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Circular Business Models: Development of a Circularity Assessment Tool For Companies

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ABSTRACT

The transition from a linear to a circular economy brings with it a variety of practical challenges for companies. To implement such a concept on the organization level, the circular business models are seen as the main driving force by combining the technical, societal, and environmental requests through a unique business plan. The literature has been focussing on the conceptualization of the circular economy (and their inherent circular business models). However, past research on circular practices has had the tendency to neglect the industrial applicability of the sustainable and circular strategies. Consequently, as the practical implementation of theoretical concepts has been "overlooked" by the scientific community, the identification and categorization of industrial practices over circular business models has shown to be a priority.

The main aim of this thesis is the development of an assessment tool that, with respect to circular characteristics, identifies and categorizes a company's current business model. To that end, a complex review of the current literature on circular business models is conducted searching for circular requirements that will then be used for the development of the assessment tool. This tool was presented to two different companies and the results show how the identification and categorization of the different circular typologies can be made. The companies' answers were interpreted and discussed, and consequently some circular strategies (such as the sharing economy and the Result-Oriented Product Service System) were considered as an additional option for the company.

The practical application on the two case studies revealed that there are aspects of the tool that need to be polished in order to improve the understanding and interpretation, not only from the users, but also from the analysts. Furthermore, some dematerializing CBM's questions were found unclear as they were not exclusive of this circular typology. Additionally, the need for supplementary information such as the origin of the materials that are processed, or simple explanations for some company's choices was made clear. These upgrades are suggested so that a reliable circularity assessment can be achieved. Moreover, they can be implemented through the revision on the dematerializing (still unclear) boundaries, and through practical tests of the key CBM considerations. This translates to future research aiming for a more consistent assessment tool.

Keywords Circular Economy, Circular Business Models, Circular Assessment Tool, Cycling, Extending, Intensifying, Dematerializing.

RESUMO

A transição para uma economia circular traz consigo uma variedade de desafios práticos para as empresas. A implementação deste conceito (economia circular) a nível industrial pode suceder-se com recurso aos chamados modelos de negócio circulares, que têm sido vistos como a principal força motriz desta transição ao combinar os requisitos técnicos, sociais e ambientais num único plano de negócios. A literatura tem-se recentemente focado na conceitualização e compreensão da economia circular (e práticas inerentes), no entanto verificou-se que tendeu a negligenciar a aplicabilidade industrial das, por enquanto teóricas, estratégias circulares. Consequentemente, percebeu-se que a identificação e categorização das práticas industriais com face a modelos de negócio circulares são uma prioridade.

Assim sendo, este estudo visa o desenvolvimento de uma ferramenta de avaliação que, com respeito a características circulares, identifique e categorize o modelo de negócio corrente de uma empresa. Para isso, foi realizada uma complexa revisão da literatura atual sobre modelos circulares de negócios, e diversos conceitos teóricos foram transformados em requisitos circulares, que serão utilizados para o desenvolvimento da ferramenta de avaliação de circularidade. Uma vez desenvolvida, esta ferramenta foi apresentada a duas empresas distintas e os resultados mostraram que a identificação e categorização das diferentes tipologias circulares podem ser efetuadas. As respostas das empresas foram então interpretadas e discutidas e, sempre que possível, algumas estratégias circulares (como a “Sharing Economy” e o “Result-Oriented Product-Service System”) foram consideradas como sugestões complementares para as empresas.

A aplicação prática nos dois casos de estudo mostrou também que há aspetos da ferramenta que precisam ser revistos para que se melhore a compreensão e interpretação, não só dos usuários, mas também dos analistas que a fornecem. Desta maneira, sendo que algumas questões relacionadas com o modelo de negócio circular “Dematerializing” revelaram não ser exclusivas desta tipologia circular, serão necessárias alterações. Além disso, ficou clara a necessidade por informações complementares, como por exemplo a origem dos materiais que são processados ou simples justificações para algumas escolhas

das empresas. Todas estas atualizações foram sugeridas de maneira que se possa obter uma avaliação sustentada e confiável, e podem ser implementadas através de uma revisão do conceito (ainda pouco claro) de "Dematerializing", e de testes práticos (utilizando empresas de diferentes setores industriais) das principais considerações feitas sobre os diferentes modelos de negócio circulares.

Tudo isto traduz-se em pesquisas futuras visando uma ferramenta de avaliação mais consistente.

Palavras-chave: Economia Circular, Modelos de Negócio Circulares, Ferramenta de Avaliação Circular, Ciclagem, Extensão, Intensificação, Desmaterialização.

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ACRONYMS / ABBREVIATIONS

Acronyms

CBM – Circular Business Model

PSS – Product-Service System

MM – Madeira & Madeira

1. INTRODUCTION

The exponential industrial growth have been extensively studied in the academic literature, and with a rising global population, the increasing resource use, and the consequential environmental impacts, it is clear that something must change in the way the society treats and depends on resources. It is a fact that today's business and social behaviours are not an option for a sustainable and healthy future (Bocken et al., 2014). However, there is still no clarity as to the sustainable and efficient path to follow.

The promotion of the circular economy (CE) has become one of the key policy objectives in the EU in the late 2010s, but it is said that as long as the growth imperative drives the economy it will likely remain a mere pipe dream *(Bauwens, 2021)*. It is critical to innovate, not only the way industrial businesses are conducted, but also the leaders and customers' mentality. In this line, aiming at a paradigm shift, some entities such as the Ellen MacArthur Foundation have helped popularize the move to a circular economy.

From a macro perspective, the circular economy can be view as an ideology that seeks to redirect the linear flow of material and energy into circular or "closed loop" systems *(Bocken et al., 2016)*. In other words, this approach contrasts with the traditional (and highly reliant on fossil fuels) take-make-use-dispose patterns and focus on strategies that use little resources for as long as possible, while extracting as much value as possible in the process *(Geissdoerfer et al., 2020)*. Enhancing the idea that it is critical to turn industrial businesses in sustainable and efficient approaches, the circular economy addresses the implementation of circular business models (CBM). Adopting these frameworks, and using their circular strategies, may enable the creation of economically viable models to continually close or slow the resource loops.

To sum up, the circular economy might be the answer for creating a sustainable and circular world, however there is still a significant lack of clarity about the circular economy's theoretical conceptualisation. As this is a wide subject, the simple and practical procedures may not have such a direct implementation across different industrial fields. The practical application of such theoretical concepts will always depend on a diverse number of factors. Additionally, due to the recent growth in CBMs attention by the scientific community, a complex literature review was conducted to search for clarifications of the "practical" circular characteristics. As a result, a huge gap was identified on the identification and categorization (with a circular perspective) of company's business models.

Therefore, the aim of this report is the development of a practical tool with the capability to identify and categorize any industrial company's current business model, over the existing CBMs' characteristics.

1.1. Thesis Objectives

The main goal of this thesis is to develop, validate, and analyse an assessment tool designed for industrial organizations. This tool will help industrial companies to identify and characterize their business models over circular and sustainable principles. Moreover, in order to develop a consistent tool, the following specific objectives are outlined:

1. Due to the lack of a uniform and widely recognised conceptualization, the first objective is the identification and categorization of the existing CBM's typologies and strategies. To accomplish this objective, a literature review is conducted aiming to collect different definitions and industrial applicability examples from each CBM.
2. The second objective is to provide a visual comparison of all the different circular approaches under technical and sustainable variables.
3. To achieve the main goal (the development of a circularity assessment tool), the transformation of common and specific criteria in questions, that can be classified through an evaluation logic, is introduced.
4. Present the developed assessment tool to two companies that will test and validate the tool, providing important results that will be then given through visual support (graphics).
5. The identification of new business opportunities align with the CBMs' principles.

1.2. Structure and Outline

This thesis is organized in six chapters, including this introduction, and all these chapters (and sub sections) are focused on different objectives. In the second chapter, an intensive literature review is presented. It aims for the collection of useful information (definitions and industrial applicability of CBMs) that will later be useful for the comparison between the different typologies, and the development of a circularity assessment tool.

The chapter number three "Methodology" comprises the development of such assessment tool. The information previously gathered is transformed in questions (that are then included in the assessment tool), and an evaluation logic is detailed.

The fourth chapter "Tool Validation" comes as practical test of the developed tool, and includes the analysis of the two companies' results. The results have visual support (graphics), and are presented objectively without any speculation.

In the fifth chapter "Discussion", a deeper and critical analysis is made to the firms' positive or negative circularity results. The key circular aspects that can be improved are pointed out, and all the tool's limitations are referred.

To conclude, the chapter number six "Conclusion" underlines some tool's limitations. Inconsistencies are indicated on the dematerializing concept, and in the way some questions are presented. Furthermore, it is important to mention that a continuous investigation for supplementary information has revealed to be crucial and enabled the proposition of next steps to achieve a more reliable tool.

2. LITERATURE REVIEW

In this chapter, the objective is the collection of useful information from the current literature on circular business models. This information will contribute to clarify some emerging concepts and to the development of the circularity assessment tool.

It includes a Circular Business Models Identification, where the different circular typologies are identified and defined. Additionally, the CBMs characterization is also presented, where a deeper and individual analysis is made to each typology (searching for definitions and industrial applicability examples).

2.1. Circular Business Models Identification

By increasing the knowledge on the identification and characterization of CBMs in the industrial context, the different actors (companies and scientific community) may shorten the current gap in practical procedures of turning industrial companies into more circular organizations. The first contact with this wide subject has the objective of solidifying the main concepts and definitions linked to the different CBMs. To achieve this, a preliminary background research process was carried out, and it consisted on the collection and analysis of theoretical information from a variety of different sources and formats.

2.1.1. Conceptual Introduction

In order to establish a clear definition of general concepts, such as "business model", "business model innovation", "circular business model" and "business model innovation for sustainability", a brief analysis was conducted. The articles specifically relevant to this initial approach were *N. M. P. Bocken et al., (2016)*, *N. Bocken et al., (2019)*, *N. M. P. Bocken et al., (2014)*, *Boons & Lüdeke-Freund, (2013)*, *Singh et al., (2019)* and *Geissdoerfer et al., (2020)*. However, this initial study was complemented with information coming from other articles, such as *Casadesus-Masanell & Zhu, (2013)*, *Osterwalder et al., (2005)*, *Chesbrough & Appleyard, (2007)* and others.

It was found that a business model is used as a plan which specifies how a business can become profitable *(Boons & Lüdeke-Freund, 2013)*. The business model's choices can define the architecture of a corporation's business, but once established, it is often found that changing them can be challenging *(N. M. P. Bocken et al., 2016)*. A business model is widely seen as a conceptual tool that helps understanding how a firm does its business, and it can be used for analysis, comparison, management, communication, and innovation *(Osterwalder et al., 2005)*.

These tools are often defined by three main elements, that are viewed as important drivers for innovation *(N. M. P. Bocken et al., 2014)*. The value proposition concerns the product or service provided, the customer segments and relationships. The value creation and delivery include all the key activities, resources, channels, partners, and technology, and the value capture comprehends the cost structure and the revenue streams.

This research has also enhanced that an organization is usually highly dependent on innovation, as it allows a company to follow and cover the constant market changes, ensuring a healthy client flow and economic wealth. Additionally, this capability to innovate business models quickly and successfully can trigger a dynamic sustainable competitive advantage for companies *(Casadesus-Masanell & Zhu, 2013; Chesbrough & Appleyard, 2007)*. The business model innovation can be viewed as the conceptualisation and implementation of new frameworks and ideas within the firm's strategy. It comprises the development and/or acquisition of entirely new business models, or simply the diversification into additional business approaches. All this transformation can affect an entire business plan, or just a combination of its main elements *(Geissdoerfer, Vladimirova, et al., 2018)*.

As the pressure to turn our world into a more sustainable place increases, it is imperative to recognise the business model innovation for sustainability as a way to maximise societal and environmental benefits. According to *N. M. P. Bocken et al. (2014)*, the business model innovation for sustainability creates significant positive impacts for the environment and society, as well as, including changes in the way an organisation and its value-network create, deliver, and capture value.

To finish the introduction to these emerging concepts, a few definitions of CBM were gathered. The concept of CBM emerged considerably more recently, and due to the increasing interest on this subject a diverse range of definitions were found. According to *Linder & Williander (2017)*, a CBM is a business model in which the conceptual logic for value creation is based on utilising economic value retained in wasted products in the production of new offerings. A CBM implies a return flow from the customers to the producers (though there can be intermediaries between the two parties). However, there are articles defending that a CBM may not necessarily be fixed to the material circular pattern, but to sustainable and ecological management options. In this line, a CBM can be defined as a business rationale which is designed in such a way that it minimises leakage in the process of creating, delivering, and capturing value, providing solutions for sustainable development *(Hollander, M den, 2016; Ünal et al. 2019)*.

To conclude, there are few different opinions about this subject. According to the research made by *Geissdoerfer et al., (2020)*, where a compilation of several CBM definitions is presented, it is possible to understand that, from a macro perspective, there is a uniform conception about this term. As a result, a CBM will be seen as the rationale of how an organisation creates, delivers, and captures value with slowing, closing, or narrowing flows of the resource loops *(Geissdoerfer, Morioka, et al., 2018; Geissdoerfer, Vladimirova, et al., 2018; Zucchella & Previtali, 2019; Oghazi & Mostaghel 2018)*.

2.1.2. Circular Business Models Typologies

During the literature review, it was possible to understand that there is still a relevant level of unclarity on some circular terms. This way, a diagram addressing the different CBMs was developed. This diagram (Figure 1) aims to ensure a conceptual consistency (avoiding the inclusion of different terms for the same approaches), and it came as a result of a deep analysis to each typology's and strategy's definitions.

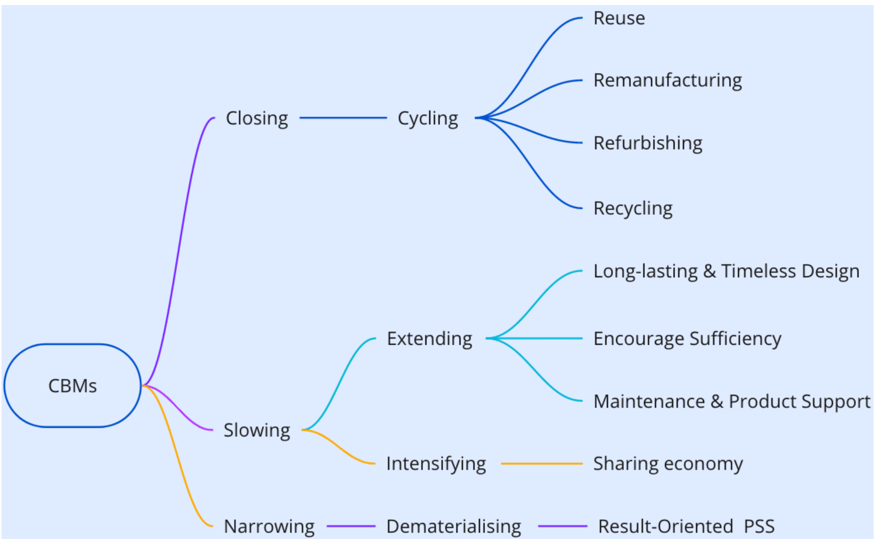

Figure 1 - Circular Business Models (Typologies and Strategies)

There are four typologies of circular business models, and according to *Geissdoerfer et al. (2020)*, who has presented a practical approach defining and characterizing them, they are known as cycling, extending, intensifying, and dematerializing. All these typologies have distinct characteristics, and based on the work of *Stahel, (2010)*, they can be divided in three different types (depending on the resource flow).

The first type is known as closing resource flows and includes typologies (cycling) that aim to close the loop between post-use and production. The second type is known as slowing resource flows, and concerns typologies (extending and intensifying) that aim to extend and/or intensify the utilization period of products, resulting in a slowdown of the flow of resources. The last type it's called narrowing resource flows and includes all the CBMs that aim to reduce the resource quantity used per product (dematerializing).

The cycling typology represents the process of extract value (materials or energy) from waste, within the system. This typology includes four different strategies that are known as reuse, remanufacturing, refurbishing, and recycling, and can be categorized as a "closing resource flow" as all of them aim to connect the "after use waste" back to the production system *(N. M. P. Bocken et al., 2016)*.

The extending typology aims for the extension of a product's use phase, and it can be done through different strategies. These strategies are known as long-lasting and timeless design, encourage sufficiency, and maintenance and product support, and they aim to slow the resource flow *(Geissdoerfer et al., 2020; N. M. P. Bocken et al., 2016)*.

The intensifying typology implies that the use phase of a product is intensified *(Geissdoerfer et al., 2020)*. This business model defends that using products for a longer period of time would result in higher demand for components and maintenance services, while reducing the demand for new goods *(Towa et al., 2021)*. The sharing economy can be seen as an intensifying strategy that contributes for the "slowing resource flow" *(N. M. P. Bocken et al., 2016)*.

In conclusion, the dematerializing resource loops describes the provision of a product utility (results) without hardware through substitution with services and/or software solutions. This CBM's goal is to reduce the use of physical products and it will be categorized as an "narrowing resource flows" typology *(Geissdoerfer et al., 2020)*.

2.2. Circular Business Models Characterization

Based on the process of background research, where the identification and definition of the different circular typologies was managed, the characterization of CBMs is performed. To complete this objective, the collection and screening of relevant articles (related to the four CBMs) is needed, as well as, conducting the analysis of the selected literature, aiming to identify all the CBMs' characteristics and criteria.

In order to guarantee the quality of the information's processing, a systematic review was conducted. This procedure included the utilization of platforms such as "Web of Science", "Science Direct" and "Scopus" which, through the intersection of relevant keywords for each typology (Table 1), led to the selection of articles published between 2015 and 2021.

Business Model	**Typology**	**Keywords**			
BM1	Cycling	Cycle/Cycling	+Business Model	+Circular	+Industry
BM2	Extending	Extend/Extending	+Business Model	+Circular	+Industry
BM3	Intensifying	Intensify/Intensifying	+Business Model	+Circular	+Industry
BM4	Dematerializing	Dematerialize/Dematerializing	+Business Model	+Circular	+Industry

Table 1 – Typologies' Keywords

Only review articles and research articles were considered in this research, and after intersecting all the different keywords for each typology, an initial sample of 169 articles came out as a result. These articles were verified through a content analysis to their abstract and conclusion sections to ensure the applicability of the initial sample of articles to the present work.

With the initial sample of papers ready to be analysed, the screening of papers started. This sorting process submitted all the 169 papers to two different questions: "Does the article refer to industrial applicability?" and "Does the article approach the development of circular business models?". This way, all the articles related to industrial application and/or CBM development were marked as relevant articles, otherwise they would be discarded (Figure 2).

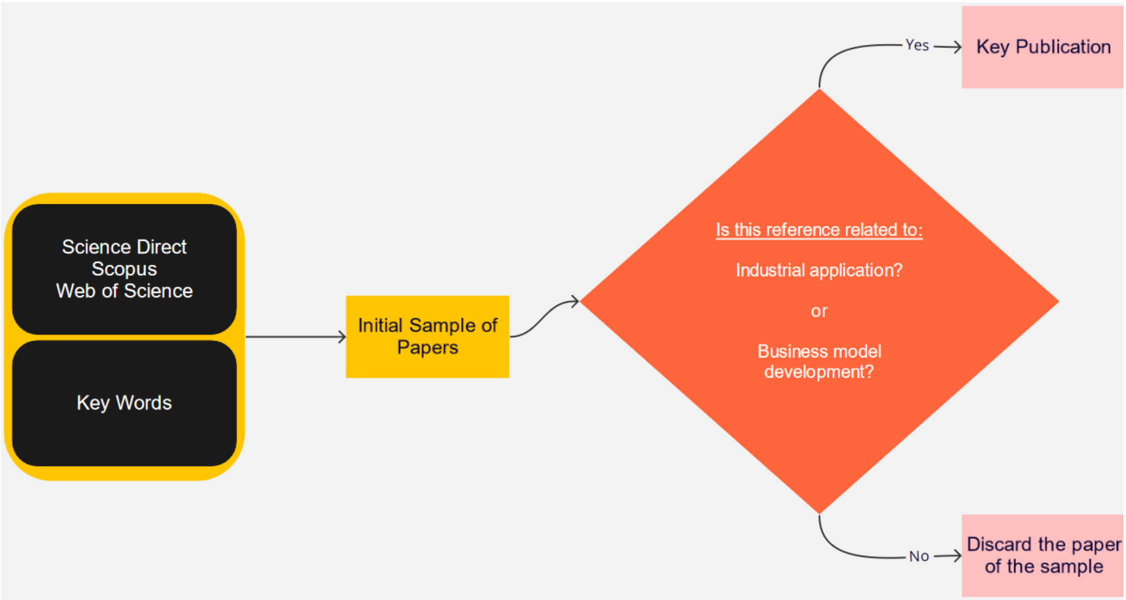

Figure 2 - Systematic Review Flowchart

After the screening of papers, the number of relevant papers fell. The cycling business model was the one that had a less visible decrease dropping from 74 to 48 papers. The extending and intensifying business models reached a total of 18 "must read" papers each, while the dematerializing business model decreased from 31 to only 15 articles. Simplifying the outcome of this process, only 99 out of the 169 papers were considered relevant and mentioned along the analysis or in the appendixes. With all the relevant papers gathered it is now possible to begin the content analysis, where the objective is to search for significant definitions, industrial applicability, and common criteria linked to each typology.

