ECONOMICS AND BUSINESS ADMINISTRATION FACULTY

VILNIUS UNIVERSITY

QUALITY MANAGEMENT

Karolina Kužmarskytė

MASTER THESIS

GYVAVIMO CIKLO VERTINIMO, MEDŽIAGŲ SRAUTŲ ANALIZĖS IR DINAMINIŲ VERSLO GEBĖJIMŲ RYŠIAI ĮGYVENDINANT ŽIEDINĖS EKONOMIKOS PRAKTIKAS ĮMONĖSE

RELATIONS BETWEEN LIFE CYCLE ASSESSMENT, MATERIAL FLOW ANALYSIS, AND DYNAMIC BUSINESS CAPABILITIES FOR CIRCULAR ECONOMY IMPLEMENTATION IN COMPANIES

Allowed to defend______________

Master's degree student _________________

Supervisor ________________________

Supervisor prof. dr. Dalius Serafinas

Date of submission of Master Thesis: 2023 01 09
Ref. No.

Vilnius, 2023

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CE – Circular economy

CBM – Circular business model

CSC – Circular supply chain

DBCs – Dynamic business capabilities

EPD – Environmental product declaration

ISO – International Organization for Standardization

LCA – Life cycle assessment

MCI – Material circularity indicator

MFA – Material flow analysis

MFCA – Material flow cost accounting

RBV – Resource based view

INTRODUCTION

Topic relevance. Due to occurring different economic and environmental volatilities in global supply chains, researchers and practitioners are increasingly exploring possibilities to implement circular economy (hereinafter – CE) (or circularity) practices in companies (Centobelli et al., 2020; Lieder & Rashid, 2016). Most widely acknowledged benefits of circular economy for business cover material savings, better environmental performance, penetration to new markets (Kumar et al., 2019), increased resource productivity (Geissdoerfer et al., 2017), improved resource self-sufficiency and reduced expenses on waste management (Farooque et al., 2019). However, the implementation of circular economy practices is complex and requires reorientation of company's processes, resource management activities or even the business model itself. An important part of this transformation is how companies are able to apply different management instruments and exploit or create new business capabilities and to benefit from it, i.e., to improve company's performance aligned with circular economy objectives. Thus, alongside the research that is focusing on the technological aspects of the implementation of CE practices, a newly emerging area of interest is the investigation of different management practices that can stimulate organizational changes towards the implementation of CE practices in companies.

One of the new areas of interest is the use of measurement methods and instruments that allow companies to assess the circularity of products, resources, and processes. It is recognised that the use of appropriate measurement instruments in companies is one of the essential first steps in forming an effective management of the implementation of CE practices. Correspondingly, there has been a significant increase in the number of measurement methods and instruments dedicated for CE practice implementation in companies, developed in recent years (Cayzer et al., 2017; De Oliveira et al., 2021; De Pascale et al., 2021; Di Maio et al., 2017; Sacco et al., 2021; Saidani et al., 2019). Among them, the prevailing focus is on the use of methods based on life cycle assessment (hereinafter – LCA) and material flow analysis (hereinafter – MFA) (Corona et al., 2019; Lindgreen et al., 2020; Pauliuk, 2018).

Another area under increasing attention is the investigation of changes in business capabilities (i.e., different managerial practices and abilities) that would support the implementation of CE practices and improve related overall performance of companies. In this context, the theory of dynamic business capabilities (hereinafter – DBCs) emerges, which focuses on unique capabilities of companies in relation to a rapidly changing market (Teece, 2018). Generally, the advancement of circular economy is seen as a significant factor influencing market developments and promoting business change. Thus, DBCs are important for companies to identify and implement business opportunities for change related to the implementation and advancement of CE practices (Khan, Daddi & Iraldo, 2020b).

However, in most of the literature, the emphasis remains on possible CE transformation opportunities for companies (e.g., peculiarities of business model and value chain reorientation (Farooque et al., 2019; Geissdoerfer et al., 2018)) but not on the process of change and integration of its constituent parts. This issue is also related to the literature on business model innovation for the CE, which is dominated by the view that such developments encompass distinct and unrelated stages (Pieroni et al., 2019). Moreover, there is a lack of analyses incorporating the roles of LCA and MFA use together with DBCs as possible influencing factors of CE practice implementation. Therefore, this Master thesis aims to provide a new integrated perspective on the processes of implementing CE practices in companies, based on the analysis of interactions between specific measurement and management methods and instruments (i.e., LCA and MFA) and business capabilities building (i.e., DBCs).

The level of exploration of the topic. Both LCA and MFA as well as DBCs as factors associated with the implementation of CE practices in companies, were mainly analysed separately. Notable work on the impact of LCA on the implementation of the circular economy has been carried out by Corona et al. (2019), Lindgreen et al. (2020) and Pauliuk (2018). In the same respect, the MFA has been analysed by Kaddoura et al., (2019), Franklin-Johnson et al. (2016), and Wen & Meng (2015). Moreover, to date, only a few studies have employed DBCs in the CE context (Khan et al., 2020b; Scarpellini et al., 2020; Seles et al., 2022). While DBCs in the LCA context was analysed by Bianchi et al. (2022), no MFA context-specific analyses were found.

The novelty of the Master thesis. This Master thesis opted to combine different approaches that analyse the conditions for implementing circular economy practices in companies, that is, the use of methods and instruments such as LCA and MFA and the role of dynamic business capabilities. This new combined approach aims to clarify enabling conditions for businesses to successfully implement CE practices and improve CE related performance, thus, contributing to the existing theoretical knowledge on CE implementation in companies. This work also addresses the need expressed by researchers to explore the links between sustainability-related capabilities, activities, and managerial practices (Buzzao & Rizzi, 2021). Furthermore, as the implementation of circular economy practices requires significant changes in the management of company resources and business processes, the model presented in the Master thesis reflects this complexity from a previously unexamined perspective.

The problem of Master thesis. Despite the identified benefits of the circular economy, companies have been slow to adopt related practices and even less likely to use LCA and MFA to facilitate this transition. It is argued that the use of LCA and MFA involves substantial resources, thus, companies are hesitant to use them without having any compelling reason or knowing potential benefits (Freidberg, 2015). On the other hand, in this context, the DBCs has the potential to highlight the resources needed by the company, on the basis of which CE practices can be introduced and the related organisational performance improved. However, no clear linkages between these two elements have been analysed so far, and, correspondingly, a knowledge gap is evident. Thus, the problem of this Master thesis can, therefore, be framed in the question of *how the use of LCA and MFA affects DBCs for the implementation of circular economy practices and related performance improvement in companies?*

The **aim** of the Master thesis is to identify the relations between the use of LCA, MFA and the enhancement of dynamic business capabilities for the implementation of circular economy practices and related performance improvement in companies.

Research object – relations between life cycle assessment, material flow analysis, and dynamic business capabilities for circular economy implementation in companies.

Research objectives:

1. To develop a conceptual research model by theoretically investigating the concepts of circular economy, life cycle analysis, material flow analysis, and dynamic business capabilities.
2. To establish a research methodology aimed at analysing how the use of LCA and MFA is associated to the implementation of circular economy practices in companies, based on a dynamic business capabilities framework.
3. To collect and analyse data determining how the use of LCA and MFA is associated to the implementation of circular economy practices in companies, based on a dynamic business capabilities framework.
4. To create a theoretical model defining the relations between the use of LCA and MFA and the implementation of circular economy practices in companies within a dynamic business capabilities framework.

The **methods used** in this Master thesis include the analysis and systematic review of scientific literature to achieve the first objective of the research, semi-structured expert interviews for empirical data collection (for second and third objectives), and constant comparison analysis of qualitative data by applying theories related to DBCs, CE, and continuous improvement (for fourth objective). Finally, data synthesis and generalisation techniques are used to formulate theoretical model (for fourth objective) and present main findings and conclusions.

Main Master thesis **difficulties and limitations** include potential bias in the results of the study, under-representation of the factors shaping market developments, and incomplete disclosure of the existing diversity of CE practices.

The Master thesis is **structured** into 4 chapters. The first chapter contains a literature review of the key concepts explored in the work. The second chapter outlines the methodology of the empirical study based on the insights from the literature review, including formulated research aim, questions, design as well as data collection and analysis procedures and instruments. The third chapter contains an analysis of the data collected in the empirical study and the overview of the resulting theoretical model. Lastly, thesis conclusions, work limitations together with suggestions for further research are presented in the fourth chapter.

The **scope** of Master thesis includes 99 pages, 8 figures, 14 tables, 4 annexes, and 185 references.

1. THEORETICAL ASPECTS OF CIRCULAR ECONOMY, LIFE CYCLE ASSESSMENT, MATERIAL FLOW ANALYSIS, AND DYNAMIC BUSINESS CAPABILITIES

1.1. Circular economy

1.1.1. Concept of circular economy

Circular economy is a relatively new field of research for which the main influences come from environmental economics, industrial ecology, blue economy, ecological economics, regenerative design, looped and performance economy, and cradle to cradle theories (Geisendorf & Pietrulla, 2018; Geissdoerfer et al., 2017; Ghisellini et al., 2016; Korhonen et al., 2018; Lieder & Rashid, 2016). While the link between the economy and the environment has long been at the forefront of the minds of academics, it is only in 2015 that there has been a marked increase in interest in CE, particularly in Europe (Reike et al., 2018; Velte et al., 2018). The novelty of this field is reflected in the fact that over 100 different definitions of the circular economy can be found in the scientific literature (Kirchherr et al., 2017; Winans et al., 2017). Most of these definitions are linked by the preservation of materials in a closed-loop system, with the aim of maximising their reuse, reducing pollution, and achieving economic growth.

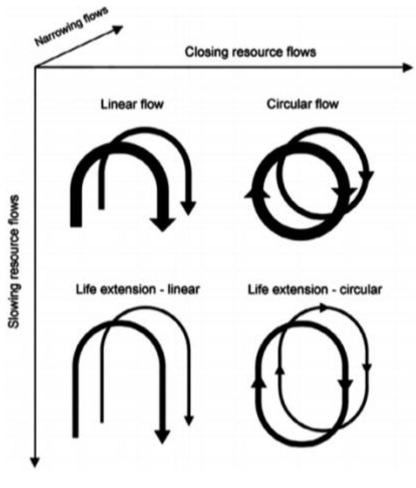

Figure 1. Types of resource flow management strategies in circular economy (Bocken et al., 2016)

One of the most used definitions of the circular economy is formulated by Geissdoerfer et al. (2017) that follows: "circular economy is a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops" (p. 759). These loops in general are understood as resource flows (see Figure 1). The aim of circular economy system is to maximize material and energy throughput flow to a tolerable level that natural systems can achieve with self-regeneration (Korhonen et al., 2018). This aim is achieved through circular design and management practices in companies that include planning, resourcing, procurement, production, and reprocessing (Murray et al., 2017). In general, the examination of circular economy contributes to efficient and higher value-adding resource and waste management practice development (Blomsma & Brennan, 2017).

The activities that are dedicated to slow, close, and narrow material and energy loops form the core strategies of applying circular economy practices in business. In this context, the slowing of loops is achieved through the design of long-life goods that can ensure a prolonged useful life of the product and of the materials it contains (Bocken et al., 2016). From a services perspective, it comprises of product-life extension opportunities, such as repair, refurbishment, and remanufacturing. The closing of loops is generally understood as recycling practices or the uptake of recycled materials that can result in circular flow of resources (Bocken et al., 2016; Geissdoerfer et al., 2018). The narrowing of loops is the most widely applied approach of circularity strategies as it covers efficiency improvements that reduce resources used per product as well as reduce or utilize production waste in a value-added manner.

Several studies include regeneration and dematerialisation of material and energy loops as additional circular economy application strategies in business (Blomsma & Brennan, 2017; Konietzko et al., 2020). Morseletto (2020) describes regeneration as the enhancement of natural systems' self-renewal ability that has been destroyed or over-exploited by human action. For the application in business, it represents the use non-toxic materials and renewable energy (Konietzko et al., 2020). Dematerialisation, on the other hand, is a completely exhausting approach of reshaping material and energy loops in order to give up their consumption. Practically it can be achieved by substituting products with services and offering performance instead of a physical good. However, there is little indication of true dematerialization, as product replacement with services requires materials and energy as well, even though in another form (Allwood et al., 2011). Therefore, in addition to slowing, closing, and narrowing material and energy loops only regeneration can be sufficiently accepted as a suitable alternative strategy for the application of circular economy practices in business.

Another part of the circular economy research framework is the typology of concrete actions that retain resource value. Widely, they are acknowledged as "R principles" and basic typology includes 3 key R principles – *reduce, reuse, recycle* (de Pascale et al., 2021; Winans et al., 2017). However, as research on the circular economy grows, analysis of the 6R principles is becoming increasingly common in the literature (Jawahir & Bradley, 2016). In comparison to basic 3R principles, it supplements the typology with actions of *recover, redesign, and remanufacture*. The latter two components involve the extension of a life cycle, i.e., the useful life of products, while recover deals with products at the end of their use stage. Moreover, there were attempts to broaden this typology even more. Reike et al. (2018) provide a list of as many as 10R principles in a literature review, dividing them into three areas: consumer choice (I), product improvement (II) and reducing the need for new resources (III). They cover *refuse (I), reduce (I), resell/reuse (I), repair (II), refurbish (II), remanufacture (II), re-purpose (III), recycle materials (III), recover energy (III), and re-mine (III)* actions. The larger amount of R principles applied represents the more complex, but at the same time longer, product life cycle. This typology, therefore, contributes significantly to the practical application of circular economy knowledge to create and maintain closed material flows or to preserve their value for as long as possible.

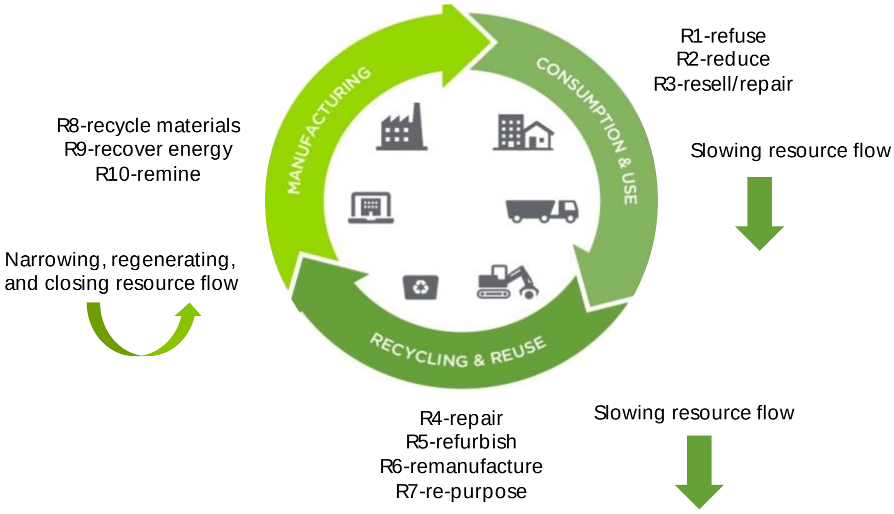

Figure 2. Application of R principles to achieve circular economy aims in a closed type of value chain (compiled by the author)

There is a strong connection and logic between the implementation strategies of circular economy (to close, slow, narrow, and regenerate resource flows) and the typology of R principles (see Figure 2). In practice, each value chain may include one or more applications of R principles, although this is influenced by internal and external barriers. Technological and regulatory barriers have the greatest impact on their applicability. However, the internal aspects of companies, such as established management practices and business models, also play an important role in the implementation of both R principles and circular economy strategies. An examination of these themes in the scientific literature is presented in the following sub-chapter.

1.1.2. Aspects of the implementation of circular economy practices in companies

The development of circular supply chains (hereinafter – CSC) is one of the essential ways of implementing R principles to attain CE aims (Yang et al., 2018). According to the explanation by Geissdoerfer et al. (2018), these kind of supply chains cover the configuration and coordination of organizational functions such as marketing, sales, research and development, production, logistics, information technology, finance, and customer service within and across companies with the aim to slow, close, narrow, or regenerate material and energy loops. This configuration is encompassed with system-wide innovations that allow to restore technical and to regenerate biological materials towards zero-waste vision (Farooque et al., 2019). Instead of a linear "take-use-waste" model, companies are purposefully deciding to loop their supply chains to cut down on expenses and produce less waste. Therefore, this supply chain transformation towards circular economy is an inclusive process involving coordination between raw material providers, manufacturers, service providers, consumers, and users.

However, based on discussion by Batista et al. (2018), academic research with direct references to 'circular' (or the concept of circularity) in supply chains remains a marginal case in the area of supply chain operations management. Some of the relevant challenges from a business perspective for it are the development of flexibility capabilities to address operational CE difficulties and limited comprehension of benefits that can be achieved with additional costs for reshaping current practices (Bai et al., 2020).

In addition, previous research is also extensively covering more advanced circular economy implementation possibilities in a form of the development of circular business models (hereinafter – CBM) (Geissdoerfer et al., 2018; Hofmann, 2019). The transition to a circular economy model is an example of a major shift that necessitates a new way of thinking and doing business, including its model operation (Bocken et al., 2016). In traditional management terms, business model is designed to create and capture value for the company, customers, and shareholders. Accordingly, CBM pursue this objective by applying strategies of circular economy, which are slowing, closing, narrowing, and regenerating material and energy loops (Oghazi & Mostaghel, 2018). A comprehensive definition of CBM is provided by Frishammar & Parida (2019) who describe it as "one in which a focal company, together with partners, uses innovation to create, capture, and deliver value to improve resource efficiency by extending the lifespan of products and parts, thereby realizing environmental, social, and economic benefits" (p. 6).

In addition to traditional business model rationale, CBM aim to reorganize value creation, delivery, and capture while taking the advantage of more sustainable approach (see Table 1). Monetary value that is created within CBM is encompassed with non-monetary (environmental and social) benefits that appear in a long-term perspective (Geissdoerfer et al., 2018). In general, this is broadly referred to business model innovation. Various research suggest that business model innovation can not only create value but also must achieve sustainability, particularly in manufacturing companies (Geissdoerfer et al., 2018; Pieroni et al., 2019; Schulte, 2013). Business model innovation in case of seeking more circular performance, assists in discovering innovative methods of giving value to stakeholders (e.g., consumers, suppliers) and investigating economic values across the life cycle of goods in order to systematically improve resource use efficiency and effectiveness (Centobelli et al., 2020; Den Hollander & Bakker, 2016). It is, therefore, considered that without these innovations, it is extremely difficult, if not impossible, to move towards a more advanced CE application, e.g., creation of closed loop value chains.

Table 1. Value creation, delivery, and capture in circular business model. Based on (Frishammar & Parida, 2019; Geissdoerfer et al., 2018; Teece, 2010)

Business model theory		**Circular business model approach**
Value creation	What type of product or service is offered to the customer?	Constructed offerings must not only generate enough revenue to cover direct and indirect costs, but they must also be designed in a circular manner, such as eco-design and design for disassembly, to ensure society's well-being and long-term capacity to address economic, environmental, and social concerns.
Value delivery	What activities and resources are needed to deliver the value for the customer?	Creation and development of stakeholders' network who share the same values and are motivated to contribute to economic viability, environmental benefits, and social concerns. The network must be prepared for long-term challenges associated with business model implementation.
Value capture	How the revenue from created and delivered value can be financially viable?	The economic value must also be encompassed with the aim to preserve natural resources and increase society's wellbeing both in the short and in the long-term.

Moreover, in literature concerning CBM innovation the importance is also drawn to systemic innovations and cooperation through the value chain stakeholders (Antikainen & Valkokari, 2016; Geissdoerfer et al., 2018). A study by Gorissen et al. (2016) resulted in findings that the involvement of stakeholders from several different sectors in a co-creation process led to the consolidation of a strategic agency that succeeded in dispersing ideas to powerful networks and in mobilizing both financial and human resources to develop new business models. In this context, cooperation towards circular economy-oriented business development depends on company's networking experience, participation in clusters, associations, knowledge hubs and other informal organizations or consortia. This becomes even more relevant from a value chain perspective that circular economy theory aims to emphasise. The development of a CBM is heavily reliant on the contributions of others and focusing exclusively on singular company and its customers is insufficient (Frishammar & Parida, 2019). Systemic change and innovations are thus required, and collaborative and inventive ecosystems are the most effective means of achieving it.

As CBM is a relatively new business development approach that goes beyond economic benefits, there are several major challenges and barriers to their existence. In a study by Frishammar & Parida (2019), companies referred to them as the needs to develop new services with limited previous experience, designing a new revenue model or improving and existing revenue model to reduce risks, establishing superior after-sale services, delivering on promised function and accessibility to the end user, ensuring quality grantees, closing circular loops by involving customers and lead users, and preserving financial costs associated with end-of-life activities. Moreover, these challenges can be accompanied by lack of supporting regulation, organizational and cultural barriers, fashion vulnerability, trust and mutual benefits among partners, and technological barriers (Oghazi & Mostaghel, 2018). All of the above challenges can be summarised in four broad barrier categories: barriers at the market and institutional level, barriers at the value chain level, barriers at the organizational level, and barriers at the employee level (Guldmann & Huulgaard, 2020). Taking the previous studies into account, it is concluded that all four types of barriers are relevant for companies that aim to maintain circular business models in operation.

The rather complex understanding and application of circular economy strategies and the barriers to their adoption mean that fully circular businesses are almost non-existent in practice. According to Lewandowski (2016), to some extent, every business model can be both linear and circular. This link stems from the reasonably widespread and even routine corporate activities to achieve cost efficiency, such as process optimization, selection of more efficient energy applications, and material saving, which are also seen as a part of the circular economy. Therefore, for the sake of accuracy Guldmann & Huulgaard (2020) suggest referring to the circularness of companies rather than to their perfect circularity. Considering these limitations, in the context of this Master thesis it is chosen not to investigate the circularness level of companies, but instead, the objective is to explore the implementation of practices that fall under different CE strategies.

1.1.3. Circular economy related performance and its improvement in companies

The application of circular economy practices is not only considered to generate economic and environmental benefits for the company in terms of preserving the environment, but also to contribute to the company's performance improvement. The literature identifies three areas of improvement in companies that are stimulated by the application of circular economy practices: material, product, and process quality (Barros et al., 2021). The three areas are closely linked to each other. Nonetheless, several studies have shown that they have varying degrees of relevance to the application of circular economy practices.

