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INTEGRATING KEY PERFORMANCE INDICATORS, BUSINESS MODELS AND CIRCULAR ECONOMY PRACTICES: OPPORTUNITIES AND CHALLENGES OF A COMPREHENSIVE FRAMEWORK

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ABSTRACT

Nowadays, the growing importance of circular and sustainable practices is driving companies to reconsider their traditional linear business models and explore circular business models. For these models to be effective and efficient, there is a need to integrate Key Performance Indicators (KPIs) with circular economy practices. This integration should occur not only at the individual organization level but also across each of the four levels of circular economy measurement—nano, micro, meso, and macro—while also considering the relationships between these levels.

The purpose of this thesis is to propose a tool for measuring circularity that enables the alignment of KPIs with circular strategies and business logics of companies and the integration of KPIs at different levels of circular economy. The need to create such a tool arises from gaps identified in the existing literature and in the measurement models analyzed during the research.

Keywords: Circular Economy; Performance Measurement; Key Performance Indicators; Sustainability; Business Models; Multi-Level Integration

ABSTRACT

Oggigiorno, l'aumentare dell'importanza delle pratiche circolari e sostenibili sta spingendo le aziende a riconsiderare i loro tradizionali modelli di business lineari e ad esplorare modelli di business circolari. Questi modelli, affinché siano efficaci ed efficienti, necessitano di essere integrati con degli indicatori chiave di performance (KPIs). Tale integrazione dovrebbe avvenire non solo a livello della singola impresa, bensì nell'ambito di ognuno dei quattro livelli di misurazione di economia circolare, ovvero nano, micro, meso e macro, considerando inoltre le relazioni che intercorrono tra questi.

La presente tesi ha lo scopo di proporre uno strumento per la misurazione della circolarità che consenta l'allineamento dei KPIs con le strategie circolari e le logiche di business delle aziende, nonché l'integrazione di KPIs relativi ai diversi livelli di misurazione dell'economia circolare. La necessità di creare tale strumento deriva da alcune lacune riscontrate all'interno della letteratura esistente e dei modelli di misurazione analizzati durante la ricerca.

Parole chiave: Economia Circolare; Misurazione della performance; Indicatori chiave di performance; Sostenibilità; Modelli di business; Integrazione multi-livello.

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INTRODUCTION

In recent years, the need to switch to more resource-efficient and sustainable systems has become increasingly apparent. The “take-make-dispose” nature of traditional linear business models is no longer sustainable in a world facing environmental degradation, resource depletion, and increasing legislative pressure (Ellen MacArthur Foundation, 2019). In response, the idea of a circular economy has emerged as a revolutionary strategy that encourages the continuous use of resources through closed-loop systems, thereby reducing waste and optimizing effectiveness (Geissdoerfer et al., 2017). Even though many firms acknowledge the theoretical advantages of circular business models, their implementation still presents a substantial challenge.

To effectively implement circular economy strategies, businesses need to be able to track, measure and optimize their efforts. KPIs play a fundamental role in this context. KPIs serve as quantifiable metrics that let businesses evaluate their progress in achieving specific goals. Integrating KPIs with circular economy strategies might provide a structured approach to assess circularity across various levels of an organization and the broader economy.

Measuring circularity could help businesses transition from linear to circular business models. Circularity metrics contribute to track resource usage, product life-cycles and waste reduction, allowing companies to align with both circular goals and profitability. Regulations, such as the European Circular Economy Action Plan (European Commission, 2020), have been key drivers in incentivizing companies to adopt circular practices by, for instance, providing financial incentives to help businesses afford the initial investments necessary to implement circular initiatives, or imposing waste taxes to accelerate the transition. However, measuring circularity could be complex. Some challenges include technical difficulties in gathering reliable data, the need for sophisticated tracking of material flows, or the necessity of cross-departmental collaboration and coordination within the company.

During the last decades, various frameworks have been developed with the purpose to measure circularity. Examples of the most common frameworks are identified in the Life cycle assessment, the Life cycle costing and the Material Flow Cost Accounting.

Despite this promise, previous circularity measurement frameworks often overlook the following key aspects:

- they tend to fail to account for different levels of circularity measurement;
- they barely consider the interactions between these circularity measurement levels;
- they barely embed circularity measurement within the business model logic of the company.

These gaps suggest the need for a framework able to measure circularity by overcoming the limitations of the previous models.

This thesis contributes to fill this gap by proposing a structured framework that integrates KPIs with circular economy at different levels, while considering the concept of interconnections existing among the nano, micro and meso levels. Moreover, the mentioned framework considers the extension of these purposes to the business models of the organizations. This aims to allow companies to more effectively monitor their progress in achieving circularity objectives and make KPIs-driven decisions to enhance circularity outcomes.

The thesis is structured in three chapters. The first chapter provides an overview of KPIs and performance measurement systems, exploring their role in business management and decision-making. The chapter discusses various definitions of KPIs, their features and their categories. It also introduces Performance Measurement Systems by highlighting the key concepts and including an overview of the main Performance measurement frameworks. The second chapter focuses on circular economy concepts, emphasizing the key principles, the regulatory landscape influencing the adoption of circular practices, and the challenges of implementing circular strategies. Furthermore, this section focuses on the importance for companies to shift from linear to circular business models, also mentioning some related frameworks. The last chapter, which represents the core of this research, delves into the development of a practical model, the Circular KPIs Canvas, which serves as an example of how KPIs can be integrated into circular practices, according to the concept of the interconnection existing among the different circular measurement levels.

CHAPTER 1: PERFORMANCE MEASUREMENT SYSTEMS AND KEY PERFORMANCE INDICATORS: AN OVERVIEW

1.1 INTRODUCTION TO KEY PERFORMANCE INDICATORS

1.1.1 Premise

The aim of this section is to highlight the importance of Key Performance Indicators (KPIs) as crucial tools of performance measurement systems, integral to both strategic and operational management within organizations. KPIs can be defined as quantifiable metrics that are employed to assess the degree to which an organization attains its principal business objectives (Parmenter, 2015). By converting complex performance data into clear and actionable insights, KPIs enable managers to systematically monitor progress, identify areas necessitating intervention, and make evidence-based decisions to foster continuous improvement (Kaplan & Norton, 1996). They play a fundamental role in ensuring that organizational activities are aligned with strategic goals, thereby facilitating the achievement of desired outcomes (Eccles, 1991). The subsequent paragraphs will provide a detailed examination of the definition of KPIs, their inherent characteristics, the various categories they encompass, and their essential function in performance monitoring and the attainment of organizational objectives.

1.1.2 Definition of Key Performance Indicators

Performance is a comprehensive concept that encompasses the effectiveness and efficiency with which an organization achieves its goals and objectives (Marasca, 2011). Performance measurement is the systematic assessment of various aspects of an organization's activities to determine how well these goals and objectives are being met. This concept is crucial in both management and organizational theory, serving as a basis for strategic decision-making, continuous improvement, and long-term sustainability.

Authors like Lebas (1995) and Eccles (1991) further elaborate on the concept of performance and its measurement, providing valuable theoretical foundations. Lebas argues that performance is not an absolute measure but a relative one, heavily influenced by the specific context and strategic objectives of the organization. He states that performance should be viewed as a construct reflecting the organization's ability to create value over time, which involves balancing short-term results with long-term sustainability and stakeholder satisfaction (Lebas, 1995). This perspective encourages organizations to adopt a holistic view of performance, considering both immediate outcomes and future potential.

Eccles (1991) highlights the importance of integrating performance measures across different levels and functions of the organization, ensuring that they support strategic objectives and facilitate strategic learning and adaptation. Eccles emphasizes the role of performance measurement in driving organizational change and fostering a culture of continuous improvement, where feedback loops and performance data are used to inform strategic adjustments and operational enhancements (Eccles, 1991).

In addition, according to Richard et al. (2009), organizational performance includes three distinct areas of company outcomes: market performance (sales, market share), shareholder return (total shareholder return, economic value added), and financial performance (profits, return on assets, return on investment). Its holistic approach guarantees that every important facet of a company's well-being is taken into account.

KPIs are widely recognized metrics used to evaluate the performance of businesses across various sectors, including industry, healthcare, education, and services (Parmenter, 2010).

The role and importance of measuring organizational performance via KPIs cannot be understated. In today's rapidly evolving business landscape, continual improvement is essential for organizational success. KPIs serve as powerful tools in this pursuit by offering both qualitative and quantitative insights into performance. They allow organizations to not only assess their current performance but also to track progress over time. By providing tangible metrics, KPIs enable organizations to identify strengths, weaknesses, opportunities, and threats, facilitating informed decision-making. Importantly, KPIs provide a means to understand complex aspects of performance that may otherwise go unnoticed. It is important to underscore the fundamental principle “If something cannot be measured, it cannot be controlled or improved” (Radovic and Karapandzic, 2005). Many other scholars also focused attention on the strong relation between KPIs and outcomes: “What you measure is what you get” (Kaplan and Norton, 1992); “What you don’t measure you’ll never know until it’s too late” (Adams and Neely, 2000); “What gets measured, gets done” (Otley, 1999).

KPIs, therefore, act as the foundation for control mechanisms and improvement initiatives within organizations. They help in setting benchmarks, establishing targets, and aligning strategies to achieve organizational objectives effectively by translating high-level goals into specific, actionable metrics that the company can work towards. Through the continual monitoring and analysis facilitated by KPIs, organizations gain valuable insights to adjust strategies, allocate resources efficiently, and drive performance improvements across all levels of the organization.

Several authors contributed to provide the following definitions of KPIs that highlight the importance of KPIs as fundamental tools for measuring and managing performance, aligning activities with strategic goals providing actionable insights to drive continuous improvement and organizational success.

Fitzgerald, Johnston, Brignall, Silvestro, and Voss (1991) describe KPIs as specific and measurable indicators used to evaluate performance in relation to strategic goals. They argue that KPIs are integral to performance measurement frameworks, helping organizations monitor progress, manage performance, and drive improvements.

Smith and Reece (1999) describe KPIs as metrics used to assess the critical areas of performance that are vital for the success of an organization. They highlight that KPIs are essential for evaluating progress towards achieving strategic objectives and for identifying areas needing improvement.

Niven (2002) defines KPIs as quantifiable metrics that reflect the critical success factors of an organization. He stresses that KPIs should be aligned with strategic objectives and provide clear, actionable insights into how well the organization is performing relative to its goals.

Ittner and Larcker (2003) describe KPIs as performance measures linked to strategic objectives that provide insights into both the effectiveness and efficiency of organizational processes. They emphasize that KPIs help in monitoring and managing performance by focusing on key areas that drive success.

Marr and Schiuma (2003) define KPIs as metrics used to evaluate the success of an organization in achieving its strategic goals. They argue that KPIs should provide meaningful and actionable data that supports decision-making and helps align organizational activities with strategic priorities.

Davis and Albright (2004) describe KPIs as performance measures that help organizations track progress toward their strategic objectives. They highlight that

KPIs are essential for monitoring key activities and ensuring that resources are allocated effectively to achieve desired outcomes.

Neely (2007) defines KPIs as quantifiable measures that are used to monitor and assess the performance of an organization in relation to its strategic goals and objectives. He emphasizes that KPIs should provide actionable insights that help organizations understand their progress towards achieving desired outcomes. Neely also highlights that KPIs are crucial for ensuring alignment between operational activities and strategic objectives, enabling organizations to effectively manage and improve their performance over time.

Jiang and Hsieh (2008) define KPIs as key metrics that provide insights into the effectiveness of business processes and operations. They emphasize that KPIs help organizations measure their performance against strategic goals and benchmarks, guiding decision-making and strategic planning.

Bryde and Lean (2009) define KPIs as specific, quantifiable measures used to assess performance against strategic goals. They emphasize that KPIs should provide relevant information that supports strategic decision-making and enhances organizational performance.

1.1.3 Features of Key Performance Indicators

Sometimes, KPIs are established by strategic and regulatory bodies to ensure comparability among organizations within the same industry (KPIStandard, 2013; Garengo et al., 2005).

Standards for KPIs exist to facilitate uniformity and comparability, such as the recent initiative to launch a committee on standards and KPIs for brand and audience campaigns in Europe (IAB Europe, 2013). The process of designing KPIs involves identifying the most critical processes within organizations (Neely et al., 2000; Strecker et al., 2012; Frank et al., 2009; Popova and Sharpanskykh, 2010). However, this can sometimes result in KPIs that are overly generalized, incorporating professional jargon and vague concepts that may lead to inconsistent interpretations across different organizations.

A body of research suggests that KPIs may not always accurately reflect actual performance; rather, they may highlight deficiencies within the performance measurement process itself (Berler et al., 2005). This underscore the pressing need for precise KPI features to design accurate and effective KPIs aligned to organizational goals.KPIs are distinguished by several fundamental characteristics that are essential for their efficacy as indicators of organizational performance. At the core of these characteristics lies the concept of SMART KPIs, which encapsulates specific attributes crucial for their effectiveness (Maskell, 1989; Kaplan & Norton, 1992; Neely et al., 1997; Globerson, 1985; Berler et al., 2005) .

First and foremost, KPIs must be specific and measurable. *Specificity* ensures that KPIs are clearly defined and targeted towards specific aspects of performance, leaving no room for ambiguity. *Measurability* enables organizations to quantify performance metrics objectively, allowing for precise evaluation and comparison over time.

Furthermore, KPIs should be *achievable*, setting realistic targets that motivate employees and drive performance improvement efforts. Unrealistic or unattainable KPIs can demotivate employees and undermine the effectiveness of performance measurement systems. By setting achievable targets, organizations can inspire their workforce to strive for excellence while maintaining a sense of attainability.

In addition to achievability, KPIs must be *relevant* to the organization's strategic objectives and goals. This relevance ensures that KPIs provide meaningful insights into areas critical for organizational success. By focusing on relevant KPIs, organizations can direct their resources and efforts towards achieving their overarching strategic priorities.

Time-boundness is another critical feature of KPIs, requiring clearly defined timeframes for achieving targets. This temporal aspect ensures that performance is monitored regularly, allowing for timely adjustments to strategies and tactics. By establishing time-bound KPIs, organizations can track progress effectively and identify areas requiring immediate attention.

SMART KPIs provide organizations with a structured framework for developing meaningful performance metrics that drive continuous improvement and align with strategic objectives.

Many authors have talked widely about KPIs design, each offering a distinct point of view. For instance, Lea and Parker, along with other scholars, argue that KPIs should be transparent and easily comprehensible. They emphasize that these measures need to be simple to understand, which makes them more accessible to all stakeholders involved in the process. Moreover, they advocate for KPIs that have a strong visual impact, allowing for quick and clear communication of performance data. These KPIs should focus on improvement rather than variance, encouraging continuous progress rather than simply highlighting deviations from the norm. Importantly, they also stress that KPIs should be visible to all, promoting transparency and inclusivity within the organization.

Lynch and Cross present a slightly different viewpoint, emphasizing the critical link between strategies, actions, and KPIs. They argue that KPIs should not be developed in isolation but should be closely aligned with the organization's strategic objectives. This perspective is supported by Dixon et al., Kaplan and Norton, and other scholars, who also highlight the importance of integrating KPIs with the broader strategic goals of the organization. This alignment ensures that the KPIs not only track performance but also drive the organization towards its long-term objectives.

Furthermore, Globerson (1985) and Maskell (1989) outlined several key factors that ensure that KPIs are effective and reflective of an organization's performance. First of all, the purpose of each KPI must be clear to guarantee that the stakeholders are aware of what is being measured and why it is important. Utilizing ratio-based KPIs rather than absolute numbers is more advisable since ratios can provide a more standardized perspective of performance, making cross-context comparison simpler. They remark the fact that objective KPIs are favored over subjective ones because they rely on measurable data, reducing the possibility of bias and increasing the accuracy of the performance measurement. Additionally, non-financial KPIs need to be implemented in order to offer a comprehensive perspective on the organizational performance, covering aspects like employee engagement, operational efficiency and customer satisfaction. Another important component is prompt feedback; KPIs should deliver information in a timely manner to enable quick corrections when required. KPIs must be under the control of the evaluated organizational unit in order for the unit to have any impact over the results being measured. Furthermore, rather than just tracking performance, KPIs should be created to promote proactive attempts to improve results and processes, thereby fostering continuous development. A further essential element is benchmarking: KPIs should encourage comparisons between businesses engaged in the same industry, fostering best practices and standards of competitive performance. To be relevant and useful, KPIs should also be flexible, adjusting to new situations as they arise.

This dynamic approach guarantees that KPIs align with the organization's operational realities and strategic objectives.

Moreover, in 2009 Wayne Eckerson has summed up some of the features listed above by developing an advanced set of ten characteristics for KPIs that align more closely with business metrics but can be readily adapted to various domains by extracting core principles.

One such characteristic is the principle of employing a select number of KPIs, which is widely endorsed within the realm of performance management. This *sparse* selection emphasizes quality over quantity, enabling managers to focus effectively on a limited number of metrics—typically between five to seven—that can significantly impact desired outcomes. By concentrating on a select few KPIs, managers can gain a deeper understanding of the behaviors these metrics are incentivizing, enabling them to fine-tune KPIs for optimal results. Moreover, there is a pragmatic rationale for limiting the number of KPIs since the data sourcing process is resource-intensive and time-consuming.

Another crucial feature is the *drillable* characteristic of KPIs, which refers to the ability of KPIs to enable users to delve into data at different levels of detail. This means that a high-level KPI can be dissected into more specific sub-metrics or data points, facilitating a deeper examination of the factors influencing the KPI's performance. This feature is relevant for understanding not only the overall results but also the specific elements that contribute to those outcomes. Drillable KPIs offer a hierarchical view of data, starting from a broad, summary-level metric and allowing users to drill down into more detailed components. For instance, a top-level KPI might reflect overall sales performance, but by drilling down, a user can analyse sales by region, product line, sales representative, and even individual transactions. This capability assists organizations in identifying the root causes of issues, uncovering trends, and gaining actionable insights that can guide decision-making and strategy.

Simplicity is also fundamental. KPIs should be straightforward and easily understandable by all stakeholders within an organization. This simplicity ensures that KPIs are not bogged down by complexity, making them accessible and actionable.

The *actionable* characteristic of KPIs is essential for ensuring that metrics not only measure performance but also drive meaningful improvements within an organization. KPIs should be designed to be easily understood and to provide clear guidance on how to influence outcomes positively. Unfortunately, in many organizations, managers struggle to interpret KPI results or determine appropriate actions, particularly when a KPI trends downward. This can be especially challenging for new managers, who might overreact to minor fluctuations, mistaking normal statistical variations for serious issues. To avoid these risks, it is important for managers to look at overall trends instead of focusing on individual data points. This approach prevents overreactions and helps address real problems more effectively. Another problem occurs when organizations share KPIs but do not give employees the power to act on them. Bureaucratic processes and hierarchical structures can prevent managers from delegating tasks, making it hard for frontline workers to solve problems. Organizations need to train managers to delegate effectively and guide employees on how to take the right actions.

Additionally, new employees might not know how to respond correctly to KPI data because they lack experience. Providing training on how to read and react to KPIs can help. Some organizations are also using guided analytics in their software, offering decision trees and suggested next steps to help employees make informed decisions based on the experience of their colleagues. This approach, though still developing, aims to improve how employees respond to KPI data.

Each KPI needs to have a specific *owner* responsible for its performance. This ensures that there is clear accountability and motivation to manage and improve the KPI. Typically, each KPI is managed by both a business owner and a data owner. The business owner oversees the KPI's importance and relevance, addressing questions about its purpose, how it is calculated, and what steps to take if performance declines. Conversely, the data owner is responsible for ensuring that the data used for the KPI is accurate and up-to-date, maintaining adherence to quality and timing standards.

The *referenced* characteristic highlights the importance of data accuracy and trust. Even if users have been depending on recognizable but less accurate reports or spreadsheets, trust in the data is essential. KPIs should provide thorough reference data in order to promote this trust, such as KPI's business and technical owners, data source, calculation method, last update date, and other relevant facts.

The *correlated* nature of KPIs emphasizes how crucial it is to make sure that KPIs have a relationship to the outcomes that are expected. The relationship between driver KPIs, which impact performance, and outcome KPIs, which quantify the outcomes, is made clear by this association, which is crucial. Variations in internal dynamics, economic situations, or competitive forces might cause changes in the influence of KPIs over time. The majority of KPIs have a limited shelf life and usually yield maximum benefits within the first year. Organizations must update KPIs or modify targets when conditions change to appropriately reflect current tactics. Without continuous review, companies run the risk of depending on obsolete or inefficient KPIs and failing to notice changes in their influence.

The idea of *balanced* KPIs lies at the heart of the Robert Kaplan and David Norton (1992) Balanced Scorecard system. Instead of concentrating only on financial measures, they contend that businesses should evaluate performance in a variety of ways including customer, operations, and learning and growth. Executives can invest in important factors that contribute to long-term growth and sustainability thanks to this well-balanced strategy. Balanced KPIs, which match indicators with strategic goals for long-term success and growth, offer a complete overview of performance.

Alignment of KPIs across various departments and functions is important to mitigate the risk of “KPI sub-optimization”, a procedure by which efforts made to improve one KPI unintentionally compromise the performance of other KPIs that are similar to it or more general organizational objectives.

Finally, KPIs must be carefully *validated* in addition to being balanced and aligned in order to be effective. This minimizes the likelihood that staff members may manipulate or get around KPIs for their own benefit. Businesses need to confirm that KPIs appropriately represent the steps needed to enhance business performance.

By embodying these characteristics, KPIs serve as effective tools for driving organizational performance and facilitating strategic decision-making processes.

1.1.4 Categories of Key Performance Indicators

Key Performance Indicators can be categorized in several ways to suit different organizational needs and contexts.

A first classification distinguishes *financial and non-financial* indicators. Historically, performance measurement has largely been centred around financial performance with vast numbers of financial KPIs like return on assets (ROA), return on equity (ROE), return on investment (ROI), profit margin, earnings per share, value per employee to name a few. These financial KPIs have been widely employed, however, the literature has significantly criticized their relevance to management control (Neely, 2007). Research shows that financial measures are inadequate to communicate strategies and priorities (Najmi et al., 2005).

One key limitation is their inherent short-term focus. Financial KPIs usually place an emphasis on immediate results, such as profit margins or quarterly earnings, which can influence decision-making that prioritizes short-term benefits above long-term strategic objectives. This can affect the sustainability of the business at the expense of future growth and stability (Kaplan & Norton, 1992).

Furthermore, financial KPIs often lack context. While they offer quantitative data on revenue, profit and costs, they do not analyse the causes of these financial outcomes (Neely et al., 1997).