2.2.1. Cycling Business Model

The analysis of the 48 cycling papers were important to understand the literature's view of what the cycling business model represents, and which strategies it suggests. From a business perspective, the value proposition of this typology includes taking back products and transforming them in new resources. The value creation and delivery concern processes that allow a product to serve another lifecycle, and its value capture is linked to the savings arising from reduced costs of resource input *(Geissdoerfer et al., 2020)*.

In summary, this typology entails the implementation of several end-of-use strategies that recover value from waste products. The strategies are known as reuse, remanufacturing, refurbishing, and recycling *(Geissdoerfer et al., 2020)*, however the literature has shown to be unpredictable. For example, *Nußholz (2018)* argues that a cycling business model, can be seen as a "Collect and Reintegrate" business model, aiming to close resource loops and extend the life of products, parts, or materials.

Aiming to characterize the different cycling strategies, several definitions were searched. Technical terms such as reuse, remanufacturing, refurbishing, recycling, loop, open-loop, closed-loop, upcycling and downcycling were defined, however it was possible to occasionally detect divergent points of view about these terms.

2.2.1.1. Definitions

In this section, all the cycling strategies previously identified were explored. In some cases, related terms were found and detailed so that a more complete business model characterization could be made.

According to *Vimal et al. (2021)*, the reuse strategy means reusing used components in the production process. *MacArthur, (2013)* states that these components serve the same purpose in its original form or with little enhancement, but some perspectives defend that a reused product can serve a different application. Additionally, there are some who support that this strategy can be seen as a priority because no energy, materials or extra labour are added in the process of returning the product to the economy.

The remanufacturing strategy is linked to the remaking of some tools (or parts) which have a short lifespan, and it refers to a process of restoring a non-functional, discarded, or traded-in product to a like-new condition *(Guidat et al., 2015)*. In other words, this is a strategy that focus on restoring parts of a used product, ensuring its "as new" or "better than new" quality *(MacArthur, 2013)*.

As an additional note, *Guidat et al. (2015)* also describes two types for the remanufacturing processes. The internal remanufacturing process, that includes all the factory floor activities performed during the whole remanufacturing process, and the external remanufacturing process which refers to the operative and logistics processes performed after or prior to the internal process.

In contrast to the remanufacturing, the refurbishing strategy includes processes of returning a product to good working condition by replacing or repairing major components that are faulty or close to failure. These processes are usually 'cosmetic', such as cleaning, changing fabric, painting, or refinishing, and can update the appearance of a product *(MacArthur, 2013)*. *Campbell-Johnston et al. (2020)* indicates that this strategy refers to the replacement of some components while a large multi-component product remains intact, resulting in an overall upgrade of the product.

The refurbishing strategy involves processes typically less intensive than remanufacturing, resulting in products that, although in good condition, may not be comparable with new or remanufactured products. In short, using a remanufacturing strategy, the resulting product is resold with performance and specifications comparable to new products, refurbished products may simply be tested for physical appearance and function *(MacArthur, 2013)*.

Finally, the recycling strategy involves processes wherein materials or components can be recycled and reconditioned to suit the same or a new purpose. This strategy can be viewed as the processing of mixed streams of post-consumer products or post-consumer waste streams to capture (nearly) pure materials *(Campbell-Johnston et al., 2020)*, and it comes to recover useful materials from waste, rather than dispose them directly in landfills *(Bertino et al., 2021)*. In this research, the recycling will be considered as a strategy that includes complex processes where materials do not maintain any of their product structure and can be re-applied anywhere *(Campbell-Johnston et al., 2020)*.

Some argue that, although this strategy includes processes that can happen indefinitely until the product (or resource) can no longer serve the desired purpose, it should be used as last resource (compared with the other strategies), since it usually embraces processes that force the consumption of new resources. In addition to the waste of all the extra value (labour, energy, or materials) that went into creating that product in the first place, *Martins et al. (2021)* adds that in the circular flow, the recycling strategy appears in the last position since it is restricted by entropy's natural law, the materials' complexity, and potential for manipulation, i.e., it is not always is possible to recycle.

To conclude, several recycling definitions were found, and all of them have one thing in common: the recycling must be always considered as a possibility to increase the industrial sustainability and circularity. This is supported by *Bertino et al., (2021)*, who states that the recycled material prevents wasting potentially useful materials, often improves sustainability in the production and use of materials, and reduces the consumption of raw materials, use of energy, and emission of associated greenhouse gases.

This typology has proved that there is a particular effort trying to understand the different circular approaches. However, there are terms that are often mentioned and are still not entirely understood by the scientific community, leading to a collision between some authors' points of view.

Upcycling & Downcycling

Upcycling and downcycling are two important concepts to establish a qualitative evaluation of cycling business model's strategies, based on the value of a processed material or new application (functionality) *(Campbell-Johnston et al., 2020)*.

According to *Sung et al., (2017)*, upcycling is an "umbrella concept" which incorporates reuse, refurbishing, recreation, and other strategies. This way, it will be considered that every cycling strategy can be categorized as not only upcycling (in case of higher value) but also downcycling (in case of inferior value). A visual summary is represented in the Figure 3.

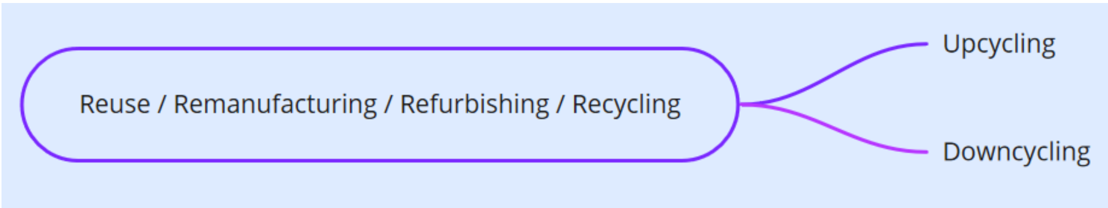

Figure 3 - Up & Downcycling's Strategies

Upcycling, according to *Singh et al., (2019)*, refers to a process in which used, or waste products are repaired, reused, repurposed, refurbished, upgraded, and remanufactured in a creative way to add value to the compositional elements. In the same line, *MacArthur, (2013)* says that upcycling is a process of converting materials into new materials of higher quality and increased functionality. In addition to increasing the lifetime of materials, reducing wastes, and encouraging sustainable consumer behaviour, the upcycling is regarded as a strategy that aims to reduce environmental impacts by combining circular material flows with slower flow of products and cycles of consumption *(Singh et al., 2019)*.

On the contrary, the downcycling concept concerns the value or purpose lost in comparison to the original item, which indicates a loss of material or product functionality due to quality *(MacArthur, 2013)*. This term is usually used to describe a product's material properties, their level of degradation, or even, if they have become impure, which leads to a loss of economic value *(Campbell-Johnston et al., 2020)*. According to *Lonca et al. (2020)*, it is considered a downcycling strategy when the quality of the recovered or processed material is lower.

In summary, the downcycling term is mentioned when a resulting product (or material) has lower value comparing to its original form, and the upcycling means that the value of a product increased after being processed. These terms are used if a quality change occurs in a product after being processed, which leads to the question "What happen if the value of a product (or material) does not change, after being processed?"

Due to the growing attention given to the cycling business models, it was possible to find some literature inconsistencies. Most of these inconsistencies rely on the definition of recycling, upcycling and downcycling, which are highly dependent on a business model's value creation and delivery. As the "value" is a subjective concept it can complicate the characterization of cycling business models.

There are different types of value: economic value, social value, environmental value, and the product's physical proprieties value. These are variables that help defining an upcycling or downcycling business model, and consequently the contrast between some studies can be explained by the difficulty quantifying and/or qualifying these different types of value.

As an example, a particular definition given by *Ottoni et al. (2020)* defends that recycling is the material processing through, e.g., shredding or melting to obtain the same (upcycling) or lower (downcycling) quality. However, *Singh et al. (2019)* says that the upcycling concept contrasts with recycling concept, where value is often at least partially lost. Other inconsistency can be witnessed when *Ottoni et al. (2020)* says that upcycling processes may make materials return to the chain to generate other products and services with much improved quality. However, this definition does not address the preservation of the products quality colliding with *Sung et al. (2017)* opinion, in which upcycled products have equal or higher quality than the compositional elements.

Given these facts, decisions must be made to clarify and facilitate the understanding of this subject. From an industrial point of view, the economic and the physical proprieties' value shall be prioritized. This means that, in this research, these values will be viewed as the reference to characterize a business model. Notice that these different values are often highly connected, and it is unlikely (but not impossible) to have situations where a processed product lost the physical proprieties but increased the economic value.

For example, if a specific cycling strategy uses industrial processes that maintain or improve a product's physical proprieties, it will be labelled as upcycling. Also, if a company recovers waste (through cycling processing) with higher economic value, it will also be seen as an upcycling process.

Closed and Open-Loop

The so called "closing the resource loops" strategies have been widely connected to the cycling typology. This way, the material circularity has raised important questions about the form it takes, leading to an increasing need for more characterizing concepts.

In addition to the previous "value assessment" terms, it is possible to characterize the cycle that a specific product takes during its lifetime. The CBMs previously presented, in contrast with the traditional linear business models of production, aim to generate profits from the flow of materials over time, guaranteeing the material circular loops and improving the resource efficiency *(N. M. P. Bocken et al., 2016)*.

Furthermore, a "loop" is the term given to the resource route in a productive cycle *(de Angelis & Feola, 2020)*, and if a company produces two different products, then it is assumed that it has two different productive cycles. All the "closing resource loops" strategies include two different types of loops: the closed and the open-loop. When a system uses a closed-loop cycle, it indicates that the inherent properties of the cycled material are not considerably different from those of the virgin material *(Huysman et al., 2015)*. This means that the product can be reintroduced in the same productive cycle, keeping their utility, functionality, and extending their value. An example of a closed-loop system is the reuse of glass bottles in Italian mineral water companies *(Tua et al., 2020)*.

On the other hand, the open-loop cycle indicates that the inherent properties of the processed material differ from those of the virgin material in a way that it is usable for other product applications *(Huysman et al., 2015)*. This means that, in contrast to some quite linear approaches (where the material eventually ends up in landfill), the product, processed or not, is introduced into a different productive cycle. It is important to recognize that an open-loop cycle is a characteristic of a closing resource loops strategy, and still creates the bridge between the post-use and production. A prime example of an open-loop cycle is recycling of PET bottles. Almost 10% of the USA PET market in 2016 was circulating in an open-loop pathway towards fibre, sheet, and film application *(Lonca et al., 2020)*.

With a divergent perception, *Williams et al. (2010)* counterposes the previous definitions of closed and open-loop cycle, by establishing an inflexible bridge between these concepts and up or downcycling. The author argues that the closed-loop occurs when either the product is recycled at the end of its life into the same productive system, or is recycled into a different productive system but with no change in inherent properties. The author adds that an open-loop cycle is only characterized by the change in the product's inherent proprieties (usually a loss of quality).

Despite these last definitions, most of the scientific community share the same vision of what the two types of loops are. For example, according to *Huysman et al. (2015)* it is underlined that in a closed-loop cycling strategy, the product's quality does not change significantly allowing its reuse in the same application. Thus, contrasting to situations where the material's quality is deteriorated (closed-loop downcycling), there is the possibility of increasing the physical properties of a processed material (closed-loop upcycling). As an example of closed-loop downcycling, the previously mentioned Italian case study *(Tua et al., 2020)* reports that each glass bottle has a maximum limit of "rotations", due to the glass's quality loss and possible damages. On the other hand, an example of closed-loop upcycling is the use of concrete demolition and waste products to produce recycled concrete aggregate (RCA) for improved concrete production (with significant improvement on its flexural and splitting tensile strength) *(Katkhuda & Shatarat, 2017)*.

It is important to notice that *Huysman et al. (2015)* also suggests a simple connection between downcycling and open-loop, however this point of view is not so "rigid" comparing to Williams et al. (2010)'s statements. According to *Lonca et al. (2020),* who supports the *Huysman et al. (2015)*'s vision, an open-loop cycled product is not necessarily forced to serve other application due to quality loss. Keeping in mind that the physical properties and economic value are the key indicators to characterize a business model, if a cycled product has superior economic or physical value (comparing to the original product), and it's used in other application, then it is possible to label the strategy as an open-loop upcycling strategy. For example, the use of recycled plastic as a concrete additive for improved chemo-mechanical properties and lower carbon footprint *(Schaefer et al., 2018)*.

Nevertheless, it is clear that the open-loop downcycling strategy is the most common situation and, as an example the Belgian company "ECO-oh!" transforms the plastic waste into pellets or granules *(Huysveld et al., 2019)*.

To conclude, it is possible to say that the characterization of a cycling business model is guided by its strategy's definition and two different indicators (that characterize the strategy): the value indicator, which defines the value change (or not) of a processed material (Figure 3), and the material cycle indicator, which defines the material's loop type. In the following diagram (Figure 4), it is represented a summary of the cycling's categorization process.

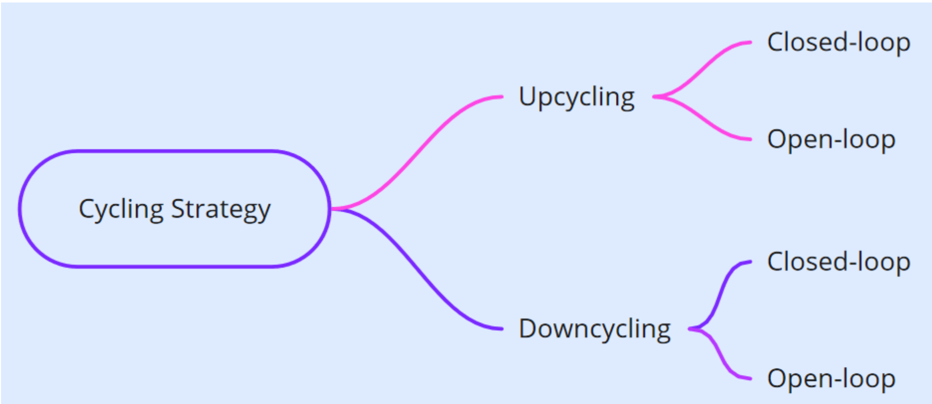

Figure 4 - Cycling Characterization Process

By way of information, all the definitions were gathered and compiled in a summary table (Appendix A).

2.2.1.2. Industrial Applicability

The application of cycling business models varies technically from one sector to another, and despite more research being needed, there are already significant advances in some industries. In this section some practical examples of cycling strategies will be referred, however a complete compilation will be presented on the Appendix B.

As the fashion industry is one of the most wasteful industries in the world, *Brydges, (2021)* presents sustainable strategies that are being implemented in the Swedish fashion industry. These interventions are linked to the positive results that come from the promotion of the reuse of natural fibres (in the take stage), the building of relationships with manufacturers encouraging more sustainable practices (in the make stage), and the investment in textile recycling and takeback programs (in the waste stage).

Despite the good results, *Leal Filho et al., (2019)* refers that limited processing technologies and social barriers are slowing down the ecological and circular progress. The technical difficulties related to some clothes' complexity, and the immature markets are the main reasons for the delay. For example, there are companies who refuse to substitute the utilization of virgin materials (such as cotton and crude oil) as they are still more economic than use or even recycling textile fibres.

In the plastic industry, *Davidson et al. (2021)* presents a critical review of the development of life cycle assessment modelling of plastic chemical recycling methods. This article does not go beyond a theoretical approach (no case studies), and because of that it won't be present in the summary table. Nevertheless, since the chemical recycling increased over the last decade, it was found interesting to analyse as it can be considered as an additional solution to the plastic industry.

In this article, the author suggests that the chemical recycling supports the mechanical recycling by processing the plastic waste, that cannot be mechanically recycled. The chemical recycling comes to convert the downcycled products into tertiary products leading to a point where the only "circular option" is to transform the waste into energy in the form of heat, via incineration.

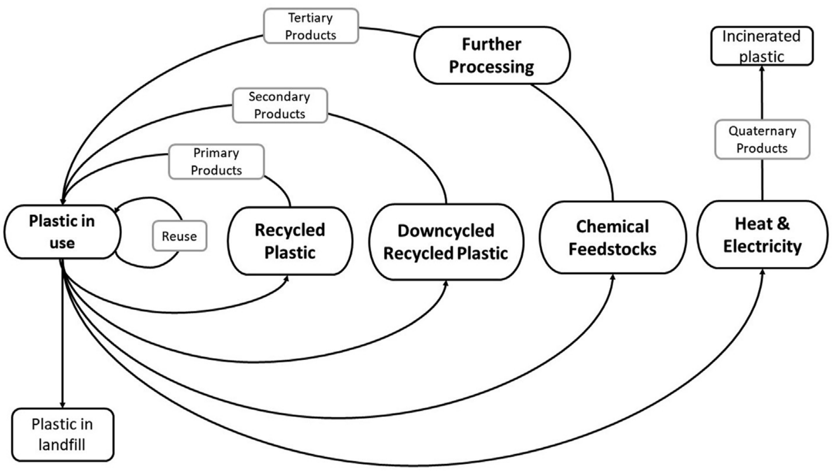

Figure 5 - Recycling Cycle (Davidson et al. 2021)

In a more practical view, *Lonca et al. (2020)* investigates whether or not PET bottle producers should increase the recycled content of their bottles to reach a higher material efficiency and environmental performance. This American case study outlines that the closed-loop cycle strategy does not necessarily give significant benefits, and concludes that in some practical cases, the recycling processes may not balance the environmental impacts (since they are more intensive compared to the supply of virgin material).

In the construction industry, *Bertino et al. (2021)* claims that the reuse of building components is a direct consequence of the deconstruction activities. In contrast to the demolition, which arbitrarily destroys a building resulting in common waste that has to be landfilled, the deconstruction allows obtaining quality materials and components that can be reused in new contexts with considerable environmental advantage. Additionally, *Katkhuda & Shatarat, (2017)* has investigated the improvement of the mechanical properties of recycled concrete aggregate produced by adding chopped basalt fibres to treated and untreated recycled aggregates. In resume, the results show that it is possible to significantly improve the concrete's flexural strength.

More research and case studies were found and compile in the Appendix B.

2.2.2. Extending Business Model

The extending's objective is to keep a product in use to the highest extent possible *(Geissdoerfer et al., 2020)*. According to the author, this typology includes strategies such as the design and production of timeless and long-lasting products, the consumer approach (encouraging the long product life), and the product support and maintenance. A similar view is introduced by *Salvador et al. (2021)* which defends that contrarily to the cycling business model, this circular approach focuses on making products last longer and consequently making resource value extend before re-enter or leave a use cycle.

Geissdoerfer et al. (2020) states that the value proposition of this business model is providing a premium product and high service levels, however *N. M. P. Bocken et al. (2014)* argues that additionally to product's high quality, the focus is on the customer relationship and influencing consumption behaviour. In practical terms, both authors attached equal importance to the reduction of consumption allowing the costumer to take advantage of a durable and functional product. The value creation and delivery are connected to the marketing and consumer education, ensuring long-term relationships. Additionally, the capture of value can be achieved through the application of "premium" margins to the product and services costs *(Geissdoerfer et al., 2020)*.

The analysis of the extending typology encompassed a review of 18 relevant papers (out of the 34 initially selected), and the business model characterization was the main objective. All the terms were compiled in the Appendix C.

2.2.2.1. Definitions

In this section, all the terms and strategies linked to the extending typology were explored and, even though there is a considerable lack of research in this specific circular approach, several perspectives were compared.