Material quality is probably the most discussed issue in circular economy research. Since the strategies of CE are based on the reuse of materials and their longevity, their quality is important for both producers and consumers. High value and quality of material cycles are crucial elements to put CE into practice (Korhonen et al., 2018). More specifically, this concerns the quality and functionality of recycled materials (Steinmann et al., 2019). The quality of recycled materials may differ from, and in some cases be worse than, that of the primary material. While loss of functionality appears in the secondary product substances, but not in the primary. One way to tackle the problem of poor recycled material quality, as suggested by Flynn et al. (2019), is by using standards. They claim that in addition to providing comfort regarding the quality of materials being exchanged, standards may be utilized to improve the overall quality of those materials even more. Therefore, it is necessary to choose and approve materials based on certain quality requirements for the performance of circular economy systems to be deemed of high quality (Barros et al., 2021).

Product quality refers to satisfying customers' needs and criteria for distinct qualities of it, i.e., function and design. In the context of the circular economy, the quality of a product is an important element in determining its longevity and whether it can be reused or not, according to the R principles. For example, Bocken et al. (2019) states that a company which produces high-quality, long-lasting goods and provides excellent customer service (value proposition) is considered to encourage sufficiency by proposing customers to use their product for as long as possible. This sufficiency principle (longer use) together with repair and other services is aligned with the circular economy strategy to slow resource flows. Results from Fonseca et al. (2018) study show that the production of high-quality products is a quite common strategy among companies that implement CE practices. High value for money strategy is reported to be very customer oriented and allows companies to seek innovative product development.

Product quality in the context of the circular economy is closely linked to process quality. While moving towards circular economy, a company must build flexibility capabilities that are necessary to address operational CE challenges and avoid potentially occurring performance degradation, increased costs, or compromised product quality (Bai et al., 2020). Therefore, the implementation of circular economy practices can help to enhance process quality, especially the one that is related with material flow and resource productivity management (Barros et al., 2021; Oghazi & Mostaghel, 2018). For example, enhancing process quality decreases scrap and rework, extends product life, and reduces product maintenance, all of which contribute to the circular economy (Lin et al., 2019). Process quality enhancement which is directly related with circular economy practices is also frequent among clusters that are mostly focused on enhancing their efficiency and supply chain optimization, as noted by Trevisan et al. (2021). Thus, the sustainable supply chain management was also found relevant for the overall business performance improvement in relation to CE practice implementation (Zhu et al., 2010).

Moving beyond the quality of materials, products, and processes to a more general management perspective, it is argued that the implementation of circular economy practices in business can lead to establishing the foundation for performance improvement if appropriate management instruments are used (Moric et al., 2020). With the aim to move towards more resource efficient and circular business model, many necessary improvements and innovations must be applied. Rethinking organization's operations for seeking new created value for the stakeholders leads to enabling business pursuit towards excellence and continuous improvement. In relation, Ferasso et al. (2020) state that the investigation of CE application and performance evaluation in terms of economic, environmental, and social dimensions is a rapidly emerging topic in the literature. For this purpose, numerous CE related performance measuring methods and instruments were developed by both scholars and non-scientific organizations in recent years, most of them relying of principles deriving from life cycle assessment and material flow analysis. A structured overview of such methods and instruments is provided in Annex 1. The use of these methods and instruments is considered to be important for companies to assess the feasibility in applying CE practices, to analyse the progress made and to consider further opportunities for improvement.

Overall, circular economy characterizes as a system that aims to slow, narrow, regenerate, and close resource flows to achieve economic, environmental, and social sustainability within the economy. In practice this is accomplished through the implementation *of concrete actions that retain resource value (R principles) and which are an integral part of business model or supply chain transformation and innovation for circular economy. The transition of companies towards CE is characterised by a variety of process, technology or product changes that range from traditional resource efficiency improvements to the creation of new value propositions for customers. Moreover, the results from different studies show that the implementation of circular economy principles can lead to business improvements covering material, product, and process quality enhancement, while the benefits can also be perceptible for the overall performance or the organization. Several examples include efficiency enhancement, better economic and environmental performance, and orientation towards innovation. To achieve them, however, it is important to use appropriate assessment methods that can facilitate improvement-oriented management practices.*

1.2. Life cycle assessment

1.2.1. Concept of life cycle assessment

Life cycle assessment is a scientifically supported and standardised method for determining the resource consumption and environmental effects of a specific product, system, or service across its full life cycle (Eberhardt et al., 2019; Klöpffer, 2012; Tóth Szita, 2017). Detailed application principles of the LCA method are given in the International Organization for Standardization (hereafter – ISO) standard 14040:2006 ("Environmental management — Life cycle assessment — Principles and framework") (see Figure 3). Whereas ISO 14044:2006 ("Environmental management — Life cycle assessment — Requirements and guidelines") standard determines specific requirements for conducting LCA (ISO, 2006b). Both life cycle assessment standards provide guidance for evaluating the environmental implications of a product or service throughout its life cycle "from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal" (ISO, 2006a, p. V). In general, ISO 14040:2006 and 14044:2006 are the primary and most essential international standards for life cycle or comprehensive environmental assessment concerning products, services, or systems (Klöpffer, 2012).

In practice, LCA is applied to different value chain scopes, e.g., "cradle-to-gate" (i.e., from raw materials to final product production), "cradle-to-grave" (i.e., from raw materials to final disposal of a product) or "cradle-to-cradle" (i.e., from raw materials to secondary use of those materials or products in new value chains) (Pieragostini et al., 2012). Each scope is foreseen in the initial stages of LCA implementation, mostly taking into account the company's objectives and the type of products produced. Based on the scope, a comprehensive inventory analysis (e.g., types and amount of material and energy used, technologies deployed) of the company and its suppliers or service providing partners is carried out and corresponding environmental impacts are assessed using a specific instrument – software system (Ormazabal et al., 2014).

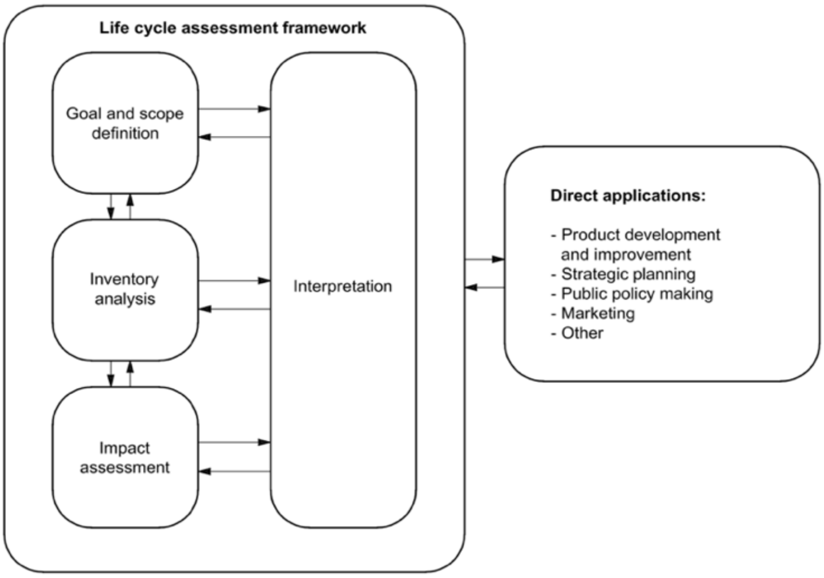

Figure 3. Life cycle assessment framework based on ISO 14040: 2006 (ISO, 2006a)

As life cycle assessment reveals the primary drivers of environmental effects, by addressing these drivers, businesses may lower their own impact and the effects of the analysed product (Testa et al., 2016). Therefore, the LCA method is used in a variety of situations to address environmental trouble spots or bottlenecks in the investigated system, and/or to analyse the environmental consequences of different alternatives that might be used in the examined system to accomplish the same purpose (Dong et al., 2018). Because LCA can be applied to analyse quantified environmental impacts associated upon each alternative, it has the potential to fill a gap wherein the different decision analyses only barely consider environmental impacts (Dong et al., 2018; Schwarz et al., 2021). This allows impacts on the environment to be considered alongside the other conventional consequences for process optimization in business (e.g., economic benefit or loss), which is a significant advantage of this method. Moreover, the ISO 14040 series is a subset of the larger ISO 14000 series on Environmental Management Systems (EMS) that includes a framework for implementing continuous improvement actions (EMS policy statement). As a result, it is evident that the ISO 14040 series is likewise concerned with progress rather than with monitoring the status quo.

Moreover, based on the LCA implementation framework presented in Figure 3, it appears that the use of this instrument and the interpretation of the results can be applied in two directions. The first (or the initial) direction starts with scope and goal formation and continues with inventory analysis, impact assessment and interpretation of results. However, a second alternative is also visible, which is a continuous act and during which the interpretation of the results leads to inputs for renewed scope and goal definition and other following actions. Therefore, the greatest benefits of the framework can be achieved through both lines of actions.

1.2.2. Links between life cycle assessment and the implementation of circular economy practices in companies

Different studies have been exploring the benefits and importance of LCA application in relation to circular economy. Firstly, by seeking to evaluate the environmental impacts of products, including end-of-life treatments, LCA is linked to the aim of the circular economy in terms of its goals (Haupt & Zschokke, 2017). Secondly, the uptake of LCA brings legitimacy and awareness of circular economy solutions both for producers and consumers. As noted by Tóth Szita (2017), product assurance that can be provided by LCA and other declarations aids to the transparency of circular economy's aims and strategies, together connecting them to relevant sustainability requirements. Environmental product declarations (EPD) or eco-labels are typical examples where the results of the LCA are applied to the CE objectives and communicated to consumers (Dong, 2018). Secondly, LCA is positioned as an appropriate method to assess the environmental advantages and disadvantages of applying circular economy practices in product development or production processes. Findings from Haupt & Zschokke (2017) work indicate that in order to achieve a good balance between costs and benefits in both new products and greater recycling, LCA is required to evaluate CE practices. More specifically, life cycle assessment results have the potential to enhance guidance to what type of circular practices in relation to CE strategies should be applied in a company, ranging from the recycling operations to the application of more advanced circular economy initiatives, e.g., repair and refurbishment services (Lucchetti et al., 2019; Tóth Szita, 2017). Thirdly, LCA promotes attention to life cycle perspective of products which is a core circular economy notion. LCA can examine a wide variety of environmental consequences connected with a product or service system, highlighting possible issue shifting throughout the life cycle phases (Dong, 2018). Therefore, this method enables the practitioner to develop suitable suggestions that lessen the negative consequences of a product and, as a result, increase the product's long-term viability and sustainability (Dieterle et al., 2018). For example, prolonging the lifespan of passive durable items may reduce the environmental effect of primary manufacturing by replacing it with low-impact repair/refurbishment procedures (Kaddoura et al., 2019).

The above listed insights are illustrated by previous studies that have used LCA in circular economy related research. From the case studies presented in Table 2, three approaches of initial goals can be identified, which are followed by LCA and CE examinations: comparison of alternatives to substitutes or new products (Civancik-Uslu et al., 2019; Lucchetti et al., 2019), assessing the environmental impact of new services or processes (Assefa & Ambler, 2017; Kaddoiura et al., 2019; Niero & Olsen, 2016; Cusenza et al., 2019), and legitimising the application of circular economy practices as a way of extending the life cycle (Colley et al., 2020; Eberhardt et al., 2019).

Table 2. Case studies in which LCA method has been applied in the context of circular economy research (compiled by the author)

Author	**Product or sector**	**Purpose of applying LCA**	**Achieved result or benefits**
Colley et al. (2020)	Meat processing	By using LCA, to determine the potential of circular economy practice implementation that would reduce the environmental impacts of small and medium-sized meat processing companies.	The LCA enabled to identify the least emitting alternative (from the energy consumption perspective) and its bottlenecks in the supply chain. Based on this result, emission offsetting activities were discussed.
Civancik-Uslu et al. (2019)	Packaging	To examine and discuss the end-of-life consequences of replacing eucalyptus wood sheets used to divide loaded pallets to avoid damage during top storage with plastic compounds made of virgin PP, recycled PP, and mineral fillers.	The LCA approach applied has led to the identification of a more environmentally friendly alternative comprising of higher number of uses, lower weight, use of recycled PP and mineral fillers, and longer lifetime.
Kaddoiura et al. (2019)	Beach flag, event tent, recycle bin, locker, waste inlet	To quantitatively investigate the feasibility of increasing the useful life of passive durable items via refurbishment and repair.	The application of LCA calculation-based proposals resulted in 45–72% reduction of environmental impact in most cases, while corresponding costs for the analysed company decreased by 8–37%.
Lucchetti et al. (2019)	Detergents	To compare the environmental implications of the Re-Detergent manufacturing process with those of a conventional soap and assess it against the results of other analyses, i.e., function of saponification.	The LCA approach allowed the identification of a more environmentally friendly alternative by pinpointing the causes of environmental impacts. This result led to proposals for the company to transition towards circular economy model.
Cusenza et al. (2019)	Battery storage systems	To assess energy use and environmental benefits of reusing batteries from plug-in hybrid electric vehicles instead of new batteries as stationary energy storage systems in buildings coupled with renewable electricity generation technologies.	The alternative selected according to the LCA calculation can save from 4% of the total energy demand and 17% of abiotic depletion potential. Areas for improvement are highlighted accordingly.

Continuation of Table 2

Eberhardt et al. (2019)	Buildings and construction	To legitimize circular economy in the building and construction industry via the use of life cycle assessment.	Based on the application of LCA it was found out that the longer the lifespan and the more reuse cycles of building components there are, the more are reduced negative impacts on the natural environment. Corresponding actions to achieve this result follow.
Assefa & Ambler (2017)	Construction	To analyse and compare the possible environmental implications of building repurposing via reuse of infrastructure and demolition scenarios followed by new construction throughout the course of their respective life cycles.	The application of LCA resulted in determining the least environmentally impactful scenario of building repurposing. It was calculated that the most promising scenario can reduce 20-41% reaching negative impact, in six of the seven environmental impact categories.
Niero & Olsen (2016)	Aluminium cans	To examine the effect of including the actual alloy composition in the life cycle assessment of aluminium can production and recycling, in order to determine whether can-to-can (i.e., closed product loop) recycling should be incentivised or not in the future.	The authors used an LCA approach to identify a more environmentally friendly alternative and based on this, determined the key actions needed to implement the chosen alternative and improve the application of the circular economy throughout the value chain.

However, despite the fact that the benefits of LCA and the associated improvements in companies have been widely reported in the literature, the answer to the question of how LCA facilitates the decision to implement CE practices in companies is not definitive. According to Pryshlakivsky & Searcy (2021), "there has been little research examining the efficacy, limitations or drawbacks of Life Cycle Assessment in the decision-making context" (p. 1). Moreover, there is also a lack of studies that analyse how LCA can contribute to fostering long-term sustainable change in companies, e.g., through building their capabilities, especially related to circular economy practice implementation. Therefore, given the rather limited literature in the context of LCA decision-making and the lack of exploration of this issue in the context of circular economy practices, the relevant question is addressed in the empirical research methodology presented in Chapter 2.

Overall, LCA is an established method for measuring the environmental impacts of a specific product, system, or service throughout different scopes of their life cycles. LCA has the benefits of identifying environmental problem areas in processes, comparing them with more advantageous alternatives and providing results in an evident based and quantified manner. The use of LCA is also seen to be associated with stronger implementation of *environmental management systems and facilitation of organizational improvement, based on continuous monitoring and re-evaluation practices. Moreover, examples from case studies in the literature show LCA's adaptability to measure and provide guidance on CE practice implementation in companies. The most common applications of LCA in the CE context relate to companies' needs to compare the alternatives of new products or their substitutes, to assess environmental impacts of new services or processes, and to legitimise the application of circular economy practices as a way of extending the life cycle. However, despite the use of LCA in the context of CE, there is a lack of insight in the literature on the impact of LCA on business decisions to implement CE practices.*

1.3.Material flow analysis

1.3.1. Concept of material flow analysis

Material flow analysis (hereinafter – MFA) is a method projecting the use of natural resources (material flows) as well as the discharge of pollutants into the environment within a system defined in space and time (see Figure 4) (Herva et al., 2011; Rochat et al., 2013). In this analysis all flows are mass-based, i.e., using mass balancing principle, (including in form of goods produced), providing a tangible representation of the system's material needs (Sendra et al., 2007). The analysis also assesses the movement of material flows between different parts of the system, thereby identifying potential sources of material losses or efficiency improvements. The MFA is considered to be a generic approach for a variety of analytical methods and measurement instruments that assess material flow accounts (OECD, 2008). The core principles of MFA are, therefore, used as a basis for other environmental analyses, including LCA.

Although MFA is often used in macro or meso analyses covering national economies, regions, or value chains (Rochat et al., 2013), it is also valuable at the company scale (Sendra et al., 2007). Graedel (2019) argues that one of the first examples of the application of MFA at company level comes from Toyota Motor Company which in 2003 had released a corporate MFA diagram "Volume of Resources Input and Volume of Substances Released into the Environment in FY2002". The results from MFA analysis enabled the company to set annual targets for material usage, emissions, and recycling. Therefore, MFA is considered to be a sustainability accounting instrument that serves as a primary evaluation of company's environmental management performance (Hörisch et al., 2015).

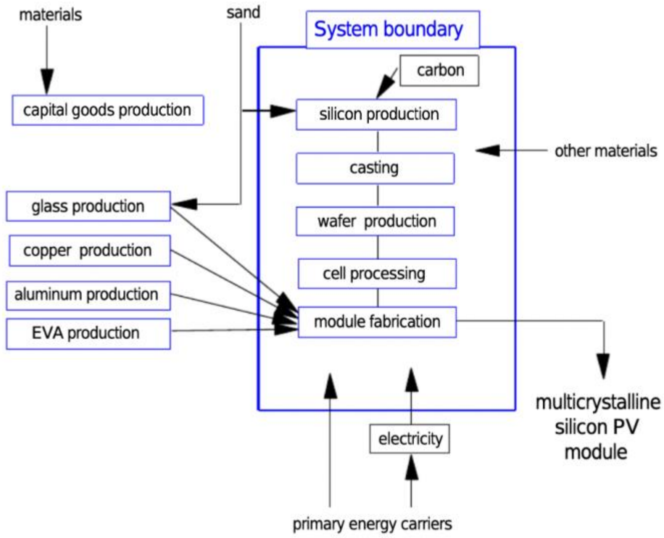

Figure 4. Example of a system boundary for material flow analysis of multicrystalline silicon solar cell module production (Phylipsen & Alsema, 1995)

In addition to the MFA being used at the corporate level, the material flow cost accounting (hereinafter – MFCA) which is a more advanced derivative of MFA, is also dominant form of analysis concerning the consumption, distribution and effects of materials used in the organization. MFCA is a technique of environmental management accounting that aims to minimize both the environmental impact and the expenses of companies (Nakajima et al., 2015). Like the LCA, the MFCA is a standardised and methodologically validated assessment method. The standards covering this method are 14051:2011 ("Environmental management – Material flow cost accounting – General framework") and ISO 14052:2017 ("Environmental management – Material flow cost accounting – Guidance for practical implementation in a supply chain") (ISO, 2011; ISO, 2017). In general, MFCA provided in the standards, "traces the flows and stocks of materials within an organization, quantifies these material flows in physical units (e.g., mass, volume) and evaluates the costs associated with material flows and energy uses" (ISO, 2017, p. 1). The material flow cost accounting is one of the most widely used environmental management accounting systems, and it is primarily intended for usage inside a single site or organization. Nevertheless, it may be used to numerous organizations within a supply chain, (i.e., regarding ISO 14052:2017 standard), to aid in the development of an integrated strategy to more efficient material and energy consumption. In general, the appeal of applying the MFCA among companies is due to the fact that it allows companies to efficiently manage material and energy flows both from economic and environmental perspectives.

Both MFA and MFCA require specialized computation algorithms that allow to utilize large datasets, systematic data structures, and simultaneous modelling at different system levels (product, component, element) (Pauliuk & Heeren, 2020). As a result of these complex computations, a robust decision-making support for companies is provided in form of identified major sources of material and energy consumption and/or loss, suggested areas for material and energy efficiency improvement, as well as identified environmental pollution causes and risks.

1.3.2. Links between material flow analysis and the implementation of circular economy practices in companies

Considering that the MFA includes an assessment of resource flows and some of their environmental impacts (e.g., waste generation), this type of analysis complements the implementation of the circular economy with quantitative data. The most significant contribution of MFA to CE is its ability to capture the inputs of natural resources, use of recyclables, and appeared losses of materials (Elia et al., 2017). This data can then be used to make and monitor decisions on narrowing, slowing, regenerating, and closing resource flows. For example, reuse and recycling decisions may be taken to even resource inputs and outputs, or to improve systems in terms of lower resource intake level (Franklin-Johnson et al., 2016). Some of the recent MFA application considering circular economy case studies in companies were investigated by Stanchev et al. (2020), Ali, Wang & Alvarado (2019), Meglin et al. (2019), Li et al. (2019), Kluczek (2019), Diener & Tillman (2015), and Wen & Meng (2015) (see Table 3). It is evident that in this context, the MFA has most often been applied to explore the feasibility of eco-efficiency (narrowing resource flows) and closed loop (slowing and closing resource flows) practices.

Table 3. Case studies in which MFA method has been applied in the context of circular economy research (compiled by the author)

Author	**Product or sector**	**Purpose of applying MFA**	**Achieved result or benefit**
Stanchev et al. (2020)	Dairy processing	To propose measuring system that would be suitable for the analysis of circular economy practices in dairy processing industry.	Based on company-wide MFA calculations, authors asses current situation and provide pathways to improve circular economy implementation by aiming to retain the material value within the system.
Meglin et al. (2019)	Gravel, cement, and concrete	To determine which business model can achieve highest resource efficiency in the context of circular economy.	Authors have identified two business models that can result in more efficient resource consumption, partly based on the usage of landfill excavated material.