Moreover, because financial KPIs typically reflect past performance, they can address the organization to a reactive rather than a proactive approach to management, without focusing on anticipating and mitigating future challenges (Marr, 2012). This approach may limit the company to innovate and adapt.

Another critical drawback regards the fact that they do not consider non-financial KPIs as fundamental factors for a company’s success, such as employee satisfaction, brand reputation and innovation. This narrow focus might lead to a distorted perception of the general health of a business (Eccles, 1991).

Additionally, financial KPIs can be unreliable due to their susceptibility to manipulation through accounting practices, such as adjusting revenue recognition or capitalizing expenses. These manipulations can create a distorted view of an organization's actual performance, leading to potentially misleading conclusions (Dechow, Sloan and Sweeney, 1995).

Financial KPIs are also heavily influenced by external economic factors, such as inflation, interest rates and currency fluctuations. These variables can distort the true financial performance of an organization (Watts and Zimmerman, 1986).Due to the several limits of financial KPIs, a tectonic shift started in the 1980s when the focus began to shift from financial metrics as (the only) measures of firm performance. Schemes increasingly included non-financial KPIs such as customer retention, customer satisfaction, environmental impact, employee turnover and the number of new products developed. It is essential to understand that effective strategy translation into operational actions necessitates a combination of both financial and non-financial metrics. These two types of measures are not alternatives but rather complementary (Keegan et al., 1989; Kaplan and Norton, 1992; Chow and Van der Stede, 2006; Kihn, 2010). Financial KPIs offer concrete data on the monetary aspects of performance, while non-financial KPIs provide insights into operational effectiveness and customer satisfaction, which are crucial for long-term success.

In their classic, “Relevance Lost” (1987), Johnson and Kaplan skewered exclusive dependence on the short-term financial metrics. Fast technology changes and reduced product cycle lives, along with production process improvements made these measures less important. They suggested that firms use a variety of non-financial KPIs aligned to their strategic objectives - including measures related to production, marketing, research and development. These non-financial KPIs, they claimed, are better predictors of long-term success than short-term financial metrics.

The integration of both financial and non-financial KPIs provides a more balanced and comprehensive view of an organization’s performance. By using both types of KPIs, organizations can ensure that their performance measurement systems are robust and aligned with their strategic objectives.

Another possible classification could be between lagging and leading KPIs Lagging KPIs measure past performance. They provide a retrospective view of what has already happened. These KPIs help identify what went wrong in the system by highlighting past failures, errors, and mistakes (Erkal et al., 2021). These measures assess completed performance results, serving primarily as a historical review, while they do not offer opportunities to change the performance that has already occurred. The insights gained from lagging KPIs help in formulating preventative measures for future projects (Elsebaei et al., 2020; Sinelnikov et al., 2015). Typical lagging KPIs include return on investment (ROI), profit margins, earnings per share, and customer satisfaction scores. On the other hand, leading KPIs measure current performance, providing insights that can forecast future outcomes. They allow organizations to influence future results by making adjustments in real time. Leading measures offer early warnings about potential issues, enabling proactive management. They help guide future decisions based on the analysis of current activities.

According to their data source and focus, KPIs can be classified into internal and external KPIs. Internal KPIs focus on optimizing internal business operations and efficiencies. Examples include internal process quality, which measures the efficiency and effectiveness of processes through metrics like defect rate and cycle time, and employee productivity, which evaluates output per employee and revenue per employee. These KPIs help organizations identify areas for improvement and ensure smooth internal operations. External KPIs, on the other hand, measure how the organization performs in the market and is perceived by external stakeholders. Examples include customer acquisition cost (CAC), which calculates the expense of acquiring a new customer, and public perception, assessed through surveys and social media sentiment analysis. These KPIs provide insights into market position, customer satisfaction, and brand reputation, enabling organizations to adjust strategies to enhance their market presence and public image.

Measures can be also categorized into input, process and output KPIs. Input KPIs focus on the resources or factors contributing to organizational activities. These metrics measure resources allocated or utilized, such as budget allocation, training hours, or raw material usage. Monitoring input metrics helps ensure efficient resource management and effective capacity planning.

Process KPIs assess the efficiency and effectiveness of internal workflows and operations. These metrics evaluate how well activities are performed within the organization. Examples include cycle time, defect rate, customer service response time, and production yield. Analyzing process metrics helps identify bottlenecks and improve overall operational performance.

Output KPIs measure the results or outcomes of organizational activities. These metrics reflect tangible results achieved by the organization, such as revenue, profit margins, customer satisfaction scores, market share, or product/service quality indicators. Monitoring output KPIs allows organizations to understand their performance in delivering value to stakeholders and achieving strategic objectives.

1.2 PERFORMANCE MEASUREMENT SYSTEMS

1.2.1 Premise

Modern management techniques are not complete without Performance Measurement Systems (PMS), which offer an organized method for assessing and improving organizational performance. These systems include a range of instruments and procedures intended to evaluate the efficacy and efficiency of an organization's activities, guaranteeing conformity with strategic aims and objectives. This section provides a thorough overview of performance measurement systems and their function and significance in corporate by delving into their definition, core ideas, and main frameworks.

1.2.2 Definition and key concepts

A PMS can be defined as a set of metrics used to quantify the efficiency and effectiveness of actions (Neely et al., 2005).

PMS is a system that enables organizations to manage their performance by measuring outputs, outcomes, and processes (Neely, Gregory, and Platts, 1995).

These systems' purpose relies on gathering, processing, and distributing data about how well organizational operations are conducted in order to support well-informed decision-making. The concept of PMS covers several key elements, including the design, implementation, and utilization of performance metrics that align with organizational goals and objectives. Furthermore, performance measurement systems play a critical role in shaping the decision-making processes within organizations by providing reliable and function-specific information that supports both decision-facilitating and accountability purposes (Artz, 2012). These two factors characterize PMS:

- decision-facilitating involves utilizing performance metrics to support organizational planning, decision-making, and problem-solving. It focuses on giving managers fast access to pertinent information so they may make decisions that support organizational goals and strategy;
- accountability refers to evaluating and recording the performance of different organizational units and individuals using performance metrics. It seeks to guarantee that resources are used effectively and that output is in line with the objectives of the company. This kind of application frequently entails keeping an eye on and assessing results to hold departments and individuals responsible for their contributions to the success of the company.

By employing well-designed PMS, functional sub-units can provide clear evidence of their contributions to organizational goals, thereby gaining greater influence and credibility within the larger organizational structure. This alignment not only supports the rational allocation of resources but also fosters a culture of continuous improvement and accountability. Consequently, the deployment of PMS is essential for organizations seeking to optimize their performance outcomes and ensure coherent, data-driven decision-making at all levels.

Designing and projecting a performance PMS requires an accurate approach that integrates established theoretical frameworks and reflects the unique business context of the organization. Drawing from Neely et al. (2005), a PMS should be developed to align with strategic objectives, enabling the organization to measure and manage performance effectively across multiple dimensions. The process begins by understanding the strategic goals and translating them into specific, actionable measures that connect strategy with day-to-day operations, as highlighted by Taticchi et al. (2011).

The Performance Pyramid by Cross and Lynch emphasizes the importance of linking performance measures at different levels of the organization, ensuring alignment from top management down to operational activities. Similarly, Keegan et al.'s (1989) Performance Measurement Matrix and Fitzgerald's (1991) Results and Determinants Framework stress the importance of balancing financial and non-financial indicators, offering a holistic view of performance.

In designing a PMS, as noted by Kanji (1998) and Bititci et al. (2000), it is essential to consider the perspectives of different stakeholders, both internal and external, ensuring that the measures reflect the needs and expectations of all parties involved. Cochran et al. (2001) and Neely (2002) emphasize the need for adaptability within the PMS, allowing it to evolve with changes in the business environment or strategic direction.

Taticchi and Balachandran (2008) argue that the design of PMS should be specific to the company's business architecture, incorporating relevant measures that connect strategy to operations and consider varying stakeholder perspectives. They support the integration of financial and non-financial indicators and the alignment of external and internal parameters. This approach is supported by Franco-Santos and Bourne (2005), who identify key factors for effective PMS design, including the use of performance measurement frameworks and strategy maps, the establishment of clear measures and targets, alignment and integration across the organization, and the development of a robust information infrastructure.

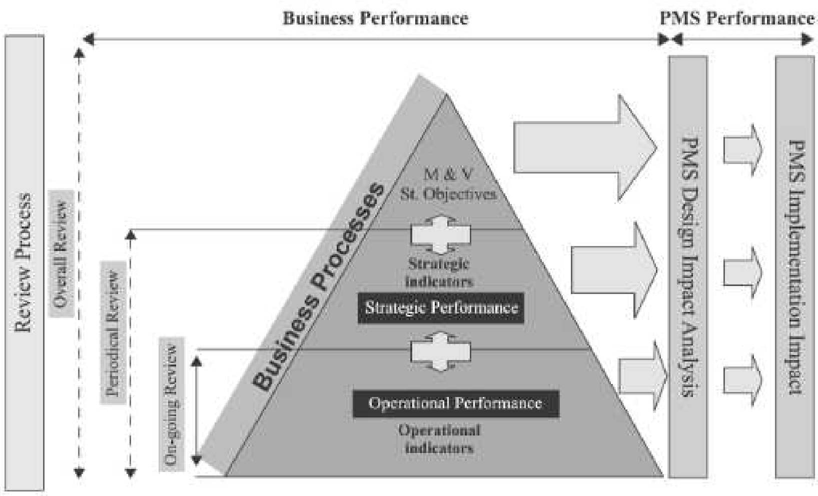
Ultimately, the design of a PMS should not be static but rather a dynamic system that fosters continuous improvement and learning. By embedding these principles into the organizational culture, the PMS can become a critical tool for driving sustained growth and maintaining a competitive edge in the market.

In order to ensure that the strategic alignment of the organization is maintained and that the performance measurement system is efficient and effective, Manoochehr Najmi, John Rigas, and Ip-Shing Fan developed a Review framework in 2005. It consists of several components: direction, processes, and measures. The company must have a clear mission, vision, and strategic objectives. It should manage its operations through defined processes and process improvement practices. The measures are the metrics attached to processes, derived from the company's strategy and direction.

The framework includes three main levels of review: ongoing review, periodic review, and overall review. Ongoing review focuses on operational performance and impacts the definition of operational indicators. Periodic review reviews the strategic performance of the company through strategic indicators. Overall review involves assessing the company's mission, vision, and strategic objectives, affecting all elements of direction, processes, and measures.

The framework divides reviews into two main categories: business performance and PMS performance (Figure 1.1).

Figure 2.1 - PMS review framework



Source: Najmi, M., Rigas, J., & Fan, I. S. (2005). A framework to review performance measurement systems. *Business Process Management Journal, 11*(2), 114.

Business performance assesses the organization's performance through the PMS. PMS performance evaluates the efficiency and effectiveness of the PMS itself, including the accuracy of mapping the business processes and the efficiency of the PMS design process.

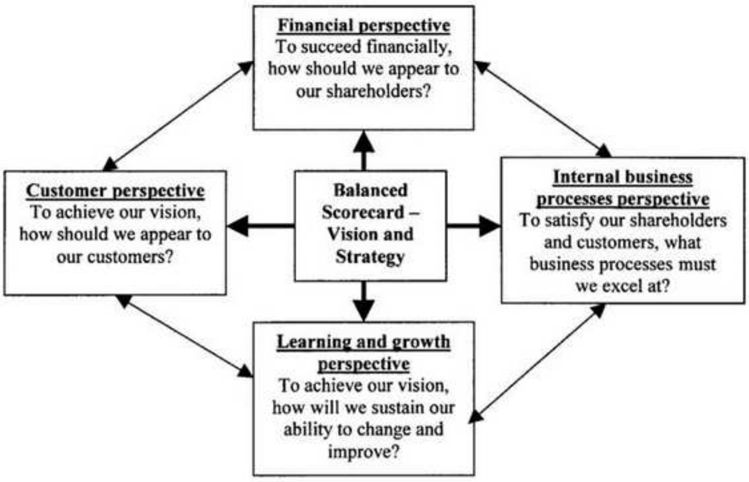
The review process is facilitated by several instruments. These involve both external tools, like benchmarking against competitors, and internal tools, such self-assessment procedures.

1.2.3 An overview of the main Performance Measurement Frameworks

Several frameworks have been developed to guide the implementation and utilization of PMS. These frameworks provide structured approaches to selecting, measuring, and interpreting KPIs. Prominent frameworks include the Balanced Scorecard (Kaplan and Norton, 1992), the Performance Prism (Neely, Adams and Kennerley, 2002), the EFQM Excellence Model **(**European Foundation for Quality Management, 1991) and the Performance Pyramid (Lynch and Cross, 1991).

The Balanced Scorecard (BSC) is a strategic performance management tool developed by Robert Kaplan and David Norton in 1992 that has gained widespread acceptance and implementation across various organizations globally. Unlike traditional PMSs that focus solely on financial metrics, the BSC offers a more comprehensive view by incorporating non-financial perspectives. This balanced approach addresses the limitations of traditional systems by including four key perspectives: financial, customer, internal business processes, and learning and growth (Figure 1.2).

Figure 1.2 – The Balanced Scorecard



Source: Kaplan and Norton, 1996

The financial perspective focuses on financial performance metrics that show whether the company's strategy and execution are contributing to bottom-line improvement. Typically, it contains KPIs like profit margin, earnings per share (EPS), and return on investment (ROI). As important measures of financial performance, a business can, for example, monitor revenue growth or expense reduction.

The customer perspective assesses the company's success in the market and its capacity of creating values for the customers. According to this perspective, market share, net promoter score (NPS), and customer satisfaction scores are examples of KPIs. For instance, a company may monitor its customer retention rates or the number of new clients acquired in a given time frame.

The internal business processes perspective looks at the efficiency and effectiveness of internal processes that produce and provide the goods and services for the company. Cycle time, quality defect rates, and process optimization metrics are a few examples of KPIs. Monitoring the time it takes to transform raw materials into completed goods or the effectiveness of supply chain management procedures are two examples.

Lastly, the learning and growth perspective indicates the organization's capacity for innovation, improvement, and learning. Employee training hours and staff turnover rate are just a few of the KPIs included in this perspective. A business that wants to demonstrate its commitment to ongoing development may monitor the proportion of sales from new items or the number of employees with advanced training.

Each perspective should contain four different aspects: objectives, measures, target and initiatives. In the realization of each perspective, in fact, the first step should consist in dividing the vision and the strategy of the organization in actionable objectives. In order to keep track of the achievement of these objectives, some measures should be established and associated with a target, which represents a short-term goal that will facilitate the evaluation of the progress of each objectives. The last step includes the implementation of initiatives, describing actions that will help the realization of each objective set at the beginning.

Furthermore, the framework emphasizes cause-and-effect relationships, introducing dynamic systems thinking that allows for a better understanding of how different perspectives of the organization interact and influence one another. These relationships are crucial in the choice of appropriate KPIs.

In the financial perspective, an organization could set as objective the increase of revenues. The achievement of this objective do not only depend on the results of the financial area, but is instead influenced by the improvement in the other areas. For example, it could depend on the enhanced customer satisfaction, associated with the customer perspective, and on well-optimized processes within the organization, referring to the internal business process perspective. These improvements lead to increased customer loyalty and higher sales, both of which contribute directly to revenue growth, thus illustrating a cause-effect relationship.

Turning to the customer perspective, the objective might be to enhance customer satisfaction. This objective is often driven by improvements within the internal business processes perspective, such as better service delivery and higher product quality. As internal processes become more efficient and products meet or exceed customer expectations, customer satisfaction naturally increases. This, in turn, leads to better customer retention and acquisition rates, which subsequently supports the organization’s financial goals.

Within the internal business processes perspective, organizations may focus on optimizing their operations. This objective is frequently driven by initiatives within the learning and growth perspective, such as investments in employee training and development. By enhancing the skills and capabilities of employees, an organization can improve its processes, resulting in higher-quality output and more efficient operations. These improvements contribute to increased customer satisfaction, thereby linking back to the customer perspective and eventually impacting the financial perspective positively.

Lastly, the learning and growth perspective typically involves developing the capabilities of employees, which is foundational for the achievement of objectives in the other perspectives. By providing ongoing training and fostering a supportive work culture, an organization provides its workforce with the skills necessary to innovate and improve processes. These enhancements in internal processes lead to better alignment with the organization’s strategic goals, which in turn drives customer satisfaction and financial performance.

These cause-effect linkages are crucial because they ensure that efforts to improve one area of the organization do not occur in isolation but instead contribute to strategic success across multiple dimensions.

In 2004 Kaplan and Norton introduced the strategy map as an extension of the BSC. This tool visually depicts an organization’s business model, translating complex strategies into actionable objectives by illustrating the links between tangible and intangible assets and value-creating processes. By clarifying the cause-and-effect relationships between strategic objectives, the strategy map allows top managers to communicate their vision effectively and align the entire organization towards common goals. It also helps identify gaps between strategy formulation and execution, enabling timely adjustments to ensure the BSC remains relevant and effective. The strategy map is especially helpful in both the planning and control stages of management. It improves comprehension of the business model during planning and ensures that KPIs align with the organization's strategy. This involvement fosters greater acceptance and commitment among managers and employees, as they contribute to the development of the strategy and BSC. During the control phase, the strategy map helps reduce biases that could otherwise compromise the effectiveness of the BSC by assisting in the alignment of BSC-based incentives with strategic goals. It also helps managers become more successful at evaluating external data, which is crucial in dynamic settings. All things considered, the strategy map not only improves the BSC's utility by offering clarity and alignment, but it also raises the perceived efficacy and objectivity of performance evaluation, which results in more successful implementation and strategic alignment across the company.

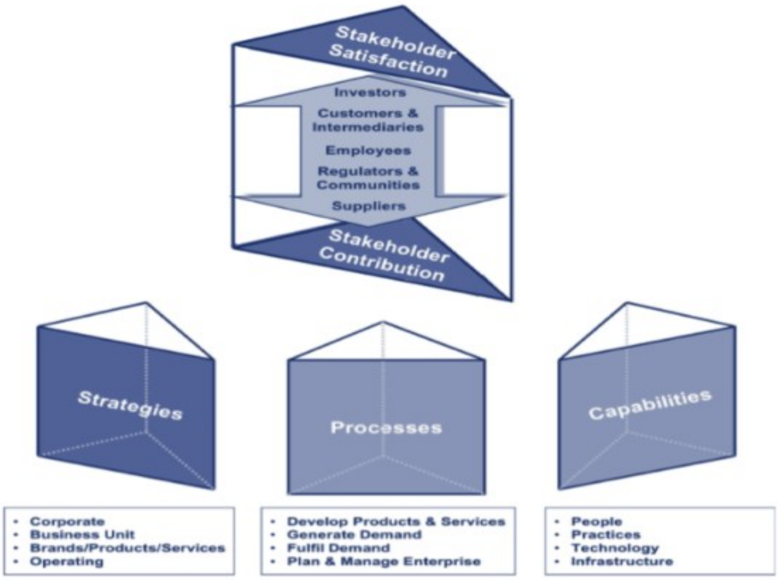
Despite its strengths, the implementation of the BSC is fraught with challenges. High failure rates are often attributed to mismanagement of metrics, an over-reliance on financial data, and difficulties in translating its general concepts into actionable measures. Critics argue that the causal relationships emphasized in the BSC are sometimes overly simplified, failing to reflect the complex interactions within organizations. Additionally, the BSC often excludes important perspectives such as competitors, regulators, and community or environmental issues, which are vital in today's dynamic business environment. This exclusion can lead to a lack of responsiveness to external changes and challenges. Another significant criticism is the static nature of the BSC, which may not adequately capture the dynamic changes in business environments. Moreover, there is limited empirical evidence to conclusively demonstrate that its implementation leads to improved organizational performance, raising questions about its efficacy.

Designing and selecting appropriate KPIs within this framework also remains a significant challenge. Despite existing guidelines, organizations often struggle with this aspect, contributing to the high rate of unsuccessful implementations. However, when implemented effectively, the Balanced Scorecard can significantly enhance the authority and impact of functional subunits within organizations by validating their strategic initiatives and ensuring alignment with broader institutional expectations for rational and accountable management practices.

Another framework is identified by the Performance Prism, developed in the early 2000s by Andy Neely, Chris Adams, and Mike Kennerley to assist organizations in selecting appropriate KPIs. It is designed to address critical business issues relevant to both profit and not-for-profit organizations. Unlike other frameworks, such as the Balanced Scorecard, the Performance Prism encourages managers to consider the interconnections between various measures more deeply and intuitively. This framework presents various positives: it extends the focus beyond shareholders and customers to include employees, suppliers, alliance partners, intermediaries, regulators, local communities, and pressure groups, ensuring a holistic approach to stakeholder management; it is designed to address contemporary business challenges, thus it is suitable for both established corporations seeking to modernize their scorecards and new organizations developing relevant performance measures for today's economic environment; the framework emphasizes the reciprocal relationship between organizations and their stakeholders, acknowledging and leveraging the contributions stakeholders make to the organization's success.

The Performance Prism includes five interrelated facets (as shown in Figure 1.3): each posing critical questions to guide the selection of performance measures: the top and bottom facets are stakeholder satisfaction and stakeholder contribution respectively. the three side facets are strategies, processes and capabilities.

Figure 1.3 – The performance prism framework



Source: Adams C., Neely A., (2000),"The performance prism to boost M&A success", *Measuring Business Excellence*, Vol. 4 Iss 3, p.20

The first facet is stakeholder satisfaction, which addresses the key question, "Who are the stakeholders and what do they want and need?" This facet includes all relevant stakeholders such as shareholders, customers, employees, suppliers, regulators, and the local community. Its purpose is to ensure that the organization understands and addresses the needs and wants of all its stakeholders.

For this facet, organizations might measure several KPIs. The customer satisfaction score assesses how satisfied customers are with the products and services provided by the company through direct surveys. Employee engagement is measured through internal surveys that evaluate levels of employee satisfaction and involvement in the organization. Supplier performance is rated by using metrics such as delivery times, quality and responsiveness. Shareholder return on investment tracks the financial returns for shareholders, such as dividends and stock performance. The regulatory compliance rate establishes the adherence to regulatory standards.

