analyses the evolution of the research field of industrial symbiosis (Yu; Davis; & Dijkema, 2014).

r) Literature Review and case study. This paper identifies the practical challenges to implementing a circular economy, based on example categorization and comments from interviews (Singh; & Ordoñez, 2016).

s) Literature Review. The scientific and legislative barriers to the generation of bioenergy derived soil conditioners are addressed in this paper (Riding et al., 2015).

t) Literature Review. The article studies the performance changes during different five-year plan stages for emission control, addressing the major challenges and identifying options for the future improvement of China's pollutant emissions reduction (Xue et al., 2014).

u) Literature Review. The similarities and differences between the terms Circular Economy and sustainability are ambiguous. This research addresses this gap and aims to provide conceptual clarity by distinguishing the terms and synthesizing the different types of relationships between them. Challenges are also discussed (Geissdoerfer, Savaget, Bocken, & Hultink, 2017).

v) Literature Review. This paper identifies a series of barriers and challenges to CE implementation in China.

Barriers

To detect the main barriers in CE, the authors read the 195 articles. To find the best coding, the NVivo software was used, and the content analysis was also carried out with the aid of the same software.

To adopt CE as a future economic model, efforts are required to refine existing measures as well as to deploy a wide range of policies to overcome these challenges (Su, Heshmati, Geng, & Yu, 2013). Each sector has its specific challenges. The coal sector, for example, lacks of post-decommissioning management, exhibits poor pollution control, lacks of technology to refill solid waste and faces increased socioeconomic and environmental pressure (Yu, 2017).

In the case of recycling, the potential benefits of improving the circular economy are the market value of recycled materials, reduced waste disposal (incineration or landfill) and the decreased extraction of natural resources (Andersen, 2007).

The lack of societal pressure, by not knowing the benefits of sustainable products, or CE, is a barrier to the implementation of new policies by business and government (Rizos et al., 2016). One of the challenges facing societies in the pursuit of sustainability is to find viable strategies and initiatives capable of decoupling economic growth from environmental pressure, within the limits of the available resources (Zhang et al., 2009).

The barriers that appear most frequently within the 195 papers are: technological, policy and regulatory, financial and economic, managerial barriers, performance indicators, customer (interest in the environment issues or lack of information on environmental impacts) and Social (Table 1).

Table 1. Barriers to CE implementation.

Barriers	Authors
Technological	(Aid et al., 2017; Álvarez; Ruiz-Puente, 2017; Cruz et al., 2017; DONG et al., 2013; Ferronato et al., 2016; Geng; & Doberstein, 2008; Mathews; Tang; Tan, 2011; Pan et al., 2014; Su, Heshmati, Geng, & Yu, 2013; Zhang, Chu, Wang, Liu, & Cui, 2011; Zhu, Geng, Sarkis, & Lai, 2014)
Policy and regulatory	(Aid et al., 2017; Álvarez; Ruiz-Puente, 2017; Cruz et al., 2017; Geng et al., 2010; Geng; Doberstein, 2008; Guo et al., 2017; Hara, Yabar, Uwasu, & Zhang, 2011; Jiao; Boons, 2014; Lieder; Rashid, 2016; Mathews; Tang; Tan, 2011; Matus; Xiao; Zimmerman, 2012; Negny et al., 2012; PAN et al., 2014; Riisgaard; Mosgaard; Zacho, 2016; Rizos et al., 2016; Su, Heshmati, Geng, & Yu, 2013; Zhang, Chu, Wang, Liu, & Cui, 2011; Zhu, Geng, Sarkis, & Lai, 2014)
Financial/ economic	(Álvarez; Ruiz-Puente, 2017; Dong et al., 2013; Ferronato et al., 2016; Geng et al., 2010; Geng; Doberstein, 2008; Mathews; Tang; Tan, 2011; Negny et al., 2012; Pan et al., 2014; Ren et al., 2013; Sakai et al., 2017; Su, Heshmati, Geng, & Yu, 2013)
Managerial	(Bey; Hauschild; Mcaloone, 2013; Negny et al., 2012; Su, Heshmati, Geng, & Yu, 2013; Zhu, Geng, Sarkis, & Lai, 2014)
Performance indicators	(Bey; Hauschild; Mcaloone, 2013; Geng, Fu, Sarkis, & Xue, 2012; Tu et al., 2011; Zhe et al., 2016)

Customer	(Baxter; Aurisicchio; Childs, 2017; Bey; Hauschild; Mcaloone, 2013; Ferronato et al., 2016; Geng; Doberstein, 2008; Guo Et Al., 2017; Riisgaard; Mosgaard; Zacho, 2016; Tu et al., 2011; Zhu, Geng, Sarkis, & Lai, 2014)
Social	(Aid et al., 2017; Ceglia et al., 2016; Golev; Corder; Giurco, 2015; Lieder; Rashid, 2016; Tu et al., 2011)

Many challenges and actions that have been taken to overcome these CE implementation barriers. However, support from governmental and non-governmental entities is needed, as well as organizations that help promote, regulate and monitor CE implementation (Su, Heshmati, Geng, & Yu, 2013). Effective performance evaluation is another barrier, found as it can aid in recognizing the key barriers on industrial symbiosis of industrial parks, so that more appropriate policies can be raised by considering local realities (Zhe et al., 2016). The CE barriers to eco-parks were also identified (Zhu, Geng, Sarkis, & Lai, 2014). The authors divided these barriers into two categories: (1) external (capital support barrier, policy support barrier and information support barrier) and (ii) internal (Tangible Resources, Intangible Resources, Capacities).

A survey of 28 organizations pointed to other barriers: lack of access to sufficient volumes, informal and illegal reuse practices, regulations, product design and patterns, and costs (Sakai et al., 2017). Any material improperly disposed of may cause environmental contamination (Baxter; Aurisicchio; & Childs, 2017). Environmental taxes are considered efficient environmental policy tools for some governments. However, pollutant emission rates are low, and so companies/institutions prefer to pay these rates, instead of taking measures to eliminate and control pollution (Sun, 2013). The eagerness for new economic gains can lead companies/industries/cities to reduce environmental standards and accept polluting projects (Yu; De Jong; & Cheng, 2016).

Rizos et al., (2016) listed the main barriers to the of CE implantation in small and medium enterprises, namely lack of supply and demand network, lack of capital, lack of government support administrative burden, lack of technical know-how, lack of information and the environmental culture of the company.

“As the global population is expected to reach 9 billion by 2050, humanity needs to balance an even increasing demand for energy and natural resources with

sustainable management of ecosystems and the vital services that they provide”. As for the management barriers that appear to date, "it is important to establish a clear management structure and procedure for the issue, in order to establish the position of an 'Eco champion' in the organization, who should work on projects and, on a corporate level, to define what environmental terms and issues are exactly meant in a particular organization and to establish, manage and communicate quantitative environmental performance indicators. ".

Metrics and social barriers appear in smaller quantities. The absence of adequate metrics and standards has been a key obstacle to the inclusion of material efficiency requirements (Tecchio, McAlister, Mathieux, & Ardente, 2017). Social barriers include informational, cooperation, community and commitment to sustainable development (Golev; Corder; & Giurco, 2015).

Conclusions

This article aids in understanding the main barriers to CE implantation. As 40% of the articles are case studies, it is clear that in-site searches concerning CE are of interest to researchers. As presented herein, 2016 and 2017 publications represent 65% of the total of papers in our database, indicating that the theme is emerging, and helping to explain why the term "circular economy" is still considered unfamiliar.

Even so, in the outliers’ analysis, few papers apply case studies, surveys or other exploratory research methods; most focus on the literature reviews, helping to identify CE gaps, challenges, barriers, initiatives and motivations, supporting more deep understanding of this emerging topic.

The analysed studies aided in understanding the similarities and differences between the CE and sustainability, an increasingly explored relation. Among the barriers identified in the literature, technological, policy and regulatory, financial and economic, managerial barriers, performance indicators, customer and Social are most frequent, being the major challenges for the implementation of CE.

Barriers and challenges from the literature analysis that can help the CE implementation obtained from the literature analysis are highlighted, and future studies

can focus on the analysis each identified barrier in-depth, including their mitigation and how governmental and non-governmental entities can support this.

This research has limitations related to the use of search engines and the methodological choices concerning the selected search strings, filters and databases. The choice of method may have guided the search result and findings. As a limitation, CE-related terms were not included in the database search. The inclusion of terms such as closed loop and cradle to cradle are suggested for future research. As the article is an overview on CE, specific barriers of different sectors are present, another study limitation. For future research, studies on CE barriers for specific sectors are suggest.

Acknowledgements

The authors would like to thank the reviewers for their suggestions, they really helped us. The authors thank to CNPq, CAPES and FAPESP, for supporting this research.

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APPENDIX E: Supplementary Article: The Role of Policies and Regulations to foster the Circular Economy: lessons from the literature

Abstract

Adequate policies and regulations are essential for promoting a circular economy paradigm. Despite the continuing struggles for the CE, there are gaps in current policies and potential for future improvement. This research aims to investigate the policies, and regulations used to foster circular economy. The methodology includes an in-depth content analysis and a systematic literature review of 829 articles. The results show that recent studies are focusing on consumer awareness in which laws must cover from design of products to waste treatment. The core topic discussed in the articles is the environmental dimension, particularly related to the principles of optimizing resource yields and reducing residual waste. Furthermore, the surveyed literature also focused on the end of life, lacking research on policies and regulations related to the beginning and middle of life.

Keywords – circular economy, sustainability, industrial ecology, biological cycles, technical cycles

Introduction

Despite being a recent topic, the circular economy (CE) has a “strong intuitive appeal” (Zink; & Geyer, 2017, p. 600), emerging as a vector that could transform the current model of production in a new paradigm of sustainability (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). Linear economics is leaving a trail of challenges for the sustainability, economic, environmental and social pillars (Bradley, Jawahir, Badurdeen, & Rouch, 2018). In the traditional linear model, results are directly proportional to material flow meaning that the higher the consumption, therefore, the productive flow, the higher the financial input into the organisation (economic value) (Vargo & Lusch, 2004).

On the other hand, “The Circular Economy is increasingly seen as a possible solution to address sustainable development” (Geissdoerfer, Morioka, Carvalho, & Evans, 2018, p. 712). Thus, according to Zhu, Chengming, Haijia, and Lei (2018), the search for sustainable development is increasingly related to CE concepts, practices

and policies. Additionally, CE could help to foster the dissemination of sustainable solutions and cleaner production (Bocken, Short, Rana & Evans, 2014), helping countries to create cleaner production and solve the problem of serious natural resource depletion and environmental pollution (Liu & Côté, 2017).

In this way, CE should be as much a goal of economic policy as of environmental policy, and all players should emphasize this point to policy makers (Hill, 2015). In fact, to foster CE, government agencies should play a leading role, coordinating different initiatives, enacting appropriate regulations, stipulating viable guidelines and standards, providing substantial financial support, and engaging in international collaboration (Geng, Fu, Sarkis, & Xue, 2012). The involvement of policymakers must always be thinking about the social and environmental good, when focusing only on the economic aspect, it can lead to failure of the laws aimed at circular economy (Sun, 2019).

Going further, CE requires the adoption of new business models (Jose, Jabbour, Beatriz, Sousa, & Sarkis, 2017), reinforcing the importance of public authorities to create adequate support through policies, environmental legislation, and economic and market instruments (Abreu & Ceglia, 2018). The bottom line is that a country or company needs strong political support to promote CE (Mathews, Tang, & Tan, 2011).

Considering the public perspective, which is the focus of this research, few countries appear to have public policies, laws and regulations created specifically for the purpose of CE; rather, more countries have regulatory instruments aimed at sustainable purposes that indirectly endorse CE principles and contribute to fostering CE. Momentarily disregarding the lack of a direct link to CE, the literature still seems to be insipient, despite the importance of the theme: "In spite of governmental policy exerting significant influence on the development of the Sustainable, such policy dynamics have not been systemically investigated” (Jiao; & Boons, 2017, p. 23).

In addition, the mitigation of pressures on the environment and the reversal of environmental degradation are needed (Zhijun; & Nailing, 2007). Countries and companies need strong political support to promote CE (Mathews; Tang; & Tan, 2011).

To narrow this gap, this research navigates on public policies, standards and regulations directly or indirectly related to CE fostering. In addition, there are several approaches and possible directives of these regulatory instruments in terms of practice area, such as resource-oriented, production-oriented, waste, and use-oriented life cycle policies (Zhu, Chengming, Haijia, & Lei, 2018) and energy conservation.

Therefore, it is important not only to list the policies, standards and regulations but also to relate them to CE, even as a way to understand the central motivations of these existing regulatory instruments, direct or indirect, when applied to a CE perspective. Moreover, this study aims to investigate the relationships among public policies, standards and regulations purposes and the conceptual set around CE, particularly principles, biological cycles, and technical cycles.

To address this objective, the following research questions were formulated: RQ1: What are the main policies, regulations, and standards related to sustainability and CE? RQ2: What is the relationship between the sustainable purposes of the catalogued public regulatory instruments and the central aspects of CE, such as area principles, biological cycles, and technical cycles? To answer these questions, our research approach is a systematic literature review combined with a content analysis. The surveyed sample encompasses 411 publications from leading journals based on a search of the Web of Science and Scopus databases.