There are three extending strategies: the long-lasting and timeless design, the encouragement to achieve sustainable consumer behaviour (encourage sufficiency), and the maintenance and product support *(Geissdoerfer et al., 2020)*. Although these strategies were often mentioned with different names, they all are concerned with extending the product life and slow the resource loops. Furthermore, despite the different nomenclature, *N. M. P. Bocken et al. (2016)* states that the "classic long-life model" (a combination of the long-lasting and timeless designs strategy, and the maintenance and product support strategy) focus on delivering long-product life, supported by design for durability and repair for instance.

Extending the use phase of a product can be a highly effective approach for reducing and slow the use of resources, and the product's design can play a major role. According to *N. M. P. Bocken et al. (2016)*, there are two different types of design strategies: the long-life product design and the design for product life extension. The first design strategy includes the design for attachment and trust (emotional durability) *(Chapman, 2015)*, the design for durability *(N. M. P. Bocken et al., 2016)*, and the design for reliability *(Moss, 1985)*. The second strategy concerns the design for maintenance and repair *(N. M. P. Bocken et al., 2016)*, the design for upgradability and adaptability *(Linton & Jayaraman, 2005)*, the design for standardization and compatibility *(Bakker et al., 2014)*, and the design for dis- and reassembly *(Bakker et al., 2014)*. Once these design "sub" strategies can be viewed as a method to reach the "long-lasting and timeless designs", they will only be defined, as additional information, in the Appendix C.

The product lifespan can also be extended through improved durability and increased maintenance (*Sandberg, 2021)*. The author defends that the product durability addresses the physical (often planed) limitations through improvements in quality and functionality. Also, the consumer's psychological effects on the continuing changing trends are view as a problem. According to *N. M. P. Bocken et al., (2014)*, the negative impacts of an increasingly unsustainable "Western way of living" can't be handled with the current initiatives solely focused on the production, however *Sandberg, (2021)* states that the consumer behaviour can be mitigated with timeless or versatile designs.

As the environmental pressures increase, more radical approaches are required to actively reduce consumption *(N. M. P. Bocken et al., 2014)*. In this line, the encourage sufficiency strategy is spotlighted as it aims to innovate the customer relationships and influence their consumption behaviour (value creation and delivery) *(N. M. P. Bocken et al., 2014)*.

The customer education and new marketing actions play a major role extending products life *(Geissdoerfer et al., 2020)*, and as the focus rely on consuming less and using products longer it may be required a fundamental shift in promotion and sales *(N. M. P. Bocken et al., 2014)*. According to the author, this "non-consumerist approach to sales" implies solutions such as no discounting, no sales commissions, supplier selection based on durability, and incentive systems to discourage "over selling". *Dyllick & Hockerts, (2002)* and *Young & Tilley, (2006)*, defend that, not only the companies, but also the individual consumers must make responsible choices and, if necessary, boycott or subvert marketing strategies that are believed to be environmentally harmful, however it is known that the company has a huge role on the consumption patterns.

The customers actions are critical, and despite the consumer education has a notorious impact on a product's destiny, every organization should promote the functional maintenance and product support *(Geissdoerfer, Vladimirova, et al., 2018)*. This strategy focuses on providing high costumer service levels *(N. M. P. Bocken et al., 2016)* which assist the client avoiding the product's loss of quality and ensuring that it does not reach an end point.

Notice that there is a significant lack of clarity between the maintenance and refurbishment terms, and it is important to establish well-defined boundaries. Although they are both usually used to describe similar practices, the refurbishment, being a cycling strategy (and respecting the definitions), will be considered as a process that implies the recovery of value from waste streams. Thus, allowing for a wasted product to re-enter a new life or productive cycle through minimal changes.

Refurbishing is highly dependent on the “waste” term (which is very subjective), clashing with the concept often used on the construction industry “building refurbishing”, which means “renovation” *(Vilches et al., 2017)*. As in this industry, the building never re-enter in a new productive or life cycle (it is just renovated or upgraded), then it fits better with maintenance strategy. In this line, the maintenance (and product support) can be viewed as a service where a client gets his product repaired, upgraded or maintained, allowing a good working condition and the use of the product, usually by the same customer. This strategy does not involve the treatment of waste streams (usually without an owner), or the product’s integration in a new productive or life cycle.

This last strategy, in addition to allowing a product to be serviced during its lifetime, creates new revenue streams through service packages or tailored contracts *(Geissdoerfer, Vladimirova, et al., 2018)*. Since the goal of this typology is to reduce sales and overconsuming, it is important to create alternative ways of generating revenue. However, *(N. M. P. Bocken et al., 2016)* states that the upfront price is often “premium”, which would typically cover the long-term service and product warrantee cost absorbed by the company. According to the author, sufficiency-based business models are often premium business models since they aim to slow the sales.

The extending CBM does not force a material circular pattern (being its only focus the extension and slowdown of the product “quite linear” loop) *(N. M. P. Bocken et al., 2016)*. This way, it is concluded that this approach only considers one product lifecycle and does not imply the product’s re-enter in a new productive cycle.

To conclude this section, it is highlighted that all the extending strategies are highly connected. There are companies combining some, or even all these approaches, and as the main objective is to slow the resource flow allowing a product use phase to be extended, all the strategies should be considered in order to get better results.

2.2.2.2. Industrial Applicability

The extending business model is widely recognized as a possibility for achieving industrial sustainability and economic balance. In the textile industry, companies like Louis Vuitton and Patagonia are working towards slowing the fast fashion cycle, by not constantly introducing cosmetic innovation and encouraging greater longevity in use *(N. M. P. Bocken et al., 2014)*. They also practice “premium” branding, addressing high quality in their restricted production volumes, and delivering sustainability through little or no discounting facilitating the reduction of consumption *(Chouinard, 2016; Chouinard & Stanley, 2013)*.

In the manufacturing industry, companies such as Vitsoe have already disassociate themselves with fast fashion, and through product redesign it is expected a significant reduction in consumption *(Evans et al., 2009)*. It is important to notice that this company "survives" applying premium prices to its durable products which allow a healthy economy flow.

The German domestic appliance company Miele has focused on producing high quality and durable washing machines. Besides these machines are guaranteed a functional lifespan of twenty years (while other brand's machines only last ten years in average), this company has refused to outsource to low-cost suppliers and move down-market to compete the price *(Bakker et al., 2014)*. These sustainable approaches can compromise the economic return, however Miele accepts a modest growth rate *(N. M. P. Bocken et al., 2016)*.

Another great example of the industrial applicability of extending strategies, but this time in the watch industry, comes from the well-known luxury watches brand "Patek Philip". This Swiss company guarantee the quality and the timeless designs in its upmarket mechanical watches, allowing its customers to make a responsible and sustainable use of their pieces. This organisation was also responsible for an iconic marketing campaign with the slogan "you never actually own a Patek Philip. You merely look after it for the next generation", which underline the durability of its products *(Naas, 2016)*.

Also, the British company Unilever has focused on providing information to customers on how to minimize usage impacts. This company encourage sufficiency by advising the consumers of the benefits of using washing detergents at low temperatures and encouraging to take shorter showers *(Rubik et al., 2009)*.

In conclusion, the extending strategies can be applied in almost every product (by almost every company), and even if it engages on additional CBMs, it can be seen as a circular typology easy to implement. Additionally, the textile and the manufacture industry have shown to be the more receptive to the application of these approaches. More examples of industrial applicability were compiled in the Appendix D.

2.2.3. Intensifying Business Model

The intensifying typology is characterised by a "deliver functionality, rather than ownership" *(N. M. P. Bocken et al., 2014)* and it implies that the use phase of the product is intensified through sharing economy solutions *(Geissdoerfer et al., 2020)*. This business model, concerns with providing services that satisfy the users' needs without forcing them to own physical products *(N. M. P. Bocken et al., 2016)*, and it leads to the implementation of new value propositions around sharing models *(Geissdoerfer et al., 2020)*. In this line, only the sharing economy strategy was identified, however, due to the literature's lack of clarity and high diversity, a more profound analysis was made to understand if all the sharing economy solutions fit the intensifying typology's ambitions.

With an economic perspective, the intensifying business model's value proposition focuses on the delivery of product's temporary availability on a "pay-per-use" basis, rather than selling ownership of a product. This means the collaborative consumption of the same product, and consequently a lower cost for the same functionality *(N. M. P. Bocken et al., 2016; Geissdoerfer et al., 2020)*. The value creation and delivery of can be enabled by capacity management (demand and supply of products), digital capabilities and logistics *(Geissdoerfer et al., 2020)*, and it may require significant changes and new obligations within the company, such as the transportation of the products *(N. M. P. Bocken et al., 2014)*. The value capture includes the pay per unit of service (i.e., time, number of uses, performance) *(N. M. P. Bocken et al., 2016)*, and it can bring increased profit margins due to savings from using products for longer, and rental or leasing fees *(Geissdoerfer et al., 2020)*.

The analysis of the intensifying typology involved the study of 18 appropriate papers (out of the 30 initially chosen) and, once again, definitions were searched in order to characterise this business model. All the terms were compiled in the APPENDIX E.

2.2.3.1. Definitions

Similarly to the extending CBM, the intensifying typology focus on the way a product is used during its life span, providing solutions that aim for the slowdown of the flow of resources *(N. M. P. Bocken et al., 2016)*. As these strategies are implemented before a product leaves the system, it is possible to conclude that this business model only considers one product's life cycle.

According to *Zhu & Liu, (2021)*, the sharing economy concept refers to the situation in which institutions (or individuals) with unused resources transfer the right to use goods to others through a third-party platform. Also, *Hou, (2018)* states that the sharing economy can be thought of as a strategy that uses digital platforms to connect consumers. Although these last perspectives fit in the current digitalized world, some authors argue that there are more "traditional" ways to implement sharing economy strategies, and it isn't required a digital platform to practice sharing economy solutions. *Mont et al., (2020)* states that the sharing economy concept refers to goods or services, skills or spaces that can be shared, exchanged, rented, or leased. However, the author also admits that new forms of sharing between strangers enabled by digital technologies are emerging.

The sharing economy is an umbrella concept *(Mont et al., 2020)*, and developing a solid definition of it is nearly impossible *(Schor J., 2016)*. According to *Hou, (2018)*, the lack of a commonly accepted definition not only obstruct the scientific community from further understanding the sharing economy, but it also blocks regulators from adopting limits for competing activities.

Being an emerging field of research *(de las Heras et al., 2021)*, several different thoughts were found about what this strategy includes. For example, the askRabbit (an "errands" site) is often included, but the Mechanical Turk (Amazon's online labour market) is not. The Airbnb is practically synonymous with the sharing economy, but traditional bed and breakfasts are left out. The Lyft, a ride service company, claims to be in, but the Uber company, another ride service company, does not *(Schor J., 2016)*.

The controversy is clear, and due to the increasing industrial and social acceptance, the sharing economy has become a more wide-ranging term. Consequently, the use of the word "sharing" has been challenged by introducing general and complementary terms, such as "access" economy, "collaborative consumption", and "on-demand services" *(Bardhi & Eckhardt, 2012; Belk, 2015; Botsman & Rogers, 2011)*.

Moreover, *M Möhlmann, (2015)*, alongside with *Martin et al. (2017)* who states that the collaborative consumption can be seen as a synonym of the sharing economy concept, indicates that collaborative consumption is often associated with the sharing economy, and takes place in organized systems in which participants conduct sharing activities in different forms (renting, lending, trading, bartering, and swapping of goods, services, transportation solutions, space, or money). Also, *Bardhi & Eckhardt, (2012)* refers that an "access-based" consumption can be defined as the transactions that can be market mediated without transfer of ownership (sharing economy).

As the undertaken CBMs characterization must be continued coherently, few adjustments and considerations must be made. There are several sustainable solutions inside the generic sharing economy concept *(Schor J., 2016)*, and some of them are aligned with other CBMs' objectives (cycling, extending, and dematerializing). Despite the sharing economy can be divided into four different categories (recirculation of goods, increased utilization of durable assets, ex-change of services, and sharing of productive assets) *(Räisänen et al., 2021; Schor J., 2016)*. Additionally, only the solutions that directly seek to intensify and/or increase the utilization of physical assets (allowing the customer to use them without owning them), will be considered as an intensifying strategy.

It is important to notice that in some cases it might be needed some maintenance procedures to the intensified product. In these situations, the company responsible for the product maintenance or repairment is using an extending business model (maintenance & product support strategy). Given these facts, it is likely to find companies which use a combination of both intensifying and extending business models. For example, the companies that allow a product to be used by different customers and are responsible for the maintenance of that product.

With an environmental and sustainable perspective, this strategy's positive impact is what characterizes and makes it so popular. Reducing the use of natural resources without forcing the acquisition or product ownership is the central advantage *(Räisänen et al., 2021)*. However, *Zhu & Liu, (2021)* adds that the sharing economy will also positively impact consumers' environmental awareness, making low-carbon, environmentally protective, and green lifestyles increasingly popular. The author also refers that these solutions are practice under the concept of sustainable development resulting in an intensive green economic growth.

Although these positive aspects, *Mont et al., (2020)* argues that there is growing criticism of the sharing economy and its effects. *Cohen, 2016; Schor J., (2016)* warn that there is little evidence to support sustainability claims of sharing, and these solutions may be seen as a threat to professionalism, public safety, privacy and health, and labour rights *(Vith et al., 2019)*.

In conclusion, despite only one intensifying strategy being available, little differences can be identified between solutions. For example, there are sharing economy solutions that allow a customer to use the product for months (or years) without having to buy it (accommodation rent or car leasing). However, comparing it to a self-service laundry or mobility digital platforms it is possible to understand that these last solutions allow the fulfilment of a bigger number of customers in the same period.

With the assessment tool in mind, since this last variable (number of different users) only focus on the quantity of customers served, it does not necessarily quantify a product's use intensity (exact number of uses). Moreover, even if the exact number of uses was known, it wouldn't be possible to take direct conclusions. This is due to the fact that fulfilling a lower amount of people's needs may possibly lead to an increased demand for new products, and consequently have an undesirable environmental impact (rebound effect). Given these facts, a quantitative evaluation of the intensification's efficiency cannot be done.

Despite some literature divergences, it is concluded that the intensifying business models are known for having a significant positive impact, and its industrial application and social acceptance has been growing for over a decade *(Mont et al., 2020)*.

2.2.3.2. Industrial Applicability

Since the sharing economy is an emerging field of research, some of the articles favour the identification of the different industrial applications in place of developing a circularity and sustainable assessment of this approach. The sustainable impacts are neglected (in some cases), nonetheless the following examples represent real companies, which promote the intensification of physical assets and at the same time reducing the costumer's need for ownership (Appendix F).

In the lodging industry, the Airbnb company is making use of a sharing economy strategy. Through a "costumer to costumer" model (C2C), this organization provides a service that connects travellers with homeowners who have rooms available for rent. In this case, the room is the intensified "product" (physical asset), and it is seen as a convenient solution by combining the functionality and lower up-front costs (comparing to a hotel reservation or buying a house) *(Zhu & Liu, 2021)*.

The famous company known as Uber is also using a sharing economy strategy *(Geissinger et al., 2020)*. According to *Wieland et al. (2017)*, Uber can be perceived as creating value for customers by providing an advanced business model that is better, faster, and cheaper than those of traditional transport companies. Additionally, it is impossible to not address the fact that this company is also a prime example of a collaborative consumption service, fulfilling the user's need without increasing the demand for new products (cars, in this case).

Also in the transportation industry, *Guyader & Piscicelli, (2019)* presents a study where a shared mobility platform (GoMore) is analysed. In line with *Sabatier et al., (2010)* which suggests the development of unique business models for each customer segment, this company provides one platform with three different sharing economy solutions: business-to-costumer (B2C) leasing, customer-to-customer (C2C) car rental, and ridesharing (or carpooling).

Furthermore, in the Netherlands, CBMs are being developed and deployed. Attempting to analyse the material and climate change impact by adopting new approaches, *Sigüenza et al., (2021)* shows two CBMs on washing machines: the product leasing (with lifetime extension) and the pay-per-wash business models.

Whilst intensifying products, these business models avoid the customer to own a washing machine. In addition to provide the same product to different clients, they also raise awareness about the water temperature and the detergent use (applying different prices according to the temperature choice, and providing information and technological improvements, respectively). In the end, the results show that these sustainable approaches perform significantly better than the regular ownership model, and that material's use could see considerable reductions (if adopted successfully).

In conclusion, the analysis of the intensifying industrial application allowed to identify situations where a merge of distinct CBMs is performed. Some companies have been adopting both extending and intensifying strategies, and although it is important for a company to adapt its business model to the business environment (in an efficient and sustainable way) *(Gao & Li, 2020)*, the lack of clear boundaries hampers the development of a reliable characterization of the different typologies.

2.2.4. Dematerializing Business Model

To conclude the CBMs characterization, the dematerializing typology is presented. This sustainable approach is known for searching for the absolute or relative reduction in the quantity of materials used and/or the quantity of physical waste generated in the production of a unit of economic output *(Goedkoop et al., 1999)*. This business model may also focus on the reduction of resources needed to provide a desired economic result through the provision of product utility without hardware. It is important to notice that this typology is still very unclear for the scientific community. Given that several different definitions were found, a critical analysis was conducted aiming to maintain the consistency of the ongoing characterizations of CBMs.

According to *Magee & Devezas, (2017)*, the dematerialization is the reduction in the quantity of materials needed to produce something useful over time. It fundamentally derives from ongoing increases in technical performance, but it can be neutralised by demand rebound (increases in usage because of increased value or decreased cost). In addition to the reduction of absolute levels of material resource consumption, dematerialization is seen by some authors as a prerequisite to tackling some of the most pressing environmental issues of our time and to achieving a sustainability transformation *(Shao et al., 2017)*.

Naturally, due to the lack of information and solid definitions, a variant of this typology was quickly found. This alternative is called "maximise material productivity and energy efficiency", and concerns a broader mission as it, additionally to the dematerializing side, also focus on reducing emissions and pollution *(N. M. P. Bocken et al., 2014)*. This perspective shows to be a little confuse, so decisions were made to clarify this different point of view.

Firstly, the reduction of emissions and pollution can be seen as a natural result of the efficient practice of any circular typology. As it cannot be directly linked to the reduction of the resource needs, it will be separated of the dematerializing typology. Secondly, the energy efficiency is broad concept, and can be view as the objective of every sustainable strategy. Additionally, it is highly considered in the cycling typology where several processes (recycling) aim to recover energy from waste streams. This way, none of these concepts are directly linked to the dematerializing business model and will be "removed" from the dematerializing concept.

From a business perspective, the dematerializing's value proposition is the reduction of the physical resources' use by creating results for the customer needs through services and software *(Geissdoerfer et al., 2020)*. This typology may also address cost convenience while improving the user experience *(Tan et al., 2010)*. On the other hand, the value creation and delivery are ensured by services or "digitalization" of physical products. The value capture can be done by implementing services subscriptions and contracts or pricing per agreed results *(Geissdoerfer et al., 2020)*. Notice that the previous business perspective must only be seen as a general overview based on the work of *(Geissdoerfer et al., 2020)*. As the dematerializing typology may include different and specific strategies, the value proposition, delivery, and capture may slightly differ.

In summary, the analysis of 15 relevant papers led to the identification of the dematerializing's objective: the replacement of physical products for services or software solutions *(Geissdoerfer et al., 2020)*, stimulating the reduction of the number of physical items produced.

2.2.4.1. Definitions

During the systematic research, it was possible to understand that this typology has some similarities with the other three business models. As a result, and before the characterization of the product-service system, a brief critical analysis will be conducted. The objective is to prove that despite there are visible theoretical differences between the distinct typologies, the practical application is divided about what are the dematerializing strategies.

Starting with this business model's resource flow type, it is known that, as the dematerializing approach aim to use fewer resources per product, it is considered that it contributes to narrowing the resource loops *(N. M. P. Bocken et al., 2016)*, contrasting to the extending and intensifying's "slowing resource loops" objective. This way, *N. M. P. Bocken et al., (2016)* claims that, although the end result of "slowing" and "narrowing" could be the same (less resources flowing through the system), the "slowing" typologies invoke a different relationship with time, whereas "narrowing" accepts the speed of resource flows. The author enhances the weaknesses of the narrowing strategies, by explaining that if the time dimension isn't considered, the resource efficiency can easily lead to further speeding up of linear resource flows and, thus resulting in a very little overall savings.