Continuation of Table 3

Ali et al. (2019)	Sheet metal	To justify the reuse of galvanized sheet metal, used in automotive industry, over its recycling, based on the environmental impacts of both processes.	Using MFA and other assessment methods, it has been found that the reuse of galvanised metal sheet saves approximately more than 30% of material costs and energy consumption, in comparison to the recycling alternative.
Li et al. (2019)	Paper	To analyse the resource consumption and environmental damage of papermaking company by assessing and quantifying its resource losses and waste discharge.	Based on the calculations, the authors of the study identified a process improvement (secondary use fibre pulping and papermaking programme) that causes a larger reduction in external environmental damage costs than the traditional approach (using wood as a raw material).
Kluczek (2019)	Heating devices	To investigate eco-efficiency of heating devices including the evaluation of environmental and economic performance in the context of process improvement.	Application of MFA together with other methods allowed author to identify eco-efficiency improvements that could reduce material losses by 2%.
Diener & Tillman (2015)	Steel components	To map out component materials and quantify potential remanufacturing and recycling improvements and related benefits.	The analysis revealed potential ways to increase material efficiency and achieve tangible environmental gains.
Wen & Meng (2015)	Circuit boards	To evaluate the contribution to circular economy of single companies covering the production chain of circuit boards, based on substance flow analysis.	The applied analysis allowed to determine actions for enhancing resource productivity for copper, water, and energy.

Furthermore, even though in the context of the circular economy, MFA and MFCA are rather generic assessment methods, according to de Pascale et al. (2021), the material flow analysis provides a notable basis for other CE indicators that are more theme specific. One relevant example is the Material Circularity Indicator (hereinafter – MCI) developed by Ellen MacArthur Foundation. Essentially, the MCI calculates circularity level of a company, or a product based on input and use of natural, renewable, and recyclable resources, loss of valuable materials together with the durability of product value (Ellen MacArthur Foundation, 2020). In a form of online tool, the MCI assesses to what extent linear material flow in a company can be replaced with circular and restorative flows, i.e., achieved through reusing and recycling resources (Azevedo et al., 2017). Despite some technical limitations, the arguments found in literature are generally favourable about this indicator, Janik & Ryszko (2019) argue that the MCI demonstrates extremely great potential for the assistance of the decision-making process, but its implementation demands a lot of effort, thorough data, and specialist skills. In addition to the latter shortcoming, it is worth noting that the MCI has a limited access to it, as the tool is the property of Ellen MacArthur Foundation. However, Linder et al. (2017) claim that MCI is one of the most solid examples of developed circularity metric on a company level.

Overall, both MFA and MFA based methods, i.e., MFCA and MCI, complement the measurement of circular economy practices' application in companies by providing a framework for tracking material supplies and movements and quantifying them in physical and monetary units. Correspondingly, based on MFA framework, other CE performance indicators can be derived (see Annex 1). MFA is also an appropriate method that could support data-driven decision-making within an organisation to improve its performance in terms of circular economy practices' implementation. However, as with LCA, there is a lack of case studies in the literature that explore in more depth the processes of companies from the choice to adopt MFA method to the actual implementation of CE practices. Moriguchi (2007) also argues that MFA and other derived indicators acts as a compass, i.e., indicates the direction in which the company can achieve improvement, but more specific actions are a subject to individual judgement. It is, therefore, not sufficiently clear whenever and how MFA contributes to the decision to adopt CE practices and implement them in the long-term, rather than just to identify opportunities for CE application or asses the effectiveness and efficiency of current systems.

In summary, MFA is a systems-based approach that calculates the movement and the use of materials in a defined space and time, e.g., a company. This method of analysis also assesses the negative environmental factors generated by the resource use within the system, such as emissions or waste. MFA is considered to be one of the instruments that support companies' environmental management decisions, as its evident-based quantitative results can be used to identify initial opportunities for more efficient use of materials and reduction of pollution. These key areas of improvement are also linked to the implementation of circular economy practices. Relevant case studies found illustrate that MFA can be used by companies to identify opportunities in resource narrowing, slowing, and closing strategies of CE. However, the literature analysed is deficient in examining a broader role of MFA as a facilitating factor for continuous implementation and monitoring of CE practices.

1.4.Dynamic business capabilities

1.4.1. Concept of dynamic business capabilities

The notion of dynamic business capabilities falls under the strategic and change management research fields, and it is based on a view that companies must evolve to be successful in the market. Dynamic business capabilities are defined as "the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments" (Teece, Pisano & Shuen, 1997, p. 516). In this context, a rapidly changing environment refers to various technological, political, social, and cultural developments that directly or indirectly affect companies while in pursuit of maintaining a market presence. Meanwhile, business capabilities in general capture company's ability to perform, adapt and improve. This is done by deploying the necessary resources to carry out the explicit processes and their tacit elements (e.g., know-how) (Wang & Ahmed, 2007). The emergence of DBCs theory was, therefore, driven by the interest in identifying business-relevant capabilities for process alterations that would be compatible with fast-changing market trends.

To better understand the distinctiveness of DBCs, it is relevant to compare them with other business capabilities that are inherent to the day-to-day running of a business, and which are defined as ordinary capabilities (see Table 4). The key distinction between ordinary and dynamic business capabilities is how they function in various capacities as the company changes. Dynamic business capabilities initiate and create change, while ordinary capabilities are being altered. The result of changes in ordinal capabilities is the change in the company's overall performance. Therefore, according to Laaksonen & Peltoniemi (2018), "dynamic capabilities cannot explain performance but rather changes in performance (i.e., Δ performance)" (p. 186). Based on this approach, ordinary business capabilities primarily relate to the company's performance and DBCs – to the adaptation and improvement.

Table 4. The distinction between different types of business capabilities (Teece, 2018)

Type of business capability	Description
Ordinary capabilities	Processes that are needed to carry out current business activities and achieve high levels of efficiency, covering employee, facility, and equipment deployment.
Lower-level dynamic capabilities	Occasional processes that form external partnerships or develop new products.
Higher-level dynamic capabilities	Activities that affect other business capabilities to be ready to successfully react to external factors.

The dynamic business capabilities are allocated into three distinct types of managerial activities (categories): sensing, seizing, and transforming (Teece, 2007). Sensing represents company's ability to identify and assess new business opportunities, seizing – ability to plan and mobilize resources necessary to capture the value of the opportunities, while transforming is the ability to enhance, combine or reconfigure tangible and intangible assets. Another categorisation of DBCs was developed by Wang & Ahmed (2007) and it includes adaptive, absorptive, and innovative managerial activities. Adaptive capabilities are referred to a timely and appropriate alignment of internal company processes with changes in the external environment. Absorptive capabilities relate to the company's ability to absorb and integrate external knowledge into internal use. Meanwhile, innovative capabilities relate to the company's ability to exploit new knowledge and processes to gain market advantage regarding new products and/or market development. Given the more extensive literature on Teece's approach to DBCs, it has been opted to adopt this author's categorization in this Master thesis accordingly.

All three types of managerial activities that form the DBCs framework are essential elements that indirectly contribute to a company's competitiveness in the market. This is evident since the essence of the DBCs framework is to support companies in building their competitive advantage by organizing and prioritizing the overwhelming amount of information they face (Teece, 2018). In recent decades, this has become particularly relevant due to the emergence of communication and digital technologies and high levels of global connectivity. The emphasis on competitiveness is also notable in the definition of DBCs by Wang & Ahmed (2007) as they describe it as "a firm's behavioural orientation constantly to integrate, reconfigure, renew and recreate its resources and capabilities and, most importantly, upgrade and reconstruct its core capabilities in response to the changing environment to attain and sustain competitive advantage". Focusing on and transforming company's unique capabilities potentially makes it more effective in competing in the market by making it difficult for competitors to replicate them (Zapata-Cantu, Delgado & Gonzalez, 2016). DBCs are, therefore, crucial for companies focused on maintaining a competitive long-term market position.

DBCs are also associated closely with the resource based view (hereinafter – RBV) theory that focuses on internal resources of a company necessary to achieve competitive advantage and a long-term performance in the market. In accordance with RBV, a competitive advantage can be obtained through the ways in which the organization sets up and manages its internal resources, such as strategic and non-strategic assets, competences, skills and other (Zapata-Cantu et al. 2016). Importantly, these resources must be valuable, rare, inimitable, and non-substitutable (Barney, 1991). The link with DBCs can be seen here, as the latter cover the internal resources of companies as well. However, it is argued that the RBV analysis tends to isolate companies from the industrial context by focusing only on their internal aspects, and it does not sufficiently address the dynamic environment that companies operate in (Wójcik, 2015). For that reason, the DBCs framework has emerged as a more advanced and appealing alternative capturing both internal and external factors that are important in keeping companies competitive.

1.4.2. Role of dynamic business capabilities in the implementation of circular economy practices in companies

The interface between the circular economy and dynamic business capabilities is mainly driven by the latest contextual development – the stringent focus of consumers and regulatory bodies on the environmental impact of companies, which can be seen as a strong driver of market change. The reorientation of companies to compete in shifting market requires a new strategic approach and corresponding capabilities to implement it. Accordingly, scholars are gradually turning their attention to this issue by highlighting the resources, capabilities and even organizational changes required for companies while being in a dynamic transition towards circular economy (Scarpellini et al. 2020). This trend is linked both to intensifying external market developments and to the complexity of implementing circular economy practices within companies themselves.

In most cases, the investigations of DBCs for circular economy fall under the broader thematical scope of business transition towards more sustainable operating models. Based on the DBCs framework, the researchers argue that sensing, seizing, and transforming capabilities are not only important for general improvement in competitiveness and innovativeness of companies but also for sustainable business model development (Bocken & Geradts, 2020; Pieroni et al. 2019). Respectively, each of the DBCs activities must have a clear sustainability-oriented priority, usually with an environmental perspective. For example, sensing capabilities should support the identification of business opportunities related to sustainability domain, while seizing and transforming capabilities should ensure changes in the environmentally related performance of companies (e.g., decreased emissions, water and energy consumption, waste generation). The more sustainability is expressed by identifying individual managerial activities of DBCs, the more accurate and valuable is their evaluation and interpretation (Buzzao & Rizzi, 2021). Therefore, based on this argument, a distinct and more circular economy-oriented line of research in the field of DBCs is observed.

In several cases, scholars have examined the links between DBCs and the circular economy in the context of innovation. Based on a systematic literature analysis, Suchek et al. (2021) states that dynamic capabilities are one of a few needed internal company factors, along with ecological design instruments and resources, for broader expansion of CE innovations. Innovation in products, processes and business models is also seen as an integral and crucial part of the transition of companies towards implementing circular economy practices. As identified by Scarpellini et al. (2020), the necessary capabilities to foster circular eco-innovations are R&D investments supporting the company's environmental improvement (i.e., emission savings), investments in renewable energy use and energy efficiency improvements, and the uptake of eco-design solutions focusing on dematerialisation. A more substantial alignment between the environmental management system and the overall corporate strategy is also seen as an enabling approach to identify potential market opportunities for the deployment of eco-innovation. Moreover, the role of DBCs can also be examined in innovation-minded value chains or networks. In the investigation of CE transition in the construction sector knowledge sharing and competitive advantage were found to have trade-offs. At the same time, open innovation and dynamic business capabilities were discovered to have a mutually beneficial connection among themselves (Köhler, Sönnichsen & Beske-Jansen, (Köhler et al., 2022). Overall, the importance of innovations for the circular economy is evident, hence the links are also found when exploring the DBCs as an approach to strengthen the development and application of corresponding innovations in companies.

A few existing studies were able to identify particular abilities and practices that companies apply in the CE context and to associate them with the DBSs framework. Most notable work was carried out by Prieto-Sandoval, Jaca, Santos, Baumgartner & Ormazabal (2019), Khan et al. (2020b), and Santa-Maria, Vermeulen & Baumgartner (2021). When identifying key strategies and resources that small and medium sized companies need to eco-innovate and build competitive advantage, Prieto-Sandoval et al. (2019) distinguished 9 DBCs (see Annex 2). Identified DBCs are a part of more complex transformation towards CE framework that includes different corporate strategy paths together with a group of internal and external factors, as noted by the authors. Meanwhile, Khan et al., (2020b) present a list of DBCs indicators that consist of 30 managerial activities (see Annex 2). The list was used to analyse DBCs and their underlying organisational activities as facilitating factors for the CE implementation among Italian companies. Moreover, based on the data analysis form the multiple case studies of successful companies working with CE, Santa-Maria et al. (2021) were able to identify 33 different business skills, process, procedures, and activities that concluded into three DBCs categories (see Annex 2). Each of the category is explained by the micro-foundations (the constituent elements) of DBCs and are the following:

- sensing: external sensitivity, adopting holistic perspectives, knowledge creation, use of sustainability-oriented instruments;
- seizing: delineating sustainable solutions and business models, stakeholder engagement and collaboration, supporting a sustainability and innovation culture;

- transforming: co-specialization of assets, trust-building communication, organizational flexibility, ecosystem orchestration, and leadership and change management capabilities.

The DBCs identified by all authors rereferred in this paragraph are claimed to be particularly important to companies that seek to not only innovate their business model towards circular economy but also to remain competitive in a market focused on sustainable transformation.

A comparison of the three sets of DBCs compiled by these researchers shows that there is a relatively wide space for interpretation of what can be attributed to each of the capability categories and the specificity can also vary, e.g., from a required human resource planning (Khan et al., 2020b) to the formulation of sustainability-oriented innovation teams (Santa-Maria et al., 2022). Buzzao & Rizzi (2021) argue that this diversification is mostly determined by authors' primary focus on particular facets of sustainable management that can either be represented in a narrower or a broader manner. More specific focus however is preferable, as it allows to deepen the perception of specific dynamics and complexities. In the case of the DBCs analysed, it is seen that the inclusion of the CE dimension is limited, and thus it is important to understand the additional context to better interpret the role of DBCs in a dynamic environment, i.e., in a market that is moving towards circular economy.

In summary, DBCs are defined as the abilities of companies to successfully respond to rapidly changing market trends. DBCs encompass different activities, decisions, skills, and procedures that enable companies to assess new market opportunities (sense), plan the necessary resources for change (seize), and implement them by reorganising existing practices (transform). DBCs act as an impetus to change traditional business practices that are seen as ordinary capabilities. DBCs are considered to be an important element ensuring the long-term competitiveness of companies due to their renewed relevance. Circular economy in this case acts as a new market trend that stimulates companies to move towards more sustainable business practices. Rapidly changing technologies, new knowledge and practices in the circular economy make it necessary for companies to embed DBCs, as this enables them to keep up with emerging market needs, especially in the form of developed innovations. The importance of CE in the context of DBCs is also evident in recent works by researchers looking at particular sensing, seizing and transforming capabilities for CE practice implementation. The investigation of CE dynamism and related accompanying DBCs are argued to be important for a better understanding of the changes taking place in companies.

2. EMPIRICAL RESEARCH METHODOLOGY FOR ANALYSING THE RELATIONS BETWEEN LIFE CYCLE ASSESSMENT, MATERIAL FLOW ANALYSIS, AND DYNAMIC BUSINESS CAPABILITIES FOR CIRCULAR ECONOMY IMPLEMENTATION IN COMPANIES

2.1. Research purpose, questions, and design

Based on the results of literature review presented in previous chapters, the following part is dedicated to the development of the empirical research methodology which constitutes as the basis for deeper analysis of the problem presented within the scope of this Master thesis – lack of research in linking the use of LCA and MFA with the DBCs in the context of circular economy practice implementation and performance improvement in companies. Therefore, **the purpose of the empirical research** is to investigate the relations between the use of LCA, MFA and dynamic business capabilities for the implementation of circular economy practices together with related performance improvement in companies. Correspondingly, the **research questions** raised are:

- **RQ1:** Which dynamic business capabilities have the greatest influence on the choice to use LCA and/or MFA?
- **RQ2:** How the use of LCA and MFA contribute to the development and enhancement of dynamic business capabilities in companies?
- **RQ3:** How dynamic business capabilities, stipulated by the use of LCA and MFA methods, are related to the implementation of circular economy practices in companies?
- **RQ4:** What is the extent and impact of the improvement in CE related organisational performance as a result of implemented CE practices, determined with the use of LCA and MFA methods?

To achieve the purpose of the empirical research, the following **research objectives** are formed:

1. To select and justify the research design.
2. To form the most appropriate data collection instrument.
3. To define how the data collected will be analysed.
4. To analyse the data collected from the LCA and MFA practitioners.

5. To create a model defining the relations between the use of LCA, MFA and dynamic business capabilities for the implementation of circular economy practices together with a related performance improvement in companies.

Research design

Considering the limited research on the topic, it is opted to adopt an exploratory qualitative study for the investigation of the relations between the use of LCA, MFA and dynamic business capabilities for the implementation of circular economy practices together with related performance improvement in companies. In general, exploratory studies are aimed at exploring "the areas that have required meagre attention or it is for checking the possibility of research in the particular domain or area" (Bairagi & Munot, 2019, p. 9). Considering that the linkages of LCA and MFA to CE and of DBCs to CE have been addressed separately in the literature so far, this research seeks to explore possible integrations of these different approaches.

This exploratory qualitative study is based on theoretical knowledge synthesis through a literature review and semi-structured interviews with practitioners who, in this instance, are the experts in the field. The relevant literature review sought to provide an insight into the concepts of the CE, LCA, MFA and DBCs and, thus, to identify a conceptual model for further exploration of the topic. Accordingly, a conceptual model was formed, including assumptions about the directions through which relations between the use of LCA, MFA and DBCs for the implementation of circular economy practices together with related performance improvement in companies (see Figure 5).

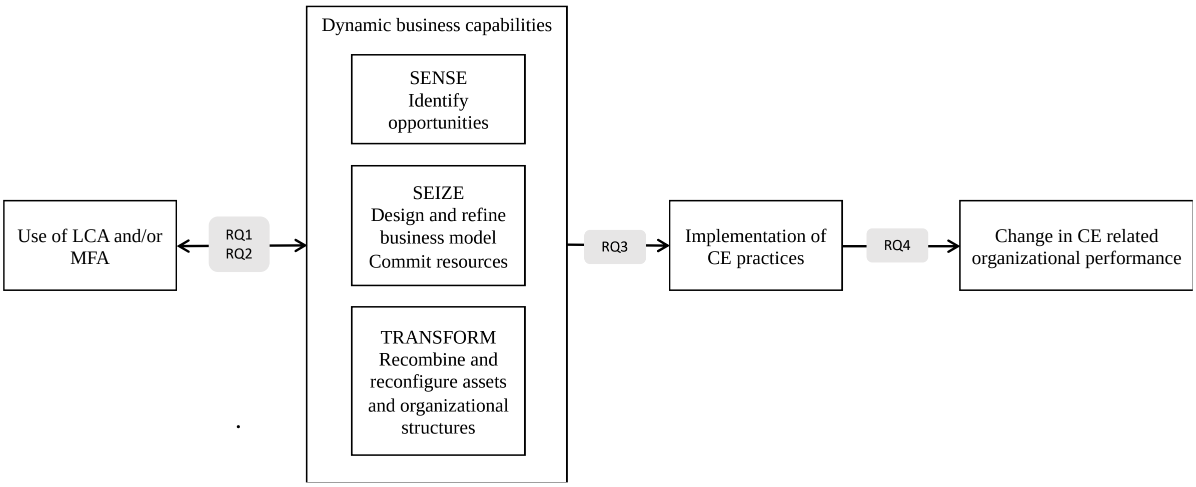

Figure 5. Conceptual research model (compiled by the author)

In this model, the use of LCA and/or MFA is perceived to have an impact on the development and reinforcement of DBCs. This assumption is based on the identified managerial benefits that the use of LCA and MFA can result into, e.g., the identification of feasible alternatives to increase resource efficiency or the improvement in environmental management practices (see subchapters 1.2. and 1.3.). Also, another assumption is made from an opposite perspective, i.e., some of DBCs (e.g., ability to analyse internal environment) can create a need and directly lead to the use of environmental management instruments, such as LCA and MFA. Secondly, in accordance with the existing evidence in the literature, it is assumed that DBCs have an impact on company's organizational changes (i.e., ordinary capabilities) and in this model these changes are considered to be the implementation of circular economy practices. Taking into account the arguments of Laaksonen & Peltoniemi (2018) on the role of DBCs in explaining the performance change in companies rather than performance itself, in this model the implementation of CE practices is featured as ordinal business capabilities that were changed (i.e., impacted by LCA and/or MFA determined DBCs). In this case, the DBCs have an indirect role in affecting the performance of companies (relying on another recommendation by Laaksonen & Peltoniemi (2018)). Finally, the implementation of CE practices is believed to impact the overall CE related performance and improve it over time.

Following the logic of the research design, the data collected during the interviews is seen to serve as a basis for the enhancement of the initial conceptual model and the compilation of the final theoretical model. The sequence of steps in the research process described is shown in the figure below.

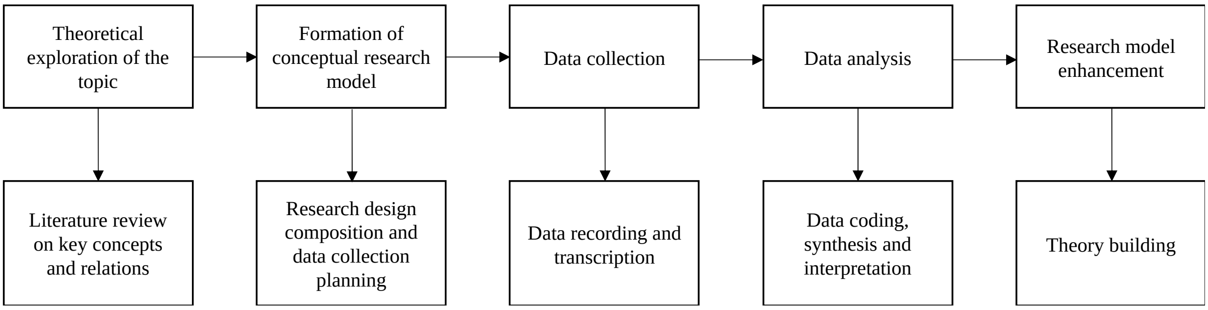

Figure 6. Research steps (compiled by the author)

2.2.Data collection procedure and instrument

In addressing the research questions raised, it is decided to apply a series of semi-structured interviews with experts. The reasoning behind the choice of semi-structured interviews as a data collection method is severalfold. Firstly, according to Bogner et al. (2009), “talking to experts in the exploratory phase of a project is a more efficient and concentrated method of gathering data than, for instance, participatory observation or systematic quantitative surveys” (p. 2). Secondly, semi-structured interviews offer the advantage of flexibility in data collection, i.e., by having a list of only key questions, it is possible for the interviewer “to explore more depending on the previous answer and knowledge of interviewee” (Bairagi & Munot, 2019, p. 37), which is particularly relevant when considering the wide range of expertise of the interviewees in the area under study. Finally, consideration is given to the experience of the use of this instrument in previous works of Freidberg (2015), Griffiths & Cayzer (2016), Boldoczki (2021), and Khan et al. (2020a) on the topics of LCA, MFA, CE, and DBCs.