This study does not aim to address all laws or regulations specific to each type of material because many strains of this type have already been researched. For example, (Hao et al., 2017) studied China's policies and regulations, mainly regarding water and ecosystem-related topics. Ng et al. (2016) listed all environmental regulations related to zinc policies, while regulations on global marine plastic were studied by Raubenheimer and McIlgorm (2017); additionally, the legal instrument regarding low-carbon governance in China was studied by (Wang; & Chang, 2014) and the lack of standards for specific materials in the Lithium-Ion Battery Waste Hierarchy was studied by (Richa et al., 2017).

Additionally, this work does not aim to measure the effectiveness of these regulatory instruments in terms of promoting CE; it seeks only to establish the link through a systematic review of the literature.

Theoretical Background

The purpose of this chapter is to present several concepts of CE and other similar strategies with certain differences. In addition, it presents a general overview of CE policies.

Circular Economy Sustainable Policies towards CE

According to Homrich, Galvão, Abadia. and Carvalho, (2018, p. 19), “CE is a operation strategy that emerges to oppose the traditional open-ended system, aiming to face the challenge of resource scarcity and waste disposal in a win-win approach with economic and value perspective”. According to (author), the CE model encompasses two cycles: (i) biologic, which consumes biologics, foods and materials such as wood or cotton, which must return to the system through composting or anaerobic digestion; and (ii) technical, which has the objective of recovering or restoring the greatest possible quantity of products or materials. In this case, the return to the economic system occurs through strategies of reuse, repair, remanufacturing or recycling.

CE is also related to some different concepts, strategies, and activities. For instance: (i) industrial symbiosis (Afshari; Farel; & Peng, 2018), (ii) Cradle-to-Cradle (Gallagher, 2017), (iii) PSS (Chen, 2018), (iv) closed economy (Geng; & Doberstein, 2008), (v) eco- innovation (Castellani; Sala; & Mirabella, 2015), (vi) eco-design (Ellen Macarthur Foundation, 2015) and (vii) waste and resource management (Hoogmartens; Eyckmans; & Van Passel, 2016). Moreover, some practical differences exist between related concepts, for instance, “the use of concepts such as cleaner production or bio economy requires less adaptations of human's mode of living and it assumes substitution between environmental and economic capitals. On the contrary, concepts such as PSS, industrial ecology, or nature-based solutions assume that structural changes are required in our societies to meet the challenges of sustainability. In addition, for sustainable development to occur, disruptive changes and radical innovations are necessary; moreover, it is necessary to integrate sustainability and business development, which the CE model offers (Ritzén; & Ölundh, 2017).

According Naustdalslid (2014), CE is endorsed by environmental organizations, by NGOs guiding their messages to industries and businesses and by “laying pressure on authorities to install enabling laws and regulations”.

The implementation of CE requires a long-term transition with deep and large-scale changes in existing production and consumption systems (Schulte, 2013; van Buren, Demmers, van der Heijden, & Witlox, 2016); thus, it is a transformation that is patently difficult to achieve without the direct participation of governments. Although the idea of CE has captured great interest and general attention (Dong et al., 2017), less structured organizations would still need governmental support to acquire the technology and technical knowledge necessary for the long CE journey (Rizos et al., 2016). Thus, for principles of CE and resource efficiency, it is essential that countries have strong strategies and management to inform and guide infrastructure policies, practices, planning and investments (Farmer; Shaw; & Williams, 2015). Other barriers that the implementation of the circular economy can face are those studied by Ritzen and Sandstrom (2017: financial, structural, attitudinal, operational, and technological. Of course, the barriers may be different at different levels in the industry or organization (Lewandowski, 2016).

To remove some of the obstacles to CE, public actors need to develop programs to encourage its implementation, which is still an exception (Schulte, 2013). Antagonistically, there is a scarcity of incentives for the development of new sustainable materials (Preston, 2012) and a lack of support from public actors (Zhang et al., 2009). According to Geng, Zhu, Doberstein, and Fujita, (2009, p. 977) “through adequate policies, flexible organizational structures, and effective tools for integrated resources management, CE aims for simultaneous positive outcomes for the economy, society, and the environment”.

In pursuit of a sustainable future, programs and policies for a CE are becoming key to issues at regional and international plans (Hobson; & Lynch, 2016). However, the implementation of these policies, which could guide strategies for standard public services, infrastructure, quality of life and the environment (He et al., 2017), finds a barrier in the lack of social pressure due to the low awareness about the benefits of sustainable products (Rizos et al., 2016).

Consequently, without proper policies or regulations, the desire for new economic gains could lead companies to reduce environmental standards and be more tolerant about polluting projects (Yu; De Jong; & Cheng, 2016). An environmental tax is an example of inadequate policy, acting contrary to the objectives of environmental

protection. Although an environmental tax is considered one of the most efficient environmental policy tools, it results in low pollution discharge rates, prompting organizations and institutions to choose to pay a fee rather than acting to eliminate and control pollution (Sun, 2013). Policy adequacy must also cover the reality of small and medium-sized enterprises, providing conditions and incentives to achieve the desired environmental standards (Hu; & Zhang, 2015).

To achieve CE, it is necessary to reduce the misalignment that persists between the intended directions, the legislation in force and the activities in practice (Augustsson, Sörme, Karlsson, & Amneklev, 2017). Industry and business administrative sectors report that one of the difficulties in implementing policies or standards for CE is a slow and bureaucratic process of regulatory approval (Rizos et al., 2016). Public policies and standards can also be barriers to the implementation of ecological parks, IS and CE (Zhu, Geng, Sarkis, & Lai, 2014), although the recent literature on the discussion of IS relationships in the context of CE indicates the importance of policies (Deutz, Baxter, Gibbs, Mayes, & Gomes, 2017). Another important point is that timely policy changes may not help to promote CE (Hu; He; & Poustie, 2018); instead, existing laws and policies must also be reformulated.

Methodological Approach

The purpose of this chapter is to present step by step how the authors arrived at the sample of 411 articles, in addition to explaining how the codes were made and present the software used to conduct the research.

Sampling procedures

The research method is a deep content analysis in a systematic literature review. Data were obtained from the scientific databases ISI Web of Science Core Collection (WoS) and Scopus by the end of September 2018, without any restrictions on academic disciplines, journals or publication dates. The initial search was performed using the search string, “circular economy” AND “"polic*" OR "public polic*" OR "government*" OR "regulat*", only refined by “published articles”, “reviews” and “articles in press” in Scopus; and “published articles” and “reviews” in WoS, for publications in English. 436 articles in the (WoS) database and 397 articles in Scopus database were published between 2005 (year of the first sample article) and September 2018. In a first

screening, 332 duplicate documents were identified and excluded. After analysing the 501 papers' abstracts, were kept 411 for both coding and content analysis. The excluded articles had no circular economy as focus, or the term only appeared once.

Data analysis

The content analysis research protocol follows the recommendations of (Duriau, Reger, Pfarrer, & Sources, 2007): planning the review (research questions, search operation strategy and coding), conducting the review (frequency counts and cross-tabulations), and reporting and disseminating the findings (interpretation of the results). Appendix 1 details the coding scheme defined and suggested by Carvalho Fleury, and Lopes (2013), applying a mix of deductive approaches based on the theoretical background. The NVivo software (Bazeley & Jackson, 2013) was used to help the sample coding process. Some codes of other authors were used: policy goals (Tecchio, McAlister, Mathieux, & Ardente, 2017), policy areas (McDowall et al. 2017) and biological, technical cycle and CE principles (Ellen Macarthur Foundation, 2015). The other codes were found through a qualitative analysis and with the help of the tree of phrases and words of the NVivo software. The code C1 identifies the methodologies, C2 indicates whether the study is qualitative or quantitative, C3 indicates whether the papers cover some dimension of the Triple bottom line (TBL), and C5 demonstrates whether the studies are more heavily focused on countries, regions, organizations, eco-parks or cities.

Statistical analyses were performed in IBM SPSS software, as correlation analysis between variables in the coding schema. Moreover, core/periphery analysis and network analysis were performed using UCINET 6 and Net Draw (Borgatti; Everett; & Freeman, 2002). The core/periphery structure is a common image in social network analysis and other fields (Borgatti; & Everett, 2000).

Results and Discussion

This chapter presents a content analysis of the 411 articles in the sample. Moreover, the results are discussed.

Content Analysis

The content analysis was performed based on an in-depth analysis of the surveyed papers, supported by NVivo software.

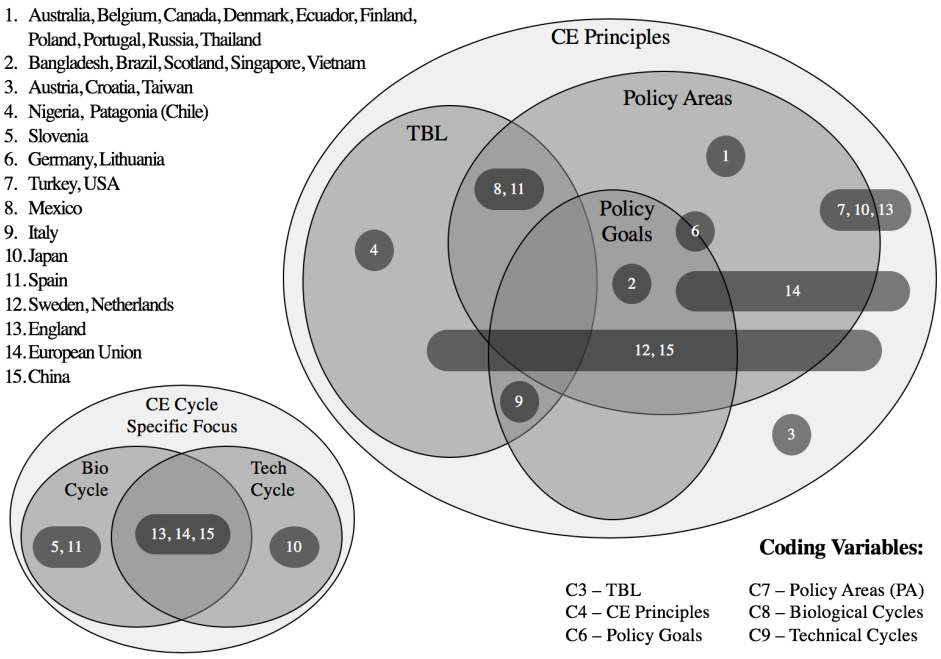
Approximately 40% of the surveyed publications are related to policies and/or regulations in China, followed by those related to the European Union, with 15% publications. In addition, 3% study only the UK without addressing the EU. Figure 1 shows the main concerns of countries/regions, considering the coding schema developed. It corroborates the strong presence of China and the EU in the literature surveyed, which presents a large range of topics.

The analysis of Figure 1 suggests the countries' response in terms of regulations based on historical, cultural and maturity aspects of the themes of sustainability and CE, according to the literature studied. Countries such as Sweden, the Netherlands and China have been publishing studies on regulations covering the entire spectrum of sustainability and CE, suggesting the concerns with and maturity of the subject, often pioneering. The EU also seems to be working on CE policies at a comprehensive but already concentrated level, which can also be explained by the holistic and integrated vision advocated by CE, as it concerns a set of countries. Germany, perhaps due to certain scandals in the automotive sector, complements the EU legislation with sectoral policies and specific targets. The USA, Japan, England, and most European countries have acted more strongly in sectoral policies, possibly influenced by CE principles, revealing a laissez-faire attitude and higher level, less detailed and ostensive goals, according to the culture and maturity of their societies. Nigeria and Patagonia, perhaps because of the richness of their natural resources, have focused on aspects more directly related to their own sustainability. Brazil and Vietnam, among others, focus on regulatory policies based on goals, revealing that they have less mature societies that likely demand enforcement and punishment to achieve adhesion. Here, it is important to explain that when the authors in the sample address policy goals, they talk about general quantifiable goals that guide policy interventions. Political areas should be the focus of follow-ups to this study.

In terms of a specific focus on cycles, the EU, China and England seek to more clearly discern the focus of policies, working on both biological and technological cycles, corroborating the idea of maturity in these countries. While Slovenia and Spain

are more concerned with biological cycles, other countries do not seem to focus on specific policies concerning the biological cycles of technological cycles.