It is known that the different CBMs have distinct objectives under the "circularity" concept. For example, the intensifying and extending typologies strive for the intensification and extension, respectively, of the product's use phase. On the other hand, the dematerializing business model enhances the direct decrease of the physical resources' utilization. Nevertheless, it was confirmed (again) that all these circular typologies are highly connected, and despite the major goal diverge between each typology, the practical implementation of different business models may lead to the same results.

According to *Zhang et al., (2017)*, the dematerialization phenomenon can be justified by distinct reasons such as the increasing share of material at different life stages (intensifying), the utilization of recycled materials (cycling), and efficiency improvements in both production processes and service provision (extending/dematerializing). In other words, if a sharing economy solution (for example) is implemented allowing a customer to, through a digital platform, intensify the use of a product, then it will also promote (indirectly) the reduction of the use of physical resources. Additionally, if an extending strategy (long-lasting design, for example) is practiced, allowing a consumer to extend the use phase of the product, a dematerialization phenomenon will be seen.

In short, every CBM may lead to an indirect dematerialization, as all their strategies result in a decrease of the need for physical materials. If a business model contributes to closing or slowing the resource loops (allowing a product to serve for a longer period) then, according to the current literature, it can be considered as a dematerializing business model. Given these facts, it is important to define and specify what does the dematerialize typology includes.

In order to maintain a certain degree of consistency on this research, meaning not repeating other typologies' strategies (even if they indirectly result in a dematerialization), the product-service system (PSS) will be analysed to confirm the ability to be seen as a dematerializing strategy. As the service economies generally require less resource' use and impact less the environment than industrial economies, a strategy shifting away from an economy of products to one of services is considered more sustainable *(Zhang et al., 2017)*.

According to *Franco, (2019)*, the product-service system strategy shifts the focus from selling products (complemented by services), to selling services that substitute products, thereby contributing to dematerialization and offering the opportunity to decouple economic gain from material consumption. In a more basic explanation, *Goedkoop et al., (1999)* states that a product-service system is a marketable set of products and services capable of jointly fulfilling a user's need. *Schuh et al., (2015)* separates product (a tangible commodity manufactured to be sold) from services (an activity often done in a commercial basis and for others) and completes this analysis saying that a system is a combination of the previous elements and their relations.

Furthermore, *Stark, (2016)* states that the product-service system is the dematerialization of solution offerings, however the PSS is a wide concept, and not every definition addresses a direct dematerialization. In this line, a more complete definition of PSS is given by *Tukker, (2004)*, who divides the PSS in three different types: “product-oriented”, “use-oriented” and “result-oriented”. This perspective allows a more specific characterization of the different PSS strategies and, consequently a better understanding of which type seek a direct dematerialization.

In this division, a product-oriented PSS focus on providing services along with a product sale, which represents an extending strategy (maintenance and product support through services). The use-oriented PSS presents similarities to the intensifying business model (sharing economy), as it provides the use and availability of a product without ownership. Only the result-oriented PSS seems to directly pursue dematerialization, as the main value is on services to completely fulfil individual customer needs, without the need for the customer to use the physical product.

In a result-oriented PSS, services can replace the product to provide desired results to customers *(Yang et al., 2010)*. In other words, the customer receives a functional product result instead of a specific physical product, even knowing that the service provider might use undefined physical products. Although the main focus of this strategy is the service provided, products still have a “background” role in the system, which can jeopardise the sustainable efficiency of this strategy.

In conclusion, not every type of PSS can be considered as a dematerializing business model. Since the first two PSS types were already included in other circular typologies (extending and intensifying), only the result-oriented product-service system will be considered as a dematerializing strategy, even knowing that the products’ use must be analysed.

As an additional note, the “digitalization” concept was sometimes founded and referred as a way to dematerialize *(Jia et al., 2021)*. However, no definitions or case studies were found (in a circular and sustainable context) for this term. Despite the unclarity of this term, a similar and specific concept is given by *Geissdoerfer et al., (2020)*. The “software instead of hardware" also leads to the reduction of the need for new physical resources. Furthermore, as the substitution of physical products for software solutions lead to the delivery of results instead of physical products, this "software instead of hardware" approach can be perceived as a "sub strategy" of the result-oriented PSS.

All the definitions were compiled in the Appendix G.

2.2.4.2. Industrial Applicability

The dematerializing business models have a constructive environmental impact and, although several strategies contribute to dematerialization (direct and indirectly), some practical application examples were analysed and presented in the industrial application section. As the service economies generally require less resource use and environmental impact than industrial economies *(Zhang et al., 2017)*, a shift away from an economy of products to an economy of services must be made.

In this section the industrial applicability of the result-oriented PSS strategy will be explored as it, by definition, seeks a direct dematerialization of a product, providing a functional result instead of a physical product *(Tukker, 2004)*. This strategy is also seen as the most promising PSS type from an environmental viewpoint *(Kanda & Nakagami, 2006)*, even though there are questions that still need to be answered.

The result-oriented PSS highlight the customers' service experience. The entire delivery process can be seen as a service process, while physical products, hardware resources, human resources and equipment facilities are included in a series of sub-processes *(Geng et al., 2019)*. In other words, the result-oriented PSS means that customers and providers agree on a result or performance, and there is no pre-determined product involved. Given these facts, since the need for physical products may exist, where is the sustainable advantage? If a company sells a service instead of a physical product, will the material consumption decrease? As the company may need to use physical products, the simple implementation of a service system does not resolve the environmental problem alone.

Once the dematerializing business model refers to the reduction of the use of physical materials, then shouldn't the result-oriented PSS avoid the use of resources? The correct answer is yes, however the total replacement of physical recourses for services or software is impossible in some cases. It is obvious that material consumption may not disappear, so additional actions must be taken so that the result-oriented PSS strategy can be considered a sustainable practice.

The result-oriented PSS is a dematerializing business model strategy because, even if a company does not deliver a specific result without a product use, it avoids the individual and unaware use of recourses. Being the company the only responsible for the products use, a professional and efficient use is easier to implement. Using different techniques or professional equipment, it can successfully deliver a result without the need for the same number of physical products that an individual customer would need. In short, the replacement of a physical product (directly sell to the customer) for a service (provided by a company), contribute for a conscious, professional, and efficient use of products, and for the reduction of the materials needed to achieve a result.

As the result-oriented PSS is the only strategy of the dematerializing typology, it is important to complement the business perspective previously made in the introduction of this typology. In this PSS type, the value proposition relies on the promise to achieve a certain customer performance, and as a performance provider, companies must build a profound knowledge of the customer's core processes to manage customer operations *(Helander & Moller, 2008)*. The value creation and delivery are characterized by the delivering of results instead of physical products, and the value capture rely on customer payments based on the result agreements *(Reim et al., 2015)*.

There are several practical examples of the result-oriented PSS, however the majority do not imply a substitution of an existing physical product for a service. Examples such as an architect's service package for house design or an annual health check-up service *(Wirtz et al., 2021)*, do not bring the valuable trade in an industrial and environmental perspective. Therefore, even though there are few practical examples, which allow for the partial substitution of physical products for services, it will only be considered a dematerializing business model if the company reduces the customer's use of physical products.

In addition to the difficulty of, on an industrial level, push physical products to the "background" and provide the same level of functionality in services, there are several functional barriers to the industrial application of services *(Wirtz et al., 2021)*. Previous research proves that when the content of a service offering remains fuzzy and constantly varying, many service managers struggle with communicating, differentiating, and pricing services *(Clemes et al., 2000; Wirtz et al., 2021)*. There is the idea that customers often find it difficult to grasp a service provider's value propositions, necessitating more concrete and clearly specified offerings (usually physical products), that reduce the sense of ambiguity and customer risk perceptions *(Jaakkola, 2011)*. Numerous services are complex, intangible, and not clearly define, which hamper customers to distinguish between different offerings and understand if what they are getting is worthwhile *(Wirtz et al., 2021)*.

In this line, *Grönroos, (2020)* suggests that services should be treated as concrete objects, albeit intangible ones, and that they need to be commercialized just like tangible products. These are "game changing" suggestions, however, the author also recognises that academic research on clearly defined service products is scarce. Given these facts, the lack of case studies in this specific business model is understandable, and the need for a social and political revolution shows to be substantial.

An example of a result-oriented PSS was given by *Kanda & Nakagami, (2006)* and it suggest the substitution of pesticides for services that control the rate of harvest loss by destructive insects. Despite it is not mentioned in the literature, the substitution of letters for electronic mail, the substitution of physical stores for the e-commerce, or even the substitution of paper maps for virtual maps software (google maps, for example) are also examples of "software instead of hardware" (result-oriented PSS).

Also, a case study of the result-oriented business model category is given by *Stoughton & Votta, (2003)*, in which chemical suppliers are paid for chemical services rather than for the volume of the chemical provided. Additionally, *Azarenko et al., (2009)* presents an example where a vertical integration of an ultra-precision, free form grinding machine is runed by the provider. Also in the construction sector, *Gruneberg et al., (2007)* presents a case study where there is a performance-based construction in which the provider and customer agree upon the outcome.

Cleaning services are also a common example of the result-oriented strategy. In this approach, the performance is agreed upon without defining the physical product(s) used to reach the outcome. One more time, it is clear that no specific product is necessarily involved in a result-oriented PSS. The supplier gets paid for a result, for which the supplier is totally responsible *(Reim et al., 2015)*.

During this practical analysis, it was possible to understand that there are common applications of these business model typology, however an increased adoption of the dematerializing business model may be empowered by a technological breakthrough. In order to facilitate the comprehension of the industrial applicability of result-oriented PSS, the "scientifically valid" practical examples of the dematerializing typology were compiled in the (Appendix H).

2.3. Business Model Comparison

Following the characterization of the different CBMs completed, this section presents a comparison between the typologies previously examined: cycling, extending, intensifying, and dematerializing. From a generic perspective, and respecting the technical, economic, environmental, and social principles, all the different strategies were confronted and analysed in the Appendix I.

In the technical dimension, industrial variables such as the existence of industrial processes or technology, the process complexity, and the logistics complexity (outside the factory floor) are the guiding parameters for the comparison. The first variable seeks to compare the need for industrial processes or technology. The process complexity expresses how difficult is to implement a specific process in the factory floor, while the logistics complexity is used to evaluate and compare the logistical arrangements on the different approaches. An industrial company may include different types of logistics, however only the external logistics (outside the factory floor) are considered. In short, only the reverse logistics (i.e., the return of goods by customers or the return of unsold goods by distribution partners), the supply logistics, the distribution logistics and the political policies are included in this comparison process.

In the economic dimension, only the variables addressing investment needs and revenue streams were considered. These needs comprise the amount of capital needed to implement a specific CBM (including the logistical and operational costs), and it is highly connected with the process complexity. Since the economic aspect of the different circular typologies is particularly important, different examples of revenue streams are presented.

In the environmental dimension, the material, energy, and water consumption are integrated in this comparison. Also, the landfill variable is included and aims to understand what typologies are closing the resource loop, thus allowing a high level of circularity.

In the social dimension, the need for different partnerships represents the company's capacity of running the CBM with (or without) the need for other identities helping in the process. Finally, the promotion of a sustainable consumerism variable compares the influence a company has on the customer' consumption behaviour.

In this comparison, a classification respecting the parameters previously presented was carried out. In this process, the variables exposed in a question form were answered with "Yes" or "No", and the others were classified with "Very Low", "Low", "Medium", "High", and "Very High" grades. When there is no answer for a specific strategy, it will be marked with "-". This way, it is expected the establishment of an easy and visual comparison between the strategies and the reception of the "minimum" knowledge needed to the development of the long-awaited tool.

Before the comparison, it is important to clarify that this analysis will have a general view over the four typologies, and it may be possible to find industrial examples that do not fit in some of the comparison's made during this classification process. This way, the comparison can be seen as a resulting personal view of the literature review (Appendix I).

2.3.1. Comparative Analysis

From a macro perspective, the cycling strategies are usually the most complex from a technical viewpoint. Comparing to the other typologies (extending, intensifying, and dematerializing), these strategies typically need complex industrial processes (as they transform waste in usable products). Consequently, as the investment needs may be connected to the strategy's technical complexity, these are marked as the most expensive to implement.

In addition to the supply and distribution logistics, all the cycling strategies imply reverse logistics, however, there is one efficient cycling strategy that is "simple" to adopt. The reuse strategy usually recovers used products directly from the final consumer, as well as, generally requiring simple cleaning and sanitation processes, which may fit into the budget of most companies. On the contrary, the recycling strategy usually uses a bigger variety of industrial processes (such as shredding, crushing, incinerating, etc…) to recover (nearly) pure materials/or energy *(Campbell-Johnston et al., 2020)*. Due to this fact, the need for specific equipment and the technical knowledge may lead to a superior consumption of resources and a higher investment requirement. Although this typology (cycling) is highly dependent on partnerships, it can be seen as a very sustainable solution as all their strategies avoid landfill (close resource flows).

The extending typology has two strategies that can use industrial processes. Due to the product's high quality and durability, the long-lasting design strategy might require a relevant investment (valuable resources), and a complex logistical scheme as usual suppliers may not be able to provide the resource's quality needed. On the other hand, as the "encourage sufficiency" strategy only focus on the customer's education and raising awareness of environmental problems, it has a "very high" classification on the promotion of sustainable consumerism.

The "maintenance and product support" is a strategy that depends on the product's functional level and may need industrial processes. The process complexity is usually low, as only maintenance and basic repairments are made. Consequently, the resource consumption was graded as "low", highlighting this strategy in the environmental dimension. Contrarily to the cycling strategies, the logistics complexity can be considered inferior because normally, it is the customer responsibility to establish the connection with the maintenance provider, even though the need for reverse logistics is real (goods return).

The intensifying business model focuses on the intensification of the product's use, and according to the previous definitions it does not require any industrial processes *(Belk, 2014)*. This typology is very connected to the extending business model because it is almost impossible for a company to intensify a product' use phase without maintenance practices. As this business model is appraised individually, it is possible to say that it may lead to sustainable results (less customers buy and own new products), nevertheless there are challenges when putting it into practice. The complex logistics associated to the constant availability and condition validation, commonly make the adoption of this business model almost impossible without the support of digital capabilities. This digital support may mean that an additional investment is needed, however, there are some cases where a good economy and sustainable performances come as a result.

As the digital support has been proving its efficiency, and since the management of the products is generally made automatically (software), the logistic complexity was marked as "medium". Additionally, this CBM focus on sharing functionality among different users, and the results usually represent a sustainable approach to the market. Thus, the promotion of a sustainable consumerism was marked as "medium".

Some dematerializing CBMs have also a complex approach to the industrial scene but, if well applied, it may conduct to a highly sustainable economy. There are examples of dematerializing business models that do not need industrial processes (only the service is provided), and examples where the substitution of a product for a result does not mean that the factory is halting production (requiring industrial processes).

The implementation of this CBM may lead to a change on the physical product's needs, but usually from an indirect way (where the proper use of products leads to a reduction on the need for them). The resource's need will most probably always exist, and because of that the material, energy and water consumption were marked as "medium". Also, there are few dematerializing approaches that totally transform a physical product in a digital tool, however, as not every product can be discarded and exchange for digital capabilities, it is possible to say that the majority of the dematerializing business models may not radically change the way a product is needed.

This specific business model only delivers a physical product's result in a service that is expected to be provided by a professional organization in a more sustainable way (using efficient products and trained personnel). This might increase the exploitation of the product to a level that a common customer could not achieve.

2.4. Circularity Assessment Tools

It is said that it is impossible to create a circular economy until it is properly measured. Despite the need for measuring a company's circularity is not widely recognised, some entities have developed tools that help the transition to a circular economy.

The "Circulytics" is the name of the tool that was developed by the Ellen MacArthur Foundation in collaboration with more than 30 companies and academic organizations. This tool uses a comprehensive set of indicators that aim to measure a company's circular economy performance, not limited to just its products and material flows.

With a global perspective, this tool shares the same vision of this study (facilitate and identify opportunities for the transition to a circular economy), however some differences can be found in the foundation of the circularity assessment tool. The main objective of this study is to provide a tool that can be used autonomously by a company, and based on simple questions that can identify and evaluate the different circular typologies (and strategies) that are being implemented, establishing a direct link to the literature on CBMs. This tool will not particularly focus on products or processes, but in the corporation's business rationale (with respect to the different CBMs frameworks).

3. METHODOLOGY

The identification and characterization of the different CBMs resulted on the transformation of the "theoretical" information into practical and tangible value for corporations who want to understand if they're implementing their business in a circular and ecological way.

The information analysed in the Literature Review chapter (definitions and industrial applicability) will be used in this methodology to develop an assessment logic, that will comprise several assessment questions based on circular requirements. These questions will be then compiled in an Excel sheet, which after being programmed, will result in an assessment tool that comes to support industrial companies identifying and categorizing their current CBM (if any).

To allow a clear view of what will be done in this chapter, the figure 6 represents a summary of all the steps (and their related objectives) that will be followed in this Methodology.

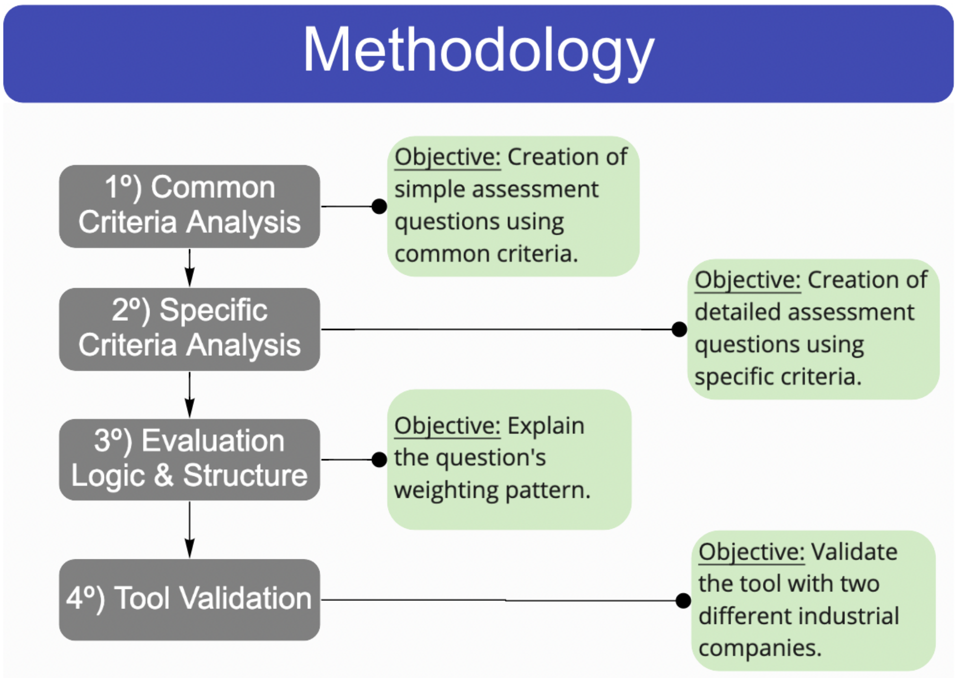

Figure 6 - Methodology's Structure

This chapter is about the transformation of the literature review's outcome in different questions (with different levels of specificity), that will be capable to categorize any company's business model. To that end, a "Common Criteria Analysis" will be conducted, in order to embrace the analysis of each typology's definitions, and related common criteria. This information is incorporated in the Literature Review chapter and will now be used to establish simple assessment questions. Subsequently, a "Specific Criteria Analysis" will be made to get more detailed information, related to each circular strategy. This information (strategies' definitions and some industrial applicability examples) will contribute for the development of several specific requirements, which will then lead to assessment questions.

As the objective is to compile all these questions and achieve a credible assessment tool, the step "Evaluation Logic & Structure" will explain the answer's impact on the categorization of the company's current business model, and the tool's structure. In conclusion, a tool validation process will be conducted where two different industrial companies will "test" the assessment tool. The results will then be presented in the Tool Validation chapter.

It is important to notice that the result of this methodology is highly connected to Literature Review chapter. In this line, the Figure 1 can be seen as the guideline for the development and analysis of common/specific criteria and their related assessment questions.

3.1. Common Criteria Analysis

In this analysis, a general overview will be conducted searching for the "standard" circular characteristics. As the objective is to transform the literature review's results into general assessment questions, all the typologies' definitions will be transformed and included in the assessment tool in form of questions.

The cycling "common criteria" were developed with respect to the compiled terms and definitions, as these represent the general characteristics that a specific business model must have to be considered as a cycling business framework. From a general perspective, if a business model extracts value from an unexplored source of wasted materials, allowing the material to initiate a new cycle, then it is possible to say that it is a cycling business model.