As mentioned above, semi-structured interviews with experts who are LCA and MFA practitioners and have a deep understanding of the application of circular economy practices in companies were used as a data collection approach. In practice, experts, who become a target group of a particular research, are considered to be professionals, experts in a certain field, with specific knowledge and experience in their field (Flick, 2009; Gaižauskaitė & Valavičienė, 2016). Based on this argument, it has been chosen to interview business consultants who have extensive experience in applying LCA and MFA methods to a wide range of companies. Given this limitation of the target group, a nonprobability convenience sampling technique was applied to ensure that a sufficient number of experts is reached. The expert sampling is also considered favourable in terms of the trustworthiness of the data collected “since experts tend to be more familiar with the subject matter than nonexperts, opinions from a sample of experts are more credible than a sample that includes both experts and non-experts” (Bhattacherjee, 2012, p. 69).

For the selected expert sampling method, a few considerations are required. First, expert knowledge and experience in LCA, MFA and CE are the conditions for assessing the suitability of an expert as a respondent. In previous practices similar selection of respondents was carried out through the screening of known business cases, involvement in relevant consulting services, and related academic publications (Kristoffersen et al., 2021; Tsui et al., 2021; Tunn et al., 2019). Second, the status of an expert is strengthened over time by correspondingly increasing experience and knowledge, thus, the length of work experience is often defined in the selection of respondents. However, in this case, the criterion of experience length in the field may be ambiguous for the experts due to the novelty of the circular economy as a distinct field of research and work and at the same time due to the long and established practice of the use of LCA and MFA. Consequently, qualitative (such as job position, practical experience, or field of expertise) rather than quantitative descriptions of experts' experience, are more often identified (Tsui et al., 2021; Tunn et al., 2019). Grounded on these insights, respondents, therefore, were selected on the basis of their involvement in LCA, MFA and CE related projects, consulting services, and research, based on screening of secondary sources (mostly LinkedIn profiles, media articles and project descriptions).

The instrument used to collect the data during the interviews was a semi-structured questionnaire that allowed to explore the thoughts and opinions together with personal practices and experiences of respondents in the area of the investigated field. The semi-structured questionnaire consisted of 3 sections and corresponding questions:

General understanding of the topic

1. What is your practical experience in applying LCA and/or MFA methods in general? What is your experience of working with companies on LCA/MFA applications?
2. What is your understanding of circular economy and the implementation of CE practices in companies?
3. Please, describe your practical experience in applying LCA and/or MFA methods in relation to the implementation of circular economy practices in companies?
4. What is your knowledge on the concept of dynamic business capabilities? *(Instruction: respondents are referenced to the operationalization of DBCs (see Annex 3)).*

The use of LCA and MFA in companies based on CE practice implementation and DBCs

5. What are the main motivations and factors for companies to use LCA and MFA methods in relation to the implementation of circular economy practices, based on your experience? Are companies aware of existing CE implementation opportunities prior to application of LCA and MFA instruments?
6. In your opinion, how does (if at all) the use LCA and MFA contribute to the particular aspects of DBCs in the context of CE practice implementation? Are there any differences in significances of these contributions? Please, provide practical examples. *(Instruction: respondents are referenced to the operationalization of DBCs (see Annex 3)).*
7. Based on your experience, please describe which particular aspects of DBCs companies rely on the most to implement CE practices after having used the LCA or MFA method. In this context, which circular economy practices are most commonly

implemented? *(Instruction: respondents are referenced to the operationalization of DBCs (see Annex 3)).*

8. What are the most common reasons why the application of LCA and MFA does not lead to a decision to apply CE practices?
9. After a company implements these CE practices, how does the organisation's performance change as a result? Please indicate the key indicators that companies use to measure improvement and how they change.

Additional important information

10. What contextual information, which has not been mentioned so far, do you think is also relevant to understand the relations between the use of LCA and MFA and the implementation of circular economy practices in companies within a dynamic business capabilities framework?

In total, 11 experts were interviewed during the data collection stage. Experts were interviewed until a tendency towards repetitiveness of their answers was observed. All interviews lasted between 40 and 80 minutes and were audio and video recorded via Microsoft Teams and Zoom applications. The recordings were transcribed and coded for further data analysis. Information about respondents is summarised in the table below.

Table 5. Description of respondents (compiled by the author)

Respondent indicator	Education degree	Country	Years of experience	Type of organization	Occupation	Industry orientation
R1	Doctoral	Lithuania	16	University	Associate professor, LCA consultant	Packaging, food and beverages, engineering industry, furniture
R2	Doctoral	Pakistan	11	University	Associate professor, LCA consultant	Textiles, construction materials
R3	Doctoral	Lithuania	9	Business consulting company	Sustainability consultant, LCA and EPD expert	Construction projects and materials
R4	Master's	Finland	7	Business consulting company	LCA and EPD business developer	Construction projects and materials
R5	Master's	United Kingdom	5	Business consulting company	LCA consultant	Construction projects and materials
R6	Doctoral	Ireland	20	Business consulting company	Senior sustainability consultant, LCA specialist	Engineering industry, furniture

Continuation of Table 5

R7	Master's	Finland	12	Business consulting company	Sustainability consultant	Furniture and wood products
R8	Master's	The Netherlands	8	Business consulting company	Sustainable business developer	Plastics, chemicals
R9	Master's	France	7	Business consulting company	Senior sustainability consultant	Packaging, food and beverages
R10	Doctoral	Finland	15	University	Professor, environmental business consultant	Bio-based industries
R11	Master's	Italy	11	Business consulting company	Senior LCA analyst	Food and beverages, packaging, waste management

Data analysis

According to Bhattacherjee (2012), the emphasis in qualitative data analysis must be directed at "understanding a phenomenon, rather than predicting or explaining" (p. 113). In this case, the transcribed recordings of the interviews were the essential source of data that was being coded and analysed by employing continuous comparison strategy. Thus, the essential variables were defined as codes based on the theoretical foundations derived from the literature review and used for thematic comparison throughout the transcribed records. The coding was based on the operationalisation of the LCA, MFA, DBCs and CE concepts, as extracted from the literature review. The operationalisation and encoding logic are specified in Annex 4.

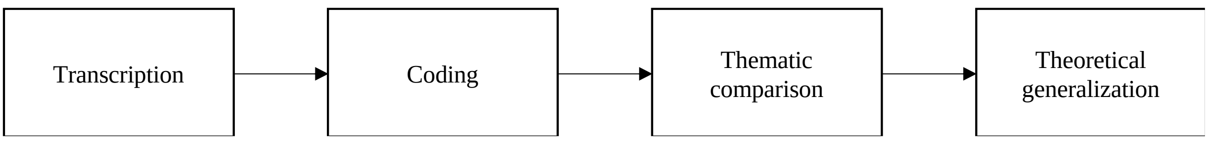

Figure 7. Steps of data analysis (compiled by the author)

Finally, the conceptual model is enhanced by utilising continuous comparison of the data collected to the theoretical viewpoint and available literature. Figure 6 presents the complete data analysis process.

2.3.Limitations of the research

The empirical study is characterised by the limitation of collecting data from experts who are working with business rather than from representatives of different companies.

Moreover, since the experiences of companies are described through an extrinsic view, they can be interpreted in a biased way or not appropriately disclosed. It is also evident that the experts primarily represent the application of LCA and MFA, which may lead to a particular preference for these methods and an overemphasis on their benefits. Finally, the answers' quality is mainly determined by the interviewer's questioning skills. In contrast, the quality of the results is determined by the analyst's ability to remain impartial and to use the literature-derived arguments for a meaningful interpretation of the results. Therefore, the author's analytical skills strongly influence the empirical study's overall quality.

3. EMPIRICAL STUDY RESULTS DEFINING THE RELATIONS BETWEEN LIFE CYCLE ASSESSMENT, MATERIAL FLOW ANALYSIS, AND DYNAMIC BUSINESS CAPABILITIES FOR CIRCULAR ECONOMY IMPLEMENTATION IN COMPANIES

3.1. Aspects of LCA and MFA use on the enhancement of dynamic business capabilities in companies

Finding 1: companies' decision to use LCA and MFA is heavily influenced by their advanced sensing DBCs (regarding RQ1)

The majority of respondents to the interviews indicated that the most frequent reasons for companies contacting them for LCA or MFA calculation and consultation services are: the need to meet the sustainability requirements of customers or specific markets, the need to be aligned with market trends; the need to differentiate company's product in the marketplace, the need to substantiate sustainability claims with data, the need to access funding opportunities or sustainability-focused investments (see Table 6). In almost all cases, companies have identified general key market opportunities in advance, but lacked analytical and data-driven insights to evaluate and support their organisational decisions. The next step for companies was, therefore, to seek for advice from LCA or MFA experts and consultants.

Table 6. Results on needs of companies to apply LCA and MFA (compiled by the author)

Category: needs of companies to apply LCA and MFA		
Sub-categories of needs	**Expert comment**	**Related DBCs**
To meet the sustainability requirements of customers or specific markets	"The requirement is that the different stakeholders comply, or do projects which are certification based, and for that they require to do a life cycle assessment." (R4) "Those companies that focus on the Scandinavian or Western European markets realise that it is no longer enough to compete with a high-quality product… clients are demanding legitimate data…of products…This is why they turn to us [business consultants], because otherwise they would not be able to enter certain markets or segments." (R1) "So, here we have a different type of our categories of industries, those industries, which are multinational, they are big industries, they are following the ISO standards and their clients are more concerned about the environment and all those things. So, they are working on LCA and carbon footprints and ESG[1] and all those things." (R2)	*Sensing*: identification of customer needs

[1] Environmental, Social, and Governance criteria used in the investment decision-making process.

Continuation of Table 6

To be aligned with market trends	"In second category we have local industries, but which are a bit established are a little bit old. So, they are trying to compare their products with the multinational companies. So, that's why they are just copying those the strategies and they are all those activities, although they are not up to that level or up to that mark, but they are just dragging." (R2)	*Sensing:* tracking new market trends; analysing competitors' actions
To differentiate company's product in the marketplace	"Companies that want Type 3 eco-label[2] declarations also contact us. Some smart furniture manufacturers contact us because they are involved in public procurement in Norway and there only green products can be procured. We were also approached by a Lithuanian company that produces reinforced concrete railway sleepers. They also sell those sleepers to the European Union's rail networks through public green procurement. The railway sleepers needed environmental declarations as an instrument to successfully compete in public procurement." (R1)	*Sensing:* tracking new market trends; analysing competitors' actions; identification of customer needs
To substantiate sustainability claims with data	"…companies are reacting to regulatory changes on product labelling and want to prepare in advance…" (R9) "… [the need to use LCA] comes from not just internal motivations of companies to improve environmental performance…but it [the use of LCA] also avoids all the greenwashing as well, if you're able to show it on a more fact proven method…" (R4).	*Sensing*: tracking new market trends; identification of customer needs
To access funding opportunities or sustainability-focused investments	"We do a lot of assessments, the vast majority of them so far are for companies that indent to use financial support instruments." (R1) "…companies that were more focused on their ESG criteria and wanted to better understand where they could improve in terms of resource management." (R7)	*Sensing:* tracking new market trends

These business needs are considered to be the result of developed use of sensing DCBs, mainly regarding the focus on the external environment and market situation that companies operate in. This is in line with idea suggested by Teece (2018) that by sensing companies are able to create and evaluate assumptions relevant for the long-term performance of companies, including consumer demand, technological developments and other forces. Therefore, companies aiming at long-term competitiveness use their resources to better understand and exploit these dynamics. In this analysis, companies using LCA and MFA are characterised by their apparent abilities to identify customer needs, track new market trends and analyse competitors' actions. They specifically use these abilities to focus on long-term sustainability priorities in the market and to find solutions to adapt or stay ahead of the competition (e.g., reducing environmental footprint of products produced).

[2] Type 3 eco-labels are referred to the environmental declarations defined in the ISO 14025:2006 standard.

Interestingly, respondents' answers reflect the idea that there is a logic of action that companies follow. In other words, companies first identify opportunities that have significant potential and only then take action to apply the relevant environmental assessments, i.e., LCA or MFA. Cases where companies behave in reverse or in parallel have not been identified. In the scientific literature, the assessment of potential environmental impacts is included in the general category of sensing (Khan et al., 2020b; Santa-Maria et al., 2022) which broadly encompasses the ability to identify and assess new business opportunities. Nevertheless, Khan et al., 2020a argues that the use of LCA is an essential step in enabling companies to sense the opportunities of the circular economy, and it is one of the prime sources for achieving this. This author's argument can be interpreted in the present analysis as follows: the sensing capabilities of projecting general market trends are important for companies to identify the direction of sustainability in which they seek to develop, and LCA allows for a more specific assessment of opportunities within the circular economy field. Accordingly, LCA focuses more on product and MFA on overall organisations' transformation, both taking into account material and energy consumption and pollution generation. Therefore, in this case it is important to underline that the use of LCA and MFA is as a follow-up solution, more focused on the analysis of internal data, while external scanning of the market remains the initial step.

With regards other to sensing capabilities for CE opportunities, references also distinguish capability of implementing research and development (hereinafter – R&D) activities for new products or processes (Khan et al., 2020a; Prieto-Sandoval et al., 2019). However, most experts tended to differentiate between LCA, MFA and R&D activities, arguing that R&D is more associated with the development of entirely new products or processes, while LCA and MFA are mostly used by companies to achieve relative alterations (based on comments from R4, R5, R7, R9, R11). Nevertheless, LCA and MFA are an important part of R&D when it comes specifically to developing more environmentally friendly and circular solutions: "…when measuring the impact of a new product, LCA is an essential instrument to assess this…" (R6); "…if we are talking about the impact achieved by a new technology through the more efficient use of different resources, the use of MFA may be indirect, but it applies…" (R10). In general, therefore, it is claimed that sensing capability of applying R&D activities is most often associated with the development of new products, technologies, or processes, where LCA and MFA act as a complementary instrument to analyse the impact of those new solutions.

Finding 2: the use of LCA and MFA tends to strengthen seizing and transforming DBCs of companies (regarding RQ2)

The second insight that emerges from the experts' comments relates to DBCs, which are reinforced by the LCA and MFA application process and by corresponding actions based on these assessments. This link is interpreted as the effect of the benefits of LCA and MFA on strengthening DBCs. In particular, six LCA and MFA benefits were highlighted by experts to have an impact on seizing and transforming DBCs (see Table 7). These benefits are mostly the ones identified in the literature review, but several additional points have been made by experts as well, i.e., the benefit of enhanced new product development, benefit of enabled environmental risk-based view, and the benefit of strengthened supplier control. With regards to different types of DBCs, the most expert examples are attributed to seizing capabilities as redesigning/transforming business models, finding strategic partners, planning investments, collaboration to acquire requisite raw materials/resources, interdepartmental cooperation. Meanwhile transforming capabilities include made slight modifications in existing technology/machinery, introduced new or significantly improved technology, adopted new business practices for organizing procedures, adopted new methods of organizing external relations, adopted new or significantly improved logistics.

Table 7. Results on the benefits of applied LCA and MFA (compiled by the author)

Category: The benefits of LCA and MFA application		
Sub-category	**Expert comment**	**Related DBCs**
Enabled holistic view to the product value chain (applicable only to LCA)	"LCA enables companies to manage the entire product system…especially when companies have become concerned not only with the profit margin of the product, but also with the environmental impact and the relationship with the customer concerned." (R1)	*Seizing:* redesigning/transforming business models; finding strategic partners; planning investments; collaboration to acquire requisite materials/resources *Transforming:* made slight modifications in existing technology/machinery; introduced new or significantly improved technology; adopted new business practices for organizing procedures; adopted new methods of organizing external relations; adopted new or significantly improved logistics
Enhanced new product development (applicable only to LCA)	"It's also a way for creating new ideas in terms of products, because then you are you're able to compare them more on an apples-to-apples basis, rather having these claims of X, Y, Z is better, for example. So it's a more evidence based approach." (R11)	*Transforming*: adopted new business practices for organizing procedures

Continuation of Table 7

Enabled holistic view to the organization resource management	"Same [ability to make informed decision] I would say in terms of projects, so get a bigger a holistic approach on their entire portfolio, what they have done so far, what materials they have used so far, what can they improve upon in terms of process efficiency, in terms of procurement, for example." (R2)	*Seizing:* redesigning/transforming business models; planning investments *Transforming:* made slight modifications in existing technology/machinery; introduced new or significantly improved technology; adopted new business practices for organizing procedures
Enabled environmental risk-based view	"When they [companies] conduct an LCA, they are identifying the potential [environmental] risks and then they know those inputs which are contributing more comparatively to the others, and then how they will mitigate" (R2)	*Seizing:* planning investments *Transforming*: adopted new business practices for organizing procedures
Strengthened supplier control (applicable only to LCA)	"…if an organisation is looking at reducing or changing their suppliers, they can actually look at the [environmental] impacts that have been associated with them so far, and then see what they can move on to or even compare different ones themselves." (R2) "… companies look at the raw materials, where they buy from, where they ship from, how far they ship…These processes are actually being reviewed, and companies are modelling and planning new ways of working…" (R3)	*Seizing:* finding strategic partners; collaboration to acquire requisite raw materials/resources *Transforming:* adopted new methods of organizing external relations; adopted new or significantly improved logistics
Improvement in environmental management practices	"[Positive impact of LCA is visible] even in terms of how they [companies] internally communicate within the various teams. They have a more consistent approach on what they want to report on as well. Organisational LCA is…where you're looking at all the activities…within the organisation…trying to see what you can reduce in terms of…employee commuting or business travel or waste generated…as well as how do you reuse materials internally and recycle them, even energy consumption on that scale." (R4) "…the MFA tells a lot about how companies use resources and what waste they generate…they are starting to rethink how savings can be made not only at the production stage itself, but also in terms of additional activities in general that relate to the organisation at large…" (R10)	*Seizing:* interdepartmental cooperation *Transforming*: adopted new business practices for organizing procedures

Following the idea that LCA and MFA can affect the subsequent evidence-based decisions of firms through their benefits (Graedel, 2019; Pryshlakivsky & Searcy, 2021), it is assumed that this influence is also reflected in the strengthening of their DBCs. Before discussing the impact of each of the different LCA and MFA benefits on DBCs, it is important to emphasise that LCA and MFA have several different benefits identified by experts. This is also closely linked to the different scopes of application of these instruments, which are discussed in more detail in subchapters 1.2.1 and 1.3.1. From these differences, it is seen that LCA mainly enhances the DBCs associated with partnerships and external relations and MFA with technological and process changes. On the other hand, both LCA and MFA reinforce general planning and new practice adoption. These differences apply to the examples discussed below.

Seizing capability of redesigning/transforming business models is largely determined by the ability of LCA and MFA to identify evidence-based environmental opportunities and implement them in accordance with the procedures set out in the corresponding ISO standards. Generally, these opportunities are identified as alternatives between several scenarios or different environmental objectives (e.g., waste reduction, air quality, reduced energy consumption) (Kluczek, 2019; Pryshlakivsky & Searcy, 2021). In this case, business model transformation should be seen as gradual improvements in products or processes, focusing on environmental objectives and creating added value accordingly (more background on business model innovation is presented under Finding 3). Correspondingly, the experts have pointed out that the most significant influence on this transformation is based on the benefits of enabled holistic view to the product value chain (of LCA), enabled holistic view to the organization resource management (of LCA and MFA), and enhanced new product development (of LCA). Based on the fact that seizing capabilities are generally associated with planning, the role of LCA and MFA in highlighting possible planning perspectives becomes apparent here.

Seizing capabilities of finding strategic partners and collaboration to acquire requisite raw materials/resources is mostly supported through LCA's identified opportunities to use more sustainable raw materials, components, or final products for projects. These opportunities are identified through a holistic value chain analysis approach - one of the strongest identified LCA benefits. Given the highly integrated nature of today's market and the long, complex value chains, suppliers are considered as one of the most important strategic partners for businesses. Therefore, LCA facilitates the partner search process for companies by identifying which type of partners would be the most environmentally beneficial.

Seizing capability of planning investments is generally attributed to the need for companies to plan investments to implement technological change. These technological developments are reflected in the results and recommendations derived from both the MFA and the LCA. Importantly, instruments originated from LCA and MFA can suggest identifiable risks and can link them to corresponding costs for the company, for example, integrated LCA and Life cycle cost accounting (Chang et al., 2014) or Material flow cost accounting (Nakajima et al., 2015). Investment planning based on risk and their management, therefore, becomes more substantiated and effective.

Seizing capability of interdepartmental cooperation is mostly stipulated by improvements and enhancements of environmental management practices. As noted by the experts (R4 and R10), both MFA and LCA have a positive impact on improving and mainstreaming these practices throughout the organizations. Strengthening inter-parliamentary cooperation was also identified by the experts not only from the environmental management side. R3 stated that the use of LCA was initiated by departments or staff responsible for quality, while R7 informed that there were cases when innovation departments in the companies were responsible for the use of both instruments.

Transforming capabilities of made slight modifications in existing technology/machinery and introduced new or significantly improved technology mostly result from the choice of companies to pursue better environmental performance by focusing on both manufacturing processes (MFA) and individual products (LCA). Decisions to acquire new technologies or improve processes are often linked to LCA and MFA, which allow different alternatives to be evaluated. Some examples of such cases are given in the case studies summarised in Table 2 and Table 3. In fact, these changes in companies are mainly driven by the LCA enabled holistic approach to the product value chain and support for the development of new products, and the MFA enabled holistic approach to the organisation's material use.