Figure 1. CE Topics and their intersections with respective countries

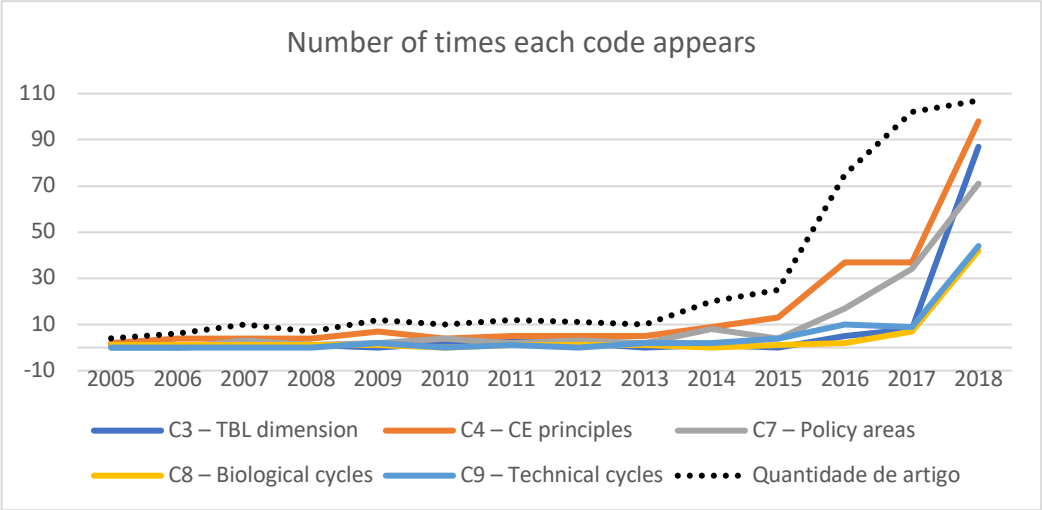


Concerning the research methods, most of the studied papers are exploratory and qualitative, applying case studies in particular (appendix B). The qualitative approach (A2 – 314 publications – 76%) surges as the dominant research approach, as case studies (KS5 – 43%) and literature reviews (KS3 – 38%) are the most commonly used research methods. Regarding the scope, nation (S1 – 40%) is the main observable unit of analysis because most policies and regulations hail from governmental initiatives aiming to enhance CE nationally. Thus, the main policy goal addressed in the articles is to reduce residual waste (PG3-43%), while the most evident policy area comprises priority sectors (PA5 – 41%), such as plastics, food waste, critical raw materials, construction and demolition waste, and biomass and bioproducts. With regard to CE principles, optimization of resource yields (CE2 – 46%) and fostering system effectiveness (CE3 – 39%) are the most cited principles. According to (author), fostering system effectiveness is about revealing negative externalities and excluding them from projects. In other words, it deals with reducing damage to products and services that humans need. There is a lack of studies on technical and biological cycles because the most mentioned biological cycle, biosphere

regeneration (BC3), appears in only 16% of the sample, while the most discussed technical cycle is recycling (TC4), mentioned in 21%.

Figure 2 shows the evolution of the coding schema over the years. Media content analysis (author) can help reveal how the concept of CE is described within public discourse (author). Thus, it is possible to observe the prevalence of CE principles, followed by policy areas, particularly after 2015, when both topics experienced sharp increases.

Figure 2: Evolution of the coding schema



Regulatory and Political Pressures

Business globalization can cause countries to face numerous social and economic pressures. Even small and private organizations have lagged in implementing environmental practices because they should anticipate these trends and proactively initiate their efforts in environmental management to avoid the risk of losing competition as the increased volume of environmental regulations are expected to run due to coercive pressures (Zhu; Sarkis; & Lai, 2012).

The CE model is prospected to decouple economic growth from environmental pressures (Hara, Yabar, Uwasu, & Zhang, 2011). Development from a traditional perspective of GDP occurs alongside environmental pressure, a consistent and recognized pattern expressed as the simultaneous development of economic and environmental pressure (Dajian 2008). Polluters are under huge public pressure, particularly if they are called to face legal action (Yu; De Jong; & Cheng, 2016).

Regarding the government's efforts to reduce energy efficiency and emissions, these industries are under significant pressure from the government to make production more environmentally friendly (Wübbeke & Heroth, 2014).

For sustainable growth in the context of mounting pressures on global resources, CE can be an economically and politically palatable response (Hobson; & Lynch, 2016). The disassociation of the environmental and economic aspects, in this case, can have benefits. To meet the environmental pressures of populations or NGOs, new ways to create technologies can be critical, thus generating new opportunities for work and development (Zhang et al., 2015).

The pressure on public authorities may come from small communities, for example, the Higueras community (China), which is pressing local politicians from a quarry company to allow the building of an open pit limestone quarry on the outskirts of the Sierra Picachos and the protected natural area (Aguiñaga et al., 2016). Another result of these pressures is that the United Nations has launched an initiative to promote sustainable public procurement, and several countries have begun to include it in their public policies (Witjes; & Lozano, 2016).

Eco-Industrial Park and Industrial symbiosis

Industrial Park development has become a critical operation strategy to promote economic development in many countries since 1980s (Zhe et al., 2016). Approximately 17% of 246 articles deal with industrial symbiosis and eco parks regulations. Currently, a great number of performance evaluation indicators seek to maximize industrial yield, leading to ecological degradation and environmental pollution. According to Boons, Spekkink, and Mouzakitis (2011), industrial symbiosis is a process at two levels: the level of the regional industrial system, and the societal level where the concept and routines of industrial symbiosis diffuse. Chertow (2007) conceptualize as the move towards increased connectivity in terms of material, energy, and information flows. This is, with material and energy flow capabilities to realize environmental and economic benefits simultaneously (Dong et al., 2013). Besides, new environmental technologies and systems can also be disseminated outside parks, thus resource efficiency can be improved (Zhang et al., 2009).

There is increasing evidence that throughout the world, firms, governmental agencies and NGOs are seeking to stimulate industrial symbiosis” (Boons, Spekkink, & Mouzakitis, 2011 p. 905). The rapid development of EIP was responsible for some problems (Zhe et al., 2016), such as the escalation of resources and environmental pollution, and a crescent pressure on climate change (Liu, Adams, Cote, Geng, & Li, 2016). In contrast, according to Chertow (p13, 2007) "Industrial symbiosis can enhance long-term resource security by increasing the availability of critical resources such as water, energy, or particular raw materials". EIP and industrial clusters are efficient approaches for governments at all levels to benefit economic and industrial progression (Geng, Zhang, Ulgiati, & Sarkis, 2010).

According to Chertow and Ehrenfeld, (2012) some companies achieve symbiosis in response to regulatory or permitting pressure, requiring industrial operators to rise resource efficiency. In addition, an intense resource saving and emission reduction can be achieved (Chertow; & Ehrenfeld, 2012). The policies, laws and regulations that appear the most in the sample are in the next topic (in bold). According to the authors, all policies help to improve CE.

Lessons from China and Europe

The economic miracle of China has been reached at the expense of its natural capital and environment (Peters, Weber, Guan, & Hubacek, 2007). The pressure for the Chinese government to promote economic growth increased considerably after 2008 due to the financial crisis. Therefore, the government should pay more attention to promoting economic development without neglecting environmental quality (Chen; Liu; & Hu, 2015). With fast industrialization and urbanization, China is facing rising emissions and a resource reduction dilemma. To comprehend sustainable development, it is critical for China to embrace the eco-industrial development approach (Liu, Adams, Cote, Geng, & Li, 2016). China has been developing IS and EIP (Liu, Adams, Cote, Geng, & Li, 2016) for decades, and it has had significant economic and environmental effects.

In 2008, China approved a law proclaiming CE as China's central development goal. To formalize CE, the Chinese government created the CE Promotion Law, which sought to chart a long-term plan to achieve sustainability, and implemented the Cleaner

Production Promotion law (Park; & Chertow, 2014). Until 2010, China had 60 EIP (Zhang et al., 2009), and by 2014, it had more than 85 (Shi; & Yu, 2014). To regulate all of EIP, a pilot plan was created with two government agencies: the Environmental Protection Agency and the National Development and Reform Commission, which are currently involved in the promotion of national pilot EIP programs (Zhang et al., 2009). To facilitate EIP construction, the Chinese government issued a series of policies and regulations, including planning guidelines, technical standards and evaluations (Shi; & Yu, 2014).

In China, laws and regulations have been enacted to facilitate CE. “It is the first country to release nationally focused CE indicators so that objective and credible information on the status of CE implementation can be recognized” (Geng, Fu, Sarkis, & Xue, 2012 p. 216). During the process of implementing new policies, the government must promote cleaner production, including the coordination of the various stakeholders, financial support, the provision of appropriate policies and capacity-building programs (Geng, Fu, Sarkis, & Xue, 2012). As China continues to rapidly develop, there is an opportunity to further implement and extend policies to improve CE (Peters, Weber, Guan, & Hubacek, 2007). According to Hu and Zhang (2015), “When other countries' consumption and emission levels reach the same standard as current China, scrap storage would also become their priority”. However, China is concerned not only with policies, as Geng, Mitchell, and Zhu, (2009) noted in his research, but also with the aim of raising students' environmental awareness; a relevant step is to take students to companies and to carry out training and practices related to IE.

The EU and its environmental policy and environmental advocacy groups have enthusiastically embraced CE. The “CE policy is an ongoing translation process, during which a policy assemblage, constituted by ideas, objects, practices and actors, is emerging and evolving under the policy label of CE, thus forming different types of policy” (Jiao; & Boons, 2017).

The recent British Standard Framework to CE (BS 8001:2017) is an example of the many efforts aimed at scaling up CE implementation. Many companies, universities and governmental agencies were involved in the development of this practical implementation guide (BS, 2017), concentrating on the move from the polluting linear

economy to the sustainable CE. This type of cooperation is essential because policies and regulations need to be appropriate.

When looking for the laws and policies that appear in all papers, we listed the ones most studied in the sample. The laws of China and Europe appear frequently, as presented in Appendix 2. Both in Europe and in China, there are specific CE laws, while the most studied laws are those that, according to the authors, promote CE. In bold, we list the policies most frequently encountered by the authors. More policies deal with waste.

Another important point is to understand how policies and regulations are framed differently in China and Europe. According to (McdowalL et al., 2017), China's policy refers to a broader response to the environmental challenges posed by rapid growth and industrialization. On the other hand, CE in Europe has a more restricted environmental scope, focusing on waste and resources. In this way, Europe's CE policies are framed in both economic and environmental terms, focusing on the potential for resource efficiency to increase competitive.

Discussion

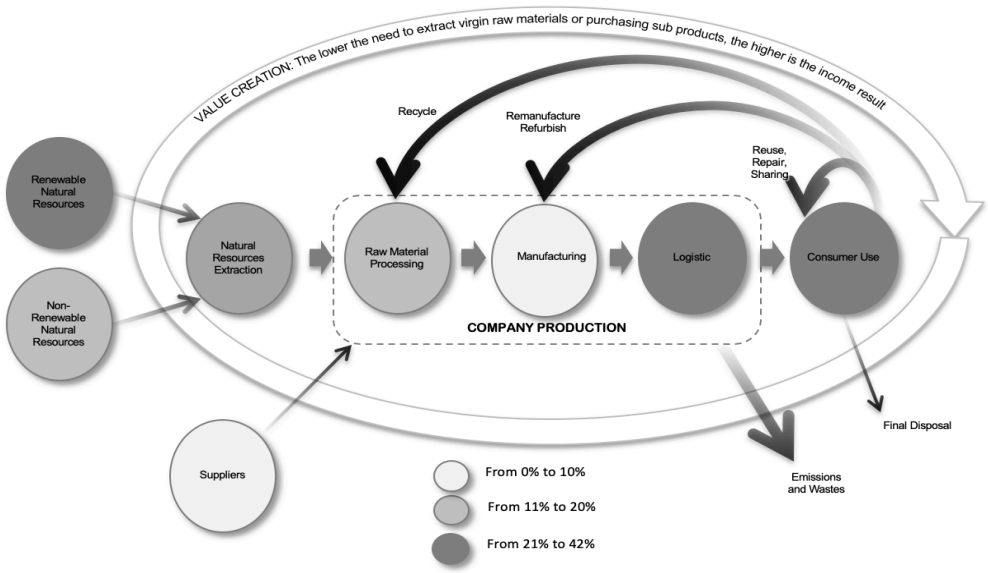
Through the in-depth analysis of 411 articles, it was possible to investigate RQ1: What are the main policies, regulations, and standards towards sustainability and circular economy?

A theoretical model built from the exploratory analysis of the content in the literature is given in Figure 3. In contrast to the traditional and current linear model, in which the generation of value is proportional to the intensity of the production flow, from the extraction to the end of life of the good, the circular model becomes more efficient as the cycles become more hermetic. That is, as the exchange with the external environment decreases, the extraction of raw material and residual disposal decrease, which are better from a CE perspective. The percentage indicates the number of times each field appeared in the sample.

Positioning the other elements captured in the literature, it is possible to verify that the most frequent topic is related to the end of life and natural resources. There is still a lack of literature on the middle of life. According to Scheepens; Vogtlander; and

Brezet (2016), metrics to analyse complex business models in CE are needed. Life cycle assessment is currently the best-defined system for analysing environmental aspects and can analyse circular systems, product-service systems, and recycling systems. An efficient performance evaluation helps to recognize the key barriers to the IS of EIP so that more appropriate policies can be raised by considering the local realities (Zhe et al., 2016).

Figure 3: CE framework and Scope of Policies



For the design and implementation of a complex circular business system, it is important to realize that regulations (laws, subsidies, and taxation) are often indispensable elements (Scheepens; Vogtlander; & Brezet, 2016). “The circular system can be organized to create sustainable value by minimizing the environmental impact,” adding value to companies (van Buren, Demmers, van der Heijden, & Witlox, 2016, p. 2). In addition, environmental pressures from society can be reduced when new environmental technologies are disseminated (Zhang et al., 2009).