On the other hand, if a company strives for a more sustainable and ecological business, providing “premium products” and high service levels, then it is possible to say that the company is using an extending business model. In addition to the “physical attempt” to make products last longer, if a company focus on establishing long-term customer relationships, where it provides a sustainable marketing and consumer education (promoting a conscious buying behaviour), the company is using an extending typology. In conclusion, what characterizes an extending business model is the preference for allowing a product to be serviced during its lifetime (through providing high quality and functionality, consumer education and high service levels), instead of a fast economic growth through boosting the sales and the produce volume.

Furthermore, it is possible to say that if a company aims to combine functionality access and cost convenience, allowing customers to take the same advantage of a product without owing it, then an intensifying business model is being used. In short, organizations that provide or facilitate the collaborative consumption of a product (regardless of the use period) are using the intensifying CBM.

To conclude, organizations which aim to substitute the delivery of a specific physical product with a functional product result, by delivering the same performance in services or software solutions, are using the dematerializing CBM. It is important to enhance that, in this circular typology, the customer does not use the physical products, but he can use digital tools, as they are seen as product’s results.

Several assessment questions were developed respecting the common criteria related to each typology (Appendix K). As an example, the following table represent the questions that came as a result of the cycling common criteria.

CBM	Criteria	Questions	Objectives
Cycling	Recovering value from waste	Do I extract value from an unexplored source of waste?	Understand if the company is fulfilling the cycling criteria.
	Closing the resource loop	Do I allow any source of waste to initiate a new lifecycle (with or without processing)?	
	Reverse logistics	Do I take-back used materials/products/organic feedstock?	

Table 2 - Cycling "Common Questions"

3.2. Specific Criteria Analysis

After the development of assessment questions over common characteristics, a "Specific Criteria Analysis" will be conducted. More detailed information, related to each circular strategy, will be analysed and several specific requirements will be enhanced. These requirements will again contribute for the development of assessment questions that will help categorize the company's current approach over circular characteristics. Just like in the previous step, an individual analysis to each typology will be conducted, but this time each typology's strategy will be appraised.

All the nine strategies were deeply analysed and covered with assessment questions (Appendix L). Furthermore, as the processing efficiency (and quality) is highly connected to the company's circularity, the upcycling and downcycling terms were also included in the analysis, aiming to provide an additional level of specificity to the assessment tool. In this line, if an organization's cycling strategy results in a product (or material) with an improved physical or economic value (comparing to the original one), then it is possible to characterize the used strategy as an upcycling.

As an example, the following questions (Table 3) represent how the definitions and information related to the reuse strategy were transformed in assessment questions.

Strategy	Criteria	Questions	Objectives
Reuse	Reuse of parts or products	Do I reuse parts or products, without any significant intermediary process, in the same and/or different application?	Comprehend if there is significant changes on the product.
	Re-sell products, without any significant modification in it	Do I take back used products and re-sell them, without any significant modification in it?	Understand if it is collecting wasted products to reuse.
	Transfer products without significant processing	Do I transfer (without selling) wasted products to a new final customer, without making any significant modification in it?	Understand if it reuses products, even if it means no economic return.

Table 3 - Reuse "Specific Questions"

3.3. Evaluation Logic & Structure

With the tool's objective in mind, an evaluation logic is needed so that the classification of the company's answers can translate into reliable and useful information. During this step, an explanation about what answers will be considered is given, and the evaluation structure is presented. After this step, the assessment tool's development is concluded, and ready to be validated.

Primarily, it is important to notice that, in this assessment tool, every typology is equally important and it will be no differences on the weighting pattern of the company's circular typologies. Moreover, all the specific answers will be considered and categorized evenly for each firm, which means that the final results will only depend on the company's acknowledgments.

In the figure 7, a summary of the assessment tool structure is presented.

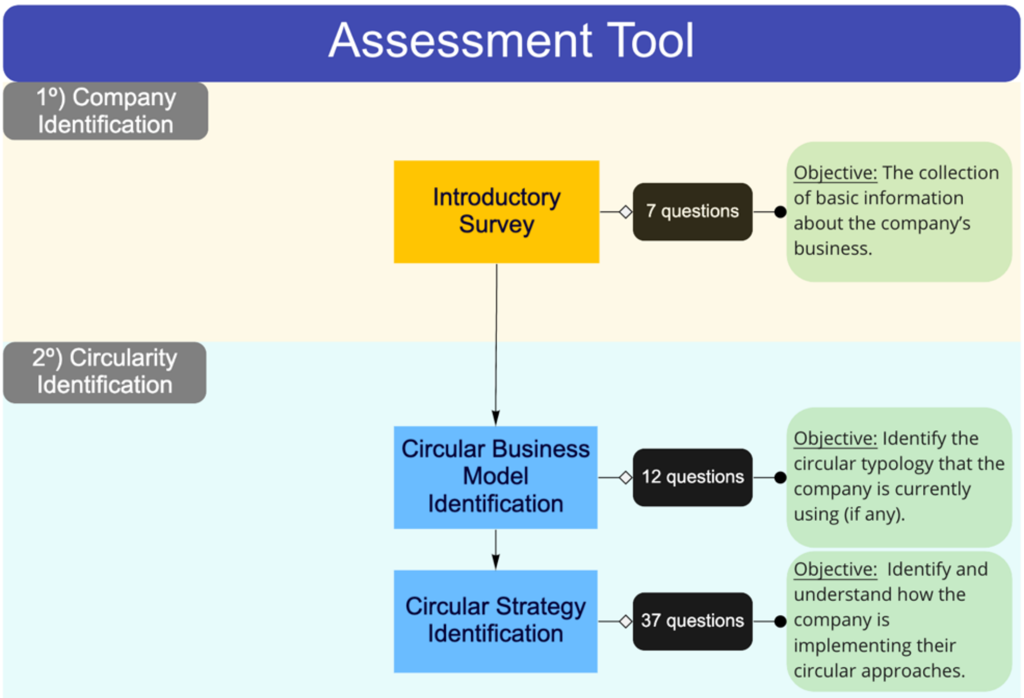

Figure 7 - Evaluation's Processes

From a macro perspective, the final assessment tool will be divided in two different sections. The first section will collect important, but superficial, technical aspects of the current company's business model, through 7 simple questions. This section is called "Company Identification" and it includes an evaluation process made through a brief introductory survey based on the standard business model characteristics.

The second section is known as the "Circularity Identification" and will use all the questions developed through the analysis of the common and specific criteria. Although they are not distinguished in the tool, this section will be dived in two different evaluation processes: the "Circular Business Model Identification" (12 questions) and the "Strategy Identification" (37 questions). A resume is presented in the Figure 7.

3.3.1. Introductory Survey

Starting with the Introductory Survey (where the collection of basic information about the company's business is conducted), a temporal relation was established with the company's value creation.

In order to conduct a reliable and simple assessment, the development of seven questions (Appendix J) was separated in the three different sectors: before, during and after. The first sector will include three questions about the procedures taken by the firm, before the value creation. The second sector will focus on the value creation process and company practices during such procedure, which incorporate two questions. The last sector also has two questions and will turn the attention to the period after the value creation actions.

The answers will provide precious information for the identification of the company's business. However, as there will be no ponderation on the company's answers to this assessment process, they will be merely used for helping the circularity identification processes. It is also important to refer that the perception of what the company is doing is highly related to the end-result of that assessment, and the more detailed the answers are, the more complex the analysis can be.

3.3.2. Circular Business Model Identification

There will be different answers for the different types of questions, and to maintain a simple approach, the questions developed during the common criteria analysis will only require "Yes or No" answers (Appendix K).

Similarly to the introductory survey, the CBM identification will only focus on identifying the company's circular typology. The firms' answers will be viewed as simple guidelines to the following circular strategy identification process. As a result, they will have no significant impact on the final assessment results (no ponderation applied).

In conclusion, this process is independent of the circular strategy identification procedure. Even if there are no circular typologies identified (only "No" answers in this step), it will always be necessary to move into the other assessment process (Circular Strategy Identification). Here, the detailed information about the company's circular strategies can be considered as useful evaluation objects.

3.3.3. Circular Strategy Identification

This section analyses the most important assessment process. The questions developed during the specific criteria analysis (Appendix L) will be treated differently, and since they represent a detailed view of the company's sustainable practices, the "Yes or No" answers will be discarded.

The company will be able to grade their practices using a five-option answer scale, that will be then scored according to the selected option. This answer scale will be responsible for the categorization of the company's current business model, and will help getting a clear view of how the company is implementing their circular approaches, and what typology is the most relevant (if more than one).

Before the development of the answer scale, it is important to remember that the assessment tool must be easy for the company to answer, but efficient at the same time. Consequently, a qualitative answer was found more appropriate than a quantitative one, so that the result can reflect how efficient and sustainable is the company's approach. In this line, the five-option answer scale will be: "No, never", "Yes, a few sometimes", "Yes, all of them sometimes", "Yes, a few always", and "Yes, all of them always", and they will be provided after every question that is developed across specific criteria.

To categorize the company's practices, the company will have to choose one of the given options, which will be then classified from 0 to 1 point with four 0,25 increments. For example, if the company selects the option "No, never", the answer will be classified with 0 points. If the company select the option "Yes, all of them always", 1 point will be attributed.

In conclusion, all the information needed for the development of the assessment tool is gathered. The completion and programming of the excel sheet (using the "offset" function) are the following steps, through which it will be possible to validate (the tool) in real industrial companies.

4. TOOL VALIDATION

In this chapter, the developed tool is demonstrated and validated in an applied setting with real case studies. As a starting point, a brief presentation and contextualization of the companies' business is provided. As for the validation process, it will be divided in two different steps: the presentation of the companies' answers to the "Company Identification" questions; and the exhibition of the companies' objective results, that are based on the "Circularity Identification" module answers.

4.1. Company Presentation

4.1.1. Case Study 1

The first case study is the Portuguese company "Madeira & Madeira, S.A.". In addition to maintenance services, this organization sells a variety of machines and tools, and it is present in the Iberian, Angolan, Cape Verdean, and Mozambican "Do-it-Yourself" (DIY) market. This market aims to help customers to improve their homes without the need for professional support, and it is expected to reach over 500 billion U.S. dollars in 2024.

A lot of information was possible to collect during the "Company Identification" section. This introductory survey was critical to understand that, in this case, no raw materials are bought and processed by the company in question. In other words, despite the packaging design that is developed in their headquarters, this company only buys finished products (including packaging) to Chinese and European companies.

The majority of the products are manufactured in Chinese factories and are then transported, by container, to their warehouse. Once in Portugal, the products can be ordered through the company's website, or directly bought in physical stores. This company's products are usually placed on the traditional segment (small and medium size stores), but also on the "modern distribution" segment (big retail stores).

4.1.2. Case Study 2

The second case study is the Portuguese subsidiary of the American “SRAM, LLC” group: “Sramport – Transmissões Mecânicas, LDA”. This organization sells mainly bicycle chains, but also other bicycle components. and is recognised at a global level (factories in four different continents).

Through the introductory survey, it was possible to identify that this company buys raw material, in this case steel and aluminium, from three different suppliers. These materials are subsequently processed, through different and complex industrial processes in Coimbra (Portugal). The finished products are then sold in “business-to-business” and “busines-to-customer” systems, to original equipment manufacturer (OEM) and aftermarket (AM) customers from all over the world.

4.2. Assessment Results

To present the objective findings of this assessment, all the “Circularity Identification” answers will be analysed. These answers presented important and crucial information, that can be used to provide interesting “visual” content and efficient ways to exhibit the company’s circularity results. Moreover, the results are automatically displayed in two graphs allowing a more dynamic view of the business model’s circularity.

The first graph consists in horizontal displayed bars and its objective is to establish a visual comparison between the circular typologies being used. In other words, it provides a clear understanding on which circular typology is playing the major role on the firm’s business model. Also, it will be provided a “performance rate” that means how the company is applying a specific typology.

The second graph consists in a radar graph, which has the objective of appraising the firm’s circular strategies. It is divided in ten different colours, so that a visual assessment can be done. Since it comes in a radial form, it is concluded that a given company has a high number of circular strategies, if the connections between each strategy are able to create a “circle” shape. Every colour represents a specific strategy, and the longer the distance to the origin, the bigger is the relevance and efficiency of that strategy (or more circular is the company, from the developed CBM typology perspective).

4.2.1. Case Study 1

Starting with the questions developed over the common criteria (Figure 8), it was possible to identify some circular characteristics in the company's current business model. Even so, these initial questions are not detailed enough to present final conclusions about the company's circular strategies.

Circularity Identification

1. Do I extract value from an unexplored source of waste?	No
2. Do I allow any source of waste to initiate a new lifecycle (with or without processing)?	Yes
3. Do I take-back used materials/products/organic feedstock?	No
4. Do I strive to maintain a product in the same user for a long period?	Yes
5. Do I directly promote a sustainable and conscious consumerism?	Yes
6. Do I promote the intensification of any product's use phase?	No
7. Do I allow different customers to use a product without owing it?	No
8. Do I use digital platforms to facilitate the sharing of products?	No
9. Do I own the products that are shared?	No
10. Do I sell results instead of physical products?	No
11. Do I sell/provide a product's result (not a physical product), using fewer physical products?	No
12. Does my customer uses physical products?	Yes

Figure 8 - Common Criteria's Questions 1

With this first input, it is clear that the company's circular characteristics may be linked to the introduction of wasted resources in new lifecycles, as well as, the extension of the product's use phase, and the promotion of a sustainable consumerism. Only the analysis to the answers of the specific criteria, can reveal which circular strategies are being implemented. However, before the graphic's analysis, it is possible to say that the company's business model is probably highly connected to the cycling and extending typologies.

Given these facts, to get an exact view of the company's circular strategies, the answers to the 37 specific questions were transformed in the following graphics (Figure 9 and Figure 10). The complete questionnaire and the respective answers are available in the Appendix M.

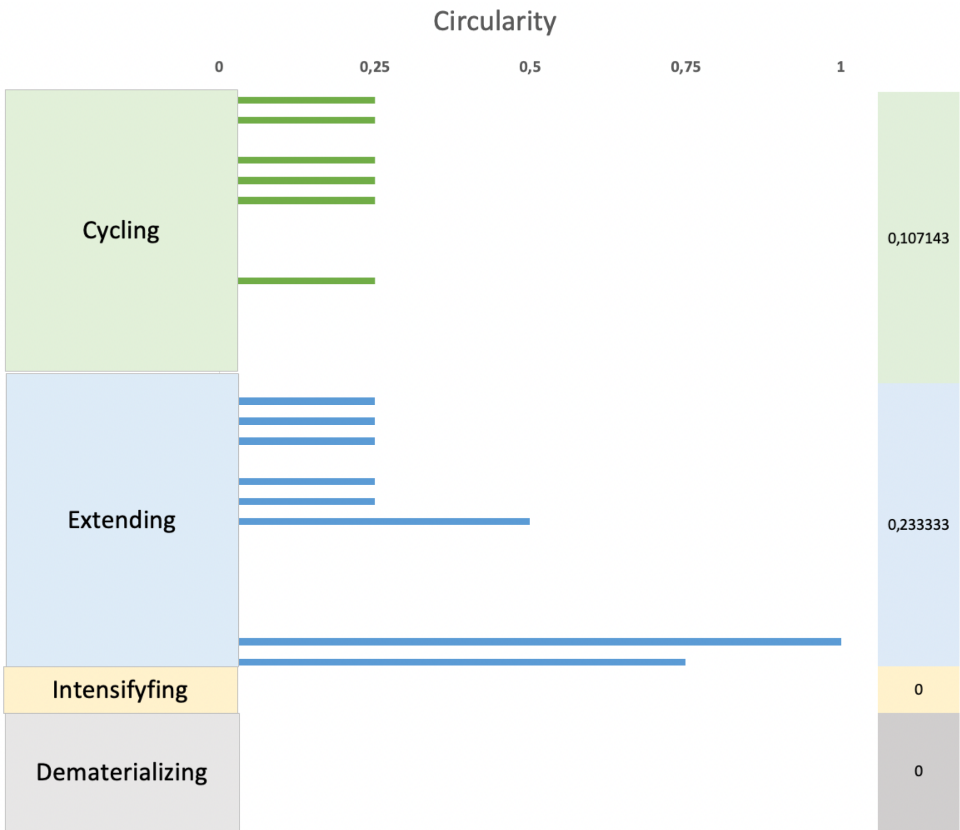

Figure 9 - Typology's Performance

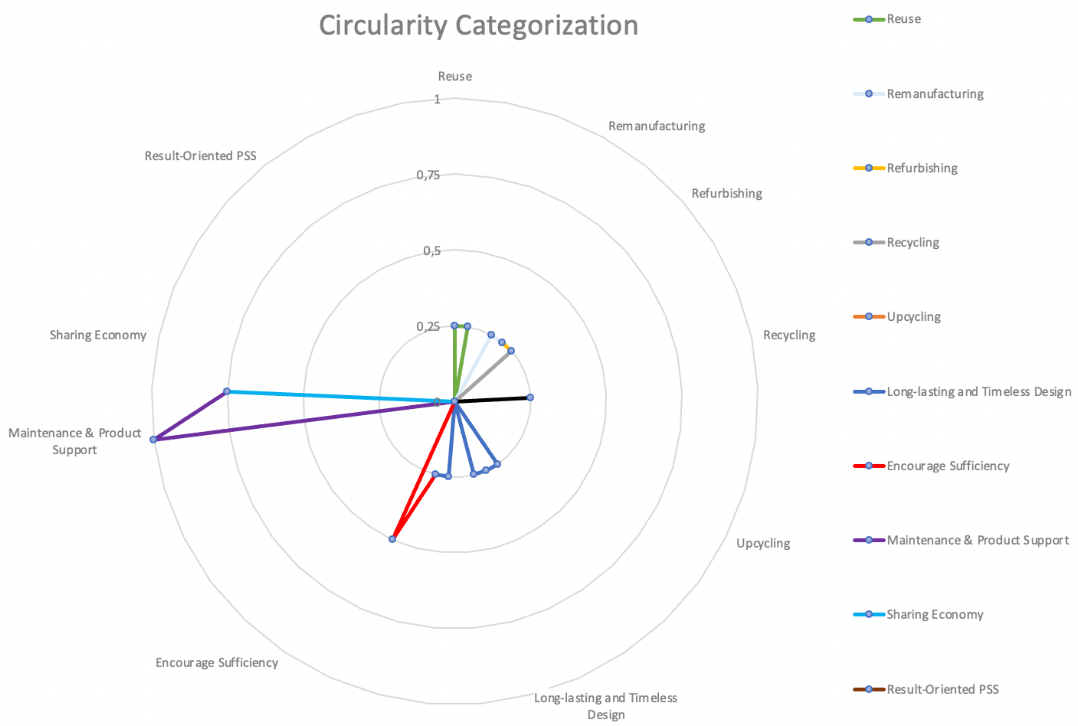

Figure 10 - Strategy's Performance

In summary, this visual analysis has confirmed that only the cycling and the extending business models are being implemented through six different strategies. Starting with the first graphic (Figure 9), is clear that the extending is the most efficient circular typology in the company's business model. In contrast with the poor performance of the cycling typology (11%), the extending had a 23% performance rate. Notice that the term "performance rate" is only evaluating the effect of the company's sustainable actions (according to the answer's classification), and is being used to compare typologies highlighting the most relevant.

The second graphic (Figure 10) was critical to identify the reuse, the remanufacturing, the refurbishing, the long-lasting and timeless design, the encourage sufficiency, and the maintenance and product support as the company's circular approaches. Additionally, the acceptance of recycled material in the production system was identified (black), however, it cannot be considered as a recycling strategy, since recycling processing is non-existent. Moreover, the results of this last graphic indicate that the "maintenance and product support" (purple), and the "encourage sufficiency" (red) strategies are the most important circular approaches in the company. The remaining strategies, which are also important for conducting a sustainable business, evidently are not as relevant (or well implemented) as the previous strategies.

4.2.2. Case Study 2

Through the examination to the initial answers, it was possible to identify six (out of twelve) circular indicators in this company's business model (Figure 11).