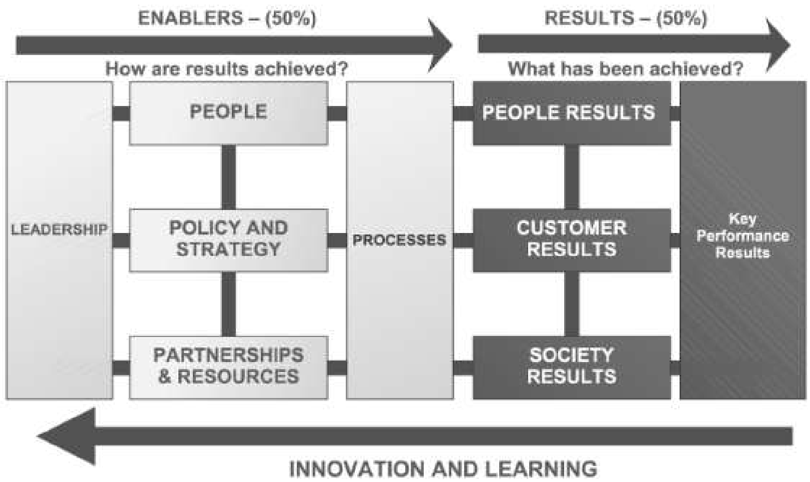
The second facet, strategies, poses the question, "What are the strategies we require to ensure the wants and needs of our stakeholders are satisfied?" Here, the approach is that strategies should be derived from stakeholder needs rather than vice versa. The purpose of this facet is to align organizational strategies with stakeholder expectations and needs. For instance, the strategic goal achievement rate tracks the percentage of strategic objectives met within a certain time and the market share growth measures the increase in market share resulting from strategic actions.

The third facet, processes, asks, "What are the processes we have to put in place in order to allow our strategies to be delivered?" This facet focuses on identifying necessary processes across common generic business areas like product development, demand generation and fulfilment, and enterprise management. Its purpose is to ensure that effective processes are in place to support strategy execution. For the processes facet, accurate KPI could be the process efficiency ratio, that assesses how effectively resources are utilized relative to the output achieved, and the on-time delivery rate, that measures the proportion of deliveries made on schedule according to customer’s expectations. The fourth facet, capabilities, addresses the question, "What are the capabilities we require to operate our processes?" This includes components such as people, practices, technology, and infrastructure. The purpose here is to assess whether the organization has the necessary capabilities to execute and improve its processes. In order to achieve this, several KPIs could be used, such as the employee skill development rate, that measures the progress in employee training and skill enhancement, the technology utilization rate, that assesses the effective use of technological resources within the organization, and the innovation capability index, that evaluates the company's ability to innovate, based for instance on investments in R&D.

The fifth and final facet is stakeholder contribution, which asks, "What contributions do we want and need from our stakeholders to maintain and develop these relationships?" This facet recognizes the symbiotic relationship between the organization and its stakeholders, where stakeholders also contribute value back to the organization. Its purpose is to encourage organizations to manage and nurture these contributions effectively. For example, the employee productivity metrics track productivity levels and the contributions of employees towards achieving organizational goals; the supplier partnership quality evaluates the effectiveness of partnerships with suppliers and the community engagement level assesses the involvement and support from the community, including volunteerism and local collaborations. By focusing on comprehensive stakeholder engagement and the symbiotic relationships between organizations and their stakeholders, it provides a robust framework for ensuring that performance measures are relevant, balanced, and aligned with contemporary business needs.

The EFQM Excellence Model, established in 1991 by the European Foundation for Quality Management (EFQM), is another framework designed to evaluate and promote organizational excellence, initially for the European Quality Award. The model includes nine elements divided into five enabler criteria (leadership, policy and strategy, people, partnerships and resources, and processes) and four result criteria (people results, customer results, society results, and key performance results) (Figure 1.4).

Figure 1.4 - The EFQM Excellence Model



Source: EFQM (2003)

Enablers describe the organization's operational methods, while results highlight achievements related to stakeholders. Each criterion is broken down into sub-criteria with specific guidance points to help organizations understand and implement necessary actions.

According to enablers, leadership is concerned with how leaders develop the mission, vision, and values, and how they facilitate their implementation; policy and strategy pertain to how the mission and vision are translated into strategies, supported by policies, plans, objectives, and processes; the people criterion addresses how the organization manages, develops, and utilizes the full potential of its workforce; partnerships and resources involve the planning and management of external partnerships and internal resources; the processes criterion looks at how processes are designed, managed, and improved to support the organization's strategy and ensure stakeholder satisfaction. Whereas, as regards results, people results examine outcomes related to employee satisfaction and performance; customer results look at outcomes related to customer satisfaction and loyalty; society results consider the organization's impact on society and the environment; key performance results measure the organization's success in achieving its strategic goals.

The model allows organizations to assess their current performance, identify areas for improvement, and stimulate innovative solutions. It emphasizes continuous improvement through eight core concepts, such as results orientation, customer focus, and innovation.

Another PMS framework could be identified by the Performance Pyramid developed by Lynch and Cross (1991). As shown in Figure 1.5, it is a hierarchical framework that aligns an organization's strategic objectives with its operational activities, ensuring coherence between long-term goals and day-to-day performance.

At the apex of the pyramid is the corporate vision, representing the long-term strategic goals of the organization. This vision drives all other levels, ensuring alignment between high-level strategies and day-to-day operations.

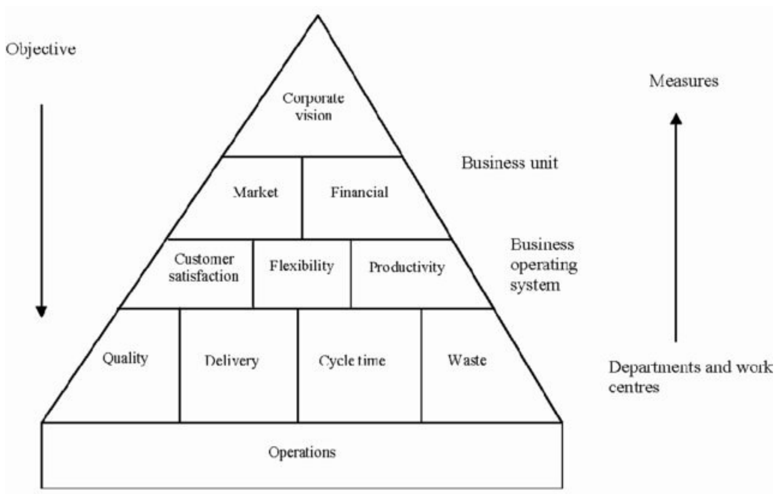
Just below the corporate vision, the pyramid splits into two branches: market and financial objectives. The market branch focuses on external factors, such as customer satisfaction, flexibility, and market competitiveness, while the financial branch addresses internal financial health through metrics like profitability and productivity.

The third level, the business operating system level, is seen as the bridge between the vision and the day-to-day operational measures. It includes objectives such as customer satisfaction, flexibility and productivity, which are crucial for maintaining market relevance and financial performance. These metrics ensure that the organization's processes are agile, efficient, and responsive to customer needs.

The base level of the Performance Pyramid deals with day-to-day operational performance. This level is concerned with the execution of specific tasks and activities that support the higher levels of the pyramid, such as quality, delivery, cycle time and waste reduction. These operational measures create a solid foundation for the achievement of the long-term success.

The pyramid also illustrates the flow of objectives and measures: strategic objectives descend from the top, guiding operational activities, while performance measures ascend, providing feedback for the higher-level strategic decisions. This ensures that all company's levels are aligned with each other, interconnected and correlated to the corporate vision.

Figure 1.5 – Performance Pyramid



Source: Lynch and Cross (1991)

CHAPTER 2: AN OVERVIEW OF CIRCULAR ECONOMY

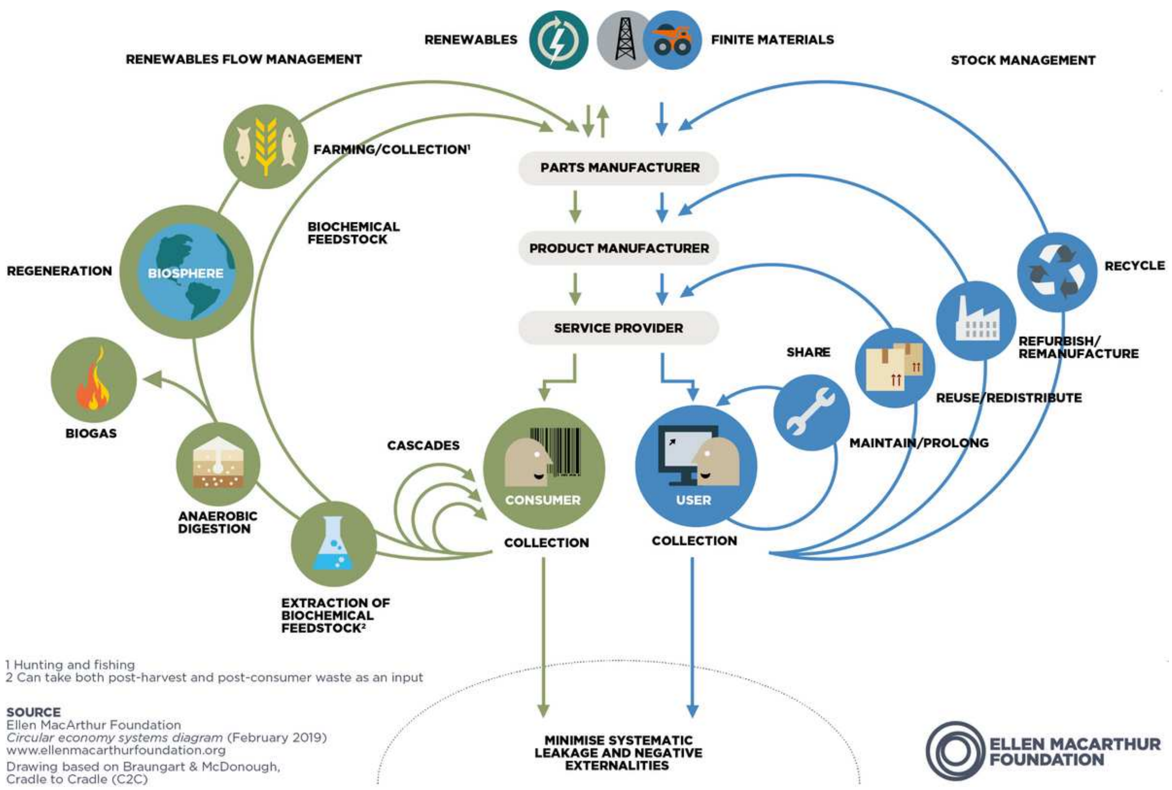
2.1 DEFINING CIRCULAR ECONOMY

The concept of a circular economy (CE) has its roots in ideas that date back several decades ago. Initially proposed by Boulding in 1966 in "The Economics of the Coming Spaceship Earth", the notion was that circular systems within the global economy are essential to sustain human life on Earth in the long term. This idea was further developed by Pearce and Turner in 1989, who argued that a traditional linear economy, which lacks recycling elements, is unsustainable and must be replaced by a circular system. They referred to the second law of thermodynamics, as stated by Georgescu-Roegen in 1986, which posits that the entropy of an isolated system will increase over time, thereby devaluing higher order energy or material.

The Ellen MacArthur Foundation (2016) provides one of the definitions of the CE that is now most widely accepted. According to this, the CE can be defined as a model that contrasts sharply with the traditional linear economy, which follows a 'take-make-waste' pattern.

Instead, CE aims to create a closed-loop system where resource input, waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. One of the fundamental principles of the CE is to minimize leakage (loss of materials from the cycles) and negative externalities (unintended adverse effects on the environment and society). This is achieved by designing products and systems that are regenerative and restorative by nature, ensuring that resources are kept in use for as long as possible and waste is designed out of the system. This concept can be visualized from the Circular economy butterfly diagram proposed by The Ellen MacArthur Foundation (Figure 2.1) .

Figure 2.1 – Circular economy butterfly diagram



Source: Ellen MacArthur Foundation (February 2019)

The diagram emphasizes two primary cycles: the biological cycle and the technical cycle.

The biological cycle, on the left side, deals with renewable, biodegradable materials. It starts with the farming and collection of renewable resources, which are then processed into biochemical feedstock. These materials undergo cascading uses, extracting value at each stage, such as being used as food, then animal feed, and finally bioenergy. At the end of their lifecycle, materials can be broken down into biochemical components through composting and anaerobic digestion, producing biogas, which serves as a renewable energy source. The final stage is the regeneration of nutrients back to the biosphere, supporting new cycles of renewable resource production.

The technical cycle, on the right side, handles non-renewable materials and focuses on maintaining, reusing, and recycling products and components. It begins with the manufacturing of parts from raw materials, which are then assembled into finished products. Service providers maintain these products, ensuring their longevity. Consumers and users engage with these products, emphasizing the importance of maintenance and prolongation of product life. At the end of their useful life, products are collected for further processing. They can be reused or redistributed, extending their lifecycle without additional resource input. Products that are no longer functional can be refurbished or remanufactured, restoring them to good condition. When products reach the end of their useful life and can no longer be reused or refurbished, their materials can be recycled, broken down into raw materials for new products.

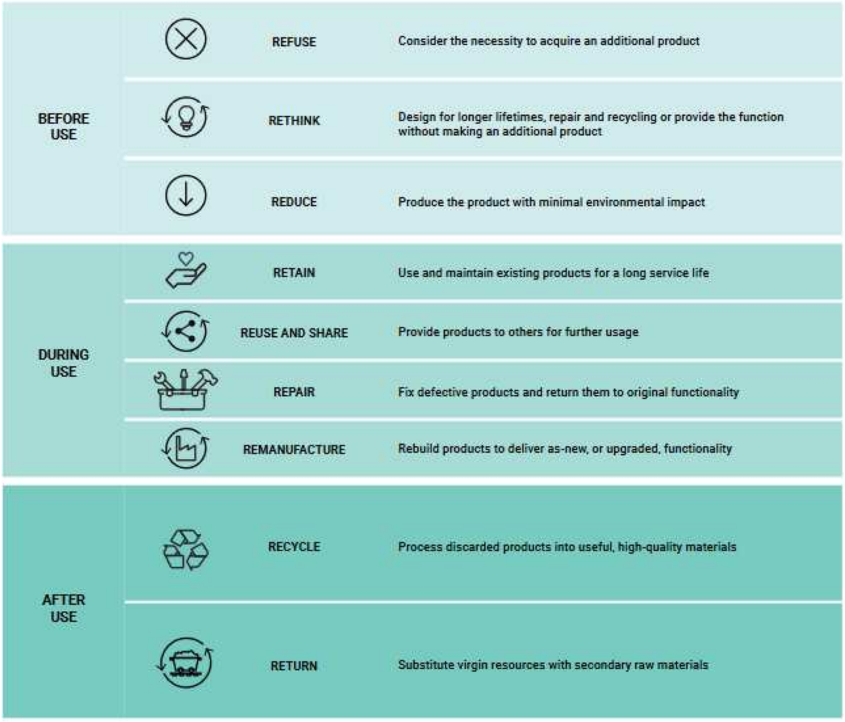
This CE model integrates biological and technical cycles, promoting the use of bio-based materials in technical products and supporting renewable energy processes with nutrients from the biological cycle.

Core elements of CE include design, production, consumption, waste management, and macro and micro perspectives. Products must be designed for longevity, repairability, and recyclability. Sustainable production methods and promoting consumer habits that support reuse, repair, and recycling are essential.

This aspect refers to the R strategies expanded upon the "Reduce, Reuse, Recycle, Recover" principles that emerged in the 1970s. They provide a comprehensive framework for implementing CE practices, from the design phase through to the end-of-life management of products. This hierarchical approach to resource management helps categorize essential CE actions, emphasizing sustainable design, efficient use, and effective disposal or recycling of materials

According to the R strategies concept, it has been created a framework that highlights a set of 10 actions divided by “before-use, during-use and after-use”, as shown in Figure 2.2 below.

Figure 2.2 - Actions for increased circularity within the product chain



Source: Developed by EEA based on Potting et al., 2017.

Before-use techniques (Refuse, Rethink, Reuse) concentrate on using fewer natural resources and having a less negative environmental impact to meet the needs of society. This can be accomplished in a few different ways: by finding more efficient ways to perform the same function or provide the same service, by increasing product utilization through shared use, or by improving procedures to consume less resources. The goal of *during-use* solutions (Retain, Reuse and share, Repair, Remanufacture) is to expand the life of current items and infrastructure, preserving their functionality for as long as feasible. *After-use* (Recycle, Return) measures are put into place when products reach the end of their useful lives to stop material resources from being wasted or destroyed. After that, these materials are brought back into the production cycle to make sure they are properly recycled and reused.

Effective systems for recycling and waste reduction are crucial, along with implementation at both the product/company level and the broader economic level to track resource flows and ensure systemic sustainability.

However, this concept involves several implementation challenges. Technological and economic barriers to achieving full circularity, the need for robust reverse logistics systems to manage asset tracking and recovery, and the development of supportive policies and infrastructure to facilitate the transition are significant obstacles.

2.2 REGULATIONS ON CIRCULARITY AND THEIR IMPACT ON BUSINESSES

Regulations that promote sustainable business activities are essential to the shift to CE. Environmental restrictions in Europe, especially those found in the Circular Economy Action Plan (CEAP), have a significant impact on how companies operate and plan. These rules seek to promote innovation and competitiveness in the European market in addition to reducing waste and increasing resource efficiency. These policies are vital in creating an environment where sustainable activities are both commercially feasible and environmentally vital because they set strict regulations and provide financial incentives. The main environmental laws in Europe are examined in this part, along with how they affect corporate plans and operations and how they encourage the use of circular practices.

2.2.1 Analysis of key European environmental regulations

In the EU and beyond, the shift to a CE will be profound, systematic, and revolutionary. All parties involved, whether at the EU, national, regional, local, or international levels, must coordinate and cooperate.

The journey towards a CE began with several key European regulations. One of the fundamental steps was the introduction of the Ecodesign Directive in 2009, a legislative measure of the EU aimed at improving the environmental performance of energy-related products. This directive sets a framework for the establishment of minimum mandatory requirements for the energy efficiency and environmental impact of products throughout their lifecycle. The primary objectives of the directive include reducing energy consumption, minimizing greenhouse gas emissions, and promoting sustainable product design and manufacturing processes. The directive covers a broad range of energy-related products, including household appliances, information and communication technologies, and industrial equipment. A crucial aspect of the Ecodesign Directive is its role in setting standards that products must meet to be marketed in the EU. These standards ensure that only energy-efficient and environmentally friendly products are available to consumers, thereby driving market demand for sustainable goods.

Building on the success of the Ecodesign Directive, the European Commission launched the Circular Economy Action Plan (CEAP) in 2015, a major block of the European Green Deal. The CEAP aims to reduce waste and promote the sustainable use of resources by ensuring the long-term competitiveness of the EU at the same time. With an emphasis on maximizing resource utilization, this plan covers the full lifecycle of products placed on the EU market, from design and production to consumption and waste management.

In 2020, a new CEAP was published, setting ambitious targets for reducing waste, including a 50% reduction in municipal waste by 2030 and the halving of residual waste. It encourages the use of secondary raw materials and supports innovations in recycling technologies to improve the quality and quantity of recycled materials. The plan also addresses specific sectors such as electronics, textiles, plastics, and construction, each with tailored measures to enhance circularity and sustainability.

Furthermore, the CEAP includes initiatives to promote sustainable consumption patterns. This involves empowering consumers with better information about the environmental impact of their purchases and supporting the right to repair. The plan also aims to combat greenwashing by ensuring that environmental claims are reliable and verifiable. To facilitate the transition to a CE, the CEAP promotes collaboration between public and private sectors, encouraging investments in circular business models and technologies. It also underscores the importance of international cooperation to address global challenges related to resource use and waste management.

One of the key components of CEAP is the Sustainable Product Initiative (SPI), launched in March 2022. The SPI aims to extend the scope of the existing Ecodesign Directive to a wider range of products, ensuring they are designed for sustainability. This initiative addresses key aspects of product design, such as durability, reparability, upgradability, and recyclability, with the goal of reducing environmental impacts and promoting resource efficiency throughout the product lifecycle. The SPI aims to decrease waste, limit the use of hazardous materials, and encourage the use of secondary raw resources by making sure that products are developed with their whole lifecycle in mind.

In parallel, the European Commission introduced the Ecodesign for Sustainable Products Regulation (ESPR) in March 2022. The ESPR aims to broaden the scope of the original directive to include a wider array of products and enhance the sustainability requirements. This regulation is another key component of the European Green Deal and the CEPA, reflecting the EU’s commitment to transitioning towards a more sustainable and circular economy.

It focuses on several key areas to improve the sustainability of products. It mandates that products be designed for durability, reparability, upgradability, and recyclability, encouraging manufacturers to use sustainable materials and reduce the environmental impact of their products throughout their lifecycle. One of the significant innovations introduced by the ESPR is the concept of a Digital Product Passport. This passport is a document that provides information about products' environmental sustainability. This information is easily accessible by scanning a data carrier and it includes product traceability and attributes such as durability and reparability, recycled content and availability of spare parts of a product. This passport promotes the EU's transition to a circular economy by facilitating improved resource management, recycling, and reusing.

Unlike the original Ecodesign Directive, which primarily focused on energy-related products, the ESPR applies to a broader range of goods, including textiles, furniture, and construction materials. This expansion ensures that more products are subject to stringent sustainability standards. Additionally, the regulation supports the EU's CE objectives by encouraging the use of secondary raw materials, reducing waste, and promoting resource efficiency. It aligns with other EU initiatives, such as the Waste Framework Directive and the CEPA. The ESPR also aims to empower consumers by providing them with better information about the sustainability of products. This includes clear labelling and communication about a product's environmental impact, helping consumers make informed purchasing decisions.

As a result of the particular aims and objectives of the CEAP, circularity principles are becoming more and more integrated into other important product-specific policies in addition to the ESPR, including:

- a European strategy for plastics in a circular economy (European Commission, 2018);
- the Farm-to-fork strategy (European Commission, 2020), to build a sustainable EU food system;
- the EU Strategy on sustainable and circular textiles (European Commission, 2022);

2.2.2 Role of regulations in incentivizing the adoption of circular practices

Regulations play a fundamental role in encouraging the adoption of circular practices by creating a framework that rewards sustainable business models and penalizes non-compliance. Financial incentives, such as tax breaks and subsidies for companies that invest in circular technologies, help offset the initial costs associated with transitioning to a circular economy.

Appropriate demand-pull instruments, for instance, focus on creating and enlarging markets for sustainable technologies and practices. These include measures like subsidies for recycled products, tax incentives for sustainable practices, and public procurement policies favouring circular products. These measures provide incentives to innovate and explore new markets without imposing specific technological choices or pollution control methods. For example, environmental taxes increase the cost of pollution, waste, and energy, incentivizing firms to invest in innovation to reduce compliance costs. The Circular Economy Action Plan

(2020) encourages the broader application of environmental taxation, including waste taxes, to accelerate the circular transition. Small and medium-sized enterprises (SMEs), which face material costs representing a significant portion of their total production costs, can particularly benefit from market-based instruments. These instruments not only reduce compliance costs but also lower resource costs in the production process (Wilts and O'Brien, 2019), encouraging firms to engage in circular economy innovation activities such as recycling and reducing waste.