Transforming capability of adopted new business practices for organizing procedures is mostly influenced by the improvement in environmental management practices that LCA and MFA stipulate. The experts' answers reflect the fact that this link is expressed at the level of the organisation as a whole and is not limited to individual products or processes. It can, therefore, be seen as a spillover effect. Moreover, the adopted new business practices for organizing procedures can also be broadly interpreted by other similar transforming DBCs such as changed organizational culture and implemented specific sustainable and circular KPI's (Santa-Maria et al., 2022), based on the experts' answers.

Transforming capability of adopted new methods of organizing external relations shares a similar logic with seizing capabilities of finding of strategic partners and collaboration to acquire requisite raw materials/resources. The new adopted approach relies heavily on selecting and controlling suppliers according to their environmental impact. Underpinning this approach are the opportunities offered by LCA to take a holistic view to the product value chain, as well as to exert more control over suppliers (e.g., by requiring them to provide data on the raw materials and energy they use in their processes, and on the types they transport products).

Transforming capability of adopted new or significantly improved logistics is usually only relevant in cases where a company's logistics have a significant relative negative impact on the environment and where the company is performing a logistics function with its own resources. In other cases (e.g., when materials, components or products are transported by external suppliers), improved logistics is reflected through adopted new methods of organizing external relations.

In summary, the use of LCA and MFA has several different interfaces with DBCs. Firms that have strong sensing DBCs in response to changing market developments and customer requirements are more likely to identify internal business opportunities using LCA or MFA. The latter have the ability not only to assess the impacts of sensed options of more environmentally preferable product or process alternatives applicable to companies, but also to enhance the seizing and transforming DBCs, correspondingly in relation to the planning and implementation of changes. This enhancement appears through the purposeful use of the benefits derived from LCA and MFA. Most notably in this manner are enhanced seizing capabilities of redesigning/transforming business models, finding strategic partners, planning investments, collaboration to acquire requisite raw materials/resources, interdepartmental cooperation. Accordingly, transforming DBCs are identified as company actions resulting in made slight modifications in existing technology/machinery, introduced new or significantly improved technology, adopted new business practices for organizing procedures, adopted new methods of organizing external relations, adopted new or significantly improved logistics.

3.2. The contribution of DBCs, enhanced by LCA and MFA, to the implementation of CE practices in companies

Finding 3: seizing and transforming DBCs create enabling conditions for the implementation of CE practices in companies (regarding RQ3)

Regarding the first two findings, it is argued that there is an evident link between the use of LCA and MFA and DBCs that promote corresponding change in companies. However, previous findings have covered the overall environmental changes observed in companies beyond the implementation of circular economy practices. Therefore, Finding 3 focuses more on the latter element.

According to Khan et al. (2020a), where potential CE practices are identified by sensing capabilities, other key actions that companies should take to successfully implement them include strategic planning, business model governance and collaboration based on seizing DBCs, and organizational restructuring, technological upgradation, knowledge integration and best practice adaptation based on transforming DBCs. Drawing on the DBCs identified from experts' answers (see Table 7), appropriate links can be made to the above-mentioned literature source: redesigning/transforming business models (under business model governance), finding strategic partners (under strategic planning and collaboration), planning investments (under strategic planning), collaboration to acquire requisite raw materials/resources (under collaboration), interdepartmental cooperation (under collaboration), made slight modification in existing technology/machinery (under technological upgradation), introduced new or significantly improved technology (under technological upgradation), adopted new business practices for organizing procedures (under organization restructuring, knowledge integration), adopted new methods or organizing external relations (under organization restructuring, knowledge integration), adopted new or significantly improved logistics (under organization restructuring, knowledge integration). Therefore, it is argued that the DBCs identified in this study, which are associated with the use of LCA and MFA, are also associated with the promotion of CE practice implementation in companies.

When analysing the underlying aspects of the importance of identified seizing and transforming DBCs to the implementation of CE practices, one of the key notions is that these DBCs should support or create enabling conditions or remove barriers for those practices. According to Rizos et al. (2016), one of such important barriers is the lack of technical and technological know-how. Evidently, this lack of expertise is widely addressed by LCA and MFA assessments and the DBCs they reinforce. In particular, DBCs related to organizational restructuring and technological upgradation that are critical for CE implementation (Khan et al., 2020a).

Another barrier for CE practice implementation regards lack of support from SMEs' supply and demand networks (Rizos et al. 2016). The results of this analysis show that LCA is particularly relevant in this respect, as one of the groups of DBCs promoted by the LCA concerns the review of relations with the company's suppliers. Initially, this is seen as collecting environmental data on raw materials, components or services provided by suppliers. This data allows for an assessment of the full environmental impact of a product's supply chain, including circularity. Besides, the application of LCA leads to the development of new business practices for assessing suppliers against relevant environmental aspects. The existence of this practice is linked to DBCs of adopted new business practices for organizing procedures and adopted new methods of organizing external relations. Moreover, DBCs for cooperation with stakeholders throughout the value chain are also identified as relevant for CE implementation in Seles et al. (2022) work. More specifically, the authors point out that these DBCs supports accessing stakeholder information, searching for strategic partners, and building collaboration in order to deploy the necessary knowledge and procure recyclable materials. Therefore, it is suggested that companies that are able to make use of their DBCs through a more proactive involvement in the value chain and in the communication with suppliers can reduce the corresponding barrier to the implementation of CE practices.

In contrast, supportive company's environmental culture that eases the transition to the circular economy was mentioned as an enabling condition by Rizos et al. (2016). Here, the linkage can be attributed to the enabled transforming DBC of adopted new business practices for organising procedures, most notably connected to improved environmental management practices. Moreover, Marrucci et al. (2022) study provides relevant evidence of DBC and environmental management incorporation potential on CE implementation facilitation and increased environmental and economic performance. Hence, DBCs that are related to new business practices in relation to the overall environmental management are seen as creating enabling conditions for the implementation of CE practices in companies.

The identified DBCs can also be linked to the enabling condition of fostering of business model innovation for the circular economy. These innovations fall under the theme of the literature on business model innovation for sustainability and according to Inigo et al. (2017), there are two types of approaches that explains the development of such innovations: evolutionary and radical. Based on the experts' responses, the identified DBCs are more related to the evolutionary approach, which is entails gradual adjustments, continual learning, and adaptation supported by discussions with stakeholders. In particular, Inigo et al. (2017) attributes seizing capabilities of integration of clean technologies and sustainability-oriented methodologies together with knowledge dissemination to design new sustainable products, services and processes to the evolutionary approach. In the case under analysis, these capabilities are reinforced by the benefits of using LCA and MFA. Moreover, the evolutionary approach also encompasses transforming capabilities of dissemination of sustainability culture, knowledge, and innovation in the organization. These capabilities are linked to the use of LCA and MFA and the improvement in environmental management practices, i.e., organisational changes that go beyond a single product or process. Therefore, it is suggested that companies that exploit the benefits of LCA and MFA to strengthen their seizing and transforming DBCs are potentially more likely to adopt an evolutionary business model innovation approach and to progressively implement circular developments in the organisation in response to the dynamics of the external environment.

However, it is necessary to underline that when interpreting these findings, it is important to refer back to the distinction between dynamic and ordinary business capabilities. Specifically, dynamic business capabilities provide the stimulus for change, while ordinary business capabilities are subject to change (Laaksonen & Peltoniemi, 2018). Enhanced seizing and transforming DBCs are the underlying and driving factor for change in companies. They also determine how ordinary skills should be integrated and re-orchestrated inside the organization, and which capabilities should be acquired (Schoemaker et al., 2018). Identifying DBCs is, therefore, a way to understand the key directions in which companies are changing. Meanwhile, the specific examples of transitions towards circular practices, that can be seen as changes of ordinary capabilities, are given in the next sub-chapter.

Finding 4: DBCs, when reinforced by the LCA and MFA, tend to lead to the application of CE practices in two directions: more circular product or project design choices and more efficient resource use (regarding RQ3)

Despite the wide range of different circular economy practices available (see sub-chapters 1.1.1 and 1.1.2), experts say that most often, in the context of using LCA and MFA, companies are able to apply two key circular economy practices: to design and produce more circular products (by incorporating CE strategies of closing and regenerating resource flows) and to increase material and energy efficiency (by incorporating CE strategies of narrowing and closing resource flows). The design of circular products is linked to the increased use of recycled and recyclable materials, as well as the use of raw materials from renewable, e.g., bio-based, sources. Several experts also identified CE practices of using closed loops in the production (see Table 8). Depending on the individual examples, these practices can be attributed either to the production of circular design products (e.g., when recycled waste, by-products or scraps generated by a company are incorporated into product design) or to the efficiency of resource use (e.g., when firms use the same resources several times in the production process). It is also noticeable that product design decisions are more associated with the application of LCA, while resource efficiency and savings are more associated with the application of MFA. This link is based on the different levels of ability to accurately calculate the environmental impacts of a product (mostly LCA) and an organisation or process (mostly MFA).

Table 8. Results on types of CE practices implemented in companies (compiled by the author)

Category: Types of CE practices implemented in companies		
Sub-category	**Expert comment**	**Relation with DBCs**
Designing and producing products to be easily biodegradable/recyclable	"A lot of companies…are using circular economy principle into building better designs, so they are able to quantify and compare what amount of material goes in, in the form of virgin material, and what amount of it can be reused or recycled into another component added at the end of its life." (R4) "...paper as a biodegradable alternative is the first choice for more circular packaging design…" (R9)	*Seizing:* redesigning/transforming business models *Transforming:* made slight modifications in existing technology/machinery; introduced new or significantly improved technology
Designing and producing products with recycled/renewable inputs Reusing by-products/recycled materials from other organizations	"… [companies are] using biomass products and renewables… also manufacturing the products by using renewable energy…and using a lot more recycled product into that as a raw material input…" (R10) "Companies are increasingly choosing to incorporate partially recycled metal raw materials as part of their circular design solutions." (R5) "Now it is not new on the market to incorporate an increasing proportion of recycled plastics in new products, but the number of such products has been rapidly increasing…" (R8)	*Seizing:* redesigning/transforming business models; finding strategic partners; collaboration to acquire requisite raw materials/resources *Transforming*: made slight modifications in existing technology/machinery; introduced new or significantly improved technology; adopted new business practices for organizing procedures; adopted new methods of organizing external relations.
Increasing material and energy efficiency of processes	"It was enough to change from a five-colour press to a six-colour press and the company automatically reduced a lot of production waste, as there was no need for frequent calibration, which leads to a lot of production waste and defects." (R1) "…building projects are very often opting for smart heating, ventilation and lighting systems…to reduce energy consumption…" (R4)	*Seizing:* planning investments *Transforming:* made slight modifications in existing technology/machinery; introduced new or significantly improved technology
Using closed loops in the production	"The company has invested in building water treatment facilities and is now able to use the same water for textile production without large discharges." (R2) "… [printing] company collects paper scraps and sends them directly to the paper recycling company with which it has a contract. Based on it, the recycled paper is returned as raw material back to the manufacturer." (R9) "Several food companies that I have been working with are now successfully using food losses…to produce new products such as food additives…" (R11)	*Seizing:* redesigning/transforming business models; finding strategic partners; planning investments; collaboration to acquire requisite raw materials/resources *Transforming*: introduced new or significantly improved technology; adopted new business practices for organizing procedures; adopted new methods of organizing external relations.

Based on the Finding 3, it is argued that the implementation of these practices is mainly facilitated by DBCs that allow companies to develop and embed the essential elements of CE transformation, including the necessary technologies, partnerships, and new ways of operating. Accordingly, these CE practices in companies can be considered as established ordinary capabilities, based on the argument that they have been in place for some time and were altered by responding to changes in the external environment (i.e., the transition towards a circular economy visible in the market and expressed by the needs or actions of different stakeholders).

However, the variety of CE practices reported to be implemented in companies is limited. No cases were discovered when companies have introduced more durable products or extended their durability practices (e.g., repair, refurbish, take back collection schemes that fall under CE strategy of slowing resource flows). A more in-depth examination of the reasons why companies in the context of this analysis tend to implement only two types of CE practices reveals several considerations. First of all, a key argument for product design improvements relates to the fact that most of the environmental impacts of products (up to 80%) are determined at their design development stage (Diaz et al., 2021), which is where most of the opportunities for achieving environmental benefits occur. The product design development phase is considered quite broadly and includes choices such as the type of raw materials and their availability, as well as the easy of recyclability, repairability, reusability and disassembly of the product, the energy intensity of the production process, etc. (Mestre & Cooper, 2017). Examples derived from experts' answers suggest that mostly companies consider types of materials and their availability together with the potential of their recyclability when implementing circular design solutions. Based on the view that DBCs identify how ordinary capabilities should operate and be managed (Schoemaker et al., 2018), it is argued that, in this context, new designs and related practices, such as novelties in choices of materials and their suppliers, are treated as ordinary capabilities that implement circular economy practices.

Secondly, general resource efficiency actions, such as switching to more modern equipment or reducing scrap, are already a common practice among companies (Lewandowski, 2016), which can be achieved with relatively low costs and changes. Actions identified by the experts that were implemented in companies for improving the resource efficiency are associated both with lower energy and material consumption per unit of production, mainly through the introduction of new technologies (R4), as well as with a reduction in waste or scrap, also resulting from the introduction of new innovative technologies (R1). In this case, there is a clear impact of the transforming DBCs of made slight modifications in existing technology/machinery and introduced new or significantly improved technology. It can, therefore, be argued that resource efficiency practices have become an ordinary capability of companies, enabling them to contribute to CE objectives.

Moreover, arguments can also be found in the literature as to why keeping resources in the economy for as long as possible (CE strategies of slowing and closing resource flows) is not a popular approach among companies' choices to implement CE practices, especially with regards to LCA and MFA application. First, Peña et al. (2021) argues that unlike the circular economy, the LCA approach does not prioritise merely keeping resources in the economy for as long as possible, but is based on the optimal, systematically evaluated alternative with environmental, social, and economic implications. Accordingly, there are cases when keeping resources in the economy for longer may actually be counter productive (e.g., when the product contains harmful substances). Several experts agreed with this insight, highlighting the following cases: "…the recycling of some construction materials is highly energy-intensive and if the technology is not available nearby...the combined recycling efforts and logistics can generate a significantly higher CO2 footprint…" (R5), "…keeping particular plastic products for longer raises concerns about the damage they cause with microplastics... The longer and more intensively such products are used, the more microplastics are released into the environment…" (R8). Second, the appropriate application of the MFA must be limited to a specific area (e.g., company facilities) in which a detailed analysis of the metabolism of the materials is performed (Pauliuk & Heeren, 2020). Thus, the MFA is not suitable for application to the whole product value chain (particularly, if those value chains are very long and cover multiple actors) when production and service alternatives are compared. Consequently, companies cannot be informed about the environmental impacts of circular practices related to slowing and closing resource flows strategies, as they involve cooperation among several actors in the value chain. Third, circular economy practices that require a fundamental rethinking of the business model, e.g., replacing or complementing goods with services, are still considered to be exceptional cases. Such business model changes are most often observed among companies with a substantial market presence and leadership (Lüdeke-Freund et al., 2019). Another group of companies that use such product life cycle extension services exists among new and innovative companies established after the circular economy has gained momentum. Fourth, companies that have identified market opportunities and seek to calculate their LCA often have a specific product and production process that they want to evaluate and improve. This need of companies already shapes and constrains the further development paths in the context of the implementation of circular economy practices. As a result, the practices that are most often implemented are those that are directly linked to the existing resources of companies, rather than the development of completely new and untested services. A similar rationale is followed by companies in the application of MFA, i.e., to improve or transform existing resource use practices within the company.

Finally, with regards to capabilities, the literature lacks more specific DBCs for CE practices that focus on keeping resources in the economy. For example, DBCs that are related to the design and development of products and processes were identified as enablers of circular economy transition in companies in systematic literature review carried out by Seles et al. (2022). However, no DBCs were allocated to other CE practices, such as remanufacturing, maintenance services and digitalization of products, as enabling factors. Given the experts' insights, the lack of evidence regarding implemented CE practices within slowing resource flows strategy remains. Therefore, it can be confirmed that business practices corresponding to different CE strategies have been analysed in different scopes.

To sum up, seizing and transforming DBCs stimulate enabling conditions for the implementation of CE practices in companies mostly through strategic planning, business model governance and collaboration (seizing), as well as organizational restructuring, technological upgradation, and knowledge integration (transforming). The use of the DBCs strengthened by LCA and MFA benefits mainly supports companies in making decisions on the implementation of CE practices related to supplier selection and stakeholder cooperation, process or product improvement or innovation, and environmental management integration. Particular CE practices commonly implemented by companies in this context fall under categories of circular product or project design choices and more efficient resource use. It is assumed that essential elements for these practices to be implemented (i.e., necessary technologies, partnerships, and the development of new ways of operating) are facilitated by DBCs. Moreover, the implementation of such practices is considered to take the form of new or modified ordinary capabilities. However, these types of CE practices are seen as among the most common activities of companies in general terms, but not fully representative of all CE resource management strategies. It is noted that practices aimed at slowing down the use of resources were not identified during the analysis, which is mainly due to the limited capacity of LCA and MFA to cover these practices, the need to assess value chains with high complexity, and the different initial needs of companies.

3.3. CE related organizational performance improvement as a result of LCA and MFA application

Finding 5: CE related organisational performance improvement is apparent in companies focusing on general continuous improvement a long-term market perspective (regarding RQ4)

A key principle for measuring and comparing the impact of implemented CE practices on the relevant performance indicators of an organisation is the repeated use of the chosen instrument (i.e., secondary LCA or MFA measurement). It is important for several following reasons: "…when [a company] is aiming for a certain measurable impact on a product or on the organisation, the measurement has to be based on the same logic and instruments that were used in the first stages... only in this way is possible to accurately assess what has actually happened…" (R7), "…a secondary assessment is needed to see if [the company] made a mistake and achieved the result that was the goal at the start [its] project… this is important because sometimes improving one aspect of a product can lead to a worse situation in another aspect" (R1), "…when [companies] have many different projects and use different instruments, it is a big challenge for them to bring everything together in one place and see the big picture [of impact]…" (R10). These ideas expressed by the experts are aligned with the impact assessment practices set out in ISO 14052:2017 and ISO 14044:2006.

Nevertheless, according to the experts, assessing the impact of LCA and MFA-driven and implemented CE practices on the overall organisational performance improvement is challenging due to several reasons:

- applying CE practices (i.e., circular design) to a relatively limited number of company products: "…it is difficult to see the improvement in the overall context of the company because, say, the LCA is only applied to one certified product or product line" (R8), "…when it comes to new product launches, it's a bit of a test…companies calculate LCA to substantiate their product's environmental claims...but the product is not necessarily a major part of the company's overall product range." (R11);
- lack of motivation for companies to invest in extensive impact re-evaluations: "After a while, the same complex calculations have to be redone and internal inventory data collected, also from suppliers… not all companies are willing to repeat this…" (R2), "...having seen the basic elements of the MFA calculation, companies sometimes think that they are able to estimate for themselves what the impact might be with the new production capacities...but this is hardly a comparable result…" (R9);

- lack of long-term vision: “some companies think that it is enough to take one assessment…buy new technologies…provide evidence to clients and that’s it... they don’t think about changes in impact too much.” (R11).

Two types of companies can be distinguished based on the impact measurement challenges outlined above. The first group of companies is characterised by a limited need to assess relevant impacts and is more focused on current market needs. Referring back to the needs of companies to apply LCA or MFA instruments (see Table 6), these companies mainly aim to respond to current customer needs (e.g., to launch a product on the market that reflects sustainability trends) (based on R8, R11 comments) or to take advantage of opportunities that already exist in the market (e.g., adopt processes used by competitors) (based on R3) comments. The second group of companies, in contrast, is focused on the long-term and, therefore, the measurement of impact is essential for them to ensure improvement and thereby a stronger market position. The needs of such companies are mainly based on not only current but also future market requirements, which are expected to become more stringent. Such companies communicate their claims in a targeted and evidence-based way and avoid risks of damaging their corporate image (based on R1 comments). They also aim to produce products that are market-leading or exceptional (based on R1 comments) and plan to attract strategic investments (based on R7 comments).

Above provided insights based on comments by the experts strongly relate to the ideas of continuous improvement theory. As Calicchio Berardi & Peregrino de Brito (2021) propose “the management of circular models needs to measure and evaluate the successive restorative and regenerative cycles that go beyond the implementation phase” (p. 7). Regular measurement of environmental impacts not only allows the company to assess the correctness of decisions, but also provides opportunities to review established practices with a possibility to integrate new and emerging circular solutions. In this way, evolving knowledge and experience can be compared and reinterpreted, and circular practices improved (Blomsma et al., 2022). This is particularly relevant in light of the continuous technological and non-technological innovation advancements in the circular economy area. Continuous improvement is also closely linked to developed DBCs. Generally, companies that are focused on continuous improvement and innovation also have strong DBCs that allow them to react and respond to stakeholder needs and overall changes in the environment (Zapata-Cantu et al., 2016). Therefore, by combining the ideas of continuous improvement with the DBCs framework and the use of LCA and MFA instruments, it is argued that the use of LCA and MFA, which can also measure change, is driven by the need for continuous improvement, and that such ongoing process results in enhanced sensing DBCs, as it can re-evaluate the dynamics of the environment (e.g., technological change).

Finding 6: most observed CE related organisational performance improvements are related to energy and material use, abilities to develop innovative and circular products (regarding RQ4)

It has been found that companies that implement CE practices are most likely to improve their performance in terms of reduced energy consumption or increased energy use efficiency, decreased material consumption or increased material use efficiency, reduced waste generation, and increased capability to introduce innovative products. The first three indicators, which are associated with CE performance, are most commonly used by companies (see Table 9). Their links to LCA and MFA are quite clear as they correspond to the environmental impact categories measured by these instruments. Differently, increased capability to develop and launch innovative and circular products is usually seen as undisclosed improvement which is not necessarily a primary concern for companies or anticipated performance indicator. However, this improvement is seen as a complementary enhancement, allowing companies to be more successful and relevant in the market.

Essentially, this finding is applicable in conjunction with Finding 5, i.e., it can only be substantiated when organisations have properly implemented continuous improvement actions and are able to see and measure the difference in performance. In addition, this result has a direct linkage with Finding 4 that indicates the limited choice of companies to adopt CE practices.