In fact, the Chinese government recognized the value of this approach because it implemented the same law for CE (Geng; & Doberstein, 2008). Understanding the key drivers of growing energy consumption and associated emissions is critical for global policy (Peters, Weber, Guan, & Hubacek, 2007).

The cross-analysis of the surveyed articles according to the coding schema allowed for the identification of the core themes through core-periphery analysis. In

Table 1, the upper-left quadrant shows the core codes, while the bottom-right quadrant contains the periphery codes. In a core-periphery analysis (such as the one in Table 1), the core represents the most central and densely connected codes and, as such, can also be considered a centrality measure (Borgatti; & Everett, 2000), while the periphery represents codes that are sparsely connected. In addition, core codes can also be well connected to those in the periphery quadrant. As shown in Table 1, the core class membership is composed of the codes TBL2 (Environment), CEP2 (Optimize resource yields), PG3 (Reduce residual waste) and PA5 (Priority sectors), with a core-periphery fit of 0.8594 (see Table 1). This core class emphasizes the focus on environmental issues in CE policies and regulations well translated by these three codes – TBL, CE2, CE3, and PG3, while PA5 shows the aim of fostering key sectors. Some countries (S1) and companies are seeking to upgrade to sustainable technologies to shift waste and by-product chains into multiple cycles of increasing returns. To optimize resource yields, it is necessary to determine what a recycling program for similar material grades could yield (author). In this case, IS could generate both economic and environmental benefits in clustered industries and communities (author), once all waste from one company can be used by another.

Table 1: Core-periphery analysis

Core/Periphery fit (correlation) = 0,8594

Core/Periphery Class Memberships:

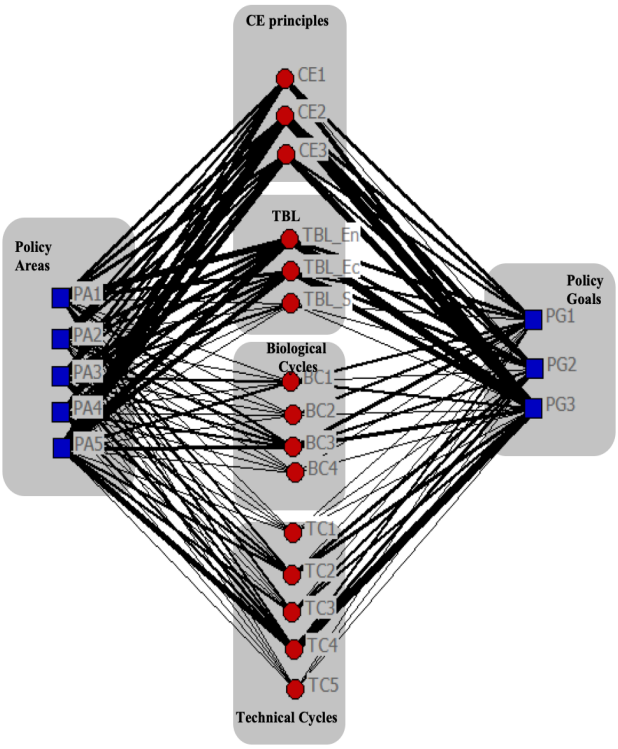
Core: TBL_En TBL_Ec CE2 CE3 S1 PG3 PA5
Periphery: TBL_S CE1 S2 S3 S4 S5 PG1 PG2 PA1 PA2 PA3 PA4 BC1 BC2 BC3 BC4 TC1 TC2 TC3 TC4 TC5

		7	2	3	5	6	14	19	1	4	10	8	9	13	11	15	16	17	18	12	20	21	22	23	24	25	26	27	28
		S1	TBL	TBL	CE2	CE3	PG3	PA5	TBL	CE1	S4	S2	S3	PG2	S5	PA1	PA2	PA3	PA4	PG1	BC1	BC2	BC3	BC4	TC1	TC2	TC3	TC4	TC5
7	S1	167	65	38	70	77	70	68	10	31	18	1	2	18	1	26	24	16	24	21	8	3	38	4	10	10	16	29	4
2	TBL_En	65	166	58	64	75	69	61	17	43	19	24	20	23	11	41	22	32	23	22	12	5	35	10	7	14	9	29	6
3	TBL_Ec	38	58	122	49	45	46	39	17	37	5	13	14	19	14	20	17	23	15	11	7	4	17	9	3	13	6	28	3
5	CE2	70	64	49	179	2	91	82	9	27	1	32	20	43	11	26	30	28	21	19	8		24	4	4	28	18	45	3
6	CE3	77	75	45	2	164	62	59	15	2	27	24	22	17	8	23	19	14	23	12	4	1	27	2	9	8	4	28	8
14	PG3	70	69	46	91	62	179	158	5	33	5	40	20	35	7	26	23	36	26	25	14	3	28	5	4	18	14	68	6
19	PA5	68	61	39	82	59	158	169	2	33	4	40	19	34	6	23	21	26	25	22	11	4	26	6	4	17	11	48	5
1	TBL_S	10	17	17	9	15	5	2	35	11	1	1	4	4	7	5	6	12	4	1	2		4	5		4		4	6
4	CE1	31	43	37	27	2	33	33	11	92	2	5	14	6	6	24	7	24	9	22	18	9	23	13	2	4	2	19	4
10	S4	18	19	5	1	27	5	4	1	2	29	6	2	1	1	4	1	3					9		1	2		3	
8	S2	1	24	13	32	24	40	40	1	5	6	60		7		4	4	4	8	3	2		5	1	1	5	3	20	3
9	S3	2	20	14	20	22	20	19	4	14	2		46	5	1	12	6	3	9	6	4	2	8	1	2	4		6	1
13	PG2	18	23	19	43	17	35	34	4	6	1	7	5	59	8	15	8	12	17	6	5		8		3	26	11	20	1
11	S5	1	11	14	11	8	7	6	7	6	1		1	8	26	9	4	10	3	3	3		2			7	3	7	1
15	PA1	26	41	20	26	23	26	23	5	24	4	4	12	15	9	68	10	19	10	14	6	5	14	4	5	11	9	16	2
16	PA2	24	22	17	30	19	23	21	6	7	1	4	6	8	4	10	50	7	3	9	3	1	9	1	2	5	5	14	3
17	PA3	16	32	23	28	14	36	26	12	24	3	4	3	12	10	19	7	63	4	18	11	3	14	5	1	13	4	25	2
18	PA4	24	23	15	21	23	26	25	4	9		8	9	17	3	10	3	4	53	10	6	3	9	2	1	11	5	14	2
12	PG1	21	22	11	19	12	25	22	1	22		3	6	6	3	14	9	18	10	50	14	7	18	2	1	3	3	7	2
20	BC1	8	12	7	8	4	14	11	2	18		2	4	5	3	6	3	11	6	14	26	1	6	1	2	2	4	8	
21	BC2	3	5	4		1	3	4		9			2			5	1	3	3	7	1	10		1			1	1	
22	BC3	38	35	17	24	27	28	26	4	23	9	5	8	8	2	14	9	14	9	18	6		67	1	2	7	2	12	2
23	BC4	4	10	9	4	2	5	6	5	13		1	1			4	1	5	2	2	1	1	1	20			1	3	
24	TC1	10	7	3	4	9	4	4		2	1	1	2	3		5	2	1	1	1	2		2		13	1		1	1
25	TC2	10	14	13	28	8	18	17	4	4	2	5	4	26	7	11	5	13	11	3	2		7		1	36	8	14	1
26	TC3	16	9	6	18	4	14	11		2		3		11	3	9	5	4	5	3	4	1	2	1		8	24	5	
27	TC4	29	29	28	45	28	68	48	4	19	3	20	6	20	7	16	14	25	14	7	8	1	12	3	1	14	5	87	1
28	TC5	4	6	3	3	8	6	5	6	4		3	1	1	1	2	3	2	2	2			2		1	1		1	14

For answer the RQ2: How is the relationship with the sustainable purposes of the catalogued public regulatory instruments, with the central aspects of the CE, as areas principles, biological cycles, and technical cycles?

The cross-tabulation and correlation analyses show the relationship between variables based on the frequency of their occurrence in the 411 publications. Figure 4 summarizes the relationships on policies and regulations in the CE context most often mentioned in the literature. The concentration of lines related to the variables represents the connections identified in the articles of the studied sample. As the number of lines increases, the correlation identified in the literature is stronger. In an overview, for example, the policy areas and policy goals variables present a more intense correlation with the CEP1, CEP2 and CEP3 variables covered under CE principles. As mentioned before, there is a lack of studies on technical and biological cycles, as corroborated by the low density of the network relating these codes with the others at the bottom of Figure 4. The exception is the case of recycling (TC4), which is addressed in a high number of studies. The studies in TC4 address the recycling of specific materials or business models with a focus, or incorporation, of recycling. The focus on policy areas and goals remains on CE principles and TBL dimensions. Among the CE principles, CEP2 (optimizing resource yields) and CEP3 (fostering system effectiveness) strongly relate to policy goals PG3 (reduce residual waste) and to policy area PA5 (priority sectors). Similarly, both codes PG3 and PA5 are strongly connected to the TBL2 (environment) dimension. As suggested by Frenken (2017, p. 1), "the nature and size of the social and environmental impacts are expected to differ greatly in each of the three scenarios”. Finally, the same two codes PG3 and PA5 are more often related to TC4 (Recycle) and BC3 (Biosphere regeneration), but the density of these relations is lower than that of the other relations noted.

Figure 4 - Relational analysis



It was explored the correlation between codes and identified insights for future research agenda. Pearson's correlation was used as a statistical method to measure the relationship and association between variables. In this method, values range from +1 to -1, where +1 indicates a positive correlation, -1 means a negative correlation and 0 shows no correlation. High degrees of correlation range from 0.5 to 1, but in the analysis in Appendix 3, correlations are significant at 0.01 and 0.05 levels, depending on the correlation of codes.

The correlation between the social dimension (TBL1) and farming collection (BC4) is significant at 0.01, which relates to how to invite people to solve problems such as organic waste so that they can benefit from the results. Solutions such as bioenergy and the bio-economy (Egea; Torrente; & Aguilar, 2018) are also proposed. Nevertheless, for the TBL1 variable, there is a correlation with the sharing economy (TC5), where it is possible for more people to access products/services and/or engage in economic activity, particularly in the crisis period.

Other correlations noted in are also discussed in the literature. To reduce residual waste (CEP3), greater efficiency is needed (Sahimaa, Hupponen, Horttanainen, & Sorvari, 2015) and there are necessary indicators of recovery and benefits for the

environment (TBL2). Concerns about production (PA1) and how it may affect TBL2 are addressed in approximately 15% of the papers on topics such as agricultural production (Chang et al., 2011; Egea; Torrente & Aguilar, 2018), metal production (Christmann, 2017) and cleaner production (Huang Et Al., 2011; Wang; & LI, 2006). It is known that the continuous depletion of natural resources (CEP1) related to current societies' lifestyles cannot be sustained indefinitely because the need for natural resource care can bring economic benefits (TBL3) (Cobo; Dominguez-Ramos; & Irabien, 2017).

As for the TC2 (reuse-redistribute) and TC4 (recycle) variables, most articles that address one theme also cover the other, such as in the articles of (Hill, 2015; Li; Zhang; Liang, 2013; Park; & Chertow, 2014). Other articles address TC2 as a way to extend the life of products (Vanegas et al., 2017). This topic is still discussed as a form of boosting markets for secondary materials, in addition to extending the life of products (PA4) (Park; & Chertow, 2014).

Waste management (PA3) has been developed in many countries and will continue to contribute to environmental benefits. Therefore, changes to extend the product lifecycle (PG2) are necessary (Arushanyan et al., 2017) to reduce the negative environmental impact (PG1) (Pratt et al., 2016) and may also be beneficial in helping to regenerate the biosphere (BC3) (Mathews, 2011). In addition, waste management (PA3) contributes to reducing residual waste (PA3) in priority sectors (PA5), such as plastics (Raubenheimer; & Mcilgorm, 2017); food waste (Sakal et al., 2017); critical raw materials (Busch et al., 2014); construction and demolition waste (Jin; Yuan; & Chen, 2019) and biomass and bioproducts (Lainez, González, Aguilar, & Vela, (2018).

Of all fields, BC2 (biogas) in biological cycles is the item that has the fewest relationships, even though the subject is treated in 7 papers. These articles more strongly address how the environment benefits from biogas but address little about regulations. The other items appear more homogeneously.

Conclusion

In addition to analysing the main differences in the application of CE by the EU and China, this study has two main contributions to the current literature, given the panorama of CE policies examined based on a large sample of 411 publications. This

study identifies the top-cited policies, regulations and standards in the literature and its evolution over the years, in which China and the EU stood out. The core topics were identified, showing that the environmental dimension of TBL is the focus of CE policies and regulations, particularly optimizing resource yields (CEP2) and reducing residual waste (PG3). The focus of the policy areas is defining the priority sectors and fields in which to invest (PA5), such as plastics, food waste, critical raw materials, construction/demolition waste, and biomass and bioproducts. Regarding CE principles, fostering system effectiveness (CEP3) is also well covered in the literature. This study finds a lack of research on with policies regulations relating to technical and biological cycles. Moreover, the surveyed literature also focused on end of life, while research on the beginning and middle of life is lacking.