According to Porter's Hypothesis (1991), regulations may promote environmental advances by establishing performance or technological targets, exposing businesses to resource inefficiencies and applying pressure for improvements in technology. The EU's circular economy package, for instance, lays out aggressive goals for waste management, including the recycling of 80% of packaging waste and 70% of municipal garbage by 2030. Tight deadlines may encourage businesses to embrace innovative waste management practices in order to mitigate the costs and constraints of regulations. Particularly SMEs may use less expensive innovative strategies to satisfy minimal legal requirements and save money on compliance.

Additionally, technology-push instruments support the development and diffusion of new technologies. Examples include grants for research and development (R&D) in circular technologies, tax incentives for R&D activities, and support for pilot projects. Public R&D investment in environmental and energy sectors significantly supports companies in redesigning products and services to minimize material use

or incorporate recycled materials in their production processes.
Regulatory measures that mandate transparency in environmental claims help combat greenwashing, ensuring that businesses are genuinely committed to sustainability. By setting ambitious targets and providing clear guidelines, European regulations not only protect the environment but also drive innovation and economic growth, fostering a market where circularity becomes the norm rather than the exception.

While regulations are crucial, their implementation can be complex due to the interdisciplinary nature of circular economy transitions. Effective policy implementation requires collaboration among various stakeholders, including government bodies, businesses, and the public. Balancing the need for innovation with environmental and health protections remains a critical challenge.
In general, regulations incentivize circular practices by setting standards and providing economic incentives, thereby driving innovation and adoption of circular economy models. Nevertheless, the effectiveness of these policies depends on their design, implementation, and the specific contexts of different industries and regions.

2.2.3 Impact of environmental regulations on business strategies and operations

Regulations related to the environment encourage businesses to innovate, adapt, and improve their sustainability practices. These regulations have a significant impact on corporate strategies and operations. Companies are compelled to innovate in product design and manufacturing processes to meet the new standards, which often involves substantial investment in research and development. The CEAP and other relevant European laws are driving important shifts in the way companies handle waste management, production, and consumption. Businesses are being forced by these rules to incorporate circularity concepts into their core strategy, which is leading to a transition from linear models to circular models that are more sustainable.

One of the main effects is the necessity for firms to consider sustainability while designing their products. Durability, repairability, upgradability, and recyclability are requirements imposed by regulations such as the Ecodesign Directive and the ESPR. This drives businesses to reconsider how they produce new products and make investments in innovative materials and technology that satisfy these exacting standards. Based on the guidelines of ISO 14062 standard, in order to meet these features, businesses are encouraged to follow a specific methodology for eco-design that is structured into several phases.

The first phase involves clearly defining the environmental drivers and business objectives, considering aspects such as environmental performance, costs, legislation, and market demands. It is crucial to identify the product in question and ensure a comprehensive understanding of the business case to innovate the product effectively from an environmental perspective.

The second phase adopts the life cycle thinking paradigm to determine the environmental impacts of the product. This involves collecting and classifying data from various stakeholders and company repositories and clearly mapping the environmental impacts for each life cycle phase. Standard methodologies such as life cycle assessment (LCA) are applied during this phase to ensure accurate and comprehensive impact analysis.

The third phase focuses on identifying critical points throughout the product's life cycle and clarifying the activities that significantly influence its environmental performance. During this phase, it is essential to select indicators that will guide the design process and create a dashboard understandable to all stakeholders involved. Environmental targets are defined and translated into design criteria to steer the product improvement and optimization phase.

The fourth phase entails conducting design development activities aimed at meeting the previously set criteria. This includes designing and optimizing the product while considering the established priorities and targets. Utilizing good design guidelines and existing knowledge supports redesign and modification activities. This phase also involves three key eco-design tools: conceptual design, embodiment design, and detailed design. These tools help in structuring the design process, ensuring that sustainability considerations are integrated at every stage of product development.

The fifth phase involves performing life cycle impact assessments during the design phase to verify choices and their corresponding environmental performance improvements. Constant verification of the design choices is necessary to avoid burden shifting, which typically requires an iterative process of modification and verification. Achieving the predetermined targets is essential, and this phase culminates in generating reports to document the improvements and modifications implemented, creating new knowledge for future projects.

The final phase focuses on reviewing and optimizing the product development process and the long-term company strategy. It involves interpreting the results obtained, identifying the company's environmental position in the market, and optimizing long-term objectives. This phase ensures that the experience gained is capitalized on for future developments, continuously enhancing the company's eco-design capabilities and sustainability performance.

Additionally, the introduction of the Digital Product Passport under the ESPR enhances transparency and traceability, requiring businesses to provide detailed information about their products' environmental impacts. This promotes accountability and encourages businesses to adopt more sustainable practices to meet consumer demand for transparent and verifiable sustainability claims. The need for compliance with these regulations also leads to the re-evaluation of supply chains, pushing companies to collaborate with suppliers who adhere to sustainable practices.

As regards the CEAP's emphasis on waste reduction and on the use of secondary raw materials, companies are incentivized to adopt circular practices based on recycling and reusing, not only to align with regulatory requirements but also to save costs and to get efficiency improvements in the long run. By following these practices, companies will reduce dependency on virgin materials and minimize waste generation.

Moreover, sector-specific regulations, including those targeting plastics, textiles, and the food system, require businesses in these sectors to develop customized strategies to increase circularity and sustainability. Businesses are required, for example, to reduce plastic waste and increase the use of recycled plastics under the European strategy for plastics in a CE. Similarly, the EU Strategy on sustainable and circular textiles encourages more sustainable textile production and consumption practices. The Farm-to-Fork strategy also attempts to decrease food waste and promote ecologically friendly agricultural techniques in order to establish a sustainable EU food system.

Businesses are driven by environmental requirements to include sustainability into their everyday operations and strategic planning. This entails significant investments in supply chain management, process optimization, and technology to meet the rising demand for sustainable products and adhere to legal requirements.

Organizations must also rethink their traditional business models and explore innovative models to not only be aligned with environmental goals, but also create opportunities for growth and profitability. Businesses that proactively adopt these changes can benefit from increased brand recognition, a competitive advantage, and an easier path to realizing the goal of a sustainable and CE.

2.3 THE CONCEPT OF CIRCULAR BUSINESS MODELS

A business model describes the rationale of how an organization creates, delivers and captures value (Osterwalder & Pigneur, 2010). It can be meant as a way in which a company analyses, controls and validates its strategic choices, but it can be not defined as the strategy itself (Shafer et al., 2005).

According to the Business Model Canvas developed by Osterwalder and Pigneur in 2010, a business model should contain several key components. The Business Model Canvas is a strategic tool used across various industries to visually outline these key components. It provides a framework divided into nine essential building blocks, each representing a critical aspect of the business: customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships and cost structure. The customer segments block identifies the different groups of people or organizations that a business seeks to satisfy. It highlights how crucial it is for organizations to understand customers' needs, behaviors and characteristics in order to properly tailor their products or services to meet specific demands; next, the value proposition block includes what differentiates the company from its competitors. It highlights the unique value that the business is able to offer to its customers, whether through innovation, quality, price, convenience or other differentiating aspects. This factor is important to attract and retain customers; the channels component refers to how the organization delivers its value proposition. This includes the sales, distribution and communication channels through which the business reaches its clients in an effective and efficient way; the customer relationships block includes the types of relationships the business needs to establish with each customer segment. This is essential to maintain customer satisfaction, loyalty and retention.; the revenue streams component refers to how a company generates revenues from the delivery of value to the customer segments; the key resources block identifies the critical assets required to deliver value, to retain customers and generate revenues. Based on the nature of the business, these resources can be physical, human, intellectual or financial; the key activities block focuses on essential actions a company must perform to create and deliver the value proposition; the key partnerships component focuses on the possibility for the company of establishing collaborations with external organizations, suppliers and partners with the aim to reduce the risk, optimize resources and acquire resources; the cost structure block refers to the major costs the company has to afford that are referred to each component of the company's business model. The costs could be both fixed and variable, such as productivity, distribution, marketing, partner-related expenses.

By considering these nine components, the company can acquire a complete view of its business and can be ready to adapt and innovate its strategies.

Traditional business models have been widely used by companies for decades and are characterized by their reliance on established structures, revenue streams and value propositions. These models include the linear business models (LBMs), that operate on a 'take-make-waste' basis. These models extract raw materials from the environment, use them to manufacture products, and dispose of these products at the end of their life cycles. LBMs typically lead to substantial resource depletion and environmental degradation, since the assumptions that resources are abundantly available, easy to extract and cheap to dispose of (EU, 2015). They are characterized by a one-way flow of materials and energy, without the intention of reclaiming value from the product after its initial use (Magretta, 2002), resulting in significant waste and pollution.

The linear approach often prioritizes short-term economic gains over long-term sustainability, leading to inefficiencies and increased costs over time in addition to limitations to adaptability and responsiveness to changing market conditions and customer preferences (Chersbrough, 2007). For instance, the lack of recycling elements in linear models makes them unsustainable as they fail to recognize the value in waste materials and overlook opportunities for resource recovery and reuse.

One of the fundamental criticisms of LBMs is their contribution to environmental issues such as climate change, loss of biodiversity, and pollution.

Despite their limitations, traditional business models remain helpful for many companies due to their simplicity and their ability to generate predictable revenue streams. However, this traditional approach has been increasingly challenged by the principles of the CE, which advocate for closed-loop systems that aim to minimize waste and maximize resource efficiency.

The transition to a CE requires the development and the implementation of different business models, more dynamic and innovate than the traditional ones, known as Circular Business Models (CBMs). Contrasting to LBMs, CBMs aim to align cost and revenue structures with both sustainability and profitability, integrating principles of the circular economy to design or redesign business activities.

Bocken et al. (2016) define CBMs as business models that extend product lifecycles, close resource loops and use regenerative production and consumption methods in order to create, deliver and capture value in a way that maximizes resource efficiency. These models are specifically made to maximize the use of products, components and materials throughout their life cycles while minimizing resource input and waste, emissions and energy leakage.

The concept of CBMs first appeared in literature in 2006 in an article by Schwager and Moser that examined several business model types for the generation of circular value. After almost a decade, it re-emerged prominently alongside the broader dissemination of the circular economy notion by influential organizations such as the Ellen MacArthur Foundation and the World Economic Forum. This resurgence is partly due to the need for business models that incentivize the adoption of advanced technologies facilitating recycling and the creation of a circular economy. Since 2015, interest in CBMs has surged, driven by increased research funding and high citation counts in academic literature. This growth is further validated by several reviews on the topic and the rising number of publications addressing CBMs.

This concept can be understood as business models that "cycle, extend, intensify, and/or dematerialize material and energy loops" (Bocken et al., 2016). This process reduces resource inputs and minimizes waste and emission leakage within an organizational system, always combining the creation of commercial value with environmental and social benefits.

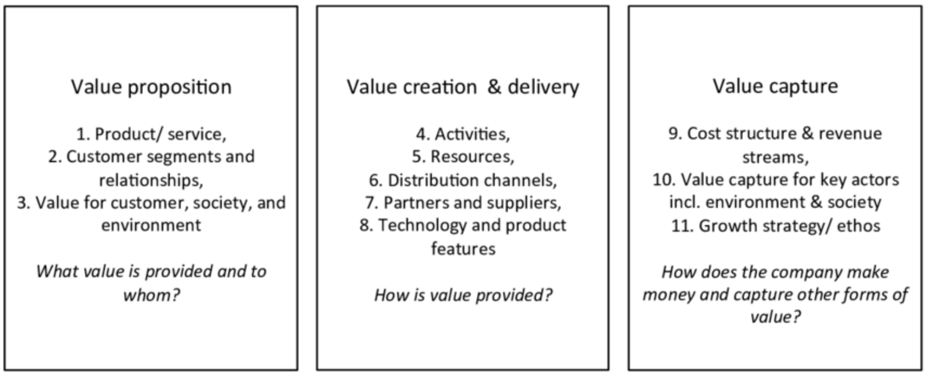
CBMs represent a holistic approach to managerial practices mainly focused on three elements: value proposition, value creation and delivery and value capture (Richardson, 2008) (Figure 2.3).

Value Proposition encompasses the benefits and offerings a business provides to its customers, society, and the environment. In a LBM, the value proposition is centred around delivering products or services to the specific customer segments targeted, primarily based on price and convenience with the goal of maximizing sales volume and market share. This frequently results in an emphasis on products designed for planned obsolescence or disposability, which promotes frequent purchases. The value provided is mostly economic, with little consideration for environmental or social impact.

A robust value proposition not only addresses customer needs and economic gains, but also contributes positively to societal well-being and environmental sustainability. This is the case of CBM value proposition, which emphasizes delivering superior value through innovative and sustainable products or services that differentiate the business from its competitors (Bocken et al., 2014) through durable, repairable, reusable and recyclable designs. The value proposition in CBMs includes innovative solutions that reduce environmental impact, such as product-as-a-service models where customers pay for the use rather than ownership. *Value Creation and delivery* in LBMs involves a linear supply chain where the primary goal is to produce and deliver products quickly and efficiently at the lowest possible cost. On the other hand, in CBMs it includes leveraging internal resources such as technology, skilled labor, and intellectual property, as well as forming strategic partnerships with suppliers and other stakeholders. Effective value creation ensures that all elements of the supply chain work harmoniously to deliver high-quality, sustainable products and services. It involves optimizing processes, fostering innovation, and maintaining strong relationships with all partners to enhance overall value to reduce waste, conserve resources and generate natural systems. Effective value delivery in CBMs ensures that all components in the supply chain are involved in generating circular flows of materials, promoting a sustainable loop rather than a one-way flow (Lüdeke-Freund et al., 2019).

Value Capture focuses on how businesses generate revenue and manage costs, while ensuring the business's financial viability and capturing value for society and the environment. This includes identifying the primary revenue sources, managing operational costs effectively, and exploring new revenue opportunities. Value capture in LBMs is mostly accomplished through one-time product sales, with an emphasis on cutting costs to optimize profitability. While production efficiency and economies of scale play a major role in cost structures, externalized costs related to the environment and society are frequently ignored when determining the product pricing. In CBMs value capture extends to creating positive societal and environmental impacts, such as reducing carbon footprints, promoting ethical practices, and supporting community development. CBMs generate revenue not just from the sale of products but also from additional services, such as maintenance, repair, leasing and other activities that foster customer relationships and loyalty. Businesses must balance profitability with sustainability, ensuring that economic gains are aligned with broader social and environmental goals (Bocken et al., 2016).

Figure 2.3 – Circular business model elements



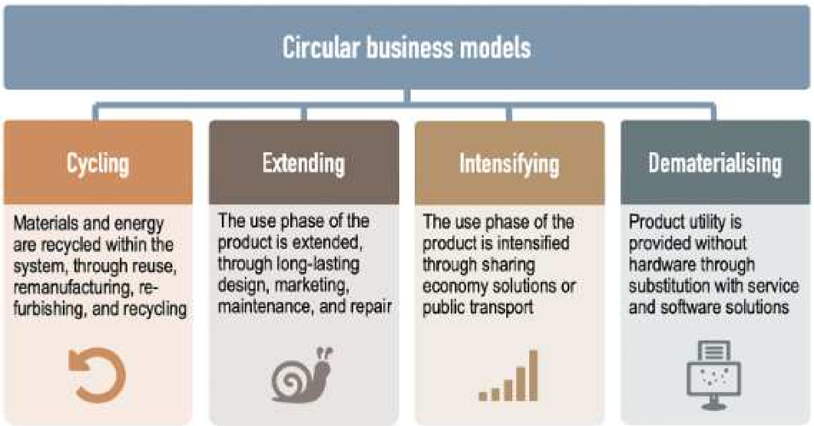
Source: adapted from Richardson and Osterwalder and Pigneur, Bocken et al. and Short et al.

2.3.1 Strategies for developing Circular Business Models

The four generic strategies for CBMs developed by Bocken et al. (2016), Geissdoerfer et al. (2018a,b), and Oghazi and Mostaghel (2018) include (Figure 2.4):

1. *cycling* means implementing recycling measures. Materials and energy are recycled within the organization;
2. *extending* implies prolonging the use phase of products;
3. *intensifying* means increasing the intensity of product use;
4. *dematerializing* stands for substituting products with service and software solutions, for example replacing physical products with services or product-service systems that accomplish the same function.

Figure 2.4 - Circular business model strategies



Source: Bocken et al., (2016) and Geissdoerfer et al., (2018a,b)

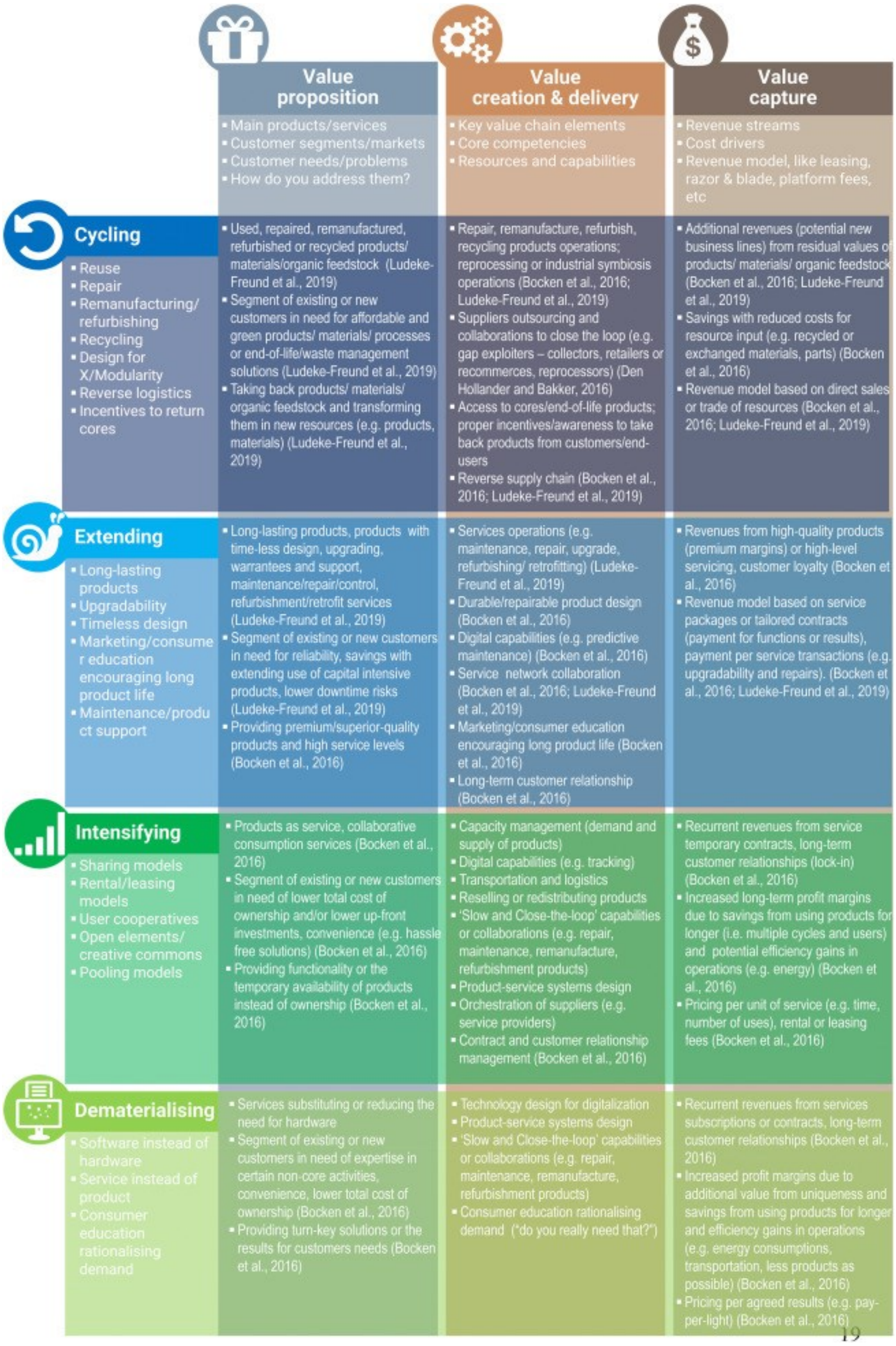
By considering these four CBM strategies, it can be possible to discuss how the implementation of them will influence the business model elements mentioned before (value proposition, value creation and delivery and value capture) (Figure 2.5).

Cycling refers to some end-of-use strategies, such as reuse, repair and remanufacturing. As regards the value proposition element, the key is taking back products and materials and transforming them in new items. This will positively affect the value capture concept since that the concept of recycling materials will be reflected in both a reduction in terms of costs of material acquisition and an increase in revenues from the potential new products. In this way, the business reduces energy and materials inputs and waste outputs.

Extending focuses on maximizing product usage by leveraging design and operational practices. Offering long-lasting products (value proposition) that receive maintenance throughout their lifecycle fosters long-term customer relationships (value creation and delivery) and generates new revenue streams (value capture) through service packages or tailored contracts during the product's use phase. This approach reduces the need for manufacturing new products. Intensifying involves creating new value propositions based on sharing models, supported by capacity management, digital capabilities, and customer relationship management. Intensifying promotes business models with strong service elements, such as Product-Service Systems, leading to recurrent revenue streams. In addition, the pricing is per unit of service (time, number of uses), rental or leasing fees. The primary environmental benefits include reducing idle time and structural waste (products discarded before their expected lifespan), thus decreasing the need for new product production and minimizing waste output.

Dematerializing aims to reduce the use of physical resources by enhancing value through intangible solutions like services and software. Value creation and delivery are achieved through slow and close-the-loop capabilities and collaborations. This strategy focuses on generating recurrent revenues, increasing profit margins, and implementing new pricing mechanisms based on agreed results.

<u>Figure 2.5</u> – Implementation of CBM strategies with BM elements



Source: Geissdoerfer et al. (2020)

2.3.2 Frameworks for developing Circular Business Models

CBMs can be effectively developed and implemented using other specific templates designed to guide businesses in their transition from linear to circular practices. These templates provide structured frameworks that help businesses to identify opportunities for circularity, design innovative solutions, and align their operations with sustainability goals. The majority of these templates has been inspired by the Business Model Canvas (BMC), developed by Osterwalder and Pigneur. This BMC is now frequently utilized in CBM research, mostly without altering its architecture. One of the templates built upon Osterwalder and Pigneur's model is represented by the “Circular Business Model Value Dimension Canvas” developed in 2023 by Md Tasbirul Islam and Usha Iyer-Raniga.