Table 9. Results on CE related organizational performance improvements in companies (compiled by the author)

Category: types of CE related organizational performance improvements		
Sub-category	**Expert comment**	**Cause of CE practice implemented**
Decreased material consumption / increased material use efficiency	"...then you have material and water [consumption] and reusability as an impact is still pretty less expressed…" (R3) "As far as the textile sector is concerned…they are mostly focusing on the water consumption. In most cases, the decisions that follow after [MFA calculations], result in reduced use of water and similarly, when they use less water, it means that they are consuming less chemicals." (R2)	Increasing material and energy efficiency of processes

Continuation of Table 9

Reduced energy consumption / increased energy use efficiency	"... energy usage is quite common as an impact indicator looked at…" (R2) "…CO_2 footprint equivalents…are mainly driven by energy consumption…so naturally, companies are reducing their energy consumption first…" (R6)	Increasing material and energy efficiency of processes
Reduced waste generation	"…the amount of waste generated by the company was significantly reduced by simply turning it into new raw materials." (R11)	Using closed loops in the production
Increased capability to introduce innovative products	"…in many cases [after LCA use], the company launches a new or at least environmentally improved product." (R8) "A completely new product is not always the first in the plans of companies, but in the course of the process, the improved product appears anyway. Especially if we are talking about changes to its composition and materials. So, companies create value of it too." (R11) "LCA makes you think about product improvement. That's the point. Otherwise, companies wouldn't see the benefit." (R7) "…[companies] very often create products that can be considered innovative because of their production method and choice of materials…" (R6)	Designing and producing products to be easily biodegradable/recyclable Designing and producing products with recycled/renewable inputs

The limited application of CE practices and the use of related indicators identified in this work confirms the problem of researchers developing specific CE measurement indicators for companies – current and most commonly used indicators do not sufficiently cover all circular economy aspects (Janik & Ryszko, 2019; Rincón-Moreno et al., 2021, Rossi et al., 2020). In principle, the collection and evaluation of more accurate data is important because the ability to measure and report on circular economy implementation is a crucial factor that determines the success of dedicated transitional decisions (Kristensen & Mosgaard, 2020). The evaluation process is also an inseparable part of CE operation control and quality, as only measurable activities can be managed (Linder et al., 2017). However, taking into account the growing availability of more accurate measurement instruments and indicators for CE (see Annex 1), it appears that there is still no significant interest from companies in using them. They, therefore, focus on essential indicators (e.g., energy and material consumption) and standardised measurement procedures (e.g., LCA and MFA) that are the easiest to communicate and compare. Despite these obvious advantages, LCA and MFA in the context of different CE practices have limitations in analysing and contributing to business decisions that could slow down resource flows (specific arguments under Finding 4).

Overall, companies with a strong focus on long-term sustainability vision and future market requirements have the greatest interest in achieving CE related performance improvement. It is recognised that achieving a competitive position in the market requires continuous improvement, one part of which is measuring the impact of change and adjusting or developing new practices accordingly. It is apparent that this permanent action is also linked to strong sensing DBCs, as it is oriented towards identification of new market opportunities. In the context of the circular economy, continuous improvement process is crucial due to rapidly changing technologies, emerging knowledge, and market requirements. In practice, however, companies are mostly able to track circular improvements related to energy and material use, while abilities to develop innovative and circular products appear as intentional, but not necessarily targeted improvement. The main reasons why companies intend to focus on these indicators are their integrability with LCA and MFA, easy comparability, and interpretability. However, the assessment of energy and material use is a limited approach to measure and manage the implementation of CE practices, especially including the ones related to slowing and closing material flows.

3.4. Developed theoretical model defining the relations between the use of LCA and MFA and the implementation of circular economy practices in companies within a dynamic business capabilities framework

Taking into account the findings presented in the previous sub-chapters, a theoretical model describing the relations between the use of LCA and MFA and the implementation of circular economy practices in companies within a dynamic business capabilities framework has been compiled (see Figure 7) (the numbers in the model are intended to make it easier for the reader to understand which relation is described by the narrative that follows the figure).

Building on the theory of DBCs, the use of LCA and MFA by firms is driven by their well-developed abilities to sense changing market trends, which in turn shape their corresponding needs (1). The observation of changing market trends, including customer needs and competitors' actions, is considered as external environmental sensing for emerging business opportunities. Correspondingly, new needs of companies (e.g., to meet sustainability requirements of customers or specific markets or to differentiate company's product in the marketplace) are addressed using LCA or MFA methods (2) that are able to identify or substantiate environmental improvements of products or processes within the organization. These and other benefits of LCA and MFA use are realised in companies when the relevant methods and instruments are applied and detailed information on organisational and value chain processes is reported (3). In addition to existing literature on the benefits of LCA and MFA application, new features are also identified in the model, such as the benefits of enhanced new product development, benefits of enabled environmental risk-based view, and the benefits of strengthened supplier control. It is also important to underline that up to this stage, the opportunities for companies to implement circular economy practices are not well defined, as the focus tends to be more on general sustainability trends and the opportunities for companies to improve their environmental performance regardless the type of practice implemented.

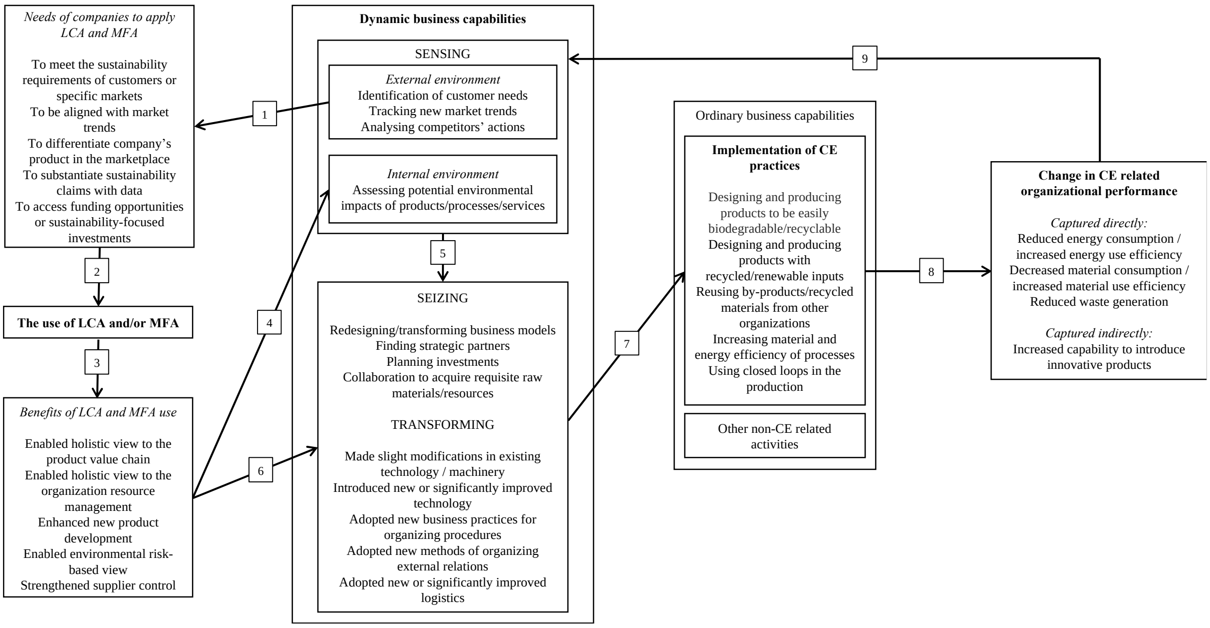

Figure 8. Theoretical model defining the relations between life cycle assessment, material flow analysis, and dynamic business capabilities for circular economy implementation in companies (compiled by the author)

Following the benefits of LCA and MFA for companies, a strong link with enhanced DBCs is evident. First, LCA and MFA contribute to the capability of sensing internal environment by analysing a company's inventory and performance indicators and providing potential areas (of major environmental concerns) to be addressed with further actions (4). These are then planned on the basis of seizing DBCs and implemented on the basis of transforming DBCs (5). Second, LCA and MFA benefits also support companies' actions regarding seizing and transforming DBCs, mainly based on the data provided by these instruments on resource use, links with suppliers, environmental impacts within the value chain or organisation, and on highlighted areas of improvement and risks (6). This data is important for companies to make decisions on how to reorient their business model (towards more efficient and environmentally friendly use of resources), develop new partnerships and business processes, secure a more sustainable supply of raw materials, and introduce or develop new technologies. At this stage, the implementation of CE practices emerges as one of the feasible options to meet the initial business needs driven by changing market trends.

In the context of LCA's and MFA's enhanced DBCs, seizing and transforming capabilities are most supportive to the implementation of CE practices, as they ensure planning and reconfiguring of essential CE transformation elements, including the necessary technologies, partnerships, and the development of new ways of operating. As a result, companies are implementing new CE practices, mainly in the areas of circular product design and resource efficiency improvement (7). These new practices are perceived as transformed ordinary capabilities of companies, which ensure the continuity of the company's day-to-day operations. After a while, when these ordinary capabilities of CE practice implementation become established, the measured CE related organisational improvement occurs in two directions (8). The first relates to improved company performance in terms of material and energy consumption. The second direction, although not directly measurable, is captured as the increased capability of companies to introduce new innovative products. Finally, based on the scale of improvement measured and achieved, a review of processes follows, both to address unachieved indicators and to identify new opportunities for improvement (9). This review is linked to sensing DBCs as it takes into account both the internal environment of the company and external developments in the market. The latter, given the rapid development of the circular economy, tends to be of particular relevance to companies focused on maintaining long-term competitiveness.

Overall, the empirical results obtained, and the theoretical model developed support the arguments regarding:

- the application of innovative approaches based on the search for value to stakeholders (e.g., consumers, suppliers) (in the analysed case – enabling DBCs and using LCA/MFA) is one of the key ways to transform companies towards a circular business model (Den Hollander & Bakker, 2016; Geissdoerfer et al., 2018);
- idea that companies that follow a circular business model are more focused on long-term value creation and improvement (Geissdoerfer et al., 2018);
- the importance of the use of measurement instruments in managing the implementation of CE practices (Kristensen & Mosgaard, 2020; Lindgreen et al., 2020);
- the links of the use of LCA and MFA methods to the identification of the feasibility of CE practices implementation in terms of their resource use and corresponding environmental impacts (Elia et al. 2017; Haupt & Zschokke, 2017);

- DBCs’ importance as an internal company factor facilitating broader expansion of CE innovations in products, processes, and business models (Suchek et al., 2021);
- DBCs’ importance to companies both in innovating their business model towards circular economy and maintaining competitive advantage in sustainability-oriented markets (Khan et al., 2020b; Prieto-Sandoval et al., 2019; Santa-Maria et al., 2022).

Most importantly, the work extends the theoretical approach towards LCA, MFA and DBCs for CE practice implementation with new following aspects:

- the use of LCA and MFA and enhanced DBCs are linked to circular supply chain development, as a strong focus is placed on assessing the environmental impacts of value chain actors, i.e., suppliers and the raw materials they provide, and on finding more attractive alternatives;
- LCA and MFA enhanced DBCs help to tackle barriers at the value chain level, (e.g., need for supplier cooperation) and barriers at the organisational level (e.g., need for specific knowledge) when CE practices are seen as a potential alternative to be implemented;
- the use of LCA and MFA is exclusively linked to the attribute of companies being focused on achieving long-term benefits and maintaining a competitive position in the market (where this is linked to sustainability trends);
- DBCs and the use of LCA/MFA are closely linked to continuous improvement as this is seen as a way to effectively respond and adapt to changing market trends;
- current research on the topic is limited to a few CE practices, so that management practices for slowing resource flows are insufficiently revealed.

Considering these results, the main conclusions and suggestions for further research are presented in the last chapter of this thesis.

4. CONCLUSIONS

The following key **conclusions** are formed based on the results derived from the overall master thesis work:

1. Circular economy (CE) is one of the emerging trends shaping the market with a new view to resource valuation and management practices, aimed at achieving economic, environmental, and social sustainability. Based on it, companies are opting to adopt new business models, innovative supply chain management practices, new technologies and develop sustainable products based on using materials more efficiently and keeping them in the market for as long as possible, thus eliminating waste. The implementation of circular economy practices in companies is also linked to their commitment of innovating and improving the quality of their product and processes, strongly focusing on the reduction of factors that contribute to negative environmental impacts and on the provision of new value propositions to their customers.
2. Life cycle assessment (LCA) and material flow analysis (MFA) are important methods for making evidence-based decisions related to the implementation of circular economy practices in companies. Their multiple benefits enable companies to identify and evaluate different alternatives for process, product improvement or technological innovations, based on a holistic approach to resource management at the level of the organisation or value chain. The importance of these methods is particularly relevant for assessing the implementation of sustainability-related decisions, as they allow environmental impacts to be measured in a scientifically valid and standardised way.
3. Dynamic business capabilities (DBCs) are a paramount part of company's abilities allowing them to proactively respond to market transformations and to implement appropriate changes within the company. DBCs are closely linked to maintaining companies' long-term competitiveness in the market due to continuous adaptation and search for new business opportunities. This is achieved by implementing sensing (opportunity identification), seizing (opportunity planning), and transforming (opportunity integration by reconfiguration of resources) activities. In this context, circular economy is considered as an influential trend shaping changes in the market, whose uptake by companies is driven by the exploitation of their DBCs. These changes are most evident through new technology uptake, knowledge and practice creation that mostly result in product, process, or business model innovations.

4. Based on the empirical study results, it was found that both LCA and MFA are associated with enhanced DBCs in companies under the following directions: 1) the use of LCA and MFA is considered to support implemented sensing activities of evaluating improvement opportunities emerging from internal environment of companies, however only companies with strong DBCs of sensing external environment are most likely to use LCA and MFA; 2) the benefits of LCA and MFA enhances seizing (planning) and transforming (reconfiguring) DBCs, as they provide relevant information and considerations on resources used and environmental impacts derived by different value chain organizations or particular processes within organization. This data supports the company's decision-making (including both planning and reconfiguring of resources) in relation to innovating business model, modifying, or deploying new technology/machinery, adopting new practices and methods for organizing internal procedures and external relations.
5. The enhanced seizing and transforming DBCs facilitates the implementation of CE practices in companies, taking into account the key outcomes of LCA and MFA application. In particular, this facilitation is related to strategic planning, business model governance and innovation, collaboration (seizing), as well as organizational restructuring, technological upgradation, and knowledge integration (transforming). On more practical level, decisions regarding the implementation of CE practices are supported by enhanced view to supplier selection and stakeholder cooperation, process or product improvement or innovation, and environmental management integration. As a result, new CE practices in form of more efficient use of resources and production of circular design products are implemented in companies. Eventually these practices become ordinary capabilities of companies that allow them to provide value to their and customers, based on a more circular business model operation. It was also found that these practices partially reflect CE opportunities available, i.e., only management practices of narrowing and closing resource flows are covered but other alternatives, such as slowing resource flows by producing more durable products or extending their durability with repair, refurbish, and remanufacturing services, are not included. The latter practices are considered to attain less interest from companies and have more limited comparative relevance to LCA and MFA.
6. Finally, CE related performance improvement is associated with a clear company's orientation towards long-term competitiveness and continuous improvement. This orientation not only encourages companies to measure change but also to take

appropriate actions to improve it. The company's aim to remain competitive in the long-term is also clearly linked to the presence of strong sensing DBCs. The latter creates a need to reassess the rapid market changes associated with the development of CE technologies, knowledge, and regulation and, accordingly, to seek new business opportunities by applying LCA and MFA to internal process re-evaluation. However, research results show that companies mainly measure CE related performance improvement through energy and material use, while their increased abilities to develop innovative and circular products are captured indirectly. These indicators are also seen as neglecting the CE objective of keeping resources in the economy for longer.

Main practical implications and **recommendations** for companies include: 1) increasing the focus on activities to identify and take advantage of market development opportunities in the area of CE by allocating necessary human, financial and other resources; 2) progressively integrate the transition to a circular economy into the overall company strategy and strengthen interdepartmental cooperation, e.g., between environmental, quality and innovation management areas; 3) incorporating new methods and indicators into performance measurement processes that include a broader view of CE, e.g., product recyclability, repairability, levels of use of secondary raw materials. Accordingly, business consultants should take into account emerging needs of companies in the area of CE and support them in providing services related to building their capabilities of using environmental assessment instruments, finding necessary partners (e.g., suppliers) for new value chain creation, supporting their abilities to innovative business model and access investments for new product creation or technology deployment.

Key **limitations** of this work include preference for collecting data on changes in companies from secondary sources, i.e., based on practices observed by business consultants rather than those reported by the companies themselves. This approach has a high risk of bias and cannot accurately reflect the experience of companies. It is also apparent that respondents' experience regarding LCA and MFA use is unevenly distributed, resulting in MFA being considered as slightly underrepresented. Another limitation relates to the isolation of the circular economy as a key determinant of market dynamics, and the failure to link it to other important topics such as digitalisation, supply chain instability, and changes in energy and raw material prices. Finally, the majority of the findings relate to a limited number of circular economy practices that have been implemented, but they do not represent the full range of CE opportunities that exist in the market.

Based on the exploratory nature of this work and identified analysis limitations, several following **directions of further research** were identified. First of all, the results of this work should be substantiated by confirmatory studies. As an option, longitudinal studies on the evolution of a companies' dynamic capabilities for CE implementation would be valuable. Second, due to the limited research on CE practices that focus on keeping resources on the market longer (i.e., slowing resource flows), it is important to carry out similar research covering business practices related to remanufacturing, repair, refurbish, provision of products as services and other related activities. This would extend the work with further possibilities to include other types of CE practices, innovations, and business models and investigate them in the context of both DBCs and LCA/MFA. Finally, considering the existence of various new measurement methods and instruments that are able to support the implementation and management of CE practices, it would be valuable to include them as new variables instead of the generic LCA and MFA methods.

LIST OF REFERENCES

Adibi, N., Lafhaj, Z., Yehya, M., Payet, J. (2017). Global Resource Indicator for life cycle impact assessment: applied in wind turbine case study. *J. Clean. Prod. 165*, 1517-1528. https://doi.org/10.1016/j.jclepro.2017.07.226.

Alamerew, Y.A., Brissaud, D. (2018). Circular economy assessment tool for end-of-life product recovery strategies. *J. Remanufacturing* 1-17. https://doi.org/10.1007/s13243-018-0064-8.

Alamerew, Y.A., Kambanou, M.L., Sakao, T., Brissaud, D. (2020). A multi-criteria evaluation method of product-level circularity strategies. *Sustainability* 12. doi:10.3390/su12125129.

Ali, A. K., Wang, Y., & Alvarado, J. L. (2019). Facilitating industrial symbiosis to achieve circular economy using value-added by design: A case study in transforming the automobile industry sheet metal waste flow into Voronoi facade systems. *Journal of Cleaner Production*, *234*, 1033–1044. https://doi.org/10.1016/j.jclepro.2019.06.202

Allwood, J. M., Ashby, M. F., Gutowski, T. G., & Worrell, E. (2011). Material efficiency: A white paper. *Resources, Conservation and Recycling*, *55*(3), 362–381. https://doi.org/10.1016/j.resconrec.2010.11.002

Ameli, M., Mansour, S., Ahmadi-Javid, A. (2019). A simulation-optimization model for sustainable product design and efficient end-of-life management based on individual producer responsibility. *Resour. Conserv. Recycl*. 140, 246-258. https://doi.org/10.1016/j.resconrec.2018.02.031.

Antikainen, M., & Valkokari, K. 2016. A Framework for Sustainable Circular Business Model Innovation. *Technology Innovation Management Review*, 6(7), 5–12. http://timreview.ca/article/1000

Assefa, G., & Ambler, C. (2017). To demolish or not to demolish: Life cycle consideration of repurposing buildings. *Sustainable Cities and Society*, *28*, 146–153. https://doi.org/10.1016/j.scs.2016.09.011

Azevedo, S. G., Godina, R., & Matias, J. C. de O. (2017). Proposal of a sustainable circular index for manufacturing companies. *Resources*, *6*(4). https://doi.org/10.3390/resources6040063

Bai, C., Sarkis, J., Yin, F., & Dou, Y. (2020). Sustainable supply chain flexibility and its relationship to circular economy-target performance. *International Journal of*

Production Research, *58*(19), 5893–5910. https://doi.org/10.1080/00207543.2019.1661532

Bairagi, V., & Munot, M. V. (2019). *Research Methodology*.

Barney, J. (1991). Firm Resources and Sustained Competitive Advantage. *Journal of Management*, *17*(1), 99–120. https://doi.org/10.1177/014920639101700108

Barros, M. V., Salvador, R., do Prado, G. F., de Francisco, A. C., & Piekarski, C. M. (2021). Circular economy as a driver to sustainable businesses. *Cleaner Environmental Systems*, *2*, 100006. https://doi.org/10.1016/j.cesys.2020.100006

Batista, L., Bourlakis, M., Smart, P., & Maull, R. (2018). In search of a circular supply chain archetype: a content analysis based literature review. *Production Planning and Control*, *29*(6), 438–451. https://doi.org/10.1080/09537287.2017.1343502

Bhattacherjee, A. (2012). *Social Science Research: Principles, Methods, and Practices* (2nd ed.). University of South Florida.

Bianchi, G., Testa, F., Tessitore, S., & Iraldo, F. (2022). How to embed environmental sustainability: The role of dynamic capabilities and managerial approaches in a life cycle management perspective. *Business Strategy and the Environment*, *31*(1), 312–325. https://doi.org/10.1002/bse.2889

Blomsma, F., & Brennan, G. (2017). The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity. *Journal of Industrial Ecology*, 21(3), 603-614. https://doi.org/10.1111/jiec.12603

Blomsma, F., Tennant, M., & Ozaki, R. (2022). Making sense of circular economy: Understanding the progression from idea to action. *Business Strategy and the Environment*. 2022, 1-26. https://doi.org/10.1002/bse.3107

Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering, 33*(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

Bocken, N., Strupeit, L., Whalen, K., & Nußholz, J. (2019). A review and evaluation of circular business model innovation tools. In *Sustainability (Switzerland)* 11 (8). MDPI. https://doi.org/10.3390/su11082210

Bogner, A., Littig, B., & Menz, W. (2009). *Research Methods Series: Interviewing Experts*. Palgrave Macmillan.