Circularity Identification

1. Do I extract value from an unexplored source of waste?	Yes
2. Do I allow any source of waste to initiate a new lifecycle (with or without processing)?	Yes
3. Do I take-back used materials/products/organic feedstock?	No
4. Do I strive to maintain a product in the same user for a long period?	Yes
5. Do I directly promote a sustainable and conscious consumerism?	Yes
6. Do I promote the intensification of any product's use phase?	Yes
7. Do I allow different customers to use a product without owing it?	No
8. Do I use digital platforms to facilitate the sharing of products?	No
9. Do I own the products that are shared?	No
10. Do I sell results instead of physical products?	No
11. Do I sell/provide a product's result (not a physical product), using fewer physical products?	No
12. Does my customer uses physical products?	Yes

Figure 11 - Common Criteria's Questions 2

Despite this information not being conclusive (the analysis to the specific criteria is needed), some circular characteristics are outlined. The introduction of value (extracted from wasted resource) in new lifecycles, the extension of the product's use phase, the promotion of a sustainable consumerism, and the intensification of a product's use, are probably the drivers for the company's circularity.

As the company's business model is probably highly connected to the cycling, extending and intensifying typologies, the following graphics (Figure 12 and Figure 13), presenting the results of the 37 specific questions (Appendix N), are displayed.

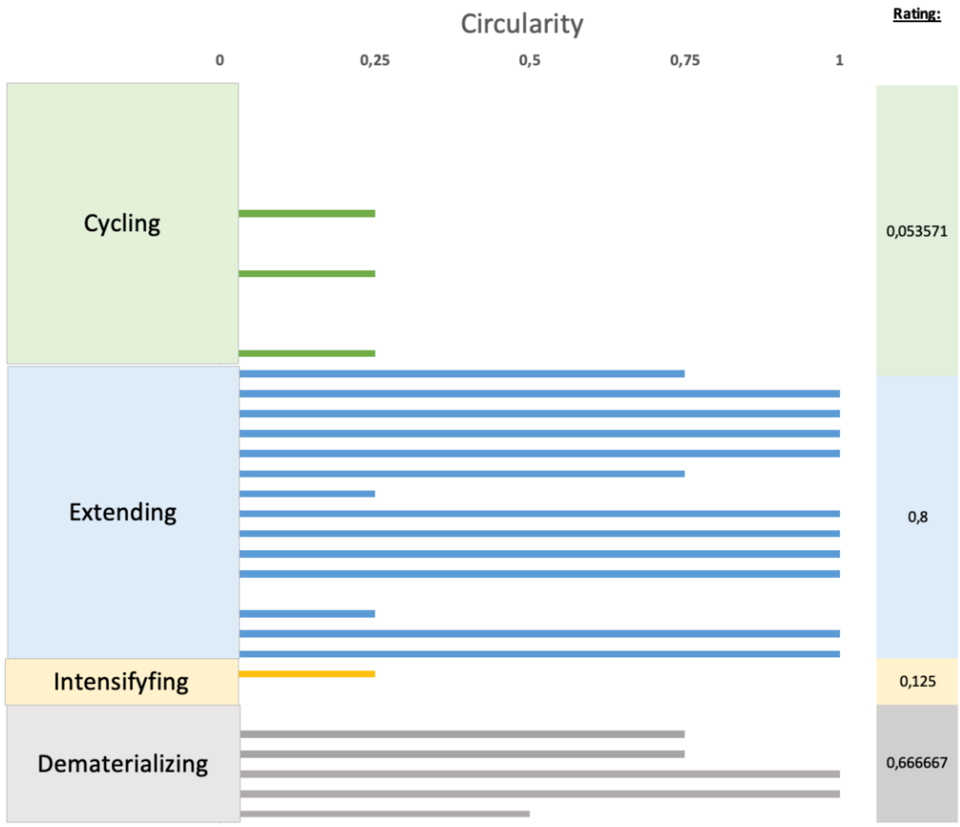

Figure 12 - Typology's Performance

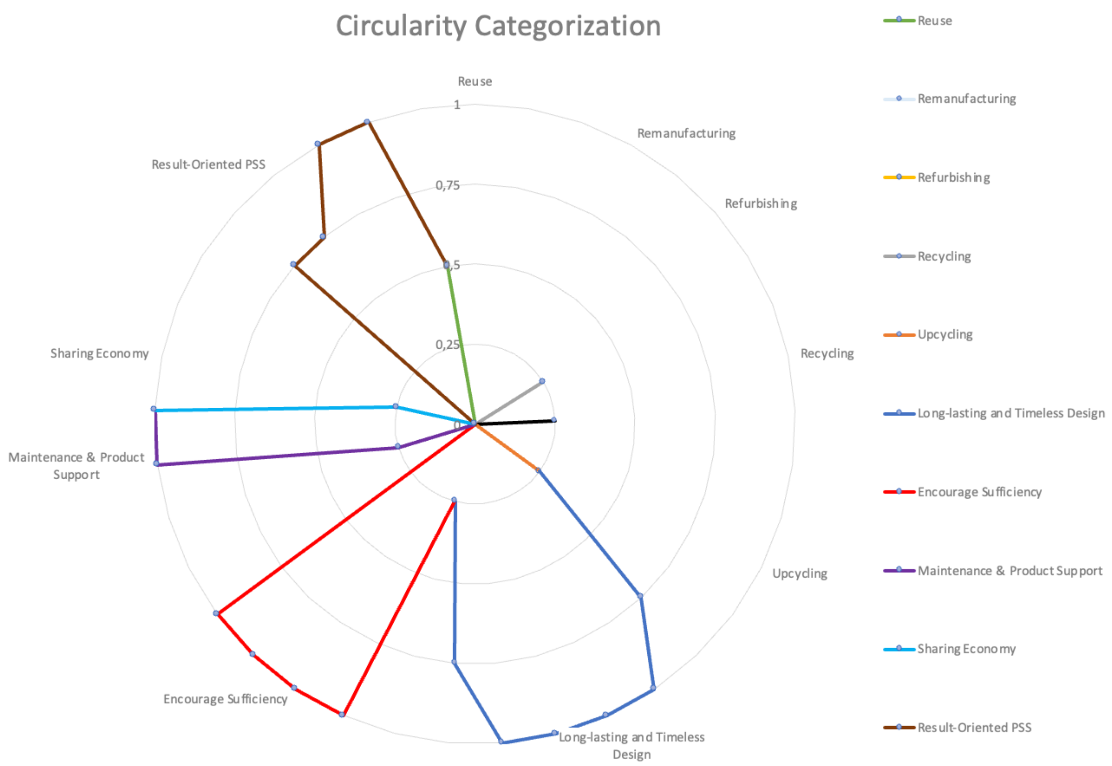

Figure 13 - Strategy's Performance

The analysis to the first graphic (Figure 12) has revealed that not three but four different circular typologies (all the CBMs) are being used. In other words, a new typology was identified (dematerializing) through the specific questionnaire, and it will be detailed in the discussion chapter.

Once again, the extending business model shows to be the most efficient typology (80%), followed by the dematerializing business model, which was only identified through the specific questions and came as a surprise, thus revealing itself as an important circular approach in this company's business model (66,7%).

The intensifying and the cycling business models are the less impacting circular typologies with a 12,5% and 5% performance rates, respectively. Despite these poor performance rates, all these circular approaches are welcome, as usually any CBM can contribute positively for the company's sustainability.

The second graphic (Figure 13) revealed that this company performs recycling procedures that can be categorized as upcycling (increasing the economic value after processing). Additionally, these results prove the positive circularity results as there are only three circular strategies not being implemented through the firm's business model (reuse, remanufacturing, and refurbishing).

In a detailed view, the “long-lasting and timeless design” (dark blue), the “encourage sufficiency” (red), the “maintenance and product support” (purple), and the “result-oriented PSS” (brown) strategies are the most relevant circular approaches in the company. The remaining approaches are also important for conducting a sustainable business, even though they are not as efficient as the previous strategies.

Finally, it is important to enhance that the manifestation of the dematerializing typology came as a surprise, showing that some answers are inconsistent and must be analysed in the discussion chapter.

5. DISCUSSION

In this chapter, a deeper analysis of the companies' results will be conducted. The objective is to interpret some of the answers' meanings in light of the given industrial context, and highlight some circularity characteristics that can be improved, if possible.

In addition to a critical examination on the companies' results, the tool's practical appliance considering the negative aspects and limitations of its utilisation will be presented. Consequently, this chapter will be divided in two different sections. In the first section, the companies' results will be discussed and deeply analysed. The second section will focus on the general aspects of the assessment tool and will outline its limitations.

5.1. Companies' Results Discussion

Before the analysis of the results linked to each company's current business model, it is important to enhance that, on the whole, the developed assessment tool led to a positive outcome. Using this tool, it was possible to identify and categorize the different companies' industrial practices, over the CBMs criteria.

This tool can be seen as an important practical step into a circular and sustainable industrial world. However, there are some technical aspects that can be upgraded, in order to provide a more complete assessment. Finally, aiming to understand which segments firms need to improve, a critical analysis to the companies' results will be presented.

5.1.1. Case Study 1

The "Madeira & Madeira, S.A." (MM) company has shown to be a circular and conscious company since it includes several cycling and extending's strategies. As this organization does not include any productive process in its business model (only buys final products to Chinese companies), it would be expected to find a modest and less positive circular result. The higher "grades" are more common on companies that treat and/or process raw resources directly, as they may have more influence on the product's destiny and efficiency. In other words, the ability to have a superior flexibility applying circular practices may mean a bigger circularity.

Nevertheless, the MM company, even without establishing a direct contact with raw resources, has been closing the resource loops (cycling) around its extending practices. In other words, apart from the extending strategies (long-lasting designs, and maintenance services), some cycling strategies, such as the reuse, remanufacturing, and refurbishing are being implemented. Furthermore, it is deducted that the cycling strategies are promoted by the company's only source of wasted or non-functional products: maintenance services.

Additionally to the maintenance services, this company recovers value from the wasted products that arrive to their service stations (instead of discarding them), allowing wasted products to serve an extra lifecycle (through reuse, remanufacturing or refurbishing). It is obvious that these cycling strategies' relevance cannot be compared to the extending strategies. Moreover, taking into consideration the fact that this company has no productive processes in practice, and there is a strong and relevant extending typology, the company's results can be taken as positive and conscious.

The positive aspects were already identified. The inclusion of cycling strategies in the extending practices increase this company's circularity level. However, as a result of the critical analysis, some improvements were found relevant for this company. Assuming that the cycling strategies cannot be scaled up (which seems unlikely), and that the use efficiency of wasted materials is on the maximum level, the analysis showed interesting data that suggests two additional options to improve the company's circularity: the intensifying and dematerializing CBMs.

Taking into consideration a circular perspective, and knowing that the value proposition of this company relies on the distribution of machines and tools (such as forestry machines and construction tools), a new possibility for the provision of such equipment is identified. A pay-per-use model could be used allowing an intensification of the product's use phase. The necessity for an intensive study on this framework is recognised, as it could easily result on a circular and economic growth, due to the convenience linked to the product use by different customers without the need for the user to own the product (pays for availability).

Additionally, aiming to substitute the physical products for results (dematerializing), the introduction of services, where the customer only pays for the result, could lead to a more conscious and professional use of products (by a professional team). This could translate into new economic revenue streams and narrowing the resource loops.

5.1.2. Case Study 2

The results of the "Sramport – Transmissões Mecânicas, LDA" company show that this company actively implements all the extending strategies. Consequently, since this company has access to different sources of wasted materials (during productive processes and maintenance services), it was disappointing not to see more cycling strategies (such as reuse, or remanufacturing) being implemented.

According to the company's answers, only the recycling strategy is being applied. The lack of the other cycling practices may be linked to the logistics' complexity of the wasted materials' exploitation (transportation, partnerships, etc…), or the technical and economic incompatibility (high investment needs). The inclusion of such cycling strategies could possibly mean a superior circularity level. However, as this study only focuses on the identification of the CBMs and not on the actual implementation of the circular typologies, a dedicated feasibility study would be necessary.

Additionally, it is important to notice that, despite only the recycling strategy being implemented, some of these processes can be labelled as upcycling (transforming waste in a product with more economic value). The acceptance of recycled materials in the productive system was identified, and it can highly contribute for an increased circularity level.

The extending and the intensifying typologies are also drivers for sustainability in this company. The intensifying has a contribution for slowing the resource loops, but it cannot be compared to the positive impact created by the extending strategies. This last typology, through its long-lasting designs, "encourage sufficiency" actions and maintenance services is the strongest and most relevant typology in the company's business model.

Despite all the circular typologies were identified, some of the "Sramport – Transmissões Mecânicas, LDA" company's answers have raised questions about their accuracy. As expected, the typologies cycling, extending, and intensifying were identified (during the initial phase of the circularity identification) and confirmed through the specific questions. However, questions were raised about a new typology (dematerializing), which was only identified during the detailed analysis of the company's circularity.

The dematerializing business model focuses on providing results through the deliverance of services, instead of physical products (where the company is the only responsible for the use of physical products), or through software capabilities that can be used by the customer to achieve the result. Since it is referred that this company's customers use their physical products (bicycles and other bicycle components), it is extremely obvious that the dematerializing is not an option in this case. Even so, and against all the predictions, several "dematerializing" practices were identified, which leads to believe that these questions were unclear and/or incomplete.

The assessment tool was developed in the light of the dematerializing definition previously presented, which was not properly explained and/or detailed to the company who tested the tool. Additionally, it was assumed that all the specific questions were clear enough to be limited to the dematerializing business model and would naturally lead to the identification and categorization of the dematerializing strategies.

Unfortunately, the results have shown that some questions do not have the minimum specificity level required to characterize this typology. In addition to the lack of support given to the company while testing this tool, the dematerializing boundaries were not correctly defined and presented through questions. For example, the question "Does my customer receive the agreed result without using physical products?" was answered with a "No, never". However, the question "Do I provide a product's result through services (even if I have to use physical products)?" was answered with a "Yes, a few always", which highlight an unclarity of the "product's result" term, and a deficient connection to the dematerializing business model.

To guarantee a reliable tool, these inconsistencies must be rectified ensuring that companies understand that there is a replacement of a physical product with services or software solutions (providing the same product's result).

5.1.3. Tool's Limitations

The analysis and discussion of the company's results led to the identification of some technical limitations in the assessment tool. Several procedural aspects were found needed or underperforming, and since there is a necessity for a reliable but independent assessment tool (without the absolute necessity for supporting companies using this tool), these aspects will be pointed out and discussed.

The most significant "weakness" is found on the tool's dematerializing questions. The concept's boundaries were left unclear through questions, and for this reason some modifications are needed. The revision must focus on the customer's use of products, ensuring that if a company reduces the consumer's use of physical products, replacing them with services or software solutions, then it is using the dematerializing circular typology.

Additionally, the need for supplementary information that, if provided by the company could be extremely relevant for the subsequent evaluation of the company's circular strategies, was considered. For example, to include conditional questions that would come as "explanations" for some company's "No, never" answers. In order to provide a simple and intuitive assessment tool, these "explanations" must be easy to provide. For example, whenever an answer is "No, never", the question "Why?" would be "unlocked", allowing the company to select one of the following options: "It's impossible", or "It could be done, but is economically risky", or "We didn't think about that". This additional information could help identify the reason for the company's lack of circular strategies, and possibly lead to new practical suggestions.

Last but not least, the cycling questions could also have an additional "side note" that could inform the origin of the wasted materials. During the result analysis, it was not possible to understand if the company was using wasted products coming from users (maintenance service points) or other industrial companies/intermediaries on the supply chain. This additional information could lead to the development of new waste streams providing a more circular approach to the company and its partners.

6. CONCLUSION

The transition to more circular business models is one of the key innovations and transformations in the management of a corporation to tackle the long and established linear economy model. As the current trends in research point out the need for companies to be able to innovate and transit their business model into a more circular one, the development of applied tools is one of the key areas considered to advance. Therefore, this study was conducted to develop a "circularity assessment tool" that could identify and categorize any company's business model. This practical tool is based upon a CBM typology framework developed through an extensive systematic literature review on the CBM literature.

In detail, this systematic literature review on the four different typologies came as a mean to collect crucial information, which enabled the comparison between typologies and the identification of circular criteria. These were treated and transformed in assessment questions, representing a key foundation for the circularity assessment tool.

The developed tool was applied in two different companies, the "Madeira & Madeira, S.A." and the "Sramport – Transmissões Mecânicas, LDA". This practical implementation served as a test to validate all the presented contents, and has shown that it is possible to identify and categorize companies' business models (over circular criteria). Through the analysis of the tool's results, it was also possible to provide comments (mainly focused on the typologies that were not being applied) and contributions on future practices that can eventually lead to a higher circularity.

Finally, by contributing to reducing the conceptual lack of clarity, a strong foundation for the practical identification and categorization of the CBMs is given. The increased simplicity in communicating which CBMs are being applied by an industrial company can ultimately lead to the development of research that will support researchers and industrial organizations with decision-making and adoption of CBMs.

6.1. Limitations and Future Work

The assessment tool presented is a strong starting point for the industrial circular transition, however some improvements are envisaged. According to the companies' results, some CBM's typologies were easily identified through the assessment questions, but others didn't. With focus on the questions developed over circular criteria, further research is needed.

The assessment tool has shown to be not assertive enough when it comes to the dematerializing questions. This concept's boundaries are still unclear so it is suggested to run practical tests of the key CBM considerations (ensuring that different industrial sectors are included), which aims to clarify the dematerializing concept, and allows the development of reliable assessment questions. The lack of explanations for some of the companies' circular practices (or absence) is also seen as a limitation of this assessment tool, so a conditional evaluation approach must be included in the assessment process. Therefore, in order to cover and understand specific industrial scenarios, future studies must be conducted to identify and find solutions for the external factors that restrain the circular practices.

This assessment tool might be the answer for the environmental pressures, but the transition into a circular industry will always depend on the capacity to treat different and specific industrial cases, which may take years to study and compile in a unique assessment tool. The ultimate objective is to provide an "all-inclusive" assessment tool, and it may require the inclusion of a global material's life cycle perspective, and a profound assessment of the existing circular options. It can eventually be made through the development of questions that characterize the companies' circular practices (including previous circular actions taken by other companies), and all stakeholders involved on the supply chain.