The template begins with the *circular goal and scope definition*, along with the *sustainability mission and action*. Unlike the traditional BMC, which primarily focuses on economic goals and market positioning, this framework aligns the business with CE principles and sustainability goals (Islam & Iyer-Raniga, 2023). This section requires businesses to articulate their vision explicitly in terms of circularity, selecting specific CE principles, whether technical or biological cycles, that they aim to achieve. This section integrates CE strategies proposed by Potting et al. (2017), aligning sustainability aspects with the Sustainable Development Goals (SDGs). In contrast to the traditional model which may not take sustainability into consideration, this circular framework incorporates sustainability as a fundamental component, guaranteeing that every company action promotes long-term environmental and social results.

Under the *value proposition* segment, the framework includes eight building blocks, such as customer relationship and collaboration, a unique circular value proposition, targeted solutions, and the benefits and burdens for customers, society, and the environment (Islam & Iyer-Raniga, 2023). This segment emphasizes understanding customer needs, problems, and challenges to develop a distinctive circular value proposition that leverages unfair advantages. Unlike Osterwalder and Pigneur's model, which focuses on economic value for customers, this circular framework encourages businesses to co-create value with stakeholders, fostering stronger collaboration that is central to driving circularity and sustainable development (Geissdoerfer et al., 2018).

The *value creation and delivery* segment comprises nine core building blocks, including essential partners and stakeholders, key activities, circular design, risk assessment, and ecosystem-level activities (Islam & Iyer-Raniga, 2023). This segment focuses on the critical resources and activities necessary to deliver the value proposition and manage associated risks and channels.

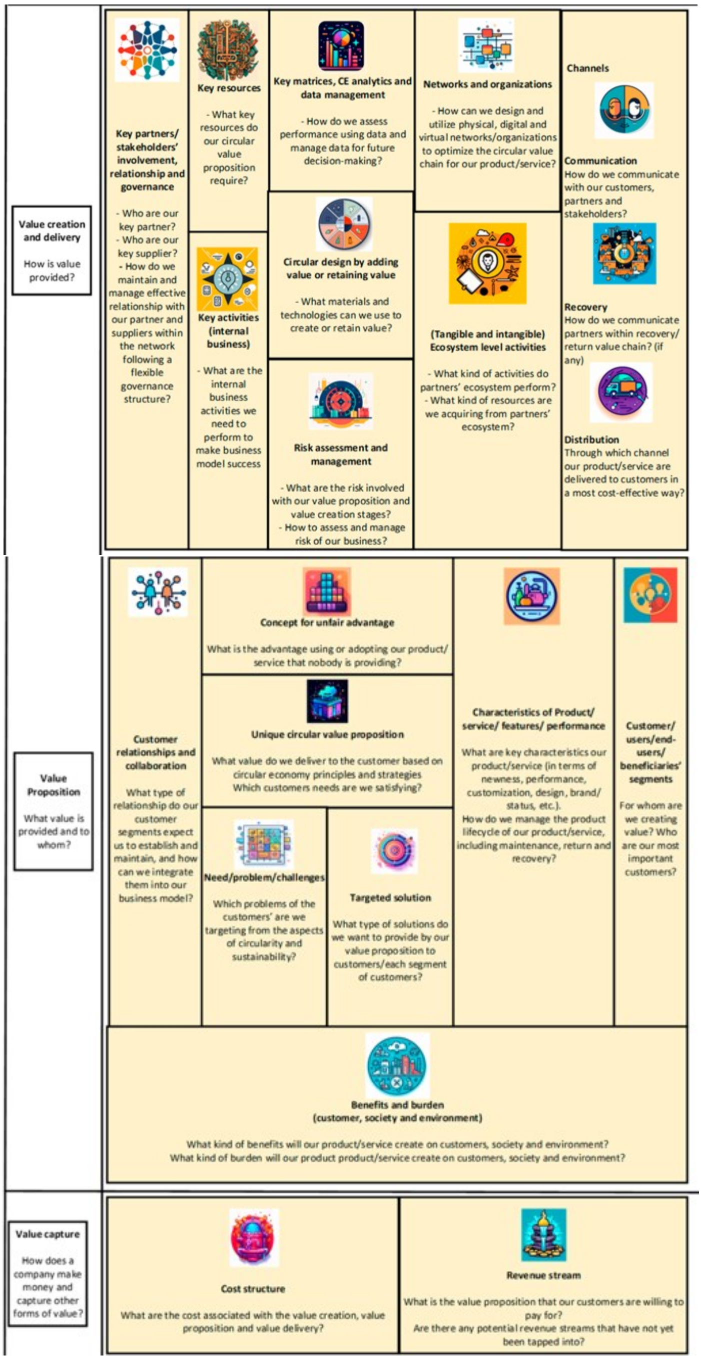
It is designed to especially address the complex nature of circular value chains, in which the generation of value entails a number of cycles and loops aimed at extending the lifespans of materials and products. In contrast to the traditional BMC strategy of "take-make-dispose," this circular framework emphasizes durability, repairability, and recyclability in design. It highlights the significance of creating robust supply chains, forming strategic alliances that put sustainability first, and applying circular design concepts to make sure that end-of-life considerations are incorporated into product design. It also recognizes that real circularity necessitates a systemic approach that extends beyond individual organizational borders and incorporates thorough risk assessment and ecosystem-level concerns (Bocken et al., 2016).

The *value capture* segment consists of the cost structure and revenue streams, directly adapted from Osterwalder and Pigneur's model, but the Circular Business Model Value Dimension Canvas places a stronger emphasis on linking these financial aspects directly with sustainable value creation and delivery (Islam & Iyer-Raniga, 2023) This segment ensures economic viability through innovative circular revenue models (leasing, repair, product-as-a-service) rather than merely through the traditional sale of products.

The suggested sequence for using the framework starts with the value proposition, identifying needs and problems, targeted solutions, and unique value propositions. This is followed by assessing and aligning resources, activities, and partners in the value creation and delivery segment. Throughout this process, it is essential to continuously evaluate cost structures and revenue streams in the value capture segment to ensure economic viability. The circular goal and scope definition and sustainability mission and action can be completed initially if the user has a clear understanding of circularity and sustainability goals, or at the end after other segments are well-defined.

The framework facilitates businesses in tracking their contributions to the greater good and their impact on customers, society, and the environment. It also provides a structure for future researchers to identify further opportunities in CBM research. The complete design of the canvas is depicted in Figure 2.6.

Figure 2.6 - Circular business model value dimension canvas



Source: Islam, M.T.; Iyer-Raniga, U. (2023). Circular Business Model Value Dimension Canvas: Tool Redesign for Innovation and Validation through an Australian Case Study. *Sustainability*, *15*, 11553

Beyond the Circular Business Model Value Dimension Canvas developed in 2023 by Islam and Iyer-Raniga., in the previous years other frameworks have expanded significantly from the original BMC by Osterwalder and Pigneur. For example, the Lean Canvas, developed by Maurya (2012), modifies the BMC to focus more on startups by incorporating building blocks like problems, solutions and unique value propositions, thereby addressing specific market and operational challenges. Similarly, Daou et al. (2020) created the ECOCANVAS, which consists of twelve building blocks, adding factors like circular value chains and environmental and social impacts, tailored to sustainable practices.

Additional modifications include Donner et al.'s Conceptual framework for business case analysis (2020), which incorporates bioeconomy principles and institutional context with traditional BMC components, and the Sustainable Business Model Canvas for Offshore Platforms (2018), which highlights eco-social costs and benefits.

Other notable contributions are the Circular Business Model Canvas and the Framework of Circular Business Model Canvas by Lewandowski (2016), which add dimensions like adoption factors, take-back systems and value influence factors.

Several specialized frameworks have also been created for particular applications, as the Circular by Design Canvas by Ballie and Woods (2020), the Smart City Business Model Framework by Giourka et al. (2020) and the Flourishing Business

Canvas, for collaborative visual business modelling (2020). These models combine environmental, social and economic perspectives, providing comprehensive tools for designing circular business models across a range of sectors.

Another example of framework designed for developing CBMs could be identified in the ReSOLVE framework developed by the Ellen MacArthur Foundation in 2015. It is structured around six key action areas: Regenerate, Share, Optimize, Loop, Virtualize and Exchange (Figure 2.7). Each action area provides a specific set of strategies and principles aimed at closing material loops, minimizing waste and maximizing the use of resources, while creating economic value and reducing environmental impact (Ellen MacArthur Foundation, 2015).

Figure 2.7 – ReSOLVE framework

Source: Ellen MacArthur Foundation (2015)

Regenerate aims to improve and restore natural systems. It motivates companies to migrate away from fossil fuels and toward renewable energy sources while enhancing ecosystem health. This activity includes methods like creating products that can naturally decompose without damaging the environment, utilizing biodegradable materials, and implementing regenerative farming practices. The goal of regenerative actions is to leave a net positive environmental impact by returning more to the planet than is extracted. Businesses that implement these strategies can increase ecosystem resilience and restore natural capital.

Share encourages optimizing the use of products by reusing them whenever feasible, sharing them among several users, and extending their life through maintenance. This tactic encourages access above ownership and questions the conventional understanding of ownership. It promotes the creation of business models like digital platforms for the sharing of products and services, tool libraries, and car-sharing. The "Share" action lowers the demand for new items by raising product usage rates, which in turn lowers resource consumption and waste production. In order to ensure that items are useful and appealing for as long as possible, this action also focuses on developing them for durability and reparability.

Optimize seeks to increase how effectively resources are used in current systems. It entails optimizing product performance, cutting waste from production processes, and utilizing technology to boost productivity. The goal is to optimize the flow of materials and energy within a system by employing strategies such as lean manufacturing, predictive maintenance, and smart technology integration. This lowers costs, minimizes pollutants, and uses less raw materials, all without significantly changing the final product. For instance, optimizing production and supply chains can dramatically lower a company's carbon footprint and operating costs.

Loop's main goal is to extend the life of goods, components, and resources in the economy, ideally in a closed-loop system. This activity has a strong emphasis on recycling materials, remanufacturing products to make new ones out of old components, and designing for product disassembly and reuse. By establishing a circular flow of materials where items are made to be continuously recycled, repaired, remanufactured, or reused, waste is to be eliminated. "Loop" strategies push companies to consider more than just a product's end of life and to focus on closing the loop in order to maintain the flow of materials through the economy.

Virtualize involves dematerializing products and services by providing them in digital or virtual formats. To cut down on material use and waste production, this action recommends substituting digital items for physical ones wherever possible. Examples include digital books, online meetings replacing travel, and virtual reality experiences substituting for physical ones. Businesses may dramatically reduce their environmental impact, save money, and improve user ease by shifting from physical to digital. In addition to lowering dependency on limited resources, virtualization creates new revenue opportunities and business models.

Exchange encourages businesses to replace old, resource-intensive processes and technologies with newer, more sustainable alternatives. This can entail using innovative methods like additive manufacturing (3D printing), which can drastically reduce waste and increase resource efficiency, or introducing new business models like product-as-a-service. It can also entail replacing non-renewable resources with renewable ones. The "Exchange" activity aims to create more resilient, sustainable company processes by embracing innovation and change. It pushes businesses to reconsider conventional strategies and think about how new tools and techniques may produce profit in a more sustainable way.

The ReSOLVE framework offers a comprehensive approach to promoting a circular economy, guiding businesses to reduce their environmental impact, enhance resource efficiency, and foster growth. It aligns with broader societal goals, promoting social equity and reducing greenhouse gas emissions (Ellen MacArthur Foundation, 2015).

The dynamic nature of CBM development and the constant need to modify current models to more accurately reflect circular principles and strategies. Additionally, it emphasizes the growing understanding of the significance of incorporating sustainability into core business strategies and the demand for models that can accurately depict the intricate interactions between economic, social and environmental factors (Osterwalder & Pigneur, 2010; Lewandowski, 2016; Ellen

MacArthur Foundation, 2015).

2.3.3 Types of Circular Business Models

According to the 4R framework (Reuse, Reduce, Recycle and Recover) and whether resource loops are slowed down or closed (Bocken, 2016), Circular Business Models are classified into four patterns that provide businesses with a set of proven strategies that can be adapted and applied to various contexts, helping them navigate the complexities of transitioning towards more sustainable, circular operations (Lüdeke-Freund et al. 2018).

Business models that contribute to slowing down resource loops can be divided into two main types. The first type is the "product-as-a-service" model, where companies maintain ownership of their products and provide them as services to customers, a concept explored in the product-service system literature (Mont, 2002; Tukker and Tischner, 2006; Lacy et al., 2014; Tukker, 2015). This model primarily aligns with the "reduce" principle of the 4R framework, as it involves rethinking product usage to minimize resource consumption. The second type is the product life extension model, which focuses on prolonging a product's lifespan through reuse, remanufacturing, maintenance, or repair. This model corresponds to the "reuse" strategy in the 4R framework.

For business models aimed at closing resource loops, there are two primary archetypes: resource recovery and circular supplies. The resource recovery model involves reclaiming resources to create new forms of value, aligning with the "recycle" and "recover" strategies of the 4R framework. Circular supplies, on the other hand, use fully recyclable, biodegradable, or renewable inputs to replace traditional linear inputs and scarce resources, fitting into the "reduce" category of the 4R framework.

Derived from product-service system (PSS) literature, *product-as-a-service model* revolves around offering products as services while retaining ownership. A product service system provides a set of products and services that are able to create customer value and opportunities with regard to sustainability. Tukker proposed three types of PSS: product-oriented, use-oriented and result-oriented.

Product-oriented systems are mainly based on LBMs, where the company encourages the consumption of products and transfers the ownership to the customer, who has a tangible value. The company, moreover, does not have responsibility for the product life-cycle and just provides maintenance and repair services;

in use-oriented systems the product is owned by the company and leased or rented to the customer that gains access to it. Furthermore, the company has the responsibility for providing life cycle services, such as maintenance, repair and control. In order to do that, it designs and creates products that can be easily reused after their first life;

in result-oriented systems, the company does not sell the product itself, but the customer will pay for the achievement of a result or outcome. For instance, instead of selling washing machines, a business can sell a laundry service guaranteeing clean clothes as the final result.

PSS suggest that, in a product-as-a-service model, the value proposition focuses on providing services instead of selling products outright, with customers accessing the products through leasing agreements. In addition, this model might also involve sharing platforms, that make efficient use of resources by allowing several users to share access to a particular good or service. This increases utilization rates and lowers the need to create new goods. Sharing platforms function inside the product-as-a-service framework by facilitating the connection between providers and users who require temporary access to items. These platforms can include co-working spaces, equipment rental services, and car-sharing programs. Sharing platforms, which make use of digital technology, provide smooth user experiences by facilitating booking, tracking, and payment of services using online interfaces or mobile apps.

The product-as-a-service model necessitates additional services to ensure product durability, often managed by third parties. These services may include maintenance, repair, and product upgrades, ensuring that the product remains functional and valuable throughout its use phase. By integrating products and services, companies can create more comprehensive solutions that meet customer needs more effectively and sustainably. Revenue generation in the product-as-a-service model is spread over time rather than being realized at the point of sale, which can tie up capital. This continuous revenue stream requires companies to have robust financial management strategies to handle the delayed return on investment. Additionally, this model requires a deep understanding of customer needs for services and entails long-term customer relationships, presenting both opportunities and challenges.

Product life extension model aims to extend the lifecycle of products by leveraging their residual value through reuse, meaning that the product can be immediately resold or reused, or product upgrades involving activities such as repair, refurbishment, or remanufacturing. The key activities involve collecting discarded products via take-back systems and reverse logistics, which can be unpredictable. The extent of technological expertise required varies with the type of product upgrade, from simple repairs to complex remanufacturing. Companies capture value by selling refurbished products, which often come at a lower price point than new ones but with similar functionality and reliability. This model can also generate revenue through service contracts and extended warranties. Success in this model is often influenced by the product's original design, which affects the ease and cost-effectiveness of extending its life. Resistance from original manufacturers and customer preference for new products pose significant challenges.

Resource recovery model focuses on recovering materials from discarded products to create new value, typically through processes like recycling, where the original product function is lost. This model involves activities such as collecting, sorting, disassembling, and processing materials to manufacture new products. Technological complexity and quality uncertainty of waste materials are notable challenges. Additionally, obtaining permits for waste reuse, and customer acceptance of recycled products can be difficult.

Circular supplies model aims to replace virgin materials with renewable, recyclable, or biodegradable alternatives in production processes. The value proposition focuses on reducing dependence on scarce resources and lowering environmental footprints. Key activities include purchasing circular materials and selecting appropriate suppliers. Financial barriers due to high initial investments and the perceived additional burden on suppliers can hinder adoption. Adjustments in product design might be necessary to accommodate new materials, and customer awareness and acceptance of sustainable products remain critical issues.

Many firms adopt hybrid models, combining elements of the above strategies to maximize their benefits and create resilient, adaptable business models. For example, a company might integrate product life extension with product-as-a-service to offer durable, serviceable products on a lease basis, ensuring longevity and continuous revenue streams. Another approach could involve combining resource recovery with circular supplies to create closed-loop supply chains where recovered materials are reintegrated into new products, enhancing sustainability and reducing costs. Hybrid models exemplify the flexibility and innovation required to succeed in a circular economy.

2.3.4 Benefits and criticalities of adopting Circular Business Models

The implementation of CBMs involves both advantages and drawbacks.

According to what is analysed in the previous paragraphs, it is evident that CBMs present several advantages. One of the primary benefits is resource efficiency. By encouraging recycling, reuse, and remanufacturing, these models maximize resource utilization by lowering the need for virgin materials and minimizing waste. Reusing products and materials allows businesses to cut material costs, which in turn lowers production costs over time. This results in more sustainable resource management and significant cost savings (Geissdoerfer et al., 2020).

CBMs also involve a positive environmental impact in terms of reducing greenhouse gas emissions, decreasing waste generation and conserving natural resources. This supports efforts to mitigate climate change and advance global environmental goals (Kirchherr et al., 2017). Furthermore, the implementation of circular business models fosters innovation in processes, materials, and product design, giving businesses that lead this field a competitive advantage through the provision of distinctive, environmentally friendly goods and services (Urbinati et al., 2017).

CBMs can also benefit from increased consumer engagement, as they can improve client satisfaction and retention by providing long-lasting, easily repaired, and upgradeable products. Greater connections can be developed by including customers in recycling and take-back initiatives. Additionally, by opening up new revenue streams through leasing, product-as-a-service, maintenance, and refurbishing, these models produce income that is more regular and predictable (Moreno et al., 2016).

Moreover, CBMs assist companies in staying ahead of rules and lowering the risk of non-compliance penalties when regulations pertaining to sustainability and waste management come under growing pressure (Rizos et al., 2017).

Despite these benefits, CBMs face several critical challenges represented by both internal and external barriers.

On one hand, internal barriers involve the lack of knowledge and technology, organizational barriers and financial and economic barriers.

The lack of knowledge and technology is a major internal limitation. Operational complexity for Product-as-a-Service models might arise from administrative barriers linked to lease agreements and legal problems pertaining to contracts. Product Life Extension (PLE) and Resource Recovery (RR) models frequently lack the technology and knowledge needed to integrate circular materials into production and handle recycling; another key issue is organizational reluctance to change. Making the transition from LBMs to CBMs necessitates extensive restructuring, which can be costly as well as hazardous. Changes that could eventually be advantageous to the company and the environment may be resisted by managers who profit from the current arrangement; as regards the financial aspect, large upfront investments in infrastructure, technology, and training are common in CBMs, and these can be difficult for small and medium-sized businesses. Circular practices can be economically hard due to higher prices and the non-viability of business models due to high service costs, particularly when product components are inexpensive (De Jesus et al., 2018).

On the other hand, external barriers encompass limitations regarding supply chain, market, regulations, cultural barriers, financial and economic barriers, confidentiality and trust issues and return flow challenges.

It is more difficult to manage circular supply chains than standard LBMs. This complexity entails managing reverse logistics effectively, keeping track of product life cycles, and collaborating with several stakeholders. Dependency on suppliers who don't prioritize waste input quality and delivery time or reuse might lead to conflicting interests in the supply chain for PLE and RR models. Moreover, low waste volume and a lack of partners can make resource recovery operations difficult; in addition, changing customer attitudes and behavior is another important external barrier. Customers may not comprehend or accept leasing contracts, particularly in PSS models, and they frequently oppose non-ownership models. PSS models are less appealing due to the market's inclination for disposable goods and the low value put on "used" goods. Although it is still difficult, educating consumers and fostering trust in circular goods and services is essential for their wider acceptance (Prieto-Sandoval et al., 2018); institutional support and regulatory frameworks are necessary for the effective application of CBMs. Navigating various regulatory standards across different areas can be resource-intensive and challenging. Principles of the CE are frequently overlooked by those with vested interests in linear economy methods, such as present accounting standards and key performance measures. Further obstacles may include the absence of legislative incentives to use trash and the intricate and inconsistent regulatory framework; common cultural obstacles include aversion to change and fear of the unknown. This reluctance is seen in society at large, where a "buy-and-own" mentality is very prevalent, as well as in companies. It is needed a considerable amount of work and time to educate people and shift their perspectives on the advantages of CBMs in order to overcome these cultural barriers (Bocken et al., 2016); apart from the financial obstacles within the organization, there are external economic factors as well. It can be challenging for businesses to plan and manage their operations in the secondary material and remanufactured product markets due to pricing and demand fluctuations. In addition, CBMs are less financially appealing because recycled materials are frequently still more expensive than new ones (Lieder & Rashid, 2016); sharing the designs and data required for circularity may give rise to intellectual property issues. Businesses could be reluctant to divulge information that rivals might use against them. Collaboration in CBMs requires mutual trust and advantages for all parties involved, although these can be challenging to attain; the capacity of reverse logistics restricts the exchange of materials. While consistent quality control can be limited by returned product condition diversity, efficient handling of returned goods is necessary to preserve the quality of recycled or remanufactured goods.

It is evident that, although there are many advantages to using CBMs over traditional linear ones, there are also many internal and external obstacles to overcome. A comprehensive strategy is needed to overcome these obstacles, by making investments in infrastructure and technology, altering organizational and cultural perspectives, creating supportive legal frameworks, and encouraging cooperation and trust among all parties involved.

CHAPTER 3: MEASURING CIRCULARITY THROUGH KPIs

3.1 CHALLENGES AND OPPORTUNITIES OF INTEGRATING KEY PERFORMANCE INDICATORS AND CIRCULAR ECONOMY PRINCIPLES

Incorporating KPIs into CE principles creates a complex environment of opportunities and challenges that businesses must manage to improve operational efficiency and sustainability.

One of the primary challenges is represented by the technical problems associated with data administration and gathering. As mentioned in the previous paragraphs, accurate KPI measurement might be limited by the fact that many companies find it difficult to collect reliable data on resource utilization, waste generation, and recycling rates. The situation is made even harder by the lack of standard methods for calculating circularity, since businesses frequently use different criteria that make it difficult to evaluate performance across sectors or geographical areas (Elia et al., 2017).