However, the literature is still in an exploratory phase, as most of the surveyed articles apply a qualitative research approach, as in case-based studies. Thus, the second contribution of this study is a detail-coding schema that helps operationalize the key variables, analyse the relationships among the variables, and identify the core relations that can help further confirmatory research in this field. The cross-tabulation and correlation analyses highlight the relation of policy areas and goals with CE principles and TBL dimensions. An interesting insight is the relation between CE principles, (CEP2 optimize resource yields) and (CEP3 foster system effectiveness) with policy goals (PG3 reduce residual waste) and priority sectors (PA5). Finally, the same two codes PG3 and PA5 are more often related to TC4 (Recycle) and BC3 (Biosphere regeneration), but the density is lower than the other relations identified.

This study also identified a list of policies, regulations and standards related to CE and can help policymakers and entrepreneurs understand how these mechanisms can help foster CE was identified. CE is related to other strategies, as discussed in this article. Therefore, specific policies, such as waste policies, directly reflect the benefits of CE. Strategies such as IE, which, like the CE, have the IS as a practical measure to reach cycles of material in closed circuit, benefit from other policies. CE policies are still evolving in some countries, while in the EU and China, they are more consolidated. Thus, some countries are still debating the issue and do not have specific regulations but rather regulate and specify the factors that related to the environmental aspects of CE, and they can use this approach to benchmark further developments. In addition to

laws, regulations and policies aimed at CE and other concepts that benefit it, it is also necessary to educate, in person (Geng, Mitchell, & Zhu, 2009) or virtually, so that new generations are more aware of sustainability issues.

This study's limitations include the exploratory nature and subjectivity of the content analysis of the surveyed sample, despite the fact that the analysis is triangulated among the researchers and a computer-aid approach that merges various types of software is used. The sampling process uses search mechanisms for the content available in the ISI Web of Science and Scopus databases, and specific search strings and filters can exclude important publications in the sample. As a suggestion for future work, a more in-depth evaluation of the effectiveness of all public instruments is recommended to support CE.

Acknowledgement

The authors would like to thank CNPQ, CAPES and FAPESP, for supporting this research.

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Appendix 2 - Policies, laws, regulations and standards from China and Europe

Waste Disposal	
1	EU Waste Policy (1970); European Waste Shipment Regulation EWSR (2006); Waste and Resources Action -Programme WRAP (2000); Directive 2003/33/EC (EC, 2003); **Directive 2004/12/EC (2004), European packaging waste (2017)**; **Directive 2008/98/EC (2008); Waste Framework Directive (2017)**; Directive 2012/19/EU (2012); Waste electrical and electronic equipment WEEE (2017); Directive 2000/76/EC (2000); Waste Incineration Directive (2017); Directive 94/62/EC (1994) and Packaging and Waste (2017).
2	**Prevention of Environmental Pollution Caused by Solid Wastes (1995); Pollution Prevention and Control of Solid Waste Law (2005);** and Regulation of Electronic Products Pollution Control (2007).
Materials Restriction and Development	

Appendix 1 – Coding Schema

C1 – Kind of study
KS1 – Modeling
KS2 – Theoretical-conceptual
KS3 – Literature review
KS4 – Simulation
KS5 – Case study
KS6 – Action-research
KS7 – Experimental

C2 – Approach
A1 – Quantitative
A2 – Qualitative

C3 – TBL dimension
TBL1- Social
TBL2- Environment
TBL3- Economic

C4 – CE principles (Ellen MacArthur 2015)
CEP1- Preserve and enhance natural capital
CEP1- Optimize resource yields
CEP1- Foster system effectiveness

C5 – Unit of Analysis
UA1- Nation
UA2- Region
UA3 City
UA4- Eco park
UA5- Firm

C6 – Policy goals (Tecchio et al., 2017)
PG1-Reduce embodied impact
PG2-Extend life time
PG3-Reduce residual waste

C7 – Policy areas (McDowall et al. 2017, EU 2015)
PA1-Production
PA2-Consumption
PA3-Waste management
PA4-Boosting markets for secondary materials
PA5-Priority areas: plastics; food waste; critical raw materials; construction/demolition waste; and biomass and bioproducts.
PA6-Innovation, investment, and "horizontal" measures
PA7-Monitoring progress

C8 – CE Biological cycles (Ellen MacArthur 2015)
BC1-Extraction of biochemical feedstock
BC2-Biogas
BC3-Biosphere - Regeneration
BC4-Farming-collection

C9 – CE Technical cycles (Ellen MacArthur 2015)
TC1-Maintain - prolong
TC2-Reuse - redistribute
TC3-Refurbish - remanufacturing
TC4-Recycle
TC5-Share

1	Directive 2006/66/EC (2006); Restriction of Hazardous Substances, RoHS Directive (2006); Raw materials operation strategy (2008); and REACH Directive (2006).
2	Value added tax exemption regulations (1995); Value-Added Tax VAT (2008) and 11th Five-Year Plan.
Resources Efficiency	
1	Roadmap to a resource-efficient Europe (2011).
2	Preferential policy of income tax on resources comprehensive utilization enterprise (1994); Policies of resource comprehensive utilization of technologies in China (2010)

Energy		Emissions	
2	Energy Policy and Conservation (1997) Renewable Energy Law (2005)	1 2	Directive 2001/81/EC (2001) Air Quality Standard (1996)

Circular Economy/ Industrial Ecology/ Cleaner Production	
1	**European Commission's Circular Economy Package (2015); Action Plan for the Circular Economy (2015);** Green Alliance circular economy task force (2012)**;** National industrial symbiosis programme (2003)**;** Integrated product policy (2003).

2	**Circular Economy Promotion Law (2008);** The Guitang Group Policies (2002)**; Management Method for the National Pilot EIP Program (2007); Application, Denomination, and Management of National Pilot EIPs (2003); Cleaner Production Promotion Law (2001).**
Recycle, reuse, remanufacture	
1	Centre for Remanufacturing and Reuse (2007); Directive 2000/53/EC (2000); End-of-life vehicles (2017) and European batterie Alliance (2017).
Sustainability & Environment	
1	ISO14001 (2017), ISO 14044 (2017); Package of policy 2014-2020 (2014) and Rough Sets Applications RSA (2012).
2	ISO14001 (2017); National Development and Reform Commission NDRC (2015); Environmental Impact Assessment Law (2002); State Environmental Protection Administration SEPA (2006) and National Environmental Accounting Database NEAD (2010).

Appendix 3 – Correlation among core variables

	TBL1	TBL2	TBL3	CEP1	CEP2	CEP3	UA5	PG1	PG2	PG3	PA1	PA2	PA3	PA4	PA5	BC1	BC2	BC3	BC4	TC1	TC2	TC3	TC4	TC5
TBL1	1	,037	,103	,054	-,080	,045	-,019	-,068	-,079	-,121*	-,020	,133*	-,046	,027	-,126*	,037	-,022	-,037	,205**	-,041	-,053	-,049	-,049	,261**
TBL2	,037	1	,125*	,010	-,107	,160**	-,075	,001	-,050	-,017	,150**	,051	,068	,043	-,024	-,014	,033	,079	-,024	,078	-,070	-,015	-,139*	-,024
TBL3	,103	,125*	1	,152**	,006	-,066	,024	-,090	,047	-,024	-,018	,041	,011	-,033	-,007	-,052	,074	-,006	,072	,000	,036	-,038	,033	-,013
CEP1	,054	,010	,152**	1	-,009	-,373**	-,045	-,015	-,106	-,056	,096	-,019	-,066	-,151**	-,068	,182**	,180**	,090	,107	-,008	-,088	-,038	-,039	,016
CEP2	-,080	-,107	,006	-,009	1	-,823**	,037	,024	,120*	,065	-,065	,113*	-,020	-,013	,040	-,037	-,111	-,045	-,016	-,073	,076	,094	,053	-,067
CEP3	,045	,160**	-,066	-,373**	-,823**	1	-,020	-,047	-,029	-,128*	-,008	-,044	,033	,065	-,098	-,076	-,042	-,002	-,045	,112	-,027	-,106	-,068	,063
PG1	-,068	,001	-,090	-,015	,024	-,047	-,035	1	-,020	,079	,028	,114*	,155**	,048	,048	,067	,053	,221**	,017	-,021	-,053	,047	-,116*	,054
PG2	-,079	-,050	,047	-,106	,120*	-,029	,055	-,020	1	,185**	,018	,010	-,011	,254**	,174**	,038	-,047	-,050	-,062	,054	,299**	,098	,187**	-,022
PG3	-,121*	-,017	-,024	-,056	,065	-,128*	-,032	,079	,185**	1	-,035	-,014	,239**	,092	,961**	,049	,059	-,057	-,020	-,079	,094	,059	,174**	,002
PA1	-,020	,150**	-,018	,096	-,065	-,008	-,038	,028	,018	-,035	1	-,029	-,045	,025	-,025	-,040	,044	,078	-,058	,166**	-,025	,116*	-,006	-,014
PA2	,133*	,051	,041	-,019	,113*	-,044	-,039	,114*	,010	-,014	-,029	1	,039	-,068	-,025	,001	,040	,041	,005	,014	,009	,067	,059	,092
PA3	-,046	,068	,011	-,066	-,020	,033	-,024	,155**	-,011	,239**	-,045	,039	1	-,093	,233**	,014	-,027	,017	-,036	,023	,110	,003	,073	-,043
PA4	,027	,043	-,033	-,151**	-,013	,065	-,039	,048	,254**	,092	,025	-,068	-,093	1	,081	,088	,039	,010	,004	-,036	,234**	,105	,127*	,035
PA5	-,126*	-,024	-,007	-,068	,040	-,098	-,035	,048	,174**	,961**	-,025	-,025	,233**	,081	1	,043	,056	-,051	-,068	-,084	,087	,025	,161**	-,002
BC1	,037	-,014	-,052	,182**	-,037	-,076	-,023	,067	,038	,049	-,040	,001	,014	,088	,043	1	,107	-,059	,066	,102	-,062	,200**	,005	-,042
BC2	-,022	,033	,074	,180**	-,111	-,042	-,012	,053	-,047	,059	,044	,040	-,027	,039	,056	,107	1	-,051	-,018	-,024	-,031	,093	,017	-,021
BC3	-,037	,079	-,006	,090	-,045	-,002	-,044	,221**	-,050	-,057	,078	,041	,017	,010	-,051	-,059	-,051	1	-,067	-,004	,022	-,034	-,099	-,031
BC4	,205**	-,024	,072	,107	-,016	-,045	-,015	,017	-,062	-,020	-,058	,005	-,036	,004	-,068	,066	-,018	-,067	1	-,032	-,042	,054	-,019	-,028
TC1	-,041	,078	,000	-,008	-,073	,112	-,021	-,021	,054	-,079	,166**	,014	,023	-,036	-,084	,102	-,024	-,004	-,032	1	,007	-,053	-,061	,052
TC2	-,053	-,070	,036	-,088	,076	-,027	-,027	-,053	,299**	,094	-,025	,009	,110	,234**	,087	-,062	-,031	,022	-,042	,007	1	,097	,198**	,022
TC3	-,049	-,015	-,038	-,038	,094	-,106	-,025	,047	,098	,059	,116*	,067	,003	,105	,025	,200**	,093	-,034	,054	-,053	,097	1	-,051	-,046
TC4	-,049	-,139*	,033	-,039	,053	-,068	,036	-,116*	,187**	,174**	-,006	,059	,073	,127*	,161**	,005	,017	-,099	-,019	-,061	,198**	-,051	1	-,090
TC5	,261**	-,024	-,013	,016	-,067	,063	-,018	,054	-,022	,002	-,014	,092	-,043	,035	-,002	-,042	-,021	-,031	-,028	,052	,022	-,046	-,090	1

Pearson Correlation: **. Correlation is significant at the 0.01 level (2-tailed).*. Correlation is significant at the 0.05 level (2-tailed).