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APPENDIX A

Identification		
Concept	**Definition**	**Reference**
Reuse	Means the reuse of used components in the production process.	(Vimal et al., 2021)
	The use of wastewater in its crude form (i.e., without prior treatment or processing) for various purposes inside or outside the loop.	(Mbavarira & Grimm, 2021)
	The use of a product again for the same purpose in its original form or with little enhancement or change. This can also apply to what Walter Stahel calls 'catalytic goods', e.g., water used as a cooling medium or in process technology.	(MacArthur, 2013)
	Bring products back into the economy after initial use, or extend the lifespan of products and their parts (through repair, second-hand markets etc.)	(Henry et al., 2020)
	It aims to make the product/resource be used for another use cycle without reprocessing, that is, without changes. Strategies can include cascades uses, and product-service systems (PSS), which would well reflect it, hence products are leased for a period and, if in good shape by the end of the lease, those can go on another cycle.	(Salvador et al., 2021)
	Second consumer of a product that hardly needs any adaptation and works as good as new.	(Campbell-Johnston et al., 2020)
	Buy second hand (good conditions, fulfils its original function), or find buyer for your non-used produced/possibly some cleaning, minor repairs.	(Ottoni et al., 2020)
Remanufacturing	The process of restoring a non-functional, discarded, or traded-in product to like-new condition.	(Guidat et al., 2015)
	A process of disassembly and recovery at the subassembly or component level. Functioning, reusable parts are taken out of a used product and rebuilt into a new one. This process includes quality assurance and potential enhancements or changes to the components.	(MacArthur, 2013)
	The full structure of a multi-component product is disassembled, checked, cleaned and when necessary, replaced or repaired in an industrial process.	(Campbell-Johnston et al., 2020)
	Use parts of discarded product in a new product with the same function.	(Ottoni et al., 2020)
	It aims to give a used product its original or a superior performance by making any necessary adjustments. Proposed strategies would be highly dependent on the type of product under consideration, but might include dismantling and replacing parts/modules.	(Salvador et al., 2021)

Refurbishing	A process of returning a product to good working condition by replacing or repairing major components that are faulty or close to failure and making 'cosmetic' changes to update the appearance of a product, such as cleaning, changing fabric, painting, or refinishing. Any subsequent warranty is generally less than issued for a new or a remanufactured product, but the warranty is likely to cover the whole product (unlike repair). Accordingly, the performance may be less than as-new.	(MacArthur, 2013)
	Referring to large multi-component product remains intact while components are replaced, resulting in an overall upgrade of the product.	(Campbell-Johnston et al., 2020)
	Restore an old product and bring it up to date.	(Ottoni et al., 2020)
	It aims to better the aesthetics of a product, with no focus on functionality. Proposed strategies would be highly dependent on the type of product under consideration.	(Salvador et al., 2021)
Recycling	The processing of mixed streams of post-consumer products or post-consumer waste streams, including shredding, melting and other processes to capture (nearly) pure materials. Materials do not maintain any of their product structure and can be re-applied anywhere. Primary recycling occurs B2B, whereas secondary recycling takes place post municipal collection.	(Campbell-Johnston et al., 2020)
	A process of recovering materials for the original purpose or for other purposes, excluding energy recovery.	(MacArthur, 2013)
	Process of converting the deconstructed waste components into new materials and objects. It involves the reduction of the consumption of raw materials and prevents the potential waste destined to landfill.	(Bertino et al., 2021)
	It aims to make a product/resource serve another use cycle, giving it the same or a new purpose. This process can happen indefinitely until the product/resource can no longer serve the desired purpose. Recycling embeds upcycling and downcycling, and a range of activities for waste collection and reintegration (upstream and/or downstream). Products might be used for different users at the end of each of their cycles as a whole product, reaching a different market niche for example.	(Salvador et al., 2021)
	Process materials to obtain the same (high grade) or lower (low grade) quality. Consumer must dispose separately; Buy and use secondary materials.	(Ottoni et al., 2020)
	The use of treated wastewater within the same loop or in the same process;	(Mbavarira & Grimm, 2021)
	Process materials through, e.g., shredding or melting to obtain the same (upcycling) or lower (downcycling) quality.	(Henry et al., 2020)
	Supports using recycled and recyclable materials and helps to reduce the extraction of raw materials and energy resources, as mentioned above. In the circular flow, this principle appears in the last position since it is restricted by entropy's natural law, the materials' complexity, and potential for manipulation, i.e., it is not always is possible to recycle.	(Martins et al., 2021)
	Refers to the rates of both recycling and downcycling (i.e., the practice of using recycled material in an application of less value than the application).	(Zhang et al., 2020)

Upcycling	Is the creation or modification of a product from used materials, components and products which is of equal or higher quality or value than the compositional elements. It is an umbrella concept which incorporates "creative repair" (eg. Darning), reuse (e.g., redesigned and remade clothing), refurbishing (e.g., upholstery), upgrade (e.g., IKEA furniture hacks), recreation (e.g., fashion items from clothing) and more.	(Sung et al., 2017)
	Process of converting materials into new materials of higher quality and increased functionality.	(MacArthur, 2013)
	Both products and services can be enhanced. The materials may return to the chain to generate other products and services with much improved quality.	(Ottoni et al., 2020)
	Upcycling increases quality and lifetimes of materials and products, reduces wastes, creates employment opportunities, and encourages sustainable consumer behaviour. This contrasts with recycling, where value is often at least partially lost. Upcycling is regarded as a strategy that aims to reduce environmental impacts by combining circular material flows with slower throughput of products and materials and slower cycles of consumption.	(Singh et al., 2019)
	Broadly describes the conversion of low-value by products into high-value materials.	(Donner et al., 2020)
	Corresponds to a process of reuse of wastes that are converted into new products or materials with added value, whether this value has an environmental or economic dimension.	(Marques et al., 2017)
	"Upcycling" (or improved recycling) is when a product is recycled and the product obtained after recycling is of greater value than the initial one.	(Martins et al., 2021)
	Involves the conversion of waste material(s) into a more valuable product(s). This product can be purely artistic, scientific, or anything simply useful.	(Pol, 2010)
	Upcycling is the process in which used materials are converted into something of higher value and/or quality in their second life.	(Sung, 2015)
Downcycling	A process of converting materials into new materials of lesser quality and reduced functionality.	(MacArthur, 2013)
	Downcycling is recycling something in such a way that the resulting product is of lower value than the original item.	(Ortego et al., 2018)
	Concerns value or purpose lost in comparison to the original item, which indicates a loss of material/product functionality due to quality. Downcycling is usually attributed to describe a product's material properties, their level of degradation, or, in the case of metals, if they have become impure, which leads to a loss of economic value.	(Campbell-Johnston et al., 2020)
	Where the quality of the recovered material is lower.	(Lonca et al., 2020)
	When a process reduces the field of application of a product or service.	(Davidson et al., 2021)
	The practice of using recycled material in an application of less value than the application.	(Zhang et al., 2020)

	Quality loss in the recycled material compared to the virgin material is called down-cycling.	(Huysveld et al., 2019)
	The umbrella term for the reduction of material quality after recycling is known as "downcycling".	(Shamsuyeva & Endres, 2021)
Loop	To circulate resources in technical and biological cycles to prevent value destruction and enhance opportunities for value creation, retention and capture.	(De Angelis & Feola, 2020)
Closed-Loop	Where a product is reused in the same application.	(Lonca et al., 2020)
	Indicates a product can be cycled back into itself, for example, if waste PET plastic bottle flakes are continued to be produced into plastic bottles, such plastic bottles can be recycled again after scrapping.	(Gu et al., 2020)
	The inherent properties of the cycled material are not considerably different from those of the virgin material.	(Huysman et al., 2015)
	The quality of the virgin material is generally better conserved in the cycled material, which can be used in the same type of product as before	(Huysveld et al., 2019)
	Refers to product systems where there is no change in the inherent properties of the recycled material.	(La Rosa et al., 2021)
	Is the re-application of cycled plastics in products with the same or similar quality requirements.	(Wagner et al., 2020)
	Occurs when either, (i) the product is recycled at the end of its life into the same product system or (ii) the product is recycled into a different product system but the materials undergo no change in inherent properties	(Williams et al., 2010)
Open-Loop	Where a product is re-used in a different application.	(Lonca et al., 2020)
	Indicates that it can be recycled into other types of products, for example, if such resources are downcycled, further recycling is difficult, leading to the eventual incineration of the majority of such material.	(Gu et al., 2020)
	The inherent properties of the recycled material differ from those of the virgin material in a way that it is only usable for other product applications, mostly substituting other materials	(Huysman et al., 2015)
	The properties of the recycled material differ from those of the virgin material, so it is used in other product applications substituting other materials.	(Larrain et al., 2020)
	The material is recycled into other product systems and undergoes a change in its properties.	(la Rosa et al., 2021)
	Is the recycling of a material from one product system into a different product system, usually a low-value application.	(Huysveld et al., 2019)
	The recycling of a material from one product life cycle into another.	(Ekvall, 2000)

APPENDIX B

Industry Applicability		
Industry	**Case Study**	**Reference**
Fashion	Circular Economy interventions are being selectively and strategically implemented at different stages (take, make, waste) of Swedish brand's (still quite linear) supply chains. These interventions aim to reduce the environmental waste and raise social awareness to the importance of slowing the resource flow. This research concludes that despite the technological limitation, the industry is taking some steps towards circularity, and these steps may lead to the growing acceptance and implementation of sustainable practices.	(Brydges, 2021)
	In this research, several textile companies with sustainable practices were examined. These are industrial examples of the application of circular principles: • The Reuse Fabric Bank (São Paulo) takes the unused pieces, prepares them and after that process resold them. The suppliers are usually design students, sustainable brands, and artisans, and for each kilogram donated, the RFB gives credits which permit the takeout of banked fabrics. • The Brandili Textile Brand (Santa Catarina) reuses textile by partnering with factories that provide raw materials for reuse in ecological yarns production. The reverse logistic is also encouraged, and post-consumer distribution channels have enabled a reverse flow of products and materials back to the start of the production cycle. • The Insecta Shoes Brand (Porto Alegre) is a vegan company which produces footwear avoiding the use of animal input. Its products are made of used clothing or wastes from fabrics or even recycled PET. • The Ecosimple Brand (S√£o Paulo) uses recycled plastic waste, discarded clothing or even fabric scraps from clothing factories to produce 100% recycled materials (linking technology with sustainability. • Egetæpper (Denmark) uses recycled fishing nets in its carpets and has a take-back system. • The Pure Waste (Finland) uses its own fibres made from 100% recycled materials to produce t-shirts. Its designers aim to reduce the number of accessories and use strategies like replacing hang labels. • The Houdini (Sweden) collects its used products from consumers for reuse and recycling. This company also use recycled nylon and polyester recovered from PET bottles to produce outdoor clothing.	(Leal Filho et al., 2019)
	This research aimed to develop a set of indicators linking circular economy principles, CBM and the pillars of sustainability. These indicators were then applied in three Brazilian companies with different CBMs. In the textile industry, the Malwee company, after the application of the indicators, saw a reduction of 0.06kg/piece in three years, increased from 50% to 100% the use of renewable energy and recycle 100% of the textile waste.	(Rossi et al., 2020)

Plastic	This research aimed to develop a set of indicators linking circular economy principles, CBM and the pillars of sustainability. These indicators were applied in three Brazilian companies which have three different CBMs. In the plastic industry, the CIMFLEX company, after the application of the indicators, reduced the raw material by more than 75%, reduced the energy consumption by 18%, reduced the incorporation of additives in the formulations of several products and uses 100% of renewable energy.	(Rossi et al., 2020)
	In this work, the upcycling is compared with two traditional plastic waste treatments: the downcycling and the incineration with energy recovery. The objective is to compare the environmental impacts of these waste management options, and for this reason a converting company from Valencia (Spain) was assessed. The results show that, despite the upcycling is aligned with the circular economy objectives, certain assumptions made in LCA analysis led to a solution where upcycling apparently causes the highest environmental burdens. As the results go against the CE principles, the author suggests a new comparison including the target market for recycled pellets in the comparison among different recycling processes.	(Horodytska et al., 2020)
Construction	This publication aimed to investigate the improvement of the mechanical properties of recycled concrete aggregate produced by adding chopped basalt fibres (BF) to treated and untreated recycled aggregates. The results show that: • Increasing the chopped basalt fibre content or using RCA caused lower workability. • Using chopped basalt fibres minimally enhanced the compressive strength of the concrete. • Increasing the content of chopped BF improved the splitting tensile strength significantly. • Increasing the content of chopped BF improved the flexural strength significantly.	(Katkhuda & Shatarat, 2017)
	This article analyses the deconstruction potential of buildings and the strategies to apply in order to low the impacts on the urban environment. Is also defines the key points to be applied during the design and planning process regardless the type of construction and suggests common principles for deconstruction as a sustainable alternative to demolition. As the deconstruction represents a process of selective dismantling of building components, part by part and avoiding damage, the results of this study suggest that some principles must be considered in the design phase of a construction project. Minimize the number of components; Use of modular components; Use of prefabricated elements; Use of reusable materials; Use of eco-compatible materials; Get access to instructions about reuse and recycling; These are some of the principles.	(Bertino et al., 2021)
	This study proposes a set of managerial practices in connection with relevant internal and external factors for creating value within a CBM. These practices were used by a small medium-sized company operating in the building industry. Some of these practices include, innovating the process to reduce energy consumption, design for biodegradability, train mor than 1000 loggers from 250 suppliers regarding sustainability and waste material specifications. The result of this study proves that circular economy in the building sector requires business model adaptability in terms of the value creation process. It is needed to shape a CBM based on internal and external factors, regenerate natural waste through managerial practices, and sustainable behaviours among supply chain actors.	(Ünal et al., 2019)

Electronic		This research aimed to develop a set of indicators linking circular economy principles, CBM and the pillars of sustainability. These indicators were applied in three Brazilian companies which have three different CBMs. In the electronic industry, the HP Brazil company, after the application of the indicators, saved about 7500 trees by reusing pallets from 2015 to 2017, decreased in 8% the intensity of use of materials for personal systems in 2017, decreased in 6% the intensity of use of materials for printers in 2017 compared to 2016, decreased the water footprint by 1% in 2017 compared to 2016, decreased the power consumption of HP's personal system products by 43% on average. Also 50% of the energy used in global operations comes from renewable sources and no toxic substances are used. All the company's waste is recycled, and the recycled plastic resin is in average 15% to 30% cheaper than virgin plastic resin.	(Rossi et al., 2020)
		This study assessed the degree of change in product attributes commonly used as inputs for LCA for a common consumer electronic product: laptop computers. The results show some reduction in weight was accomplished in large part due to a shift from plastics to light metals, however the overall decrease in product weight is less than 2% per year. It also proves that some amount of functional dematerialization is occurring at the component level, however for a mature product like the laptop computer, it may be limited by lock-in to a 'typical product' form factor.	(Kasulaitis et al., 2015)
		This research assessed the environmental and economic performance of recovering metal elements (aluminium (Al), copper (Cu), gold (Au), lead (Pb), nickel (Ni), silver (Ag), tin (Sn), zinc (Zn), and iron (Fe)) and two non-metal materials (resin and glass-fibre) from the waste printed circuit boards (PCBs). Data were collected from recycling plants in Taichung City, Taiwan, and the results show that despite the recycling had a net positive economic benefit, only the recycling of Au from the waste PCBs is beneficial for the human recyclers.	(Pokhrel et al., 2020)
Manufacturing	Glass Industry	In this study, the environmental impacts of the life cycle of glass bottles used for mineral water have been assessed as a function of the number of uses. One of the objectives of this publication was to identify the impact contribution of the main stages (RBs production and end of life, RBs reconditioning, and RBs distribution) in order to provide companies with indications for a more sustainable management. Italian mineral water bottle were studies and the results show that the impacts of the RBs system are mainly associated to the distribution stage, in particular to the transportation of the bottles from the bottling plant to the local distributor. It is also possible to conclude that comparing to the single-use bottles system, for a local market (within 200km), the use of refillable bottles is by far preferable just starting from two deliveries. For a 400km distance, at least four uses of the refillable bottles are required to achieve better environmental performances. For 800km or more, the RBs system is not convenient.	(Tua et al., 2020)
	Metal Industry	In this study, seven scenarios, comprising specific systemic changes, are compared to the current aluminium recycling practice of the used beverage can in the UK. The efficiency of any aluminium recycling system can be characterized by the totality of metal recovery. However, in most cases metals are recycled in open recycling loop where dilution and quality losses occur. The results prove the need for technology able to improve the waste quality and a consequently reduced impact on abiotic resource depletion.	(Stotz et al., 2017)
Water		The aim of this study is to determine what the economic and operational system effects of CE are on water utilities, informing them of CE's potential to change their business operations and business model while highlighting its associated challenges. These approaches have the potential to support lower operational costs through network efficiencies and boost revenue generation through new service offerings and cascading of reused water and secondary resource products.	(Mbavarira & Grimm, 2021)

APPENDIX C

Identification		
Concept	**Definition**	**Reference**
Long-Lasting and Timeless Design	This strategy is concerned with creating long-life products and extending the product's life, once in use.	(N. M. P. Bocken et al., 2016)
	Long-life product design is supported by design for attachment and trust (i.e., emotional durability) and reliability and physical durability. Design for product life extension can be facilitated through design for: maintenance and repair; upgrading and upgradability; standardization and compatibility; and dis-/reassembly.	(Chapman, 2015; Linton & Jayaraman, 2005; Moss, 1985)
	"Designing for attachment and trust" refers to the creation of products that will be loved, liked or trusted longer.	(Chapman, 2015)
	"Design for durability" relates to physical durability, for example, the development of products that can take wear and tear without breaking down. Material selection for durability is an important part of the design process.	(N. M. P. Bocken et al., 2016)
	"Design for reliability" refers to designing for a high likelihood that a product will operate throughout a specified period without experiencing a chargeable failure, when maintained in accordance with the manufacturer's instructions.	(Moss, 1985)
	"Design for Maintenance and Repair" enables products to be maintained in tip-top condition.	(N. M. P. Bocken et al., 2016)
	"Design for upgradability and adaptability" is designing products to allow for future expansion and modification.	(Linton & Jayaraman, 2005)
	"Design for standardization and compatibility" is about creating products with parts or interfaces that fit other products as well.	(Bakker et al., 2014)
	"Design for dis- and reassembly" is about ensuring that products and parts can be separated and reassembled easily.	(Bakker et al., 2014)
Encourage Sufficiency	This strategy is about make products last longer, however a "non-consumerist" approach to sales" is emphasized.	(N. M. P. Bocken & Short, 2016)
	This strategy includes solutions that actively seek to reduce end-used consumption, in particular through a non-consumerist approach to promotion and sales (e.g., not overselling, no sales commissions).	(N. M. P. Bocken et al., 2014)
	The main principle of "encourage sufficiency" is to make products that last and allow users to hold on to them as long as possible through high levels of service. The manufacturer creates high-quality durable products and offers high levels of service. In addition, the company takes a non-consumerist approach to selling – fewer high-end sales rather than "built-in obsolescence".	(N. M. P. Bocken et al., 2016)

Maintenance and Product Support	Value creation and delivery focuses on durable product design and high customer service levels. This strategy is concerned with the extension of the use period of goods through the introduction of service loops to extend product life, including maintenance, repair, and technical upgrading.	(N. M. P. Bocken et al., 2016)
	Maintenance is the performance of inspection and/or servicing tasks (technical, administrative, and managerial) to retain the functional capabilities of a product.	(Linton & Jayaraman, 2005)

APPENDIX D

Industry Applicability		
Industry	**Case Study**	**Reference**
Textile	Patagonia is an outdoor clothing brand and has long supported activist groups to pursue their environmental causes and has worked to integrate sustainability initiatives throughout their business. Advertisements augment these initiatives to create environmental awareness among their consumers. This organisation is known as a "premium brand" in the way that it includes high quality and in its restricted production volumes. A famous marketing action, encouraging customers to make things last, was the "Don't buy this jacket", however the overall sales did rise.	(N. M. P. Bocken & Short, 2016; Chouinard, 2016; Chouinard & Stanley, 2013)
Textile	Cucinelli is an Italian fashion luxury brand. In order to make its products last, this company is based on premium pricing, offering customers exclusive and high-quality products hand-made in Italy. The timeless design (without brand logos), the natural colors and materials that can be reused and the artisanal production creates high social and customer value with low environmental impact.	(N. M. P. Bocken & Short, 2016)
Manufacturing	Vitsoe is a premium, high service and quality brand. This furniture manufacturer's vision is to produce furniture that last as long as possible, by producing products that are durable, easily extendable, and reparable. Vitsoe have already disassociate themselves with fast fashion, and through product redesign it is expected a significant reduction in consumption (Evans et al., 2009). The main objective is to build trust and long-term relationships with customers and because of that, Vitsoe only sells its products directly in its physical and online stores, or by phone (to keep the personal contact with the customer and control the sales).	(N. M. P. Bocken & Short, 2016; Evans et al., 2009)
Manufacturing	The German company Miele is an example of the "Long-lasting and Timeless Designs" and "Encourage Sufficiency". Miele produces high-quality washing machines that can last for twenty years. Despite the modest growth, Miele refuse to outsource to low-cost suppliers and still provide optimal service life, design for upgradability, products with low energy consumption and low resource input.	(N. M. P. Bocken et al., 2016)
Manufacturing	The Swiss company Patek Philip, known for producing luxury watches, guarantee the quality and the timeless designs in its upmarket mechanical watches. This organisation was also responsible for an iconic marketing campaign with the slogan "you never actually own a Patek Philip. You merely look after it for the next generation", which underline the durability of its products encouraging its customers to make a responsible and sustainable use of their pieces.	(Geissdoerfer et al., 2020)
Manufacturing	The British multinational company Unilever also encourage sufficiency by providing information to its customers. The consumers are informed about the benefits of using washing detergents at low temperatures and encouraged to take shorter showers.	(Rubik et al., 2009)

	The mobile phone manufacturer Fairphone goes against the trends in smartphone design that is not easily reparable, by creating an easy-to-disassemble and repair phone.	(Pesce, 2015)