Another major difficulty is organizational limitations. Initiatives aimed at promoting the CE frequently call for coordination and cooperation across departments amongst different corporate units, including sales, manufacturing, and procurement. Additionally, the resistance to changes, especially well-established companies, may obstruct the successful integration of circular KPIs. Internal conflicts may result from staff members' reluctance to embrace new procedures or departments' preference for short-term financial gains over long-term sustainability goals (Bocken et al., 2017).

Regulatory constraints present another major obstacle for circular KPIs effectiveness, since, as explained in Chapter 2, regulations need to be aligned with CE objectives. While certain countries, like the European Union, have made significant progress toward advancing laws related to the CE, other regions lack well-defined legislative frameworks that would lead companies in their circular aims. Setting relevant and consistent KPI targets can be challenging for enterprises due to the inconsistent regulatory landscape. Additionally, adhering to various regulations in different markets may result in higher expenses and more administrative work (Avdiushchenko & Zajac, 2019).

Furthermore, the integration process can be challenged by market dynamics. Customers' demand for circular products and services can vary by industry and area, therefor companies are limited when finding a market for circular innovations if clients are not willing to pay higher prices for sustainability. Furthermore, it can be challenging for businesses to afford circular investments due to changes in raw material costs, which can affect how cost-effective recycling and resource recovery initiatives are (Grafström & Aasma, 2021).

Despite numerous challenges, integrating KPIs and CE also offers several benefits for businesses. One of the most significant advantages relies on the opportunity for innovation. The concepts of the CE encourage businesses to reconsider their resource usage, product design, and business strategies, which results in the creation of new, sustainable goods and services. Companies can promote a culture of creativity and continuous development by utilizing KPIs to track and measure circular innovations, which will have a positive financial and environmental impact (Cainelli et al., 2020).

Cost saving is another major opportunity. Despite the investments the business have to afford at the beginning, circular practices such as recycling, reusing materials, and cutting waste can lead to significant cost savings over time. By tracking KPIs regarding waste management and resource efficiency, organizations can identify areas where they are wasting resources and implement changes to avoid those kinds of losses. Furthermore, recurrent revenue streams can be generated offering long-term financial stability (Guldmann & Huulgaard, 2020).

Integrating circular KPIs well can also improve a business's reputation. Businesses that show their commitment to sustainability are likely to gain a competitive advantage as consumers become more environmentally sensitive. By providing transparency, circular KPIs allow companies to communicate their progresses in terms of reducing waste, conserving resources and lowering their environmental impact. This improved reputation has the potential to strengthen consumer loyalty, attract new customers and increase relationships with stakeholders (Burström et al., 2021).

Furthermore, the adoption of circular KPIs can facilitate regulatory compliance. Many governments, particularly in the EU area, are enacting more stringent regulations pertaining to resource usage, waste management, and carbon emissions. By proactively integrating KPIs, businesses can achieve regulatory requirements while positioning themselves as sustainability leaders, lowering the risk of future compliance expenses and fines (Avdiushchenko & Zajac, 2019).

To overcome the challenges and leverage the opportunities linked to the integration of KPIs into the CE landscape, organizations need to adopt a multifaced approach. One of the main recommendations relies on the investments on advanced data management and gathering systems. By introducing digital technologies, companies can enhance the efficiency, accuracy and transparency of data collection processes.

Encouraging cross-departmental collaboration is another essential step. Integrating circular KPIs requires strong leadership and effective communication to overcome organizational constraints. By creating cross-functional teams, a business can ensure that all of its departments are working toward the same goals and integrating KPIs into their daily operations in line with the CE. In addition to promoting consistency, this collaborative strategy allows circular activities to be integrated into every facet of the company (Bocken et al., 2017).

It is also essential that companies remain informed about policies and regulations. This will result in an alignment between KPIs and regulatory requirements. By proactively incorporating circular KPIs, businesses can avoid potential penalties and become leaders in sustainability, demonstrating their adherence to legal requirements and environmental responsibilities.

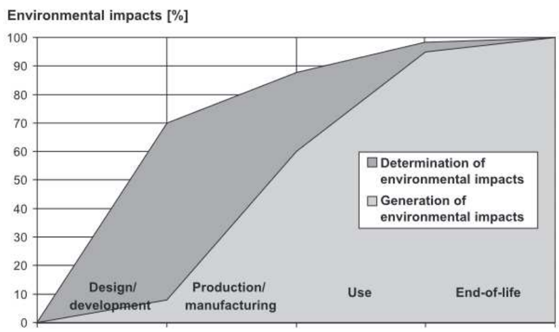
Moreover, in order to handle market dynamics, businesses need to focus on informing and involving stakeholders. Organizations can stimulate demand for circular innovations by educating stakeholders, investors, and customers on the advantages and worth of circular goods and services. Emphasizing the circularity's benefits for the environment and economy not only expands the market but also enhances the company's reputation as a progressive, sustainable business.

3.2 FRAMEWORKS FOR MEASURING CIRCULARITY IN A BUSINESS

Measuring circularity in businesses and tracking the performance of CE activities can result complex. There exist numerous frameworks and methodologies that help businesses improve their circular practices. Most of them examine practices or businesses concerning their operations, products, and services to find out how well they minimize waste, maximize the efficiency of resources, and create closed-loop systems (Geissdoerfer et al., 2017).

One of the most common frameworks is the *Life Cycle Assessment* (LCA), a tool used to keep track of the environmental impact and resource usage of a specific product during its life cycle, from the acquisition of raw materials to waste management. The term "product" refers both to physical goods and services. When adopting an LCA, the design/development phase should also be considered since the decisions made during the design and development phase have a significant effect on the environmental impact in other life cycle stages, as shown in Figure 3.1.

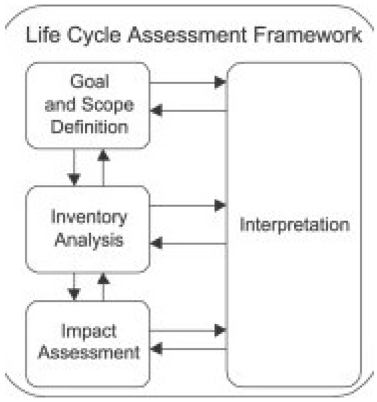
Figure 3.1 - Determination and the generation of environmental impacts in a product's life cycle



Source: Rebitzer, 2002

The LCA framework, based on ISO 14040 and ISO 14044, originally includes four phases: goal and scope definition, inventory analysis, life-cycle impact assessment and interpretation of inventory and impact assessment results (Consoli et al., 1993) (Figure 3.2)

Figure 3.2 – Phases of LCA



Source: ISO 14040, 1997

The first phase concerns the definition of the purpose of the LCA study, the establishment of the system boundaries, assumptions and limitations, including the determination of which processes and life cycle stages, such as raw materials extraction, production, use and disposal.

After the definition of the system boundaries, in the second phase, the life-cycle inventory analysis, the objective is to gather data about inputs and outputs of each process in the life-cycle of the product, which includes material flows, energy use, emissions and waste. These data are aggregated across the whole system. The inventory is an essential stage in calculating the environmental load since it quantifies the resources used and emissions produced throughout every step, providing the foundation for the impact assessment that follows (Rebitzer et al., 2004). In the third phase, the life-cycle impact assessment, the potential impacts associated with the inventory data are evaluated. The inventory data are classified into relevant impact categories (global warming potential, acidification, impact of land and water use, etc.) and successively they are converted to common impact units to quantify the contribution of each resource/emission to the impact categories (Finkbeiner et al., 2006). Then, the results are compared to a reference value to understand the strength of the impacts (Hauschild et al., 2017).

The final phase aims to analyse the results of Life cycle Inventory and Life cycle impact assessment in order to identify the key issues and provide recommendations based on the assessment and the scope and goal defined in the first phase.

LCA has traditionally been used to assess and improve specific product systems, mainly to assist business decision-making about eco-design, supply chain management and process optimization. Its application is particularly beneficial during these early stages of product and process design, when significant modifications can be applied. However, recently companies are increasingly adopting LCA results to report on important environmental issues at the corporate level. This includes identifying the value chain segments where product portfolios have an influence and providing an overview of the company's mitigation strategies (Guinée, 2002). This can be achieved through greater collaboration with other value chain actors, through the development of new products and technologies and the exchange of materials and energy (Mattila et al., 2012) to create synergies among the industrial neighbors. LCA also supports sustainable consumption and production efforts by identifying major environmental impact drivers in national economies, such as housing, mobility, and food in Europe.

LCA is not just about protecting the environment; it can also be an indispensable tool for strengthening competitive dynamics and reducing costs (Rebitzer et al., 2004). However, the adoption of LCA framework for measuring circularity also presents some challenges, particularly in terms of data gaps, consumer behavior integration and databases accessibility.

Circularity in businesses can also be measured by the *Life cycle costing* (LCC) framework. LCC is a tool that evaluates the economic impact of a product, process or service over its whole life cycle, taking into account all costs associated with acquiring, operating, maintaining and disposing of the product. This means that this framework has to consider all the costs that will be incurred during the lifetime of a product or a service: the purchase price including all related expenses, such as delivering, setup and insurance, the operational expenses (electricity, water and fuel consumption, maintenance, etc.) and the end-of-life costs or residual value (European Commission, 2014)

LCC goal concerns providing a comprehensive financial analysis that can help manage decision-making activities and optimize cost-effectiveness (Hauschild et al., 2017).

A distinction could be made between conventional LCC, environmental LCC, and societal LCC. Conventional LCC focuses solely on economic evaluation and costs directly borne by a specific actor, typically considering the perspective of either the producer or consumer alone. This method does not consider external costs or impacts, such as environmental or societal factors, and may overlook end-of-life operations, often using discounted costs (Guinée, 2002). For example, a conventional LCC might consider the cost of virgin material, delivery and manufacturing without taking into account the long-term environmental damage (greenhouse gas emissions) caused by resource extraction. While effective for short-term financial planning, conventional LCC tends to fail to observe broader sustainability concerns, making it not so suitable for CE applications. Environmental LCC, on the other hand, uses system boundaries and functional units equivalent to those in LCA. It includes costs directly borne throughout the product life cycle, incorporating internalized external effects and expected future internalizations (Rebitzer et al., 2004). For instance, when a business invests in sustainable packaging, it may afford higher initial costs but, at the same time, it can see savings in waste management and regulatory compliance in the long run. This method complements LCA by including all costs within the value chain that involve real money flows (Finkbeiner et al., 2006). Environmental LCC ensures an alignment between the business' financial goal and environmental sustainability.

Societal LCC extends beyond both conventional and environmental LCC by incorporating additional monetized externalities. It includes broader societal impacts such as health effects, resource depletion, and other environmental impacts, using fictitious values to monetize various environmental effects, such as public health expenses resulting from pollution (Hauschild et al., 2017). This aspect provides a deeper comprehensive view of a product’s effects on both the environment and human well-being. This strategy is especially important in the context of the CE, where the main goals are to maximize society's benefits and minimize external costs.

According to this, it is clear that environmental LCC and social LCC are crucial for measuring circularity as they include the externalities associated with resource use, waste generation, and environmental impacts. By internalizing these costs, organizations can make more informed decisions that support CE principles, such as reducing waste and minimizing environmental footprints (Geissdoerfer et al., 2017).

LCC helps organizations understand the long-term benefits of circular practices, making it an essential component of strategies aimed at achieving circularity.

Moreover, the *Material flow cost accounting* (MFCA) framework can also be considered. Within the larger field of Environmental Management Accounting, MFCA is a complex framework designed to improve resource efficiency through careful analysis and management of material flows within an organization. MFCA was first introduced in Germany and quickly gained popularity in Japan. Since then, it has developed into a vital tool for companies looking to reduce waste and maximize resource utilization. The core of the framework is the tracking of material inputs and outputs during the production process, which is divided into three categories: material losses, material in stock, and product output (Finkbeiner et al., 2006). By doing this, MFCA is able to quantify the cost factors that are related to material loss as well as the costs of materials, energy, systems, and waste management.

The implementation of MFCA includes several key phases: determining the scope of analysis, gathering comprehensive information on material flows and costs, mapping these flows to show inefficiencies, and allocating costs to material losses (Geissdoerfer et al., 2017). Through this method, businesses are able to identify the areas of material losses, assess the true financial effect of these losses, and create plans to cut down on waste and boost resource efficiency. Significant operational improvements, such as process optimization, product redesign for improved recyclable content, and the adoption of more environmentally friendly company practices, can be driven by the insights acquired through MFCA (Rebitzer et al., 2004).

This framework is supported by international standards such as ISO 14051, which provides instructions in order to implement it effectively. The MFCA's standardization guarantees its application across a range of sectors, including services, manufacturing, and even public sector entities (Guinée, 2002). Businesses that use MFCA may gain several benefits, including increased economic performance due to cost savings, better environmental results from less waste and resource consumption, and increased adherence to sustainability-related regulations (Finkbeiner et al., 2006).

Global usage of MFCA is rising, which is evidence of the increased appreciation of its benefits. Businesses are using it to boost stakeholder communication and sustainability reporting in addition to improving internal processes (Geissdoerfer et al., 2017).

Material Circularity Indicator (MCI) developed by the Ellen MacArthur Foundation provides another comprehensive framework for measuring circularity in a business (Ellen MacArthur Foundation, 2015). This indicator offers a quantitative assessment of how efficiently materials are used, reused, and cycled within the economy, minimizing waste and reducing the demand for virgin materials. A number of core principles underpin the MCI's operations, including the use of recycled or reused feedstock, component reusability, and increasing product longevity and usage intensity. The MCI streamlines external communication about sustainability activities and helps with internal decision-making by reducing a product's lifecycle into a single statistic. There are several phases involved in calculating the MCI. First, the product and the boundaries of the company's operations must be identified. Next, extensive data must be gathered from internal and external sources. The computation of essential elements, such as virgin feedstock and unrecoverable waste, which are crucial in figuring out the overall circularity score, is supported by the data.

The Linear Flow Index (LFI) and the Utility factor (X) are important metrics in the circularity calculation (Ellen MacArthur Foundation, 2015). The LFI quantifies the percentage of material flows that are linear (virgin inputs and unrecoverable outputs) compared with the total material flows. A high LFI indicates that a product relies heavily on virgin materials and contributes significantly to waste, thus reducing its circularity. The Utility factor X refers to two components: the product's lifespan and intensity of usage. This factor compares the actual lifespan of the product with the industry average, accounting for how long the product lasts and how intensively it is used. Products with a higher lifespan and/or a higher usage rate contribute positively on circularity. These elements are combined to create the MCI, which has a range of 0 (totally linear product) to 1 (fully circular product). The formula for computing the MCI is:

$$MCI = 1 - LFI * F(X)$$

The formula's general structure is straightforward: an ideal circular product is represented by an MCI that starts at a perfect score of 1. MCI decreases, suggesting a move away from circularity, when linear material use increases (higher LFI) or product usage becomes less efficient (lower X). The factor F(X), indeed, is built on a function F of the utility X, which represents the impact of the product's utility on its MCI (Ellen MacArthur Foundation, 2015).

At company-level, the MCI is obtained as a weighted average of the products-level MCI.

The MCI could be used alongside the End-of-life Recovery Index (EOL-RI), which assesses the material recovery efficiency at the end of a product's life. This index is computed as a ratio between the mass of materials recovered at the end-of-life and the total mass of the product. A higher EOL-RI shows that a considerable amount of a product's materials are recovered and reused, promoting a more circular system. On the other hand, a lower EOL-RI indicates that a significant portion of the product's materials are lost near the end of its useful life, usually as a result of degradation or disposal, which makes the system more resource-intensive and linear.

Furthermore, the MCI is not only a measurement tool but also a framework for successfully communicating companies' circular economy initiatives as they become increasingly conscious of the significance of sustainability. The MCI provides insightful information about material flows, but it must be used in conjunction with other indicators that focus on the larger effects on the environment and the economy.

3.3 INFLUENCE OF KEY PERFORMANCE INDICATORS ON CIRCULAR PRACTICES WITHIN ORGANIZATIONS

3.3.1 The influence of Key Performance Indicators from a technical and a behavioural perspective

KPIs are essential tools for driving circular practices within organizations by setting measurable targets that align with CE principles. KPIs provide businesses a tool to measure the amount of waste they are reducing, increasing recycling rates, and optimizing resource efficiency. By implementing KPIs, organizations may track their progress toward accomplishing goals related to the CE, identify areas for development, and compare their results to internal or industry benchmarks. A KPI focused on waste reduction, for instance, can motivate a business to adopt more efficient waste management techniques, such raising recycling rates, decreasing landfill disposal, or recycling items that would otherwise be discarded (Geissdoerfer et al., 2017). Similarly, KPIs related to resource efficiency can incentivize organizations to maximize their use of raw materials, energy, and water during their manufacturing processes. This can contribute to a reduction of environmental impact and promote a more sustainable business model (Franco, 2017).

Organizations can ensure that their operations are both economically and environmentally feasible by aligning KPIs with CE objectives.

The adoption of KPIs on CE practices can significantly influence both the technical aspect and the behavior of the organization.

From a technical perspective, KPIs help organizations align their business models with the principles of the CE. This leads the shifts from LBMs to CBMs, as well as from a product-based to a service-based model (Lewandowski, 2016). As already mentioned in the previous chapter, these changes frequently need a redesign of products to extend their capacity to be recycled, or facilitate their disassembly and reuse. For example, companies may use design principles like standardization or modularity to make it simpler to recycle, repair or refurbish products, extending their life-cycle and reducing waste (Bocken et al., 2016). KPIs can incentivize companies to implement these activities. Businesses may implement sustainable purchasing practices that provide preference to suppliers who use recyclable or renewable resources. This may entail establishing KPIs to track the amount of recycled material in raw materials as well as the decrease in the consumption of new resources. By promoting cooperation with suppliers to guarantee that inputs are in line with the CE's principles, these KPIs help enhance supply chain management.

On a behavioral level, KPIs may also drive changes in corporate culture by fostering a mindset focused on sustainability and circularity. When employees understand the specific targets they need to achieve, such as reducing energy consumption by a certain percentage or increasing the proportion of recycled materials used in production, they are more likely to engage in behaviors that support these goals (Moktadir et al., 2018). For example, KPIs that measure energy efficiency or waste reduction can motivate employees to identify and implement process improvements or operational efficiencies. Organizations may identify areas of inadequate performance and initiate corrective action when they assess their progress against certain KPIs. This feedback loop encourages organizations to improve their circularity refining their strategies, procedures and products. Furthermore, using KPIs increases accountability and transparency within the company by giving clear, quantifiable goals that are easy to monitor and report on. Customers, investors, and regulators are a few stakeholders who may benefit from this transparency as they show a growing interest in an organization's sustainability performance. By establishing and sharing KPIs related to CE activities, businesses can enhance their credibility as sustainability leaders and foster trust.

From the aspects of KPIs' adoption in CE practices mentioned above, it emerges that the goals of this kind of implementation cover both the internal management within the organization, for instance, aiming to guide strategic shifts, drive product and process design, enhance supply chain management and seek for continuous improvement, and the external environment, helping promote transparency and communication with several stakeholders.

The influence of KPIs on circular practices can be analysed through quantitative lenses. In fact, organizations can use data-driven approaches to assess the effectiveness of specific KPIs in achieving circular economy outcomes. For instance, by analysing data on material flows, waste generation, and recycling rates over time, companies can determine the effectiveness of their KPIs in promoting circular practices (Saidani et al., 2019). This type of analysis can help identify which KPIs are the most suitable and effective at measuring and driving circularity and which may require to be adjusted or replaced. Nevertheless, acquiring and managing data may result difficult.

3.3.2 An example of Key Performance Indicators implementation leading to improvements in circularity

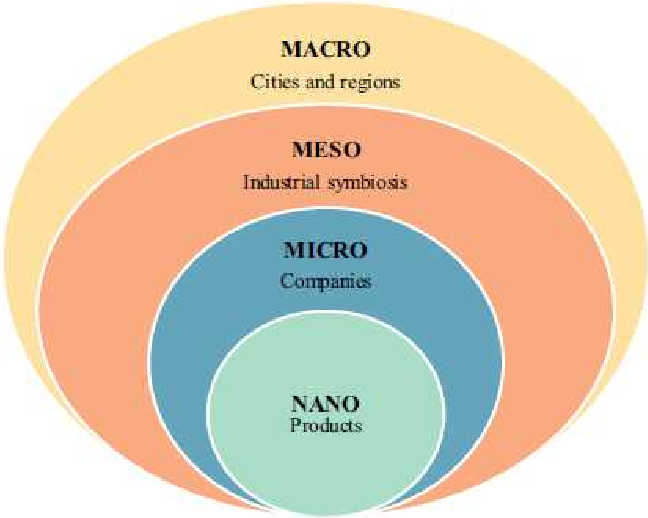
Several real examples show how the application of KPIs has significantly improved circularity in a variety of industries. One notable example is Philips, one of the global leaders in health technology, which has created the extensive sustainability initiative "Healthy People, Sustainable Planet" to promote circularity and sustainability in all aspects of its business operations. This program includes a wide range of circularity-related KPIs, such as material recycling rates, energy efficiency and product lifecycle management. By tracking the percentage of materials recycled or reused, Philips has been able to assess the effectiveness of its material recovery operations and improve the percentage of recycled materials used in its products from 10% in 2015 to 15% by 2020. Additionally, Philips measures energy consumption across its product range, which has led to the development of energy-efficient products and optimized manufacturing processes, achieving a 40% reduction in energy use compared to conventional lighting solutions. Furthermore, Philips uses KPIs to manage product lifecycles, focusing on extending product lifespans through modular design, reparability, and circular business models like leasing, which allows for product take-back, refurbishment, and reuse. This approach has resulted in a 25% increase in the number of refurbished products sold annually, demonstrating a shift from linear to circular product flows (Philips, 2020). The systematic measurement and reporting of these KPIs have enabled Philips to identify gaps, track progress, and communicate successes, fostering cross-departmental collaboration and driving innovation across the organization. By aligning its business model with CE principles, Philips has positioned itself favourably to adapt to regulatory changes and market demands, underscoring the critical role of KPIs in promoting circular practices and achieving long-term sustainability goals.

3.4 THE CIRCULAR ECONOMY MEASUREMENT LEVELS: NANO, MICRO, MESO AND MACRO

3.4.1. An overview of the measurement levels

CE includes four distinct measurement levels representing different scales of analysis: nano, micro, meso and macro. These levels offer an extensive basis for assessing the circularity of systems at all scales, from individual products to entire economies (Figure 3.3). This allows implementing focused strategies and interventions that address particular issues at each level (Blomsma & Brennan, 2017; Kirchherr et al., 2017).