Appendix 3 – Summary of the content analysis of the 411 articles surveyed

References	C1	C2	C3	C4	C5	C6	C7	C8	C9
Ma et al, (2015)	KS5	A2	TBL2	CE2	S1	PG3	PA5	CB1	
Feng et al, (2016)	KS3	A2	TBL2	CE2	S1	PG3	PA5	CB3	TC3
Zhu al, (2017)	KS8	A1	TBL2	CE3	S2	PG3	PA5		
Moreno et al, (2016)	KS3	A2		CE3	S1	PG2/PG3	PA5		
Liu and Côté, (2017)	KS5	A2		CE3	S1/S4				
Tsiliyannis, (2016)	KS5	A2	TBL2	CE3		PG2/PG3	PA2/PA5		
Kuznetsova et al, (2016)	KS1	A1		CE3	S4				
Ng et al, (2016)	KS3/KS5	A2	TBL3	CE3		PG2/PG3	PA5		
Brand et al, (2016)	KS5	A2	TBL2	CE2	S1	PG1/PG3	PA3/PA5		
Fu, (2008)				CE2		PG2/PG3	PA5		
Liu et al, (2009)	KS1	A1	TBL1/TBL/TBL3	CE2					
Zambon et al, (2016)	KS5	A2		CE2	S1	PG3	PA4/PA5		
Veenstra et al, (2010)	KS3	A2		CE2	S1	PG1/PG2/PG3	PA4/PA5	CB1	TC3
Greyson, (2007)	KS3	A2	TBL3	CE1		PG3	PA5		TC4
Egea et al, (2017)	KS5	A2		CE2	S3	PG3	PA1/PA5		
Zhe et al, (2016)	KS7	A2		CE3	S1/S4	PG3	PA5	CB3	TC2
Zhang Cet al, (2010)	KS1	A1		CE3					
Andersen, (2007)	KS4	A2	TBL2/TBL3	CE3	S2				
Wei et al, (2009)	KS1	A1		CE3	S3		PA1		
Pinheiro et al, (2017)	KS5	A2		CE2	S1	PG3	PA5		
Huang et al, (2007)	KS5	A2	TBL2/TBL3	CE3	S3				
Zhang et al, (2008)	KS8	A1	TBL2	CE3	S1		PA1		TC1
Li et al, (2015)	KS3	A2		CE2	S1	PG3	PA5		TC3
Stahel, (2017)	KS3	A2		CE3	S2	PG3	PA5		TC2/TC4
Balasescu and Seguin, (2017)	KS3	A2	TBL3	CE2		PG2			
Cao et al, (2012)			TBL2/TBL3	CE2	S1	PG2/PG3	PA1/PA5		TC1
Xu Yet al, (2006)	KS7	A2		CE2	S3				
Cruz et al, (2017)	KS5	A2		CE2	S1	PG3	PA5		TC4
Hu et al, (2017)	KS5	A2		CE2	S3		PA1/PA2		
Zhang and Chen, (2015)	KS1	A1		CE2	S1	PG2		CB3	TC3
Dong et al, (2017)	KS4/KS5	A1	TBL1	CE3	S1	PG3	PA4/PA5		
Chen et al, (2015)	KS5	A2	TBL2/TBL3	CE1/CE2	S3		PA2	CB3	TC2
Dajian, (2008)	KS3	A2		CE3	S1				
Zhu et al, (2015)	KS3	A2		CE3	S1/S4				
Wieser, (2016)	KS5	A2		CE3	S1		PA2	CB3	TC1
Whalen et al, (2017)	KS5	A2		CE3	S1	PG3	PA5		TC3
Wolde, (2016)			TBL3	CE2	S2	PG2			TC2/TC4
Sansom and Avery, (2014)	KS8	A1		CE2	S1	PG2/PG3	PA4/PA5		TC2/TC4
Cooper, (2016)	KS3	A2	TBL2	CE3	S1	PG1/PG3	PA3/PA5		
Wang et al, (2017)	KS5	A2		CE3	S3		PA4		
Aguiñaga et al, (2016)	KS5	A2	TBL3	CE1	S1	PG3	PA5		
Laurenti et al, (2017)	KS3	A2		CE1		PG1/PG3	PA2/PA5		
Wubbeke and Heroth, (2014)	KS3	A2		CE3	S1				TC4
Peters et al, (2007)		A1	TBL2	CE2	S1	PG1	PA2	CB3	
Mathews et al, (2011)	KS5	A2		CE3	S1/S4	PG3	PA5	CB3	TC4
Mo et al, (2009)	KS5	A2		CE2	S3	PG3	PA1/PA5		TC4
Kama, (2015)	KS8	A2		CE2	S2	PG3	PA5		
Rattalino, (2017)	KS5	A2	TBL1/TBL2/TBL3	CE3	S1				TC5
Prendeville et al, (2016)	KS3/KS5	A2	TBL2	CE3	S2	PG3	PA5		
Duet al, (2009)	KS5	A2	TBL2, TBL3	CE3	S3	PG3	PA4/PA5	CB1	TC4

References	C1	C2	C3	C4	C5	C6	C7	C8	C9
Yaduvanshi et al, (2016)	KS5	A2		CE3	S1	PG3	PA2/PA5		TC4
Naustdalslid, (2014)	KS3	A2	TBL2	CE3	S1		PA1		TC1
McDowall et al, (2017)	KS3	A2		CE3	S2	PG3	PA5		TC5
Han et al, (2006)	KS5	A2	TBL1/TBL3	CE1	S3			CB4	
Li and Jong, (2017)	KS5	A2		CE1	S3				
Yu, (2017)	KS5	A2	TBL2	CE1/CE2	S3	PG3	PA1/PA5	CB3	
Xiang et al, (2014)	KS5	A2		CE3	S1	PG3	PA5		
Zhu et al, (2015)			TBL2/TBL3	CE2	S2				
Zhang et al, (2009)	KS5	A2	TBL2/TBL3	CE3	S3/S4		PA1		
Liu et al, (2016)	KS5	A2		CE3	S2/S4				
Zhao et al, (2017)	KS5	A2		CE3	S1/S4				
Liu et al, (2017)	KS3	A2	TBL2	CE3	S1	PG2/PG3	PA4/PA5	CB3	
Chang et al, (2011)	KS5	A2	TBL2/TBL3	CE1	S1	PG3	PA2/PA/PA5	CB2	TC3
Ribic et al, (2017)	KS3	A2	TBL2	CE3	S3	PG2/PG3	PA5		
Ren et al, (2012)				CE2	S1				TC3/TC4
Shen et al, (2013)	KS3	A2	TBL2/TBL3	CE3		PG3	PA5	CB4	
Liu et al, (2012)	KS5	A2	TBL2	CE1	S1	PG1/PG3	PA5	CB3	TC4
Wang and Hazen, (2016)	KS3/KS7	A1		CE2	S1		PA2		
Xi et al, (2011)	KS5	A2		CE2	S3		PA4	CB3	
Park et al, (2010)	KS5	A2	TBL2/TBL3	CE3	S1	PG3	PA1/PA2/PA3		TC2/TC3/TC4
Turunen, (2017)				CE3	S2	PG3	PA5		
Peiro et al, (2017)	KS5	A2		CE2	S2	PG3	PA5		
Dupont and Borg, (2017)	KS3	A2		CE2	S2		PA5		
Farmer et al, (2015)	KS3	A2		CE3	S1	PG1/PG3	PA3/PA5		TC4
Zhu et al, (2011)			TBL3	CE1	S1				
Geng and Doberstein, (2008)	KS3	A2	TBL2	CE3	S1				TC4
Zhang et al, (2011)	KS5	A2	TBL2	CE2	S1		PA1/PA2		TC3
Reuter, (2016)	KS7	A1		CE2	S2				TC4
Hobson and Lynch, (2016)	KS3	A2	TBL1	CE2	S2		PA2/PA4		TC5
Alaranta and Turunen, (2017)	KS3	A2		CE2	S2	PG3	PA5		
Wen and Liang, (2007)	KS1	A1		CE2	S1				
Vanegas et al, (2017)	KS1/KS5	A1, A2	TBL2/TBL3	CE2	S2	PG2/PG3	PA1/PA5		TC3
Sun et al, (2017)	KS1	A1	TBL2	CE3	S3		PA4		TC2
Flynn et al, (2016)	KS5	A2	TBL2	CE1	S1				
Richa et al, (2017)	KS5	A2		CE3	S1	PG3	PA3/PA5		
Guo et al, (2016)	KS5	A2	TBL1	CE3	S3				
Huang, (2015)	KS8	A1	TBL1/TBL2/TBL3	CE1/CE2	S3	PG3	PA2/PA5		
Shi and Yu, (2014)	KS5	A2	TBL2	CE3	S1/S4				
Zhang et al, (2010)	KS3	A2		CE3	S1/S4				
Yang et al, (2006)	KS5	A2	TBL2	CE3	S3			CB3	
Beccarello and Di Foggia, (2016)	KS5	A2	TBL2/TBL3	CE3	S1	PG3	PA3/PA5		TC4
Naims, (2016)	KS3	A2	TBL3	CE3		PG1			
Martins, (2016)	KS3	A2	TBL2/TBL3	CE3					
Wu et al, (2014)	KS1	A1		CE2	S1	PG3	PA5		
Zorpas et al, (2017)	KS5	A2	TBL2	CE3	S2	PG1/PG3	PA5		TC5
Geng et al, (2010)	KS5	A2	TBL2	CE3	S1/S4			CB3	
Chen et al, (2017)	KS5	A2	TBL3	CE3	S3				
Geng et al, (2014)	KS5	A2	TB3	CE3	S1	PG2	PA4	CB3	
Zhang et al, (2015)	KS3	A2	TBL1/TBL2/TBL3	CE3	S1		PA2	CB3	
Jensen and Remmen, (2017)	KS3	A2		CE1/CE2		PG2			

References	C1	C2	C3	C4	C5	C6	C7	C8	C9
Li et al, (2010)	KS3/KS5	A2	TBL2	CE3	S1	PG1	PA1	CB3	TC1
Hara et al, (2011)	KS5	A2	TBL2	CE2	S3	PG1			TC2
Jimenez-Rivero et al, (2017)	KS5	A2		CE3	S1	PG2/PG3	PA2/PA3/PA5		TC4
Dong et al, (2013)	KS5	A2	TBL2/TBL3	CE3	S2	PG3	PA4, PA5		
Arushanyan et al, (2017)	KS1	A1	TBL2	CE3	S1	PG2/PG3	PA5		
Zhao et al, (2009)	KS5	A1/A2	TBL2	CE3	S4				
Zhu et al, (2011)	KS8	A1		CE3	S1	PG2			
Park and Chertow, (2014)	KS5	A2		CE2	S2	PG2/PG3	PA3/PA5		TC2/TC4
Zhu et al, (2011)	KS8	A1	TBL2	CE3	S1		PA4		
Zhao et al, (2017)	KS4	A1		CE3	S1/S4				
Yu et al, (2015)	KS5	A2	TBL2/TBL3	CE3	S1		PA1/PA4/PA5		
Rivero and Navarro, (2017)	KS8	A1		CE2	S2	PG3	PA2/PA5		TC4
Ranta et al, (2017)	KS5	A2	TBL3	CE3	S2				TC4
Wang et al, (2015)	KS4	A1		CE2					TC4
Case et al, (2017)	KS8	A1		CE1	S1		PA5	CB1	
Iacondini et al, (2015)	KS5	A2	TBL3	CE3	S1	PG3	PA4/PA5		TC4
Gorazda et al, (2017)				CE1	S2	PG3	PA1/PA5	CB1	TC3
Slavic, (2017)	KS5	A2		CE3	S1				
Oguntoye and Evans, (2017)	KS5	A2		CE3	S1				
Scheinberg et al, (2016)	KS3	A2		CE2	S2	PG2/PG3	PA4/PA5		TC2/TC4
Mohamed et al, (2017)	KS1/KS3	A1/A2		CE3				CB3	
Cobo et al, (2017)	KS3	A2	TBL3	CE3		PG2/PG3	PA5		
Wilts et al, (2016)	KS5	A2		CE2	S2	PG3	PA5		
Sautter, (2016)	KS3	A2		CE2	S2				TC2/TC3
Yu et al, (2016)	KS3/KS5	A2	TBL2/TBL3	CE1/CE2	S3		PA2		
Ska, (2016)				CE2	S2	PG3	PA5		TC4
Hsieh et al, (2017)	KS5	A2		CE3	S1				TC4
Matus et al, (2012)	KS3	A2	TBL2	CE2	S1		PA1/PA4		
Loiseau et al, (2016)	KS3	A2	TBL2/TBL3	CE2		PG3	PA5		
Engelage et al, (2016)	KS3	A2	TBL2	CE2					
Qian et al, (2007)	KS3	A2	TBL3	CE2					
Xu, (2016)				CE2	S1				TC3
Islam, (2017)	KS5	A2		CE2	S1	PG1/PG3	PA4/PA5	CB3	
Zhu and Chertow, (2016)	KS5	A2	TB3	CE1	S3	PG3	PA1/PA5	CB2	TC4
Saidani et al, (2017)	KS8	A1		CE3	S2				
Li and Hu, (2017)	KS1	A1		CE1	S3	PG1		CB1/CB2	
Zhang, (2017)	KS3	A2		CE2					TC4
Zeng and Zhang, (2012)	KS1	A1	TBL2/TBL3	CE3	S1			CB3	
Dente and Tavasszy, (2016)	KS1	A1	TBL2	CE2	S1		PA2	CB3	
Rizos et al, (2016)	KS3/KS5	A2		CE2	S1		PA2		
Budzianowski, (2017)	KS5	A2	TBL3	CE3	S1		PA5	CB3	
Ferdousi and Qiang, (2017)	KS8	A1		CE1/CE2			PA2		TC5
Tesfaye et al, (2017)	KS7	A2	TBL2	CE2	S2	PG3	PA5		TC4
Tecchio et al, (2016)	KS3/KS5	A2	TBL3	CE2		PG2/PG3	PA5		TC2
Schreck and Wagner, (2017)	KS3	A2	TBL3	CE2	S5	PG3	PA5		
Sperandio et al, (2017)	KS1/KS5	A2		CE1		PG3	PA5		
Fan et al, (2014)					S1	PG3	PA1/PA5		
Li et al, (2015)	KS5	A2		CE3	S3	PG2/PG3	PA4/PA5	CB3	
Iacondini et al, (2014)	KS3	A2	TBL3	CE3	S1	PG3	PA4/PA5		
Dalhammar, (2016)	KS5	A2		CE1/CE2		PG2/PG3	PA5		TC4