APPENDIX E

Identification		
Concept	**Definition**	**Reference**
Sharing Economy	The sharing economy generates abundance by enabling access to underutilized assets and by lowering transaction costs, thus facilitating exchanges via a platform logic which in turn enables unprecedented scalability.	(Acquier et al., 2017)
	Refers to the situation in which institutions (or individuals) with unused resources transfer the right to use goods to others through a third-party platform.	(Zhu & Liu, 2021)
	Collaborative consumption, often associated with the sharing economy, takes place in organized systems or networks, in which participants conduct sharing activities in the form of renting, lending, trading, bartering, and swapping of goods, services, transportation solutions, space, or money.	(M Möhlmann, 2015)
	Access-based consumption, defined as transactions that can be market mediated but where no transfer of ownership takes place	(Bardhi & Eckhardt, 2012)
	The sharing economy is an umbrella term for a great variety of organisational models that are transforming marketplaces and cityscapes, where goods and services, skills and spaces are shared, exchanged, rented or leased.	(Mont et al., 2020)
	Sharing economy is here defined as a two-sided online platform that allows people to exchange directly underutilized capacity with each other. This definition includes most self-proclaimed sharing platforms, such as online sales marketplaces (eBay, Amazon and Taobao), short-term rentals (Airbnb, office sharing, car sharing), and service sharing (Uber, Blablacar, TaskRabbit).	(Hou, 2018)
	Sharing Economy describe different organizations that connect users/tenants and owners/suppliers through Consumer-to-Consumer (C2C) (e.g. Uber, Airbnb) or Business-to-Consumer (B2C) platforms (e.g. Zipcar, WeWork) based on the exchange, sharing, rental of goods, resources or services, usually between strangers seeking to meet latent needs.	(Belk, 2014)
	The sharing economy enables the use of expensive physical assets without a need to purchase. Is a way of sharing a resource (know-how, assets, or information) safely, with or without payment, with other people through a digital platform. Important aspects of this definition are that access to resources is temporary and that sharing happens relatively safely.	(Räisänen et al., 2021)
	Sharing economy refers to the situation in which in-situations or individuals with idle resources transfer the right to use goods to others through a third-party platform for payment. The owners gain value by sharing their idle resources, while the demanders obtain goods at a lower price, thus improving the utilization rate of goods.	(Zhu & Liu, 2021)

APPENDIX F

Industry Applicability		
Industry	**Case Study**	**Reference**
Lodging	The Airbnb company is providing a service that connects travellers with homeowners who have rooms available for rent. Using a C2C model, the room is the intensified physical asset, and it is seen as a convenient solution by combining functionality with lower up-front costs (comparing to a hotel reservation or buying a house).	(Zhu & Liu, 2021)
Transportation	Uber is a company that, through a C2C model, can be perceived as creating value for customers by providing an advanced business model that is better, faster, and cheaper than those of traditional transport companies. It is impossible not to touch on the fact that these company is also a prime example of a collaborative consumption service, fulfilling the user's need without increasing the demand for new products (cars, in this case).	(Wieland et al., 2017)
	The GoMore company provides three different sharing economy solutions (in the same digital platform): business-to-consumer (B2C) leasing, peer-to-peer (P2P) car rental, and ridesharing (or carpooling). All these solutions provide access instead of ownership for a variety of users.	(Guyader & Piscicelli, 2019)
	Bike-sharing services have become increasingly popular in recent years. The objective of this study was to analyze how firms achieve sustainability through innovating on business models to adapt to business environments. Two case-studies were analyzed: Mobike UK and Mobike China. The results show that sharing economy provides sustainability, however, to achieve sustainable development, firms need to properly understand its business environment. Additionally, the sharing economy needs adequate and efficient government supervision to survive and become sustainable - especially in developing countries.	(Gao & Li, 2020)
Manufacturing	Attempting to analyze the material and climate change impact related to the adoption of circular approaches, two circular business models were used on washing machines: the product leasing (with lifetime extension) and the pay-per-wash business models. The results show that these sustainable approaches perform significantly better than the regular ownership model, and that material uses could see considerable reductions (if adopted successfully).	(Sigüenza et al., 2021)
	HOMIE is a new venture which started in 2016. This company provides consumers access to high quality appliances while stimulating sustainable consumption patterns through a pay per use business model. HOMIE installs washing machines in customer's home for free, and they only pay each time they use the product. To stimulate a sustainable consumption, HOMIE charges a bigger value for a high temperature wash than a low temperature one. Moreover, the pay per wash strategy aims to make people more conscious about often they wash.	(N. Bocken et al., 2019)

APPENDIX G

Identification		
Concept	**Definition**	**Reference**
Result-Oriented Product Service System	A result- oriented PSS is a business model that mainly focuses on a service with the product. In this type of business, before service offering, providers and receivers first contract a Service Level Agreement that states customer requirements. The providers then use any means to satisfy the customer's requirements.	(Muto et al., 2016)
	Result-oriented PSS emphasizes the customers' service experience. The entire delivery process can be seen as a service process, while physical products, hardware resources, human resources and equipment facilities are included in a series of sub-processes.	(Geng et al., 2019)
	In Result-Oriented PSS, however, services can replace the product to provide desired results to customers. Therefore, Result-Oriented PSS has the highest level of servicing, in which value creation mainly comes from the service content.	(Yang et al., 2010)
	Result-oriented PSS: selling a result or capability instead of a product (e.g., Web information replacing directories, selling laundered clothes instead of a washing machine). Companies offer a customized mix of services where the producer maintains ownership of the product and the customer pays only for the provision of agreed results.	(Baines et al., 2007)
	The circularity of products and consequently the resource-use efficiency can be achieved through implementation of result-oriented PSS, because the customer will pay only for the provision of desired results, which is also considered as a service, and not for the consume nor product ownership.	(Michelini et al., 2017)
	Sharing economy refers to the situation in which in-situations or individuals with idle resources transfer the right to use goods to others through a third-party platform for payment. The owners gain value by sharing their idle resources, while the demanders obtain goods at a lower price, thus improving the utilization rate of goods.	(Zhu & Liu, 2021)

APPENDIX H

Industry Applicability		
Industry	**Case Study**	**Reference**
Manufacturing/Chemical	The substitution of pesticides for services that control the rate of harvest loss by destructive insects.	(Kanda & Nakagami, 2006)
	Chemical suppliers are paid for chemical services rather than for the volume of the chemical provided.	(Stoughton & Votta, 2003)
	Material efficiency services (chemicals) in which the provider is responsible for material.	(Halme et al., 2007)
Machine Tool	Vertical integration of an ultra-precision, free form grinding machine is runed by the provider	(Azarenko et al., 2009)
Construction	Performance-based construction in which the provider and customer agree upon the outcome	(Gruneberg et al., 2007)
Household	Cleaning services, where the performance is agreed upon without defining the physical product(s) used to reach the outcome.	(Reim et al., 2015)
Defence	Service contracts that ensure the availability of certain defence equipment.	(Ng et al., 2009)

APPENDIX I

Circular Business Model		Technical Variables			Sustainable Variables								
					Economic		Environmental				Social	
		Industrial processes or technology required?	Process complexity	Logistic complexity (outside the factory floor)	Investment needs	What are the revenue streams?	Material consumption	Energy consumption	Water consumption	Avoids landfill?	Need for partnerships?	Promotion of sustainable consumerism
Cycling	Reuse	Yes	Very Low	High	Low	- Savings with reduced costs for resource input. - Additional sales.	-	-	Low	Yes	Yes	High
	Remanufacturing	Yes	Medium/ High	High	High		Medium	Medium	Medium	Yes	Yes	Medium

	Refurbishing	Yes	Low	High	Medium		Low	Low	Low	Yes	Yes	Medium
	Recycling	Yes	Very High	Very High	Very High		High	High	High	Yes	Yes	Medium
Extending	LL & Timeless Design	Yes	High	Medium	High	- Premium margins or high-level servicing. - Additional sales due to customer loyalty.	Medium	Medium	Medium	No	Yes	Low
	Encourage sufficiency	No	-	Low	Medium		-	-	-	No	Yes	Very High

	Maintenance & Product support	Yes	Low	Medium	Low		Low	Low	Low	No	Yes	Medium
Intensifying	Sharing Economy	No	-	Medium	High	Recurrent revenues streams from services	Low	-	-	No	Yes	Medium
Dematerializing	Result-oriented PSS	Depends on the result agreement or company	-	Medium	Depends on the result agreement	Recurrent customer payments, based on the result agreement	Low	Low	Low	-	Yes	Medium

APPENDIX J

When?	Questions	Objectives
Before	Which raw materials do I buy?	Understand the resource needs that a company have to produce the value they want to sell.
	How do I buy?	Understand if there is any inherent logistics to the resource acquisition.
	To whom do I buy from?	Understand who the key partnerships and/or suppliers of the company are.
During	What do I sell?	Understand what is the value that the company produce.
	How do I produce what I sell?	Understand if there is any need for industrial processes and/or technology.
After	How do I sell?	Reveal how the value is delivery and what channels are used to link the value to the client.
	To whom do I sell?	Underline the “target audience” of the company.

APPENDIX K

CBM	Criteria	Questions	Objectives
Cycling	Recovering value from waste	Do I extract value from an unexplored source of waste?	Understand if the company is fulfilling the cycling criteria.
	Closing the resource loop	Do I allow any source of waste to initiate a new lifecycle (with or without processing)?	
	Reverse logistics	Do I take-back used materials/products/organic feedstock?	
Extending	Providing durable and functional products	Do I strive to maintain a product in the same user for a long period?	Understand if the company is fulfilling the extending criteria.
	Promoting sustainable behaviour from the customer	Do I directly promote a sustainable and conscious consumerism?	
Intensifying	Product's use phase intensified	Do I promote the intensification of any product's use phase?	Understand if the company is fulfilling the intensifying criteria.
	Functionality access and cost convenience	Do I allow different customers to use a product without owing it?	
	Company's role	Do I use digital platforms to facilitate the sharing of products?	Receiving additional information about the company's role
		Do I own the products that are shared?	
Dematerializing	Replacement of physical products for results	Do I sell results instead of physical products?	Understand if the company is fulfilling the dematerializing criteria.
	Reduction of the need for physical products	Do I sell/provide a product's result (not a physical product), using fewer physical products?	
	No need for the customer to use products.	Does my customer use physical products?	

APPENDIX L

Strategy	Criteria	Questions	Objectives
Reuse	Reuse of parts or products	Do I reuse parts or products, without any significant intermediary process, in the same and/or different application?	Comprehend if there is significant changes on the product.
	Re-sell products, without any significant modification in it	Do I take back used products and re-sell them, without any significant modification in it?	Understand if it is collecting wasted products to reuse.
	Transfer products without significant processing	Do I transfer (without selling) wasted products to a new final customer, without making any significant modification in it?	Understand if it reuses products, even if it means no economic return.
Remanufacturing	Processing at the component level	Do I conduct recovery and disassembly processes at the subassembly or component level, allowing a wasted product to serve another lifecycle?	Evaluate if it harnesses the functional material of a wasted product.
	Process that leads to a like-new condition	Do I restore a discarded product into a "like-new" condition?	Comprehend if it is applying processes that transform wasted products into "as new" products.
Refurbishing	Superficial and "aesthetic" changes	Do I implement "aesthetic" changes in a wasted product, such as cleaning, changing fabric, painting, or refinishing, so that I can return a product to an acceptable working condition?	Understand if it returns products to a good working condition

Recycling	Recover resources through complex processing of waste	Do I process wasted streams to recover minerals or raw materials?	Understand if it uses any industrial process to recover resources.
		Do I process wasted streams to recover thermal energy or electric energy?	
		Do I process wasted streams to recover water?	
	-	Do I use recycled materials in my production process?	Understand if it uses recycled resources in the productive system.
		Do I use recycled energy in my production process?	
		Do I use recycled water in my production process?	
Upcycling	Higher physical proprieties	Does the resulting product of a waste processing maintain or improves its physical proprieties?	Understand if its processes result in products with more value.
	Higher economic value	Does the resulting product of a waste processing have more economic value, comparing to the original one (before the processing procedure)?	
Long-lasting and Timeless Design	Provide emotional value	Do I create products that will be loved or trusted longer (with high emotional value)?	Understand if it is using any "long-life product design" technic.
	Provide "premium" materials	Do I select "premium" materials/resources in order to provide products with a long lifetime (rejecting low-quality suppliers)?	
	Provide reliability	Do I create products that are highly reliable and likely to operate throughout a specified period without experiencing a chargeable failure?	
	Facilitate the maintenance of the products	Do I enable an easy maintenance (or repairment) of the products I create through design?	Understand if it is using any technic of design for "product life extension".
	Facilitate the upgrade of the products	Do I allow future expansion and/or modification of the products I create, through design?	
	Providing "easy to find" parts	Do I create products with standard parts that fit other products and systems as well?	
	Facilitate the substitution of parts	Do I ensure that the parts of my product can be easily separated and reassembled?	

Encourage Sufficiency	Promotion of ecological marketing actions	Do I build marketing actions that focus on educate the customer on how to give a proper use to products?	Understand if it is directly awakening the customer.
		Do I build marketing actions that focus on consuming less?	
	Provide the product's environmental cost	Do I expose a bill of materials along with the products I sell or provide?	
		Do I provide resource consumption information along with the products I sell or provide?	
	Reduce the promotion to sales	Do I avoid paying sales commissions to my employees?	Understand if it promotes a sustainable and conscious consumerism
		Do I avoid selling my products with discounts?	
Maintenance & Product Support	Provide maintenance and repair services	Do I provide maintenance and repair services to my client's products?	Understand if it avoids the product's loss of functionality, allowing not to discard a product.
	Provide convenient programs (and/or guarantee contracts)	Do I provide extended guaranties or insurance programs along with my products?	Understand if it allows the customer to have an easy and convenient solution when the product fails.
Sharing Economy	Provide functionality to different customers	Do I allow different customers to use and share my products, for free?	Comprehend if it promotes the intensification of a product even if it means no economic value.
	Selling availability, instead of ownership	Do I sell the product's availability instead of ownership, allowing different customers to use the same product?	Understand if it allows different customers to use a product for an affordable price.

Result-Oriented PSS	Avoid the customer's use of products	Does my customer receive the agreed result without using physical products?	Understand if it avoids the customer use of physical products.
	Replacement of products for services	Do I provide a product's result through services (even I have to use physical products)?	Understand how it delivers the product's result.
	Replacement of products for software	Do I provide a product's result through a software solution (that my customer can use)?	
	Ensure professional use of products	Do I provide campaigns of training with a sustainable perspective to all the staff that provide the service?	Understand if it promotes a professional use of products.
	Ensure efficient/ professional equipment	Do I use efficient equipment or solutions to provide results (not physical products), with minimal environmental impact?	Understand if it uses professional and efficient equipment.
	Avoid the replacement of the service for customer's product use	Is it hard for a customer to, by himself and through the use of products, achieve the same result quality that I provide?	Understand the customer acceptance and the service vulnerability.

APPENDIX M

1. Do I reuse parts or products, without any significant intermediary process, in the same and/or different application?	Yes, a few sometimes
2. Do I take back used products and re-sell them, without any significant modification in it?	Yes, a few sometimes
3. Do I transfer (without selling) wasted products to a new final customer, without making any significant modification in it?	No, never
4. Do I conduct recovery and disassembly processes at the subassembly or component level, allowing a wasted product to serve another lifecycle?	Yes, a few sometimes
5. Do I restore a discarded product into a "like-new" condition?	Yes, a few sometimes
6. Do I implement "aesthetic" changes in a wasted product, such as cleaning, changing fabric, painting, or refinishing, so that I can return a product to an acceptable working condition?	Yes, a few sometimes
7. Do I process wasted streams to recover minerals or raw materials?	No, never
8. Do I process wasted streams to recover thermal energy or electric energy?	No, never
9. Do I process wasted streams to recover water?	No, never
10. Do I use recycled materials in my production process?	Yes, a few sometimes
11. Do I use recycled energy in my production process?	No, never
12. Do I use recycled water in my production process?	No, never
13. Does the resulting product of a waste processing maintains or improves its physical proprieties?	No, never
14. Does the resulting product of a waste processing have more economic value, comparing to the original one (before the processing procedure)?	No, never
15. Do I create products that will be loved or trusted longer (with high emotional value)?	No, never
16. Do I select "premium" materials in order to provide products with a long lifetime (rejecting low-quality suppliers)?	Yes, a few sometimes
17. Do I create products that are highly reliable and likely to operate throughout a specified period without experiencing a chargeable failure?	Yes, a few sometimes
18. Do I enable an easy maintenance (or repairment) of the products I create through design?	Yes, a few sometimes
19. Do I allow future expansion and/or modification of the products I create, through design?	No, never
20. Do I create products with standard parts that fit other products and systems as well?	Yes, a few sometimes
21. Do I ensure that the parts of my product can be easily separated and reassembled?	Yes, a few sometimes
22. Do I build marketing actions that focus on educate the customer on how to give a proper use to products?	Yes, all of them sometimes
23. Do I build marketing actions that focus on consuming less and using products longer?	No, never
24. Do I expose a bill of materials along with the products I sell or provide?	No, never
25. Do I provide resource consumption information along with the products I sell or provide?	No, never
26. Do I avoid paying sales commissions to my employees?	No, never
27. Do I avoid selling my products with discounts?	No, never
28. Do I provide maintenance and repair services to my client's products?	Yes, all of them always
29. Do I provide extended guaranties or insurance programs along with my products?	Yes, a few always
30. Do I allow different customers to use and share my products, for free?	No, never
31. Do I sell the product's availability instead of ownership, allowing different customers to use the same product?	No, never
32. Does my customer receive the agreed result without using physical products?	No, never
33. Do I provide a product's result through services (even if I have to use physical products)?	No, never
34. Do I provide a product's result through a software solution (that my customer can use)?	No, never
35. Do I provide campaigns of training with a sustainable perspective to all the staff that provide the service?	No, never
36. Do I use efficient equipment or solutions to provide results (not physical products), with minimal environmental impact?	No, never
37. Is it hard for a customer to, by himself and through the use of products, achieve the same result quality that I provide?	No, never

APPENDIX N

1. Do I reuse parts or products, without any significant intermediary process, in the same and/or different application?	No, never
2. Do I take back used products and re-sell them, without any significant modification in it?	No, never
3. Do I transfer (without selling) wasted products to a new final customer, without making any significant modification in it?	No, never
4. Do I conduct recovery and disassembly processes at the subassembly or component level, allowing a wasted product to serve another lifecycle?	No, never
5. Do I restore a discarded product into a "like-new" condition?	No, never
6. Do I implement "aesthetic" changes in a wasted product, such as cleaning, changing fabric, painting, or refinishing, so that I can return a product to an acceptable working condition?	No, never
7. Do I process wasted streams to recover minerals or raw materials?	Yes, a few sometimes
8. Do I process wasted streams to recover thermal energy or electric energy?	No, never
9. Do I process wasted streams to recover water?	No, never
10. Do I use recycled materials in my production process?	Yes, a few sometimes
11. Do I use recycled energy in my production process?	No, never
12. Do I use recycled water in my production process?	No, never
13. Does the resulting product of a waste processing maintains or improves its physical proprieties?	No, never
14. Does the resulting product of a waste processing have more economic value, comparing to the original one (before the processing procedure)?	Yes, a few sometimes
15. Do I create products that will be loved or trusted longer (with high emotional value)?	Yes, a few always
16. Do I select "premium" materials in order to provide products with a long lifetime (rejecting low-quality suppliers)?	Yes, all of them always
17. Do I create products that are highly reliable and likely to operate throughout a specified period without experiencing a chargeable failure?	Yes, all of them always
18. Do I enable an easy maintenance (or repairment) of the products I create through design?	Yes, all of them always
19. Do I allow future expansion and/or modification of the products I create, through design?	Yes, all of them always
20. Do I create products with standard parts that fit other products and systems as well?	Yes, a few always
21. Do I ensure that the parts of my product can be easily separated and reassembled?	Yes, a few sometimes
22. Do I build marketing actions that focus on educate the customer on how to give a proper use to products?	Yes, all of them always
23. Do I build marketing actions that focus on consuming less and using products longer?	Yes, all of them always
24. Do I expose a bill of materials along with the products I sell or provide?	Yes, all of them always
25. Do I provide resource consumption information along with the products I sell or provide?	Yes, all of them always
26. Do I avoid paying sales commissions to my employees?	No, never
27. Do I avoid selling my products with discounts?	Yes, a few sometimes
28. Do I provide maintenance and repair services to my client's products?	Yes, all of them always
29. Do I provide extended guaranties or insurance programs along with my products?	Yes, all of them always
30. Do I allow different customers to use and share my products, for free?	Yes, a few sometimes
31. Do I sell the product's availability instead of ownership, allowing different customers to use the same product?	No, never
32. Does my customer receive the agreed result without using physical products?	No, never
33. Do I provide a product's result through services (even if I have to use physical products)?	Yes, a few always
34. Do I provide a product's result through a software solution (that my customer can use)?	Yes, a few always
35. Do I provide campaigns of training with a sustainable perspective to all the staff that provide the service?	Yes, all of them always
36. Do I use efficient equipment or solutions to provide results (not physical products), with minimal environmental impact?	Yes, all of them always
37. Is it hard for a customer to, by himself and through the use of products, achieve the same result quality that I provide?	Yes, all of them sometimes