Figure 3.3 – CE levels



Source: de Oliveira C.T., Dantas T.E.T and Soares S.R., 2021

Nano level focuses on the smallest unit of analysis: individual products and components. At this level, circularity measures can concern the intrinsic qualities of a product (Figge et al., 2018; Franklin-Johnson et al., 2016), such as its durability, recyclability and material health. For instance, assessments can include toxicity levels of materials used, the ease with which a product can be disassembled for recycling, or the potential for extending its lifespan through design improvements. By focusing on products at the nano level, it is possible to identify opportunities to reduce waste and increase the sustainability of resources from the initial phase of a product lifecycle (Morseletto, 2020; Stahel, 2016; Saidani et al., 2017).

Micro level refers to individual businesses. The focus shifts to the operational practices within a single entity. Indicators might refer to waste reduction, energy efficiency and the use of renewable resources used in production processes (Ghisellini, Cialani, & Ulgiati, 2016). Furthermore, organizations may enhance supply chain management, look at the sourcing of raw materials, waste management practices and product end-of-life strategies. The micro level is important for businesses aiming to transition towards CBMs, as it helps to identify areas where immediate changes can lead to significant improvement in circularity (Ellen MacArthur Foundation, 2015).

The meso level represents an intermediate stage of analysis, which usually evaluates industrial symbioses or sets of organizations belonging to the same sector, or even groups of companies connected by a limited geographical area. At meso level the emphasis shifts to optimizing the flow of resources between different entities. In order to minimize waste and maximize the utilization of by-products, various strategies can be implemented. These include resource sharing, where businesses collaborate to share essential resources like energy or water. Additionally, coordinated waste management strategies can be developed, allowing organizations to work together to effectively handle and reduce waste. A further approach involves creating networks for exchanging materials that might otherwise be discarded, enabling the reuse and recycling of resources and lowering the reliance on virgin materials (Chertow, 2000).

By adopting these strategies, businesses are encouraged to collaborate in forming closed-loop systems, where the waste generated by one process is transformed into a resource for another, enhancing resource efficiency and reducing environmental impact (Park et al., 2008).

Finally, the macro level corresponds to larger scales, encompassing cities, regions, nations, or the entire global economy. At this level, the data required is significantly greater than that identified for a single organization, and the analyses conducted are more complex due to both the volume of data and the multiplicity of systems considered (Su et al., 2013). It is necessary to rely on databases, apply conversion factors to aggregate data coherently, and often make approximations where data is lacking or entirely absent. This macro perspective is essential for policymakers and global organizations, as it offers valuable insights into the systemic changes required to promote a more sustainable and circular global economy (Korhonen, Nuur, Feldmann, & Birkie, 2018).

3.4.2 In-depth exploration of Key Performance Indicators used to assess circularity at each level

Measurement methodologies include circularity indicators at various levels—product, component (Alamerew & Brissaud, 2018), material (Heisel & Rau-Oberhuber, 2020), supply chain, industrial symbiosis, city (Gravagnuolo et al., 2019), national, government and policy. Each level of measurement—nano, micro, meso, and macro—requires specific indicators to monitor and achieve CE goals effectively (Saidani et al., 2019).

Some of the KPIs helping to assess the effectiveness of CE measurement strategies and practices across the four different levels are listed in the tables below:

Table 1 - Nano level Key Performance Indicators

Key Performance Indicators	*Description*	*Reference*
Recyclability rate	Measures the percentage of a product's materials that can be recycled at the end of its life. Higher recyclability rates indicate better circularity.	Ellen MacArthur Foundation, 2013
Material health	Assesses the toxicity and environmental impact of materials used in a product. Products with lower toxicity levels and environmentally friendly materials score higher.	Heisel and Rau-Oberhuber, 2020
Product durability	Measures the lifespan of a product to reduce the need for replacements.	Stahel, 2016
Repairability index	Indicates how easily a product can be repaired to extend its lifecycle.	Bocken et al., 2016

Recycled content proportion	Percentage of recycled materials used in the production of new products.	Ellen MacArthur Foundation, 2013
Design for disassembly	Ease with which a product can be disassembled for repair or recycling. Products designed for easy disassembly facilitate material recovery.	Kirchherr et al., 2017
Material demand quantification	Measures the demand for materials used in products, focusing on minimizing virgin material use.	Eurostat, 2023
End-of-life recovery rate	Percentage of a product that can be recovered, reused, or recycled.	Saidani et al., 2019
Embedded energy content	Amount of energy embedded in a product's materials and production processes.	Heisel and Rau-Oberhuber, 2020
Eco-design implementation	Degree to which products are designed considering environmental impacts over their entire lifecycle.	Eurostat, 2023
Upcycling rate	Percentage of materials upcycled to retain or enhance material quality.	Kirchherr et al., 2017

Material efficiency	The ratio of the material utilized in the product versus the total material input. High efficiency indicates minimal waste.	Eurostat, 2023
Waste generation per product unit	The amount of waste generated per unit of product produced, aiming for minimization.	Eurostat, 2023

Table 2 - Micro level Key Performance Indicators

Key Performance Indicators	*Description*	*Reference*
Waste reduction rate	Reduction in waste generated by a business compared to a baseline year.	Ghisellini et al., 2016
Energy efficiency metrics	Energy consumption per unit of production output.	Ghisellini et al., 2016
Use of renewable energy	Proportion of a company's energy that comes from renewable sources.	Ghisellini et al., 2016
Resource recovery rate	Percentage of resources recovered from waste in the production process, aiming for maximization.	Eurostat, 2023

Water use efficiency	Amount of water used per unit of production.	Ghisellini et al., 2016
Water recycling rate	Proportion of water that is treated and reused in the production cycle.	Eurostat, 2023
Closed-Loop production rate	Measures the extent to which a company reuses materials within its own production processes	Ellen MacArthur Foundation, 2015
Green procurement rate	Percentage of materials and products purchased that meet certain environmental criteria, such as being recycled or biodegradable.	Smol et al., 2017
Product take-back program participation	Percentage of products sold that are returned through take-back programs for recycling or repurposing.	Ellen MacArthur Foundation, 2013
Supply chain circularity rate	Evaluates the circularity practices of suppliers, including their use of recycled materials, waste management practices, and energy efficiency.	Ghisellini et al., 2016

Circular supply chain initiatives	Implementation of initiatives aimed at improving the circularity of supply chains, such as logistics optimization and use of circular materials.	Eurostat, 2023
Recycling rate of packaging	Proportion of recycled packaging waste compared to all packaging waste.	Eurostat, 2023
Financial KPIs related to circular practices	Cost savings from waste reduction and revenue from recycling activities.	Ghisellini et al., 2016
Employee engagement in circular practices	Level of employee involvement in sustainability and CE initiatives.	Ghisellini et al., 2016
Sustainable product portfolio percentage	Proportion of products designed with CE principles.	Saidani et al., 2019
LCA compliance	Adoption and implementation of LCA for products and processes.	Ghisellini et al., 2016

Table 3 - Meso level Key Performance Indicators

Key Performance Indicators	*Description*	*Reference*
Resource exchange rate	Amount of materials exchanged between companies to reduce waste and improve efficiency.	Eurostat, 2023
By-product utilization rate	Percentage of by-products used as inputs by other companies in a cluster.	Park et al., 2008
Shared infrastructure utilization	Extent to which companies share infrastructure to enhance resource efficiency.	Chertow, 2000
Collaborative waste management efficiency	Efficiency of shared waste management practices among companies.	Park et al., 2008
Waste heat recovery rate	Proportion of waste heat recovered and reused within an industrial cluster	Eurostat, 2023

Energy symbiosis rate	Percentage of energy needs met through shared or exchanged energy resources within a cluster.	Chertow, 2000
Material recovery rate in symbiotic systems	Percentage of materials recovered and reused in an industrial symbiosis network.	Chertow, 2000
Water sharing and reuse rate	Extent of shared water resources and reuse practices among companies.	Park et al., 2008
Environmental impact reduction through collaboration	Reduction in environmental impacts achieved through collaborative efforts.	Chertow, 2000
Supply chain circularity index	Implementation of circular practices throughout supply chains in a cluster.	Eurostat, 2023
Shared logistics efficiency	Efficiency achieved by sharing logistics resources among companies to reduce emissions.	Eurostat, 2023

CBM adoption rate	Percentage of companies adopting circular business models, such as leasing or product-as-a-service.	Ghisellini et al., 2016
Collaborative innovative rate	Frequency and success of joint innovation projects aimed at enhancing circularity.	Park et al., 2008
Inter-company resource optimization	Efforts to optimize resource use and waste reduction across multiple companies within a cluster.	Eurostat, 2023
Industrial symbiosis index	Effectiveness of industrial symbiosis in achieving circular economy objectives.	Chertow, 2000

Table 4 - Macro level Key Performance Indicators

Key Performance Indicators	*Description*	*Reference*
National recycling rate	Percentage of total waste recycled at the national or regional level.	Eurostat

Material footprint	Total raw materials consumed by an economy, adjusted for material efficiency.	Gravagnuolo et al., 2019
CE policy adoption rate	Number and effectiveness of policies promoting CE practices.	Geissdoerfer et al. (2017)
Greenhouse gas emission reduction through circular practices	Decrease in emissions attributable to CE initiatives.	Eurostat, 2023
CE employment rate	Number of jobs created in sectors related to the CE.	Korhonen et al. (2018)
Sustainable public procurement rate	Proportion of public sector purchases meeting circular economy criteria.	European Union
Urban circularity index	Circularity performance of cities, including waste management and sustainable urban planning.	Gravagnuolo et al., 2019
CE GDP contribution	Proportion of GDP derived from CE activities.	Gravagnuolo et al., 2019

National waste diversion rate	Percentage of waste diverted from landfills through circular practices.	European Union
Circular public infrastructure development	Development of public infrastructure projects that incorporate circular economy principles.	Eurostat, 2023
Cross-border material flow efficiency	Efficiency of material flows between countries in international supply chains.	Eurostat, 2023

3.4.3 Synergies and frictions among different levels of circular economy measurement

The interdependencies and potential conflicts that exist among the nano, micro, meso and macro levels of measurement can be clarified by the concepts of cause-effect relationships and strategy map developed by Kaplan and Norton (2004).

Synergies emerge among these levels of CE measurement when actions or improvements at one level cause positive effects on another, thereby reinforcing CE principles throughout the entire system.

For instance, at the nano level, enhancing the recyclability rate or improving the design for disassembly of individual products can lead to significant benefits at the micro level by reducing waste and improving material recovery processes within individual organizations (Ellen MacArthur Foundation, 2013).

Similarly, improving the durability and repairability index of products at nano level can reduce the frequency of product replacements at the micro level, leading to lower waste generation and resource consumption. In turn, this strengthens the circular supply chain initiatives that are crucial at the meso level and encourages increased levels of closed-loop production.

At micro level, companies implement closed-loop production rates or increase the use of renewable energy not only gain advantages for themselves but also contribute to the meso level by supplying excess renewable resources or recyclable materials to nearby organizations, fostering industrial. This collaboration can further advance regional sustainability objectives at the macro level, such as boosting national recycling rates or reducing the overall material footprint, thereby supporting policies aimed at promoting a CE (Gravagnuolo et al., 2019).

Furthermore, synergies between levels can improve the resource exchange rate and by-product utilization rate within industrial clusters at the meso level. When organizations within a cluster effectively share resources and by-products, they not only minimize waste but also establish a more resilient supply chain network. This collaboration between firms can lead to reduced costs and environmental impacts, thereby contributing to macro level objectives such as greenhouse gas emission reduction and CE policy adoption rate. This dynamic aligns with Kaplan and

Norton's cause-effect logic, where advancements at localized levels (nano and micro) drive broader strategic outcomes at higher levels (meso and macro) (Kaplan & Norton, 2004).

To strengthen the concept of interconnection of actions between the nano, micro, meso and macro levels, the Eurostat provides the EU monitoring framework on the CE. This framework encompasses key areas such as production and consumption, waste management, secondary raw materials, competitiveness and innovation and global sustainability and resilience (Eurostat, 2023). The circularity in the European region is monitored in the framework by multi-level indicators. Metrics including durability, material composition, and recyclability are tracked at the product level by the framework. It contains indicators for waste generation, resource productivity, and sectoral material flows at the supply chain and sectoral levels. On a broader scale, recycling rates, overall resource efficiency, and the GDP contribution from circular activities are measured by national and EU-wide measures.

These indicators within the monitoring framework are interconnected, highlighting the inherent cause-effect relationships among the CE levels.

However, there are also frictions between different levels of CE measurement, often due to misaligned incentives, differing priorities or insufficient infrastructure. For instance, at the nano level, the focus on product durability and extended lifecycles may conflict with micro level business models that depend on frequent product sales or shorter product lifespans for profitability (Bocken et al., 2016).

Additionally, while a company at the micro level may optimize its internal processes for waste reduction and energy efficiency, it may encounter difficulties integrating these practices into a broader meso level strategy, such as joining an industrial symbiosis network. These networks necessitate cooperation and strategic alignment among multiple firms, which may have differing operational practices or objectives. At the macro level, policy measures intended to enhance resource productivity or enforce strict recycling rates might impose additional costs or operational challenges on micro level businesses, potentially reducing their competitiveness or willingness to engage in CE practices. For instance, macro level initiatives to enforce sustainable public procurement and raise the national recycling rate may put pressure on micro level companies to follow regulations that may not be in line with their existing capacities or business strategies.

These frictions highlight the necessity for alignment across levels, as illustrated by Kaplan and Norton's strategy maps, where clear connections and shared objectives can help alleviate conflicts and promote cohesive strategy execution (Kaplan & Norton, 2004). Aligning goals and establishing common value propositions can help reduce these frictions. For example, government incentives at the macro level could be structured to support businesses transitioning to CBMs at the micro level while also encouraging meso level collaborations that benefit the broader economy. Ensuring coherence between regulatory frameworks at the macro level and the practical capabilities of firms at the micro and meso levels is essential for minimizing friction and optimizing the overall impact of CE strategies.

3.5 APPLYING THE THEORY OF BUSINESS MODELS AND KEY PERFORMANCE INDICATORS TO CIRCULAR ECONOMY

3.5.1 Circularity measurement gaps in existing frameworks

From an analysis of the literature about CE measurement methods, it emerges that it lacks comprehensive frameworks that consider the integration of KPIs across the four levels of circularity, while also addressing the connections and interdependencies between these levels, and integrating circularity into the business logic of a company.

For instance, several tools currently used to assess circularity, such as LCA, LCC, MFCA and MCI, exhibit certain limitations in adopting a multi-level approach in terms of circularity measurement. The mentioned tools usually focus on a specific level of circularity, typically the product or process level. LCA, for example, evaluates environmental impact based on a product's life cycle (nano level) (Guinée, 2002) without analysing circularity at broader scales. Similarly, LCC focuses on measuring costs associated with a product's life cycle, without accounting for how cost efficiencies might involve different levels of circularity. Furthermore, MFCA refers to material flow within a company (micro level) but, while useful for internal material flow efficiency, it does not extend to larger systematic perspective, ignoring inter-organizational resource-sharing opportunities that could enhance circularity at meso and macro levels.

The MCI evaluates material usage efficiency by specifically focusing on the nano level of circularity measurement. As regards MCI, it could be noticed the relationship between nano and micro levels, since the material circularity of a company can be determined from the material circularity of all product types of that organization, which are then aggregated using an appropriate weighting. However, it does not observe relationships with the meso and macro levels.

Moreover, also the conceptual framework and the related indicators presented in a report of the OECD in June 2024, that have been established with the purpose of monitoring progress and supporting the implementation of policies to shift towards a more sustainable and circular economy, fail to encompass the cause-and-effect relationships existing among the different levels of circularity measurement. The report, indeed, highlights the focus of the framework at national and sub-national levels (macro level). The analysis of the KPIs within the framework only reflects environmental and societal impact in a specific geographic area, that could be implemented by countries seeking to achieve a transition to CE (OECD, 2024).

Furthermore, these tools do not adequately integrate circularity into the overall business logic of companies. LCA, for example, is effective at measuring environmental impacts but does not directly tie those impacts into the business strategy, such as how circularity could be incorporated into customer relationships, value propositions, or revenue streams. Similarly, MFCA and MCI can provide useful insights into material efficiency and waste reduction but do not show how these practices could be embedded into core business functions or leveraged for innovation in business models.

In addition, it is essential to integrate KPIs within business models from the formulation of measurable objectives for the performance of the newly designed business models (Heikkilä et al. 2014; Montemari et al. 2019; Gilsing et al. 2021b) to the performance monitoring and control phases once the business model has been implemented, in order to make improvements and adaptations (di Valentin et al. 2013; Globocnik et al. 2020). By keeping track of business model KPIs, companies can compare the actual achievements with the expected ones (Globocnik et al. 2020). However, numerous CBMs do not include the implementation of circular KPIs within the framework to effectively measure circularity (Bianchini, et al. 2019). Examples can be identified in the Ellen MacArthur Foundation model (Ellen MacArthur Foundation, 2013), the Moonfish model (MoonFish, 2014), the EIT Raw Materials model and the Reike model (Reike et al., 2018). In order to overview the limitations of the mentioned CBMs, Bianchini et al. proposed a CBM visualization tool, including the possibility to quantify resource flows and circular indicators, while focusing not only on the product but also involving the company and the entire supply chain (Bianchini et al., 2019). Nevertheless, once again, the intercorrelations between KPIs across the levels of circularity measurements are not specifically taken into account.

The gap in literature and practice emphasizes the need for a new framework that allows the integration of circular KPIs across the CE measurement levels (nano, micro, meso and macro), putting a strong focus on the existence of cause-and-effect relationships and interactions between them. Moreover, it is necessary that the various indicators and the CE practices are incorporated within the business model of the company, which is fundamental for ensuring CE goals are aligned with core business strategies.

3.5.2 Some inspiring principles

To effectively implement CE strategies, it is fundamental to develop a comprehensive system that enables the joint assessment of KPIs across the various CE measurement levels. The system should track performance, facilitate data integration, enable continuous improvement and ensure alignment with CE objectives. The creation of this system could involve the following key components: KPIs integration, robust data management, effective performance tracking and the willingness to continuously improve.

Developing a coherent assessment framework requires integrating KPIs at all levels of CE measurement, as mentioned in the previous paragraph. Businesses must, at the micro level, make sure that their operational plans support both short-term and long-term sustainability objectives by matching their KPIs with more general CE aims. Firstly it is important to define CE objectives, such as reducing material waste, prolonging the lifespan of products or increasing the use of recycled materials within the organization's processes. Next, it is crucial to select the appropriate and SMART KPIs, that will be helpful to monitor the advancement and the achievement of the CE goals previously established. The choice of pertinent and accurate KPIs for organizations that promote circularity and gain a better understanding of process interdependencies could be also driven by industrial ecology frameworks, such as LCA, LCC and MFCA.

To align with nano level indicators like product durability and recyclability, for instance, KPIs like waste reduction rates, energy efficiency, and the use of recycled materials should be developed (Ellen MacArthur Foundation, 2015). Recent research indicates that aligning these indicators might improve material efficiency and lower waste generation at the product level, supporting organizational sustainability initiatives.

Additionally, incorporating meso level KPIs, such as resource exchange rates and by-product utilization rates, allows businesses in industrial clusters to collaborate with one another, resulting in improvements in overall. At the macro level, coordinating efforts across various sectors to meet policy objectives is possible by matching national recycling rates and material footprints with business-level KPIs. Data collection, integration and management are essential to precisely measure and monitor the functioning of the CE at various levels. Multi-level data collection is necessary for effective systems: nano level product lifecycle assessments, operational data from businesses at the micro level, collaborative data from industrial clusters at the meso level and aggregate economic and environmental data at the macro level (Ellen MacArthur Foundation, 2015). Advanced data management tools, such as blockchain technology and Internet of Things devices, have emerged as potent solutions for real-time data integration and transparency, allowing improved resource efficiency and material flow tracking and transparency (Abdel-Baset et al., 2020).

These technologies enable enterprises to collect and analyze massive datasets more effectively, ensuring that all pertinent data points are taken into account in decision-making processes and that the goals of the CE are satisfied.

Performance tracking is essential to understand the effectiveness of CE initiatives and identify areas for improvement. A performance tracking system should be built to track KPIs in real-time and deliver useful information to businesses and policymakers so they may make well-informed decisions. At micro level, businesses can graphically monitor their performance against important KPIs like waste reduction, energy efficiency and supply chain circularity by using digital dashboards and scorecards (Geissdoerfer et al., 2021). Businesses can track success at the meso and macro levels by integrating these technologies with more comprehensive PMSs, which will help them understand how their actions align with CE objectives. Advancements in artificial intelligence and machine learning have led to improved capacities for trend prediction and adjustment suggestions, assisting firms in optimizing their strategies. There is a definite cause-effect relationship between individual actions and systemic outcomes; for instance, an organization that enhances its waste management practices at the micro level may also have a positive macro impact on the overall waste diversion rate (Kaplan & Norton, 2004).

Continuous improvement, whereby companies and governments continually examine and adapt their tactics to maximize sustainability outcomes, is an essential principle of the CE. Through the utilization of data and insights derived from performance tracking systems, companies are able to discern deficiencies in their existing strategies and formulate focused interventions to mitigate these concerns.

Businesses might, for example, use KPI data to identify inefficiencies in their manufacturing processes or supply chains and make adjustments to decrease waste and boost resource efficiency (Bocken et al., 2016; Stahel, 2021). Similarly, industrial clusters at the meso level might improve their collective circularity performance by using performance data to find areas for further cooperation and resource sharing (Chertow, 2000). Aggregate data can be used by policymakers to evaluate national CE policies at a macro level and make necessary revisions to improve their impact.

3.5.3 The Business Model Canvas as the framework to integrate circular economy measurement levels

The integration of KPIs and CE practices within the micro level could be implemented by creating an innovative template according to the BMC developed by Osterwalder and Pigneur (2010). This adapted CE Business Model Canvas will help businesses align their operations and strategies with CE principles, focusing on sustainability and resource efficiency. It could be possible to directly integrate KPIs specific to CE activities within each of the nine components of the traditional BMC, thus by focusing on the micro level. This innovative template, the Circular KPIs Canvas , is shown below in Figure 3.4.