References	C1	C2	C3	C4	C5	C6	C7	C8	C9
Standing et al, (2008)	KS3	A2	TBL3	CE1/CE2	S1				
Kennedy et al, (2016)	KS3	A2	TBL3	CE1/CE2	S1	PG3	PA5	CB3	
Ghisellini et al, (2014)	KS5	A2	TBL2	CE3	S1	PG3	PA5	CB2	
Kilkiş and Kilkiş, (2016)	KS5	A2	TBL2	CE3	S3	PG3	PA5		
Yabar et al, (2009)			TBL2/TBL3	CE2	S1	PG3	PA3/PA5	CB3	
Cong et al, (2017)	KS6	A2		CE2		PG3	PA5		
Gao, (2005)			TBL2	CE2					
Shi et al, (2012)	KS3	A2		CE3	S1		PA4		
Zhu et al, (2012)	KS8	A1	TBL2	CE1	S1				
Gregson et al, (2015)	KS3	A2	TBL3	CE2	S2	PG3	PA2/PA5		TC4
Guo et al, (2017)	KS8	A1	TBL2	CE3	S1		PA4		
Zhang et al, (2013)	KS5	A2		CE3	S1	PG1/PG3	PA2/PA5	CB3	
Raubenheimer and McIlgorm, (2017)	KS5	A2		CE1	S3	PG3	PA5	CB1	TC1
Scharff, (2014)	KS3/KS5	A2		CE2	S1	PG3	PA5		
Hoogmartens et al, (2016)	KS4		TBL2/TBL3	CE2	S1	PG3	PA3/PA5		TC1
Barrie et al, (2017)	KS3	A2		CE3					
Svanstrom et al, (2017)	KS3	A2	TBL2	CE3	S1	PG3	PA5		
Birat, (2015)	KS3	A2		CE2	S5	PG2			TC4
Busch et al, (2014)	KS1/KS5	A1/A2		CE2	S1				
Hao et al, (2017)	KS6	A2		CE2	S1			CB1	
Moriguchi, (2007)	KS3	A2	TBL3	CE2	S1	PG3	PA5		
Pratt et al, (2016)	KS5	A2	TBL2	CE3	S1	PG1	PA2/PA4		
Ortlepp et al, (2016)	KS1	A1		CE2	S1	PG3	PA5		
Zhu et al, (2014)	KS1	A1	TBL2/TBL3	CE1/CE2	S1				
Di Maio et al, (2017)	KS5	A2		CE2	S1			CB4	
Lu et al, (2017)	KS3	A2		CE1/CE2	S1				
Sahimaa et al, (2015)	KS3/KS8	A1/A2		CE2	S1	PG3	PA2/PA5		
Thomas and Birat, (2013)	KS3	A2	TBL2	CE2	S2	PG3	PA5		TC4
Garcia and Ferat, (2017)	KS3/KS5	A2	TBL1	CE3	S1				
Wang and Geng, (2012)	KS8	A2	TBL2	CE2	S3	PG3	PA1/PA5		
Mathews, (2011)	KS5	A2	TBL3	CE1	S1	PG1		CB3	
Kuokkanen et al, (2006)	KS3	A2		CE3	S1		PA5		
Dienst et al, (2013)	KS5	A2		CE2	S3	PG1		CB3	
Ji et al, (2017)	KS5	A2	TBL2	CE3	S2/S4				
Yuan, (2006)	KS5	A2	TBL2	CE3	S4	PG3	PA2/PA5		
Augustsson et al, (2017)	KS5	A2	TBL2	CE2	S1	PG1/PG3	PA5		
Mishenin and Koblianska, (2017)	KS3	A2		CE3		PG3	PA2/PA5		TC4
Bigano et al, (2016)	KS3	A2	TBL2	CE2	S2	PG3	PA1/PA5		
Jiao and Boons, (2017)	KS3	A2	TBL2/TBL3	CE2	S1	PG3	PA5		
Stahel, (2013)	KS3	A2		CE3		PG2/PG3	PA5		TC2
Frenken, (2017)	KS3	A2	TBL3	CE2		PG1/PG2/PG3	PA2/PA5		TC5
Zhang and Luo, (2005)			TBL2/TBL3	CE1/CE2	S1			CB4	
Liu et al, (2010)	KS8	A1	TBL2	CE2	S1		PA4	CB1	
Eras et al, (2017)			TBL2	CE2		PG3	PA2/PA5		TC4
Cutaia et al, (2016)	KS5	A2		CE3	S3	PG3	PA4/PA5		TC5
Dong et al, (2013)	KS5	A2	TBL2	CE3	S3	PG3	PA4/PA5	CB3	
Feng and Yan, (2007)	KS3	A2		CE3	S1				TC1
Golev and Corder, (2017)	KS3	A2		CE2	S1	PG1/PG3	PA4	CB4	TC3
Gordeeva, (2017)	KS6	A2	TBL2	CE2	S2				
Geng et al, (2016)	KS3	A2		CE3	S1/S4				

References	C1	C2	C3	C4	C5	C6	C7	C8	C9
Viani et al, (2016)	KS5	A2	TBL2	CE2	S1	PG3	PA5		
Van Schaik and Reuter, (2016)	KS4	A1		CE2	S2				TC4
Husgafvel et al, (2016)	KS4	A2		CE3	S2	PG2/PG3	PA1/PA4/PA5		TC4
Machacek et al, (2015)	KS3/KS5	A2	TBL3	CE1		PG3	PA5	CB1	TC4
Zhu et al, (2015)	KS1	A1	TBL2, TBL3	CE1/CE2	S3				
Geng et al, 2010	KS5	A2	TBL2	CE1/CE2	S3	PG1	PA1		
Daddi et al, 2016	KS3	A2	TBL2	CE3	S2/S4				
Geng et al, (2011)	KS3/KS5	A2		CE1/CE2	S1		PA1		
Endemann et al, (2017)	KS3	A2		CE3					TC4
Liu and Zhang, (2014)	KS3	A2	TBL2/TBL3	CE1/CE2	S1				
Hazen et al, (2017)	KS8	A1	TBL2	CE2	S1		PA2		TC3
Wen-hu et al, (2009)			TBL3	CE3	S1		PA2		TC2/TC4
Wei et al, (2009)	KS3/KS5/KS8	A1/A2	TBL1	CE3	S1		PA2	CB1/CB4	TC4
Kalmykova et al, (2016)	KS5	A2		CE1/CE2	S3	PG3	PA5		
Fernández, (2007)	KS8	A1	TB3	CE2	S1	PG2	PA2		TC4
Deutz et al, (2016)	KS5	A2		CE3	S2	PG1/PG3	PA5		
Pérez, (2016)				CE2	S2			CB3	
Li et al, (2013)	KS1	A1		CE3	S1	PG2/PG3	PA1/PA4/PA5		TC2/TC3
Lahl and Zeschmar-Lahl, (2013)	KS3	A2	TBL2	CE3	S2	PG2/PG3	PA5		TC4
Xuan and Yue, (2017)	KS4	A1	TBL2	CE2	S1	PG1/PG3	PA2/PA5	CB3	
Diener and Tillman, (2016)	KS5	A2		CE2					
Dhakal et al, (2016)	KS3	A2		CE2		PG2			
He et al, (2017)	KS5	A2	TBL3	CE2	S2				
Tisserant et al, (2017)				CE2	S2	PG3	PA2/PA5		
Xue, (2010)				CE2	S1			CB3	
Lainez et al, (2016)	KS5	A2	TBL2/TBL3	CE2	S1	PG3	PA5		
Pantazopoulo et al, (2017)	KS7	A1		CE2	S2	PG3	PA5		
Karayannis et al, (2017)	KS7	A1		CE2		PG3	PA5		
Han et al, (2017)	KS3	A2		CE2	S1	PG2/PG3	PA5		TC4
Pan et al, (2014)	KS3	A2	TBL3	CE1		PG3	PA5	CB3	
Mohan, (2016)	KS3	A2		CE3		PG3	PA5		
Nguyen and Ye, (2015)	KS5	A2		CE3	S1	PG1	PA1/PA2		
Hu and Zhang, (2015)	KS3	A2		CE2	S1	PG1	PA1	CB3	
Liu, (2009)	KS1/KS8	A1		CE1/CE2	S1				
Mo et al, (2005)	KS3	A2		CE3	S1			CB1	TC3
Zou, (2006)	KS3	A2		CE1/CE2	S1				
Zhang et al, (2016)	KS3	A2		CE2	S1	PG3	PA3/PA5	CB3	TC2
Nowakowski et al, (2017)	KS1/KS5	A2		CE2	S3	PG1/PG3	PA5		
Xue et al, (2010)	KS8	A1		CE3	S1				TC1/TC5
Blengini et al, (2017)	KS3	A2	TBL3	CE2	S2	PG2/PG3	PA5		TC4
Lee, 2017	KS5	A2	TBL2	CE3				CB3	
Kominko et al, (2017)	KS7	A1		CE2		PG3	PA1/PA5		
Ness, (2008)	KS3	A2		CE1	S1	PG1/PG3	PA5	CB3	
Mosquera-Losada et al, (2017)	KS7	A1		CE2	S1				
Liu and Matsumoto, (2009)	KS3	A2		CE3	S2/S4				
Vega-Quezada et al, (2017)	KS5	A2	TBL3	CE1	S1		PA1	CB3	
Albertario, (2016)				CE3					
Angelis-Dimakis et al, (2016)	KS5	A2		CE2					
Hobson et al, (2016)	KS5	A2		CE3	S1		PA2		
Wysokinska, (2016)	KS3	A2	TBL2	CE3	S2	PG3	PA5	CB3	

References	C1	C2	C3	C4	C5	C6	C7	C8	C9
He and Ma, (2009)	KS1	A1		CE2		PG3	PA5		TC4
Chase, (2016)	KS3	A2		CE3	S1				
Flachenecker, (2017)	KS3	A2	TBL2/TBL3	CE3	S2				
Peiry, (2014)	KS3	A2		CE2	S2	PG3	PA5		
Brears, (2015)	KS3	A2		CE1	S2	PG3	PA5	CB4	
Yong, (2007)	KS4	A2	TBL2	CE3	S1				
Murray, et al, (2017)	KS5	A2	TBL3	CE2	S2	PG3	PA5	CB3	TC4
Esposito et al, (2017)				CE3			PA5		
Hill, 2015	KS3	A2	TBL2	CE2		PG2/PG3	PA4/PA5		TC2/TC4
Wang and Hui, (2006)	KS3	A2	TBL2	CE3	S1/S4		PA1		
Wang and Chang, (2014)	KS3	A2	TBL2	CE3	S1/S4		PA1	CB3	
Boons et al, (2011)	KS3	A2		CE3	S5				
Sun, (2013)	KS5	A2		CE3	S3	PG3	PA1/PA5		TC4
Hageluken, (2017)				CE2	S2	PG3	PA5		TC4
Chen et al, (2012)	KS5	A2	TBL2	CE3	S1	PG3	PA4/PA5		TC4
Lee et al, (2014)	KS1	A1	TBL2	CE1	S2	PG3	PA3/PA5	CB1/CB3	
Kemp et al, (2017)	KS3/KS5	A2		CE1	S1	PG3	PA5		
Bellantuono et al, (2017)	KS3	A2		CE3	S2/S4				TC1
Gilbert et al, (2017)	KS5	A2		CE2		PG1		CB3	
Silva et al, (2016)	KS5	A2	TBL2	CE1	S1	PG3	PA5		TC4
Varžinskas et al, (2016)	KS5	A2		CE2	S1	PG3	PA5		
Viglia et al, (2017)	KS3	A2	TBL1/TBL2	CE1	S1		PA1		TC5
Prieto, (2016)	KS7	A1		CE2		PG3	PA5		
Gu et al, (2017)	KS3	A2		CE2	S1	PG1/PG2/PG3	PA4/PA5	CB1	TC3
Bodova, (2017)	KS3	A2	TBL2	CE3	S2	PG3	PA5		
Ness and Xing, (2017)	KS5	A2	TBL2	CE1/CE2	S1			CB3	
Winning et al, (2017)	KS3	A2	TBL3	CE2	S2				
Yap, 2005	KS3	A2	TBL2/TBL3	CE3	S1		PA1		TC1
van Buren et al, (2016)	KS5	A2		CE3	S1	PG3	PA5		
Witjes and Lozano, (2016)	KS3	A2	TBL2	CE3	S2	PG3	PA5		
Christmann, (2017)	KS3	A2	TBL3	CE2		PG3	PA5		
Geng et al, (2012)	KS3	A2		CE1/CE2	S1				
Dong et al, (2016)	KS5	A2	TBL2	CE3	S3	PG1/PG2/PG3	PA1/PA4/PA5	CB3	
Johansson et al, (2012)	KS5	A2	TBL2	CE2	S1	PG3	PA5		
Wu et al, 2017	KS1	A1		CE2	S1	PG1	PA2	CB3	
Scheepens et al, (2016)	KS2/KS5	A2	TBL2	CE1/CE2	S1/S3				
Wu et al, (2015)	KS1	A1		CE3	S1	PG3	PA5	CB3	TC2/TC5
Liu et al, (2016)	KS6	A2	TBL2	CE3	S1/S4			CB3	
Tingley et al, (2017)	KS3/KS5	A2		CE2	S1	PG2	PA4		TC2
Laurenti et al, (2016)	KS3	A2	TBL2/TBL3	CE2		PG2/PG3	PA2/PA5		
Satchatippavarn et al, (2016)	KS5	A2		CE2	S3	PG3	PA3/PA5		
Wang et al, (2014)	KS5	A2		CE1	S1		PA1	CB3	TC4
Andrade et al, (2017)	KS5	A2	TBL2	CE1/CE2/CE3	S3	PG2	PA2	CB1	TC1
Cross, (2017)	KS5	A2	TBL2	CE2	S3	PG2/PG3	PA4/PA5		TC2/TC4
Qianet al, (2011)	KS5	A1/A2	TBL3	CE3	S3				
Skorupskaite and Junevicius, (2017)	KS3	A2		CE3	S1	PG1/PG3	PA3/PA5		
Malinauskaite et al, (2017)	KS3	A2	TBL2	CE3	S2	PG1/PG3	PA3/PA5		
Sakai et al, (2017)	KS3	A2		CE2	S1	PG2/PG3	PA4/PA5		TC1/TC2/TC4
Cucchiella and D'Adamo, (2016)	KS1	A1		CE1	S2	PG3	PA5		
Saritas and Proskuryakova, (2017)	KS3	A2		CE2	S1	PG3	PA2/PA3/PA5		