Boldoczki, S. (2021). Assessment of the Contribution of Preparation for Reuse to the Goals of a Circular Economy [University of Augsburg]. In *Journal of Cleaner Production* (Vol. 211). https://doi.org/10.1016/j.jclepro.2018.11.264

Braun, A. T., Kleine-Moellhoff, P., Reichenberger, V., Seiter, S. (2018). Case study analysing potentials to improve material efficiency in manufacturing supply chains, considering circular economy aspects. *Sustainability 10*. doi:10.3390/su10030880.

Buzzao, G., & Rizzi, F. (2021). On the conceptualization and measurement of dynamic capabilities for sustainability: Building theory through a systematic literature review. *Business Strategy and the Environment*, *30* (1), 135–175. https://doi.org/10.1002/bse.2614

Calicchio Berardi, P., & Peregrino de Brito, R. (2021). Supply chain collaboration for a circular economy - From transition to continuous improvement. *Journal of Cleaner Production*, *328*. https://doi.org/10.1016/j.jclepro.2021.129511

Cayzer, S., Griffiths, P., & Beghetto, V. (2017). Design of indicators for measuring product performance in the circular economy. *International Journal of Sustainable Engineering*, *10*(4–5), 289–298. https://doi.org/10.1080/19397038.2017.1333543

Centobelli, P., Cerchione, R., Chiaroni, D., del Vecchio, P., & Urbinati, A. (2020). Designing business models in circular economy: A systematic literature review and research agenda. *Business Strategy and the Environment*, *29*(4), 1734–1749. https://doi.org/10.1002/bse.2466

Chang, D., Lee, C. K. M., & Chen, C. H. (2014). Review of life cycle assessment towards sustainable product development. *Journal of Cleaner Production*, *83*, 48–60. https://doi.org/10.1016/j.jclepro.2014.07.050

Circle Economy. (2018). The circularity gap report. Available at: https://www.circle-economy.com/resources/the-circularity-gap-report-our-world-is-only-9-circular Accessed 25.09.21.

Circularity IQ and KPMG (2020). Circularity IQ: product circularity improvement program. Available at: https://www.circular-iq.com/product-circularity-improvement-program/. Accessed 25.09.21.

Civancik-Uslu, D., Puig, R., Ferrer, L., & Fullana-i-Palmer, P. (2019). Influence of end-of-life allocation, credits and other methodological issues in LCA of compounds: An in-company circular economy case study on packaging. *Journal of Cleaner Production*, *212*, 925–940. https://doi.org/10.1016/j.jclepro.2018.12.076

Colley, T. A., Birkved, M., Olsen, S. I., & Hauschild, M. Z. (2020). Using a gate-to-gate LCA to apply circular economy principles to a food processing SME. *Journal of Cleaner Production, 251*. https://doi.org/10.1016/j.jclepro.2019.119566

Cong, L., Zhao, F., Sutherland, J.W. (2019). A design method to improve end-of-use product value recovery for circular economy. *J. Mech. Des.* 141, 044502. https://doi.org/10.1115/1.4041574.

Corona, B., Shen, L., Reike, D., Rosales Carreón, J., & Worrell, E. (2019). Towards sustainable development through the circular economy—A review and critical assessment on current circularity metrics. In *Resources, Conservation and Recycling* (Vol. 151). Elsevier B.V. https://doi.org/10.1016/j.resconrec.2019.104498

Cradle to Cradle Products Innovation Institute. (2016). Material reutilization. In: McDonough Braungart Design Chemistry. Cradle to Cradle Certified Product Standard. Version 3.1. Cradle to Cradle Products Innovation Institute, pp. 48-54.

Cullen, J. M. (2017). Circular economy: theoretical benchmark or perpetual motion machine. *J. Ind. Ecol.* 21, 483–486. doi:10.1111/jiec.12599.

Cusenza, M. A., Guarino, F., Longo, S., Ferraro, M., & Cellura, M. (2019). Energy and environmental benefits of circular economy strategies: The case study of reusing used batteries from electric vehicles. *Journal of Energy Storage, 25*. https://doi.org/10.1016/j.est.2019.100845

De Oliveira, C. T., Dantas, T. E. T., & Soares, S. R. (2021). Nano and micro level circular economy indicators: Assisting decision-makers in circularity assessments. In *Sustainable Production and Consumption* (Vol. 26, pp. 455–468). Elsevier B.V. https://doi.org/10.1016/j.spc.2020.11.024

De Pascale, A., Arbolino, R., Szopik-Depczyńska, K., Limosani, M., & Ioppolo, G. (2021). A systematic review for measuring circular economy: The 61 indicators. *Journal of Cleaner Production*, *281*. https://doi.org/10.1016/j.jclepro.2020.124942

Den Hollander, M., & Bakker, C. (2016). Mind the Gap Exploiter: Circular Business Models for Product Lifetime Extension. *Proceedings of Electronic Goes Green 2016+: Inventing Shades of Green*, 1–8.

Di Maio, F., Rem, P. C., Baldé, K., & Polder, M. (2017). Measuring resource efficiency and circular economy: A market value approach. *Resources, Conservation and Recycling*, *122*, 163–171. https://doi.org/10.1016/j.resconrec.2017.02.009

Diaz, A., Schöggl, J. P., Reyes, T., & Baumgartner, R. J. (2021). Sustainable product development in a circular economy: Implications for products, actors, decision-making support and lifecycle information management. *Sustainable Production and Consumption*, *26*, 1031–1045. https://doi.org/10.1016/j.spc.2020.12.044

Diener, D. L., & Tillman, A. M. (2015). Component end-of-life management: Exploring opportunities and related benefits of remanufacturing and functional recycling. *Resources, Conservation and Recycling*, *102*, 80–93. https://doi.org/10.1016/j.resconrec.2015.06.006

Dieterle, M., Schäfer, P., & Viere, T. (2018). Life Cycle Gaps: Interpreting LCA Results with a Circular Economy Mindset. *Procedia CIRP*, *69*, 764–768. https://doi.org/10.1016/j.procir.2017.11.058

Dong, Y., Miraglia, S., Manzo, S., Georgiadis, S., Sørup, H. J. D., Boriani, E., Hald, T., Thöns, S., & Hauschild, M. Z. (2018). Environmental sustainable decision making: The need and obstacles for integration of LCA into decision analysis. *Environmental Science and Policy*, *87*, 33–44. https://doi.org/10.1016/j.envsci.2018.05.018

Eberhardt, L. C. M., Birgisdóttir, H., & Birkved, M. (2019). Life cycle assessment of a Danish office building designed for disassembly. *Building Research and Information*, *47*(6), 666–680. https://doi.org/10.1080/09613218.2018.1517458

Ecopreneur. (2019). Circularity Check: how circular are the products and services your company puts on the market? Available at: https://ecopreneur.eu/circularity-check-landing-page/. Accessed 25.09.21.

Elia, V., Gnoni, M. G., & Tornese, F. (2017). Measuring circular economy strategies through index methods: A critical analysis. *Journal of Cleaner Production*, *142*, 2741–2751. https://doi.org/10.1016/j.jclepro.2016.10.196

Ellen Macarthur Foundation (EMF). (2020). Circulytics – measuring circularity. Available at: https://www.ellenmacarthurfoundation.org/resources/apply/circulytics-measuring-circularity. Accessed 20.09.21.

Farooque, M., Zhang, A., Thürer, M., Qu, T., & Huisingh, D. (2019). Circular supply chain management: A definition and structured literature review. In *Journal of Cleaner Production*, *228*, 882–900. Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2019.04.303

Favi, C., Germani, M., Luzi, A., Mandolini, M., Marconi, M. (2017). A design for EoL approach and metrics to favour closed-loop scenarios for products. *Int. J. Sustain. Eng.* 10, 136-146. https://doi.org/10.1080/19397038.2016.1270369.

Ferasso, M., Beliaeva, T., Kraus, S., Clauss, T., & Ribeiro-Soriano, D. (2020). Circular economy business models: The state of research and avenues ahead. *Business Strategy and the Environment*, *29*(8), 3006–3024. https://doi.org/10.1002/bse.2554

Figge, F., Thorpe, A.S., Givry, P., Canning, L., Franklin-Johnson, E. (2018). Longevity and circularity as indicators of eco-efficient resource use in the circular economy. *Ecol. Econ.* 150, 297-306. https://doi.org/10.1016/j.ecolecon.2018.04.030.

Flick, U. (2009). An introduction to qualitative research. Sage Publications.

Flynn, A., Hacking, N., & Xie, L. (2019). Governance of the circular economy: A comparative examination of the use of standards by China and the United Kingdom. *Environmental Innovation and Societal Transitions*, *33*, 282–300. https://doi.org/10.1016/j.eist.2019.08.002

Fogarassy, C., Kovacs, A., Horvath, B., Borocz, M. (2017). The development of a circular evaluation (CEV) tool. *Hung. Agricul. Eng*. 31, 10-20.

Fonseca, L. M., Domingues, J. P., Pereira, M. T., Martins, F. F., & Zimon, D. (2018). Assessment of circular economy within Portuguese organizations. *Sustainability (Switzerland)*, *10*(7). https://doi.org/10.3390/su10072521

Franklin-Johnson, E., Figge, F., & Canning, L. (2016). Resource duration as a managerial indicator for Circular Economy performance. *Journal of Cleaner Production*, *133*, 589–598. https://doi.org/10.1016/j.jclepro.2016.05.023

Fregonara, E., Giordano, R., Ferrando, D. G., Pattono, S. (2017). Economic-environmental indicators to support investment decisions: a focus on the buildings' end-of-life stage. *Buildings* 7, 65. doi:10.3390/buildings7030065.

Freidberg, S. (2015). It's Complicated: Corporate Sustainability and the Uneasiness of Life Cycle Assessment. *Science as Culture*, *24*(2), 157–182. https://doi.org/10.1080/09505431.2014.942622

Frishammar, J., & Parida, V. (2019). Circular business model transformation: A roadmap for incumbent firms. *California Management Review*, *61*(2), 5–29. https://doi.org/10.1177/0008125618811926

Gaižauskaitė, I., & Valavičienė, N. (2016). Socialinių tyrimų metodai: kokybinis interviu. Mykolo Riomerio universitetas.

Garza-Reyes, J.A., Valls, A. S., Nadeem, S. P., Anosike, A., Kumar, V. (2019). A circularity measurement toolkit for manufacturing SMEs. *Int. J. Prod. Res.* 57, 7319–7343. doi:10.1080/00207543.2018.1559961.

Geisendorf, S., & Pietrulla, F. (2018). The circular economy and circular economic concepts—a literature analysis and redefinition. *Thunderbird International Business Review*. 2018(60), 771–782 https://doi.org/10.1002/tie.21924

Geissdoerfer, M., Morioka, S. N., de Carvalho, M. M., & Evans, S. (2018). Business models and supply chains for the circular economy. *Journal of Cleaner Production*, *190*, 712–721. https://doi.org/10.1016/j.jclepro.2018.04.159

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? In *Journal of Cleaner Production*. https://doi.org/10.1016/j.jclepro.2016.12.048

Genovese, A., Acquaye, A.A., Figueroa, A., Koh, S.C.L. (2017). Sustainable supply chain management and the transition towards a circular economy: evidence and some applications. *Omega* 66, 344e357.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Giacomelli, J., Kozamernick, D., Lah, P. (2018). Evaluating and monitoring circularity. *Macro Regul. Environ*. EU Slovenia.

Gorissen, L., Vrancken, K., & Manshoven, S. (2016). Transition thinking and business model innovation-towards a transformative business model and new role for the reuse centers of Limburg, Belgium. *Sustainability (Switzerland)*, *8*(2). https://doi.org/10.3390/su8020112

Graedel, T. E. (2019). Material Flow Analysis from Origin to Evolution. *Environmental Science and Technology*, *53*(21), 12188–12196. https://doi.org/10.1021/acs.est.9b03413

Griffiths, P., & Cayzer, S. (2016). Design of Indicators for Measuring Product Performance in the Circular Economy. *Smart Innovation, Systems and Technologies*, *52*, 307–321. https://doi.org/10.1007/978-3-319-32098-4_27

Guldmann, E., & Huulgaard, R. D. (2020). Barriers to circular business model innovation: A multiple-case study. *Journal of Cleaner Production*, *243*. https://doi.org/10.1016/j.jclepro.2019.118160

Haupt, M., & Zschokke, M. (2017). How can LCA support the circular economy?—63rd discussion forum on life cycle assessment, Zurich, Switzerland, November 30, 2016. *International Journal of Life Cycle Assessment*, *22*(5), 832–837. https://doi.org/10.1007/s11367-017-1267-1

Herva, M., Franco, A., Carrasco, E. F., & Roca, E. (2011). Review of corporate environmental indicators. *Journal of Cleaner Production*, *19*(15), 1687–1699. https://doi.org/10.1016/j.jclepro.2011.05.019

Huysman, S., De Schaepmeester, J., Ragaert, K., Dewulf, J., De Meester, S. (2017). Performance indicators for a circular economy: a case study on post-industrial plastic waste. *Resour. Conserv. Recycl*. 120, 46–54. doi:10.1016/j.resconrec.2017.01.013.

Huysveld, S., Hubo, S., Ragaert, K., Dewulf, J. (2019). Advancing circular economy benefit indicators and application on open-loop recycling of mixed and contaminated plastic waste fractions. *J. Clean. Prod.* 211, 1–13. doi:10.1016/j.jclepro.2018.11.110.

Hörisch, J., Ortas, E., Schaltegger, S., & Álvarez, I. (2015). Environmental effects of sustainability management tools: An empirical analysis of large companies. *Ecological Economics*, *120,* 241–249. https://doi.org/10.1016/j.ecolecon.2015.11.002

Iacovidou, E., Velenturf, A.P.M., Purnell, P. (2019). Quality of resources: a typology for supporting transitions towards resource efficiency using the single-use plastic bottle as an example. *Sci. Total Environ.* 647, 441-448. https://doi.org/10.1016/j.scitotenv.2018.07.344.

IDEAL&CO Explore. (2016). Circularity Calculator [WWW Document]. Available at: http://www.circularitycalculator.com. Accessed 20.09.21.

Inigo, E. A., Albareda, L., & Ritala, P. (2017). Business model innovation for sustainability: exploring evolutionary and radical approaches through dynamic capabilities. *Industry and Innovation*, *24*(5), 515–542. https://doi.org/10.1080/13662716.2017.1310034

International Organization for Standardization. (2006a). Environmental management — Life cycle assessment — Principles and framework (ISO Standard No. 14040). Retrieved from https://www.iso.org/standard/37456.html

International Organization for Standardization. (2006b). Environmental management — Life cycle assessment — Requirements and guidelines (ISO Standard No. 14044). Retrieved from https://www.iso.org/standard/38498.html

International Organization for Standardization. (2011). Environmental management — Material flow cost accounting — General framework (ISO Standard No. 14051). Retrieved from https://www.iso.org/standard/50986.html

International Organization for Standardization. (2017). Environmental management — Material flow cost accounting — Guidance for practical implementation in a supply chain (ISO Standard No. 14052). Retrieved from https://www.iso.org/standard/54811.html

Janik, A., & Ryszko, A. (2019). Circular economy in companies: an analysis of selected indicators from a managerial perspective. *Multidisciplinary Aspects of Production Engineering*, *2*(1), 523–535. https://doi.org/10.2478/mape-2019-0053

Jawahir, I. S., & Bradley, R. (2016). Technological Elements of Circular Economy and the Principles of 6R-Based Closed-loop Material Flow in Sustainable Manufacturing. *Procedia CIRP*, *40*, 103–108. https://doi.org/10.1016/j.procir.2016.01.067

Jiménez-Rivero, A., García-Navarro, J. (2016). Indicators to measure the management performance of end-of-life gypsum: from deconstruction of production of recycled gypsum. *Waste Biomass Valorization* 7, 913–927. doi:10.1007/s12649-016-9561-x.

Kaddoura, M., Kambanou, M. L., Tillman, A. M., & Sakao, T. (2019). Is prolonging the lifetime of passive durable products a low-hanging fruit of a circular economy? A multiple case study. *Sustainability (Switzerland)*, *11*(18). https://doi.org/10.3390/su11184819

Khan, O., Daddi, T., & Iraldo, F. (2020a). Microfoundations of dynamic capabilities: Insights from circular economy business cases. *Business Strategy and the Environment*, *29*(3), 1479–1493. https://doi.org/10.1002/bse.2447

Khan, O., Daddi, T., & Iraldo, F. (2020b). The role of dynamic capabilities in circular economy implementation and performance of companies. *Corporate Social Responsibility and Environmental Management*, *27*(6), 3018–3033. https://doi.org/10.1002/csr.2020

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources*, *Conservation and Recycling*, *127*(September), 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Kluczek, A. (2019). Assessment of manufacturing processes eco-efficiency based on MFA-LCA-MFCA methods. *Environmental Engineering and Management Journal*, *18*(2), 465–472.

Klöpffer, W. (2012). The critical review of life cycle assessment studies according to ISO 14040 and 14044. In *International Journal of Life Cycle Assessment* (Vol. 17, Issue 9, pp. 1087–1093). https://doi.org/10.1007/s11367-012-0426-7

Köhler, J., Sönnichsen, S. D., & Beske-Jansen, P. (2022). Towards a collaboration framework for circular economy: The role of dynamic capabilities and open innovation. *Business Strategy and the Environment*, *31*(6), 2700–2713. https://doi.org/10.1002/bse.3000

Konietzko, J., Bocken, N., & Hultink, E. J. (2020). A tool to analyze, ideate and develop circular innovation ecosystems. *Sustainability (Switzerland)*, *12*(1). https://doi.org/10.3390/SU12010417

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular Economy: The Concept and its Limitations. *Ecological Economics*. https://doi.org/10.1016/j.ecolecon.2017.06.041

Kristensen, H. S., & Mosgaard, M. A. (2020). A review of micro level indicators for a circular economy – moving away from the three dimensions of sustainability? In *Journal of Cleaner Production* (Vol. 243). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2019.118531

Kristoffersen, E., Mikalef, P., Blomsma, F., & Li, J. (2021). Towards a business analytics capability for the circular economy. *Technological Forecasting and Social Change*, *171*. https://doi.org/10.1016/j.techfore.2021.120957

Kumar, V., Sezersan, I., Garza-Reyes, J. A., Gonzalez, E. D. R. S., & AL-Shboul, M. A. (2019). Circular economy in the manufacturing sector: benefits, opportunities and barriers. *Management Decision*, *57*(4), 1067–1086. https://doi.org/10.1108/MD-09-2018-1070

Laaksonen, O., & Peltoniemi, M. (2018). The Essence of Dynamic Capabilities and their Measurement. *International Journal of Management Reviews*, *20*(2), 184–205. https://doi.org/10.1111/ijmr.12122

Lewandowski, M. (2016). Designing the business models for circular economy-towards the conceptual framework. *Sustainability (Switzerland)*, *8*(1), 1–28. https://doi.org/10.3390/su8010043

Lèbre, É., Corder, G., Golev, A. (2017). The role of the mining industry in a circular economy: a framework for resource management at the mine site level. *J. Ind. Ecol*. 21, 662–672. doi:10.1111/jiec.12596.

Li, Z., Zeng, H., Xiao, X., Cao, J., Yang, C., & Zhang, K. (2019). Resource value flow analysis of paper-making enterprises: A Chinese case study. *Journal of Cleaner Production*, *213*, 577–587. https://doi.org/10.1016/j.jclepro.2018.12.158

Liang, W.-Z., Zhao, G.-Y., Hong, C.-S. (2018). Performance assessment of circular economy for phosphorus chemical firms based on VIKOR-QUALIFLEX method. *J. Clean. Prod*. 196, 1365–1378. doi:10.1016/j.jclepro.2018.06.147.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation : a comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, *115*, 36–51. https://doi.org/10.1016/j.jclepro.2015.12.042

Lin, K. P., Yu, C. M., & Chen, K. S. (2019). Production data analysis system using novel process capability indices-based circular economy. *Industrial Management and Data Systems*, *119*(8), 1655–1668. https://doi.org/10.1108/IMDS-03-2019-0166

Linder, M., Sarasini, S., van Loon, P. (2017). A metric for quantifying product-level circularity. *J. Ind. Ecol.* 21, 545e558. https://doi.org/10.1111/jiec.12552.

Lindgreen, E. R., Salomone, R., & Reyes, T. (2020). A critical review of academic approaches, methods and tools to assess circular economy at the micro level. In *Sustainability (Switzerland)* (Vol. 12, Issue 12). MDPI AG. https://doi.org/10.3390/su12124973

Lucchetti, M. G., Paolotti, L., Rocchi, L., & Boggia, A. (2019). The Role of Environmental Evaluation within Circular Economy: An Application of Life Cycle Assessment (LCA) Method in the Detergents Sector. *Environmental and Climate Technologies*, *23*(2), 238–257. https://doi.org/10.2478/rtuect-2019-0066

Lüdeke-Freund, F., Gold, S., & Bocken, N. M. P. (2019). A Review and Typology of Circular Economy Business Model Patterns. In *Journal of Industrial Ecology* (Vol. 23, Issue 1, pp. 36–61). Blackwell Publishing. https://doi.org/10.1111/jiec.12763

Mandolini, M., Favi, C., Germani, M., Marconi, M. (2018). Time-based disassembly method: how to assess the best disassembly sequence and time of target components in complex products. *Int. J. Adv. Manuf. Technol.* 95, 409-430. https://doi.org/10.1007/s00170-017-1201-5.

Marconi, M., Germani, M., Mandolini, M., Favi, C. (2018). Applying data mining technique to disassembly sequence planning: a method to assess effective disassembly time of industrial products. *Int. J. Prod. Res.* 7543,1-25. https://doi.org/10.1080/00207543.2018.1472404.

Marrucci, L., Daddi, T., & Iraldo, F. (2022). Do dynamic capabilities matter? A study on environmental performance and the circular economy in European certified organisations. *Business Strategy and the Environment*, *31*(6), 2641–2657. https://doi.org/10.1002/bse.2997

Meglin, R., Kliem, D., Scheidegger, A., & Kytzia, S. (2019). Business-models of gravel, cement and concrete producers in Switzerland and their relevance for resource management and economic development on regional a scale. *IOP Conference Series: Earth and Environmental Science*, *323*(1). https://doi.org/10.1088/1755-1315/323/1/012170

Mesa, J., Esparragoza, I., Maury, H. (2018). Developing a set of sustainability indicators for product families based on the circular economy model. *J. Clean.Prod. 196*, 1429-1442. https://doi.org/10.1016/j.jclepro.2018.06.131.