Figure 3.4 – Circular KPIs Canvas

As regards the Key partners component, establishing partnerships plays a fundamental role in ensuring the circularity of the supply chain. The collaboration with recyclers, manufacturers and waste management companies can help the organization to effectively close the loop of the production processes. The introduction of KPIs such as the Eco-design implementation, the Supply chain circularity rate, the Green procurement rate, the Resource exchange rate, the Collaborative waste management efficiency, the Shared infrastructure utilization and the Energy symbiosis rate allows the company to measure how the supply chain partners are contributing to CE goals. The company might prefer establishing partnerships and collaborations with suppliers that implement Eco-design activities. Furthermore, the Supply chain circularity rate, for instance, ensures that materials are recycled and reused within the business' supply chain, while the Green procurement rate monitors the proposition of materials purchased from suppliers with an environmental certification, guaranteeing that the inputs comply with CE guidelines. The choice of Key partners could also be influenced by their positive contribution to the Resource exchange rate, the Collaborative waste management efficiency, the Shared infrastructure utilization and the Energy symbiosis rate within the industry in which they operate.

The Key activities necessary to put CE practices on action, such as recycling, refurbishing, designing sustainable products and launching waste reduction programs, are essential for the company's business model. Tracking the efficacy of these initiatives requires the use of KPIs like the Design for disassembly, the Eco-design implementation, the Upcycling rate, Closed-loop production rate, the Energy efficiency metrics, the Waste reduction rate, the LCA compliance and the Use of renewable energy. The Design for disassembly and the Eco-design implementation ensure that products can be easily recycled, repaired or reused. The Closed-loop production rate measures how effectively the company is able to minimize the requirement for virgin materials by reusing resources inside its production processes. By monitoring the amount of energy used in relation to industrial output, Energy efficiency metrics encourage the Use of renewable energy sources and lower total energy consumption. By tracking the decrease in waste production through the Waste reduction rate, the business can make sure that its activities are becoming more effective. Finally, the LCA compliance demonstrates the company's commitment to monitoring the environmental impact of its products' lifecycle.

The company's Value proposition should focus on delivering durable, repairable and recyclable products made from sustainable materials. To evaluate how well the products meet these criteria, KPIs like Product durability, Repairability index, End-of-life recovery rate and Recycled content proportion can be selected. Product durability and Repairability index ensure long product lifecycles, reducing the frequency of replacement and waste. The End-of-life recovery rate is a useful indicator since it measures how much a product can be recovered for reuse or recycling. The Recycled content proportion ensures that a significant percentage of products are manufactured from recycled materials, reducing the demand for virgin materials and the environmental impact.

Customer relationships based on transparency, education and engagement in sustainability practices are essential for a CE-oriented organization. The effectiveness of these relationships can be tracked by some KPIs like Product take-back program participation, Material health and Design for disassembly. Product take-back program participation, a measure that allows customers to return products for recycling or reuse at the end of their utility life, builds customer engagement in sustainability initiatives. Material health indicator guarantees the safety of the company's products providing transparent data sharing with its customers to maintain a strong relationship. Moreover, Design for disassembly can engage and/or retain customers since they are aware of the possibility of repairing a single component instead of replacing the entire product.

The Key resources essential to the company include recycled materials, renewable energy, sustainable packaging and a skilled workforce. The KPIs aimed to monitor the availability and use of the resources could be identified in the Use of renewable energy, Resource recovery rate, Employee engagement in circular practices, and Water recycling rate. The Use of renewable energy measures the proportion of energy sourced from renewables, reducing the carbon footprint. Resource recovery rate and Water recycling rate are example of the company's efficiency in terms of resource management. Employee engagement in circular practices reflects the commitment of the workforce to achieving the company's sustainability goals.

Delivering value to customers through environmentally friendly Channels, such as the utilization of direct-to-consumer models or digital platforms is crucial. The sustainability of the distribution channels of an organization can be assessed by KPIs like Eco-design implementation, Recycling rate of packaging and Shared logistics efficiency. Eco-design implementation is one of the fundamental metrics in terms of green distribution channels because it can enhance reductions in packaging waste by designing packaging that requires less materials and easier to recycle. This can lead to transportation efficiency since products designed for stackability or modularity can optimize shipping loads by reducing the waste of space and, consequently, the number of trips and fuel consumption. The Recycling rate of packaging also contributes to waste reduction during the distribution process, since the packaging may include biodegradable or reusable materials. As regards the Shared logistics efficiency indicator, it demonstrates the sustainability of distribution channels by optimizing the transport routes. Businesses can reduce the number of trips, and the corresponding fuel consumption and emissions by combining shipments with other companies.

The Cost structure of the company might focus on investments in recycling technology, sustainable materials and employee training. The financial efficiency of these investments and their impact on waste reduction are measured by Financial KPIs related to circular practices. These KPIs monitor cost savings from the implementation of circular initiatives, such as the optimization of materials and energy resource efficiency or the adoption of more sustainable distribution practices that lead to a reduction in shipping costs. However, circular initiatives can also increase the company's costs. for instance, the adoption of secondary raw materials as key resources could be more expensive than the purchase of virgin raw materials. The last component of the framework, the Revenue streams, could refer to revenues resulting from models designed to support circularity like leasing, subscription services and product-as-a-service. The Financial KPIs related to circular practices, such as revenues from recycling activities, track the financial performance of the CBM. These KPIs ensure that the company's revenue-generating activities are not only profitable but also aligned with its commitment to sustainability and CE principles.

This template ensures that specific KPIs can be integrated into CE practices at the micro level, helping track the effectiveness of the circular initiatives of the organization and ensuring that every aspect of the business is aligned with the contribution of a more circular and sustainable economy.

3.5.4 Interdependencies between circular economy measurement levels within the Circular KPIs Canvas

The decision of adopting a template like the Circular KPIs Canvas is a starting point for integrating KPIs and CE practices. In fact, can be effective in the overall CE scenario because such a tool can significantly influence and have interdependent relationships with the nano, meso and macro levels of CE measurement. Actions at the micro level can create effects across the other levels, promoting broader systematic change (Geissdoerfer et al., 2021).

The Circular KPIs Canvas puts emphasis on the operational practices of individual businesses, particularly in how they design, produce and manage product. This has a direct effect at the nano level, which deals with the circularity of individual products and components. Nano-level KPIs like Recyclability rate, Material health and Repairability index, for instance, are directly affected by decisions made in the Value proposition and Key activities sections of the template, such as emphasizing product durability, repairability and use of sustainable materials (Bocken et al., 2016; Kirchherr et al., 2017).

By implementing these micro level practices and designing items that are easier to disassemble, repair and recycle, businesses can improve the overall circularity of their product. This impact guarantees that the products themselves are more aligned with the CE, reducing waste and enhancing material efficiency from the outset. Furthermore, the success of product take-back programs and the proportion of recycled content utilized in production, both tracked by micro level KPIs, reinforce nano level goals of producing products with minimal environmental impact (Ellen MacArthur Foundation, 2013).

The Circular KPIs Canvas has significant implications for the meso level, which focuses on the collaborations and interactions between various businesses, frequently inside industrial clusters or value chains. In order to promote industrial symbiosis, companies are encouraged to work with recyclers, remanufacturers and other supply chain stakeholders through the Key partnerships and Key activities components of the Circular KPIs Canvas (Chertow, 2000).

These collaborations can improve meso level KPIs like Resource exchange rate, by-product utilization rate and Supply chain circularity index. By engaging in these partnerships, companies can share resources, exchange by-products and collectively handle waste, creating closed-loop systems that are advantageous to the whole industrial network. This can result in a reduction of costs and environmental impact for individual businesses, while also enhancing overall performance across the broader industrial ecosystem.

Moreover, the adoption of sustainable procurement practices and the use of shared infrastructure at the micro level contribute to the meso level objective of building more robust and effective industrial symbiosis network. Thus, as a result, these networks reinforce the financial sustainability of CE projects within the cluster and promote more general regional sustainability goals (Park et al., 2008).

On a national or regional scale, the cumulative effect of more companies using CE methods can result in a significant decrease in waste production and resource consumption. This supports government initiatives to satisfy recycling goals, reduce greenhouse gas emissions and encourage sustainable economic growth

(Gravagnuolo et al., 2019).

Furthermore, the macro level policy-making process can be impacted by the financial and operational performance of the Circular KPIs Canvas. When policymakers observe the benefits that CE practices have for the environment and the economy, they are more willing to embrace and support CE measures, such as tax incentives for sustainable practices or resource-saving regulations. This creates a positive feedback loop, where micro level initiatives drive macro level policy changes, which then further encourage businesses to adopt CE practices.

From the analysis conducted above, it is clear the Circular KPIs Canvas could serve as a foundational tool that aligns business practices with CE principles. Its impact extends beyond the company itself; at the nano level, it influences product design; at the meso level, it promotes cooperation and resource efficiency; at the macro level, it supports broader sustainability objectives.

The interconnected impact underscores the importance of integrating KPIs and CE practices into business models, as this creates synergies across all levels of circularity and drives to a systematic shift towards a more sustainable and resilient economy (Stahel, 2016; Geissdoerfer et al., 2021).

3.5.5 Enriching the Circular KPIs Canvas with cause-and-effect relationships

The adoption of the concept of cause-and-effect relationships (Kaplan & Norton, 1992) could be significant for enhancing the Circular KPIs Canvas for the numerous benefits it provides.

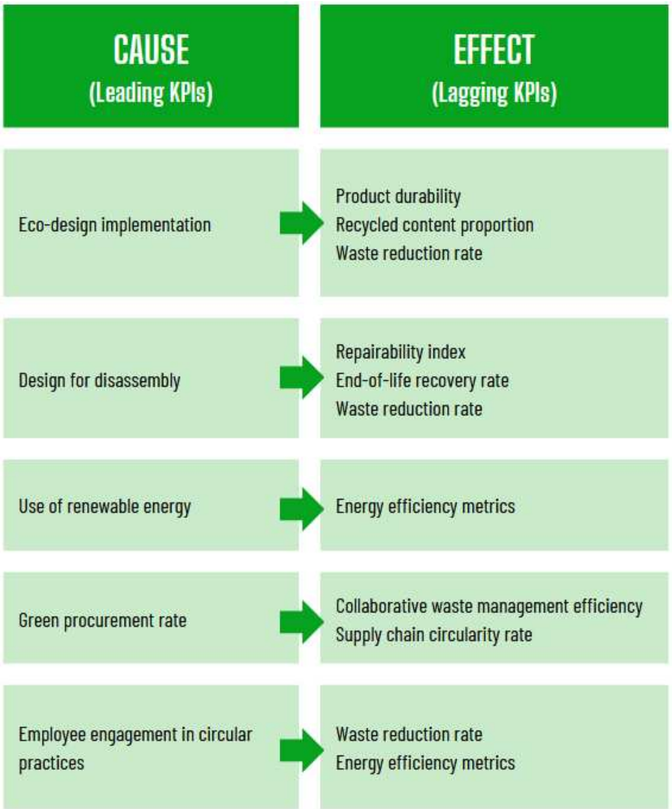
The most important advantage, according to this research, relies on the opportunity that cause-and-effect relationships provide companies to assist them in identifying and linking particular KPIs to their strategic goals and actions. This could entail aligning pertinent operations and goals with KPIs such as recycling rates, material efficiency, and customer participation in take-back programs.

The cause-and-effect relationships demonstrate how improvements in one area, like increasing product recyclability, can positively influence other areas, like reducing raw material costs or strengthening customer loyalty, while clarifying which KPIs are essential for accomplishing particular goals. This connected viewpoint promotes a more integrated approach to CE operations and an in-depth understanding of performance metrics.

To explore cause-and-effect relationships between the KPIs within the developed Circular KPIs Canvas, it can be applied the concept of leading and lagging indicators, according to the aspects mentioned in Chapter 1. Leading KPIs are predictive and indicate current and future performance, allowing real-time adjustments, while lagging KPIs measure the outcomes of actions already taken and do not offer the opportunity to change the performance. However, they can offer insights for future actions (Elsebaei et al., 2020; Sinelnikov et al., 2015).

Below are some of the hypothetical cause-and-effect relationships between the KPIs contained in the template (Figure 3.5).

Figure 3.5 – Cause-and-effect relationships among Key Performance Indicators



Source: elaborated according to the Circular KPIs Canvas

With reference to the content of Figure 3.5, one of the key relationships is the implementation of eco-design, which influences several KPIs. By focusing on eco-design, companies can create more durable products, contain higher proportions of recycled materials, and reduce overall waste.

Another crucial relationship is found in the design for disassembly, which leads to improvements in the repairability index, end-of-life recovery rate, and waste reduction rate. By designing products that can be easily disassembled, companies make it simpler to repair, reuse, or recycle components. This not only extends the lifespan of products but also ensures that materials can be recovered and reintegrated into the production cycle, significantly reducing waste.

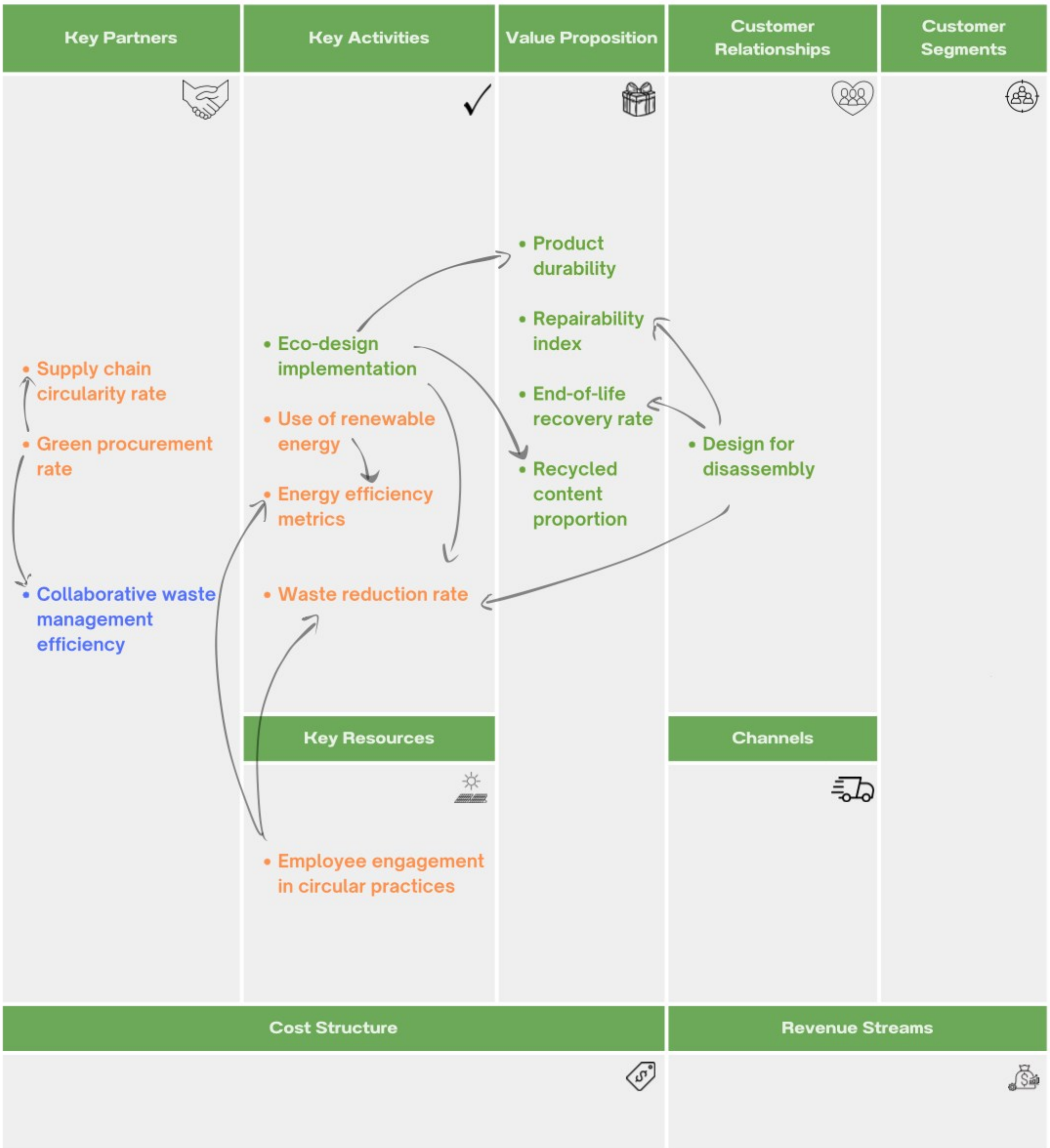
The use of renewable energy serves as another important leading KPI, with direct effects on energy efficiency metrics. Shifting to renewable energy sources reduces dependence on fossil fuels, improving operational energy efficiency.

Green procurement plays a pivotal role in enhancing both collaborative waste management efficiency and the supply chain circularity rate. By sourcing environmentally friendly and sustainable materials, companies foster greater collaboration with partners in managing waste more effectively. This also drives improvements in the supply chain circularity rate, as green materials can be recovered, reused, or remanufactured, creating a closed-loop system that supports circular practices.

Moreover, employee engagement in circular practices, such as training, awareness programs, and incentives, drives behavior changes that directly influence waste reduction and energy efficiency. When employees are actively involved in circular initiatives, they contribute to reducing waste and improving energy usage.

These few examples of cause-and-effect relationships among KPIs in the Circular KPIs canvas can be visualized in the figure below (Figure 3.6).

Figure 3.6 – Cause-and-effect relationships among Key Performance Indicators in the Circular KPIs Canvas



Cause-and-effect relationships also identify crucial components including Key activities, Key resources, and Customer relationships and provide a visualization of how an organization's strategic objectives connect with its CE goals. The previously mentioned visualization underscores the significance of incorporating and highlighting CE principles in specific areas. It illustrates, for instance, how increasing the lifespan of products is coherent with the overall goal of reducing waste and boosting resource efficiency. This kind of alignment guarantees that every corporate activity supports the overall circular strategy and facilitates decision-making.

Moreover, cause-and-effect relationships serve as a communication tool to help departments coordinate around common circularity goals. They encourage cross-departmental collaboration by clearly illustrating how various components contribute to CE goals. For example, they can show how the supply chain's efforts to acquire sustainable materials and the R&D department's emphasis on eco-design support one other, promoting cooperation, teamwork and a cohesive approach to meet the goals of the CE.

Organizations may additionally identify areas for improvement and discover gaps in their current strategy by considering the cause-and-effect relationships aspect. Businesses may pinpoint areas for development or where they could fail to meet the implementation of CE practices by mapping the linkages between strategic objectives and the template components. For instance, it could happen that, although a business succeeds in product design and recyclability KPIs, it does not have robust metrics for measuring customer involvement in sustainability programs. To better reduce these gaps, this understanding may inspire the development of new projects or the improvement of already-effective tactics.

Businesses can also efficiently manage resources and prioritize initiatives to achieve their CE aims with the help of the interpretation of cause-and-effect relationships. They offer a clear picture of which strategic goals are most important and which parts of the company need the most work or funding. The company may decide to invest in technology that improves product traceability and recycling procedures if the results of a cause-and-effect relationship show that achieving circularity requires better product lifecycle management. This focused strategy guarantees effective resource allocation for the accomplishment of circular goals.

The consideration of these relationships provides a dynamic framework that can be changed as the company changes, which further promotes continuous improvement. This flexibility makes sure that the company is flexible and responsive to shifts in the CE environment, always improving its strategy, aligning it with the KPIs, with the aim to improve sustainability performance and accomplish long-term circular objectives.

Finally, the cause-and-effect relationships show how micro level activities contribute to larger circular objectives, including industry-wide recycling initiatives or national sustainability legislation, ensuring that the Circular KPIs Canvas is in line with broader CE levels—nano, meso, and macro. This alignment demonstrates how the business model not only helps achieve its own circular goals but also promotes larger-scale initiatives to establish a CE.

CONCLUSIONS

This thesis provides a contribution to the integration of KPIs with CE principles by offering a comprehensive analysis of CE measurement across the four distinct levels: nano, micro, meso, and macro.

By adopting a multi-level approach, the research underscores the critical interdependencies that exist between these levels, which have been largely neglected in prior frameworks. The thesis illustrates how decisions or improvements at one level, such as increasing product recyclability at the nano level, can have cascading effects across broader business practices (micro) and even sectoral systems (meso). This interconnectedness highlights the need for an integrated approach when developing and implementing CE strategies and measurement initiatives, as isolated efforts are unlikely to generate the systemic change required for circularity goals achievement.

A key and original contribution of this thesis is the development of the Circular KPIs Canvas, introduced in Chapter 3. This framework is based on the traditional Business Model Canvas but has been adapted to include specific KPIs that reflect CE dimensions. The Circular KPIs Canvas offers a structured method for companies to include circularity into their core business functions, ensuring that circularity is integral to key areas such as resource management, product design, and value creation. By focusing on the micro level, this model enables businesses to track and assess their circular performance in a detailed and practical way, providing actionable insights that can guide operational adjustments. Moreover, the framework acknowledges the importance of aligning KPIs across all levels of CE, thus allowing businesses to monitor and adjust their circular strategies in line with broader circularity goals at the nano, micro and meso levels.

The Circular KPIs Canvas addresses several critical gaps in previous circularity measurement frameworks. First, many existing frameworks fail to account for the need to measure circularity at multiple levels. This thesis emphasizes that a single-level focus—whether it is on individual products or entire systems—is insufficient for capturing the complexity of CE practices. The proposed framework ensures that businesses consider how circularity requires implementation at different levels, offering a more comprehensive understanding of circularity performance. The Circular KPIs Canvas, indeed, includes KPIs related to three different levels. Second, this research overcomes the issue of interactions between these levels, which previous frameworks tend to overlook. It shows that circularity improvements at one level can significantly impact performance at another, making the case for an integrated, cross-level measurement approach. Finally, the thesis highlights that circularity must be embedded within the business model itself, not treated as a separate or external goal. This integration ensures that circular principles are reflected in the company's operations, customer relationships, and value propositions, ultimately driving long-term sustainable business practices.

Furthermore, the thesis demonstrates how the integration of KPIs across these levels can provide multiple benefits to businesses. By aligning circular objectives with measurable KPIs, companies can stimulate innovation in product design, improve resource efficiency by reducing waste and energy use, and create significant cost savings over time. The ability to track performance at multiple levels also allows businesses to remain flexible, adjusting their strategies as needed to achieve better circular outcomes. The research stresses the importance of aligning CBMs with performance measurement tools, enabling companies to gain a competitive edge in the marketplace through enhanced sustainability credentials. As regulatory pressures for sustainability intensify, this alignment can help businesses avoid compliance risks while leveraging their sustainability efforts to attract eco-conscious consumers and stakeholders.

In conclusion, this research offers a pathway for businesses seeking to navigate the increasingly complex demands of circularity. By providing both theoretical insights and practical tools, such as the Circular KPIs Canvas, this research may contribute to lead companies to transition from linear to circular business models effectively. The framework presented in this thesis thus could serve as a useful tool for businesses aiming to implement circularity and face the growing connected challenges.

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