References	C1	C2	C3	C4	C5	C6	C7	C8	C9
Pitkanen et al, (2016)	KS5	A2		CE2	S2	PG3	PA5		
Yu et al, (2015)	KS3/KS5	A2	TBL2	CE3	S3/S4				
Sultan et al, (2017)	KS1	A1		CE2	S1	PG2			TC4
Yuan et al, (2008)	KS3	A2		CE1/CE2	S1		PA1	CB3	TC4
Lahti et al, (2018)	KS3	A2	TBL3	CE3	S5		PA1/PA2		
Pan et al, (2018)	KS3	A2	TBL2	CE1			PA4	BC4	
Milios, (2018)	KS3	A2		CE2					
Egea et al, (2018)	KS5	A2	TBL1/TBL2/TBL3	CE1			PA1/PA3	BC4	
Wen et al, (2018)	KS3/KS5	A1/ A2	TBL2/TBL3	CE1/CE3	S1/S2/S4	PG3		BC3	TC4
van Loon and Van Wassenhove, (2018)		A1	TBL2/TBL3	CE2	S5	PG2	PA1/PA4		TC2
Mangla et al, (2018)	KS1/KS3	A1/ A2	TBL3	CE3					
Kirchherr et al, (2018)	KS8	A2		CE3					
Huybrechts,et al, (2018)	KS5	A2	TBL2	CE3					
Cui and Zhang, (2018)	KS3	A2			S1				
Mengal et al, (2018)	KS3	A2	TBL2/TBL3	CE1			PA4		
Ammenberg et al, (2018)	KS5	A2	TBL2	CE1		PG1	PA1/PA3	BC2	
Turner, (2018)		A2	TBL2	CE1	S5	PG1/PG3	PA1/PA2/PA3/PA5	BC1	TC4
Whalen et al, (2018)	KS5	A2	TBL3	CE2	S5	PG2/PG3	PA3/PA5		TC2/TC3/TC4
Ross and Omelon, (2018)	KS5	A2	TBL2	CE2		PG3	PA3	BC4	TC4
Zacho et al, (2018)	KS5	A2	TBL1/TBL2/TBL3	CE2	S5	PG2	PA3		TC2
Oliveira et al, (2018)	KS5	A2	TBL3	CE3	S3/S5		PA1/PA2/PA3		
Rattalino, (2018)	KS3	A2	TBL1/TBL2	CE3	S5				TC5
Kalmykova et al, (2018)	KS3	A2	TBL2	CE3	S1	PG3	PA1/PA2		TC4
Hishammuddin et al, (2018)	KS3	A2	TBL3	CE1		PG1	PA3	BC1	
Ievdokymov Vet al, (2018)	KS3	A2	TBL2/TBL3	CE3					
Leising et al, (2018)	KS5	A2	TBL2	CE3			PA1		
Anttonen et al, (2018)	KS1	A1	TBL1/TBL2/TBL3	CE3					TC5
Korhonen et al, (2018)	KS2	A2	TBL3	CE3					
Portillo-Tarragona et al, (2018)		A2	TBL2/TBL3	CE2	S5				
Vaneeckhaute Cet al, (2018)	KS1	A1	TBL3	CE1		PG3	PA1/PA3/PA5	BC4	TC4
Velenturf et al, (2018)	KS6	A2	TBL2	CE1		PG3	PA1/PA3	BC3	TC4/TC5
Bringsken, et al, (2018)	KS5	A2	TBL1	CE3			PA3		
Liu et al, (2018)	KS5	A2	TBL1/TBL2/TBL3	CE3	S1/S4			BC3	
Zhao et al, (2018)	KS1	A1	TBL2/TBL3	CE3	S1/S4				
Sabbaghi and Behdad, (2018)	KS8	A1	TBL3	CE2/CE3			PA2		
Veleva and Bodkin, (2018)	KS5	A2	TBL2	CE2	S4/S5	PG2	PA1/PA3		TC2
Pauliuk, (2018)	KS5	A2	TBL2	CE2		PG3			TC4
Whicher et al, (2018)	KS5	A2	TBL2	CE3					
Singh et al, (2018)	KS2	A2	TBL2/TBL3	CE3	S5				
Andersson and Stage, (2018)	KS5	A2	TBL2	CE2	S2	PG3	PA3		TC4
Garmulewicz et al, (2018)	KS5	A2	TBL1/TBL3	CE3			PA4		
Moktadir et al, (2018)	KS1	A2	TBL2/TBL3	CE3	S1/S4		PA3	BC3	
Jiao et al, (2018)	KS5	A2	TBL3	CE3	S1				
Pivnenko et al, (2018)	KS1	A1	TBL1/TBL2	CE2		PG3	PA1/PA3		TC4
Vanegas et al, (2018)	KS5	A2	TBL2/TBL3	CE2		PG2/PG3	PA1/PA3		TC2/TC3/TC4
Han et al, (2018)	KS5	A1/ A2	TBL2	CE1	S1/S4	PG3	PA3/PA5	BC3	TC4
Ryen et al, (2018)	KS1	A1	TBL3	CE2		PG3	PA2/PA3/PA5		TC4
Picatoste et al, (2018)	KS3, KS8	A2	TBL1/TBL2/TBL3	CE3			PA1/PA2		
Işıldar et al, (2018)	KS3	A2	TBL2	CE1			PA3/PA4	BC3	
Veleva and Bodkin, (2018)	KS5	A2		CE2	S5	PG2	PA1/PA3		TC2/TC3

References	C1	C2	C3	C4	C5	C6	C7	C8	C9
Brandoni and Bosnjakovic, (2018)	KS3, KS5	A2	TBL1/TBL3	CE1			PA3		
Gallego-Schmid et al, (2018)	KS3, KS5	A1/ A2	TBL2	CE2			PA2/PA3		
Yeom et al, (2018)	KS4	A1	TBL2	CE2			PA3		
Ghisellini et al, (2018)	KS3	A2	TBL2	CE2	S1		PA1/PA3		
Ranta Vet al, (2018)	KS5	A2	TBL3	CE2	S1	PG3			TC4
Núñez-Cacho et al, (2018)	KS5	A2	TBL3	CE3	S5		PA1		
Drejerska et al, (2018)	KS5	A2		CE1	S5		PA3/PA5		
Sorensen, (2018)		A2	TBL2	CE3		PG3		BC3	TC4
Saidani et al, (2018)	KS8	A1	TBL3				PA4		
Kalverkamp, (2018)	KS5	A2	TBL2	CE2		PG2			TC3
Alaerts et al, (2018)	KS3, KS5	A2		CE1		PG3	PA5	BC3	
Di Foggia and Beccarello, (2018)	KS5	A2	TBL3	CE2			PA3		
Esposito et al, (2018)	KS3	A2		CE3					
Landi, et al, (2018)	KS1	A1/ A2	TBL2/TBL3	CE1/CE2		PG1/PG2	PA3	BC1	TC2
Marra et al, (2018)	KS3	A1/ A2	TBL1/TBL3		S1				
Repo et al, (2018)	KS1	A1	TBL1	CE2		PG2	PA2		TC2
Shemfe et al, (2018)	KS4, KS5	A1/ A2	TBL3	CE1/CE2		PG1/PG2	PA1/PA3/PA5	BC1	TC2
Jesus and Mendonça, (2018)	KS5, KS8	A1	TBL3	CE3					
Biernaski and Silva, (2018)	KS3	A2		CE1	S1	PG1	PA4	BC2	
Fuldauer et al, (2018)	KS5	A2	TBL2/TBL3	CE1	S5	PG1/PG3	PA3/PA5	BC1	TC4
Sastre et al, (2018)	KS5	A2	TBL1/TBL3	CE2	S5	PG3	PA3		TC4
Jiang, (2018)	KS3	A2	TBL2	CE2	S5	PG2	PA5	BC3	TC2
Mew et al, (2018)	KS3	A2	TBL3	CE1	S5		PA4		
Milios et al, (2018)	KS3, KS5	A2		CE1/CE2		PG2/PG3	PA1/PA3/PA5		TC2/TC4
Silva, (2018)	KS1, KS8	A1	TBL3	CE3	S3	PG3	PA3		
Rigueiro-Rodríguez et al, (2018)	KS5	A2	TBL1/TBL2/TBL3	CE1				BC4	
Zabaniotou, (2018)	KS3	A2	TBL1/TBL2/TBL3	CE1			PA3	BC4	
Lyytimäki, (2018)	KS3	A2	TBL2/TBL3	CE1		PG1		BC2	
Vainio, (2018)		A2	TBL2	CE1	S5	PG1	PA1	BC1	
Yuan et al, (2018)	KS2	A1	TBL1	CE3	S5	PG3	PA3/PA4		TC4
Bodar et al, (2018)	KS5	A2	TBL2	CE1		PG2/PG3	PA3	BC1	TC4
Sadhukhan et al, (2018)	KS5	A2		CE1		PG1	PA1/PA3	BC2/BC4	
Carpenter et al, (2018)	KS5	A2	TBL1/TBL2/TBL3	CE1	S1				
Ghenţa and Matei, (2018)		A2	TBL2/TBL3	CE2/CE3		PG3			TC4
Shemfe et al, (2018)	KS5	A1/ A2	TBL1	CE1		PG1	PA3	BC1	
van der Leer, et al, (2018)		A2	TBL1	CE3	S1/S3				
Swagemakers et al, (2018)	KS5	A2	TBL1	CE1			PA3		TC5
Lainez et al, (2018)	KS5	A2	TBL2	CE1			PA5	BC4	
Kunz et al, (2018)	KS3	A2		CE3		PG3			
Geissler et al, (2018)		A2	TBL3	CE1					
Misheninet al, (2018)	KS3	A2	TBL2/TBL3	CE1					
Pesce et al, (2018)	KS5	A2	TBL1	CE3	S5				
Quina et al, (2018)	KS3, KS5	A2	TBL2	CE1		PG1/PG3	PA1/PA3	BC1	TC4
Liu et al, (2018)	KS3, KS5	A2		CE2	S1	PG2	PA1		TC2/TC3
D'Odorico et al, (2018)	KS3	A2		CE1			PA5	BC4	
Fiol et al, (2018)	KS4	A1	TBL3	CE1		PG1/PG3	PA3	BC1	TC4
Zhou et al, (2018)	KS5	A2	TBL2/TBL3	CE3	S1		PA1	BC3	
Favot et al, (2018)		A2	TBL3	CE2		PG3	PA3		TC4
Ait-Mouheb et al, (2018)	KS5	A2	TBL1/TBL2	CE2		PG2	PA1/PA3		TC2
Kauppila and Anker, (2018)	KS3, KS5	A2	TBL2	CE1				BC3/BC4	
Joseph et al, (2018)	KS5	A2	TBL2/TBL3	CE1		PG1	PA1/PA4	BC2	
Eneng et al, (2018)	KS5	A2	TBL1	CE1					
Tong et al, (2018)		A1		CE2	S1	PG3	PA3		TC4
Flores et al, (2018)	KS5	A2		CE3			PA3	BC3	
Palm et al, (2018)		A2	TBL2	CE1			PA1/PA5	BC4	
Mehr et al, (2018)	KS5	A1/ A2	TBL3					BC4	
Krystofik and Gaustad, (2018)	KS5	A2	TBL2/TBL3	CE2	S5	PG2/PG3	PA1/PA2		TC2/TC3/TC4
Sánchez et al, (2018)		A2	TBL2	CE1		PG1	PA1/PA3/PA4	BC1	
Markou et al, (2018)		A2		CE1		PG1	PA1/PA3/PA5	BC2	
Blazquez et al, (2018)	KS5	A1/ A2	TBL3					BC4	
Kjellen, (2018)	KS3	A2	TBL1/TBL2	CE2		PG2	PA3	BC3	TC2