Mestre, A., & Cooper, T. (2017). Circular Product Design. A Multiple Loops Life Cycle Design Approach for the Circular Economy. *The Design Journal*, *20*(sup1), S1620–S1635. https://doi.org/10.1080/14606925.2017.1352686

Mohamed Sultan, A.A., Lou, E., Mativenga, P.T. (2017). What should be recycled: an integrated model for product recycling desirability. *J. Clean. Prod.* 154, 51-60. https://doi.org/10.1016/j.jclepro.2017.03.201.

Moric, I., Jovanovic, J. Š., Dokovic, R., Pekovic, S., & Perovic, D. (2020). The effect of phases of the adoption of the circular economy on firm performance: Evidence from 28 EU countries. *Sustainability (Switzerland), 12*(6). https://doi.org/10.3390/su12062557

Moriguchi, Y. (2007). Material flow indicators to measure progress toward a sound material-cycle society. *Journal of Material Cycles and Waste Management*, *9*(2), 112–120. https://doi.org/10.1007/s10163-007-0182-0

Morseletto, P. (2020). Restorative and regenerative: Exploring the concepts in the circular economy. *Journal of Industrial Ecology*, *24*(4), 763–773. https://doi.org/10.1111/jiec.12987

Murray, A., Skene, K., & Haynes, K. (2017). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*. https://doi.org/10.1007/s10551-015-2693-2

Nakajima, M., Kimura, A., & Wagner, B. (2015). Introduction of material flow cost accounting (MFCA) to the supply chain: A questionnaire study on the challenges of constructing a low-carbon supply chain to promote resource efficiency. *Journal of Cleaner Production*, *108*, 1302–1309. https://doi.org/10.1016/j.jclepro.2014.10.044

Niero, M., Kalbar, P.P. (2019). Coupling material circularity indicators and life cycle based indicators: a proposal to advance the assessment of circular economy strategies at the product level. *Resour. Conserv. Recycl.* 140, 305-312. https://doi.org/10.1016/j.resconrec.2018.10.002.

Niero, M., & Olsen, S. I. (2016). Circular economy: To be or not to be in a closed product loop? A Life Cycle Assessment of aluminium cans with inclusion of alloying elements. *Resources, Conservation and Recycling*, *114*, 18–31. https://doi.org/10.1016/j.resconrec.2016.06.023

Nuñez-Cacho, P., Górecki, J., Molina-Moreno, V., Corpas-Iglesias, F. A. (2018). What gets measured, gets done: development of a Circular Economy measurement scale for building industry. *Sustainability (Switzerland)10(7)*. doi:10.3390/su10072340.

OECD. (2008). *Measuring material flows and resource productivity: Volume I. The OECD Guide*.

Oghazi, P., & Mostaghel, R. (2018). Circular business model challenges and lessons learned-An industrial perspective. *Sustainability (Switzerland)*, *10*(3). https://doi.org/10.3390/su10030739

Ormazabal, M., Jaca, C., & Puga-Leal, R. (2014). Analysis and comparison of life cycle assessment and carbon footprint software. *Advances in Intelligent Systems and Computing*, *281*, 1521–1530. https://doi.org/10.1007/978-3-642-55122-2_131

Pauer, E., Wohner, B., Heinrich, V., Tacker, M. (2019). Assessing the environmental sustainability of food packaging: an extended life cycle assessment including packaging-related food losses and waste and circularity assessment. *Sustainability 11*, 925. doi:10.3390/su11030925.

Pauliuk, S. (2018). Critical appraisal of the circular economy standard BS 8001:2017 and a dashboard of quantitative system indicators for its implementation in organizations. *Resources, Conservation and Recycling*, *129*, 81–92. https://doi.org/10.1016/j.resconrec.2017.10.019

Pauliuk, S., & Heeren, N. (2020). ODYM—An open software framework for studying dynamic material systems: Principles, implementation, and data structures. *Journal of Industrial Ecology*, *24*(3), 446–458. https://doi.org/10.1111/jiec.12952

Peña, C., Civit, B., Gallego-Schmid, A., Druckman, A., Caldeira-Pires, A., Weidema, B., Mieras, E., Wang, F., Fava, J., Canals, L. M. i., Cordella, M., Arbuckle, P., Valdivia, S., Fallaha, S., & Motta, W. (2021). Using life cycle assessment to achieve a circular economy. *International Journal of Life Cycle Assessment*, *26*(2), 215–220. https://doi.org/10.1007/s11367-020-01856-z

Phylipsen, G. J. M., & Alsema, E. A. (1995). Environmental life-cycle assessment of multicrystalline silicon solar cell modules. Utrecht: Department of Science, Technology and Society, Utrecht University.

Pieragostini, C., Mussati, M. C., & Aguirre, P. (2012). On process optimization considering LCA methodology. In *Journal of Environmental Management* (Vol. 96, Issue 1, pp. 43–54). https://doi.org/10.1016/j.jenvman.2011.10.014

Pieroni, M. P. P., McAloone, T. C., & Pigosso, D. C. A. (2019). Business model innovation for circular economy and sustainability: A review of approaches. In *Journal of Cleaner Production* (Vol. 215, pp. 198–216). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2019.01.036

Prieto-Sandoval, V., Jaca, C., Santos, J., Baumgartner, R. J., & Ormazabal, M. (2019). Key strategies, resources, and capabilities for implementing circular economy in industrial small and medium enterprises. *Corporate Social Responsibility and Environmental Management*, *26*(6), 1473–1484. https://doi.org/10.1002/csr.1761

Pryshlakivsky, J., & Searcy, C. (2021). Life Cycle Assessment as a decision-making tool: Practitioner and managerial considerations. In *Journal of Cleaner Production* (Vol. 309). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2021.127344

Reike, D., Vermeulen, W. J. v, & Witjes, S. (2018). Resources , Conservation & Recycling The circular economy : New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. *Resources, Conservation & Recycling*, *135*(August 2017), 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027

Rendemint. (2016). PRP circular e-procurement. Available at: https://www.rendemint.nl/en/circular-e-procurement-tool. Accessed 30.09.21.

ResCoM. (2017a). Circular Pathfinder: identify promising circular design strategies. Available at: https://www.rescoms.eu/platform-and-tools. Accessed 30.09.21.

ResCoM (2017b). Circularity Calculator: quickly compare the potential of different circular design strategies. Available at: https://www.rescoms.eu/platform-and-tools. Accessed 30.09.21.

Rincón-Moreno, J., Ormazábal, M., Álvarez, M. J., & Jaca, C. (2021). Advancing circular economy performance indicators and their application in Spanish companies. *Journal of Cleaner Production*, *279*. https://doi.org/10.1016/j.jclepro.2020.123605

Rizos, V., Behrens, A., van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R., Papadelis, S., Hirschnitz-Garbers, M., & Topi, C. (2016). Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. *Sustainability (Switzerland)*, *8*(11). https://doi.org/10.3390/su8111212

Rochat, D., Binder, C. R., Diaz, J., & Jolliet, O. (2013). Combining material flow analysis, life cycle assessment, and multi attribute utility theory: Assessment of end-of-life scenarios for polyethylene terephthalate in Tunja, Colombia. *Journal of Industrial Ecology*, *17*(5), 642–655. https://doi.org/10.1111/jiec.12025

Rossi, E., Bertassini, A. C., Ferreira, C. dos S., Neves do Amaral, W. A., & Ometto, A. R. (2020). Circular economy indicators for organizations considering sustainability and business models: Plastic, textile and electro-electronic cases. *Journal of Cleaner Production*, *247*. https://doi.org/10.1016/j.jclepro.2019.119137

Sacco, P., Vinante, C., Borgianni, Y., & Orzes, G. (2021). Circular Economy at the Firm Level: A New Tool for Assessing Maturity and Circularity. *Sustainability*, *13*(9) https://doi.org/10.3390/su13095288

Saidani, M., Yannou, B., Leroy, Y., Cluzel, F. (2017.) How to assess product performance in the circular economy? Proposed requirements for the design of a circularity measurement framework. *Recycling 2*, 6.

Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., & Kendall, A. (2019). A taxonomy of circular economy indicators. In *Journal of Cleaner Production* (Vol. 207, pp. 542–559). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2018.10.014

Santa-Maria, T., Vermeulen, W. J. V., & Baumgartner, R. J. (2022). How do incumbent firms innovate their business models for the circular economy? Identifying micro-foundations of dynamic capabilities. *Business Strategy and the Environment*, *31*(4), 1308–1333. https://doi.org/10.1002/bse.2956

Scarpellini, S., Valero-Gil, J., Moneva, J. M., & Andreaus, M. (2020). Environmental management capabilities for a "circular eco-innovation." *Business Strategy and the Environment*, *29*(5), 1850–1864. https://doi.org/10.1002/bse.2472

Scheepens, A.E., Vogtlander, J.G., Brezet, J.C. (2016). Two life cycle assessment (LCA) based methods to analyse and design complex (regional) circular economy systems. Case: making water tourism more sustainable. *J. Clean. Prod.* 114, 257-268. https://doi.org/10.1016/j.jclepro.2015.05.075.

Schoemaker, P. J. H., Heaton, S., & Teece, D. (2018). Innovation, Dynamic Capabilities, and Leadership. *California Management Review*, *61*(1), 15–42. https://doi.org/10.1177/0008125618790246

Schulte, U. G. (2013). New business models for a radical change in resource efficiency. *Environmental Innovation and Societal Transitions*, *9*, 43–47. https://doi.org/10.1016/j.eist.2013.09.006

Schwarz, A. E., Ligthart, T. N., Godoi Bizarro, D., de Wild, P., Vreugdenhil, B., & van Harmelen, T. (2021). Plastic recycling in a circular economy; determining environmental performance through an LCA matrix model approach. *Waste Management*, *121*, 331–342. https://doi.org/10.1016/j.wasman.2020.12.020

Seles, B. M. R. P., Mascarenhas, J., Lopes de Sousa Jabbour, A. B., & Trevisan, A. H. (2022). Smoothing the circular economy transition: The role of resources and capabilities enablers. *Business Strategy and the Environment*, *31*(4), 1814–1837. https://doi.org/10.1002/bse.2985

Sendra, C., Gabarrell, X., & Vicent, T. (2007). Material flow analysis adapted to an industrial area. *Journal of Cleaner Production*, *15*(17), 1706–1715. https://doi.org/10.1016/j.jclepro.2006.08.019

Stanchev, P., Vasilaki, V., Egas, D., Colon, J., Ponsá, S., & Katsou, E. (2020). Multilevel environmental assessment of the anaerobic treatment of dairy processing effluents in the context of circular economy. *Journal of Cleaner Production*, *261*. https://doi.org/10.1016/j.jclepro.2020.121139

Steinmann, Z. J. N., Huijbregts, M. A. J., & Reijnders, L. (2019). How to define the quality of materials in a circular economy? In *Resources, Conservation and Recycling* (Vol. 141, pp. 362–363). Elsevier B.V. https://doi.org/10.1016/j.resconrec.2018.10.040

Suchek, N., Fernandes, C. I., Kraus, S., Filser, M., & Sjögrén, H. (2021). Innovation and the circular economy: A systematic literature review. *Business Strategy and the Environment*, *30*(8), 3686–3702. https://doi.org/10.1002/bse.2834

Teece, D. J. (2007). Explicating dynamic capabilities: The nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal*, *28*(13), 1319–1350. https://doi.org/10.1002/smj.640

Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Planning*, *43*(2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003

Teece, D. J. (2018). Dynamic capabilities as (workable) management systems theory. *Journal of Management and Organization*, *24*(3), 359–368. https://doi.org/10.1017/jmo.2017.75

Teece, D. J., Pisano, G., & Shuen, A. (1997). Dynamic capabilities and strategic management. *Strategic Management Journal*, *18*(7), 509–533.

Testa, F., Nucci, B., Tessitore, S., Iraldo, F., & Daddi, T. (2016). Perceptions on LCA implementation: evidence from a survey on adopters and nonadopters in Italy. *International Journal of Life Cycle Assessment*, *21*(10), 1501–1513. https://doi.org/10.1007/s11367-016-1106-9

Tóth Szita, K. (2017). THE APPLICATION OF LIFE CYCLE ASSESSMENT IN CIRCULAR ECONOMY. *Hungarian Agricultural Engineering*, *31*, 5–9. https://doi.org/10.17676/hae.2017.31.5

Trevisan, A. H., Zacharias, I. S., Liu, Q., Yang, M., & Mascarenhas, J. (2021). Circular economy and digital technologies: A review of the current research streams. *Proceedings of the Design Society*, *1*, 621–630. https://doi.org/10.1017/pds.2021.62

Tsui, T., Peck, D., Geldermans, B., & van Timmeren, A. (2021). The role of urban manufacturing for a circular economy in cities. In *Sustainability (Switzerland)* (Vol. 13, Issue 1, pp. 1–22). MDPI AG. https://doi.org/10.3390/su13010023

Tunn, V. S. C., Bocken, N. M. P., van den Hende, E. A., & Schoormans, J. P. L. (2019). Business models for sustainable consumption in the circular economy: An expert study. *Journal of Cleaner Production*, *212*, 324–333. https://doi.org/10.1016/j.jclepro.2018.11.290

Van Loon, P., Van Wassenhove, L.N. (2018). Assessing the economic and environmental impact of remanufacturing: a decision support tool for OEM suppliers. *Int. J. Prod. Res*. 56, 1662-1674. https://doi.org/10.1080/00207543.2017.1367107.

Van Schaik, A., Reuter, M.A. (2016). Recycling indices visualizing the performance of the circular economy. *World Metall. - ERZMETALL* 69, 201-216

Vanegas, P., Peeters, J.R., Cattrysse, D., Tecchio, P., Ardente, F., Mathieux, F.,Dewulf, W., Duflou, J.R. (2018). Ease of disassembly of products to support circular economy strategies. *Resour. Conserv. Recycl. 135*, 323-334. https://doi.org/10.1016/j.resconrec.2017.06.022.

Veleva, V., Bodkin, G., Todorova, S. (2017). The need for better measurement and employee engagement to advance a circular economy: lessons from Biogen's "zero waste" journey. J. Clean. Prod. 154, 517-529. https://doi.org/10.1016/j.jclepro.2017.03.177.

Velte, C. J., Scheller, K., & Steinhilper, R. (2018). Circular Economy through Objectives - Development of a Proceeding to Understand and Shape a Circular Economy Using Value-focused Thinking. *Procedia CIRP*. https://doi.org/10.1016/j.procir.2017.11.031

Verbene, J. (2016). Building Circularity indicators: an Approach For Measuring Circularity of a Building. Eindhoven University of Technology, Eindhoven, Netherlands. Masters Dissertation.

Vogtlander, J.G., Scheepens, A.E., Bocken, N.M.P., Peck, D. (2017). Combined analyses of costs, market value and eco-costs in circular business models: eco-efficient value creation in remanufacturing. *J. Remanufacturing 7*. https://doi.org/10.1007/s13243-017-0031-9.

Wang, C. L., & Ahmed, P. K. (2007). Dynamic capabilities: A review and research agenda. In *International Journal of Management Reviews* (Vol. 9, Issue 1, pp. 31–51). https://doi.org/10.1111/j.1468-2370.2007.00201.x

Wen, Z., & Meng, X. (2015). Quantitative assessment of industrial symbiosis for the promotion of circular economy: A case study of the printed circuit boards industry in

China's Suzhou New District. *Journal of Cleaner Production*, *90*, 211–219. https://doi.org/10.1016/j.jclepro.2014.03.041

Winans, K., Kendall, A., & Deng, H. (2017). The history and current applications of the circular economy concept. In *Renewable and Sustainable Energy Reviews* (Vol. 68, pp. 825–833). Elsevier Ltd. https://doi.org/10.1016/j.rser.2016.09.123

World Business Council for Sustainable Development (WBCSD). (2020). Circular Transition Indicators V1.0 – metrics for business, by business.

Wójcik, P. (2015). Exploring Links Between Dynamic Capabilities Perspective and Resource-Based View: A Literature Overview. *International Journal of Management and Economics*, *45*(1), 83–107. https://doi.org/10.1515/ijme-2015-0017

Yang, M., Smart, P., Kumar, M., Jolly, M., & Evans, S. (2018). Product-service systems business models for circular supply chains. *Production Planning and Control*, *29*(6), 498–508. https://doi.org/10.1080/09537287.2018.1449247

Zapata-Cantu, L., Delgado, J. H. C., & Gonzalez, F. R. (2016). Resource and dynamic capabilities in business excellence models to enhance competitiveness. *TQM Journal*, *28*(6), 847–868. https://doi.org/10.1108/TQM-03-2014-0030

Zhu, Q., Geng, Y., & Lai, K. (2010). Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications. *Journal of Environmental Management*, *91*(6), 1324–1331. https://doi.org/10.1016/j.jenvman.2010.02.013

Zore, Ž., Čuček, L., Kravanja, Z. (2018). Synthesis of sustainable production systems using an upgraded concept of sustainability profit and circularity. *J. Clean. Prod.* 201, 1138–1154. doi:10.1016/j.jclepro.2018.07.150.

SUMMARY IN LITHUANIAN

GYVAVIMO CIKLO VERTINIMO, MEDŽIAGŲ SRAUTŲ ANALIZĖS IR DINAMINIŲ VERSLO GEBĖJIMŲ RYŠIAI ĮGYVENDINANT ŽIEDINĖS EKONOMIKOS PRAKTIKAS ĮMONĖSE

Karolina KUŽMARSKYTĖ
Magistro darbas
Kokybės vadybos magistro programa
Ekonomikos ir verslo administravimo fakultetas, Vilniaus universitetas
Darbo vadovas prof. dr. Dalius Serafinas, Vilnius, 2023

99 puslapiai, 8 paveikslai, 14 lentelių, 4 priedai ir 185 šaltiniai.

Magistro darbo tikslas – nustatyti gyvavimo ciklo vertinimo (GCV), medžiagų srautų analizės (MSA) ir dinaminių verslo gebėjimų (DVG) sąsajas įgyvendinant žiedinės ekonomikos (ŽE) praktikas įmonėse bei gerinant su ŽE susijusius įmonių veiklos rezultatus. Konkretūs darbo uždaviniai buvo šie:

1. Sukurti konceptualų tyrimo modelį, teoriniu aspektu nagrinėjant žiedinės ekonomikos, gyvavimo ciklo vertinimo, medžiagų srautų analizės ir dinaminių verslo gebėjimų sąvokas.
2. Sukurti tyrimo metodologiją, skirtą išanalizuoti, kaip GCV ir MSA naudojimas susijęs su žiedinės ekonomikos praktikų įgyvendinimu įmonėse, remiantis dinaminių verslo gebėjimų sistema.
3. Surinkti ir išanalizuoti duomenis, apibūdinančius, kaip GCV ir MSA naudojimas susijęs su žiedinės ekonomikos praktikų įgyvendinimu įmonėse, remiantis dinaminių verslo gebėjimų sistema.
4. Sukurti teorinį modelį, apibrėžiantį GCV ir MSA naudojimo sąsajas su žiedinės ekonomikos praktikų įgyvendinimu įmonėse, remiantis dinaminių verslo gebėjimų sistema.

Pagrindiniai darbe naudoti metodai, kuriais buvo siekiama tyrimo uždavinių: mokslinės literatūros analizė ir sisteminė apžvalga, pusiau struktūruoti interviu su ekspertais, kokybinių duomenų nuolatinio palyginimo analizė, taikant teorijas, susijusias su DVG, ŽE ir nuolatiniu tobulinimu, taip pat duomenų apjungimo ir apibendrinimo metodai.

Remiantis duomenimis, gautais atlikus 11 interviu su verslo konsultantais-ekspertais, ir papildomais literatūros šaltiniais, buvo sukurtas teorinis modelis, apibrėžiantis gyvavimo ciklo vertinimo, medžiagų srautų analizės ir dinaminių verslo gebėjimų, skirtų žiedinės ekonomikos

praktikų įgyvendinimui įmonėse, ryšius. Pagrindinės šio darbo išvados yra šios: 1) GCV ir MSA metodų naudojimas stiprina įmonių gebėjimus nustatyti naujas verslo galimybes, susijusias su ŽE praktikų įgyvendinimu, analizuojant vidinius įmonių procesus, ir gerina jų gebėjimus planuoti ir transformuoti esamus procesus, pasinaudojant naujomis tobulinimo galimybėmis; 2) GCV ir MSA sustiprinti DVG padeda įmonėms įveikti barjerus, ribojančius ŽE praktikų įgyvendinimą ir apimančius su strateginiu planavimu, verslo modelio valdymu ir inovacijomis bei bendradarbiavimu susijusius aspektus, taip pat DVG skatina spartesnį organizacinį ir technologinį atnaujinimą bei žinių integraciją; 3) šiame kontekste įmonėse dažniausiai yra diegiamos efektyvesnio išteklių naudojimo ir žiedinio gaminių projektavimo praktikos bei gerėja atitinkamai susiję organizaciniai veiklos rezultatai; 4) įmonių suinteresuotumas išlaikyti ilgalaikį konkurencingumą rinkoje (stiprių DVG požymis) skatina jas reguliariai naudoti aplinkosauginio vertinimo priemones (GCV ir MSA), siekiant geriau reaguoti į kintančius rinkos poreikius ir reguliavimą žiedinės ekonomikos srityje.

Pagrindiniai šio tyrimo rezultatai buvo pristatyti ir aptarti Lietuvos inovacijų centre – inovacijų paramos paslaugas įmonėms teikiančioje organizacijoje.

Reikšminiai žodžiai: žiedinė ekonomika, gyvavimo ciklo vertinimas, medžiagų srautų analizė, dinaminiai verslo gebėjimai.

SUMMARY IN ENGLISH

RELATIONS BETWEEN LIFE CYCLE ASSESSMENT, MATERIAL FLOW ANALYSIS, AND DYNAMIC BUSINESS CAPABILITIES FOR CIRCULAR ECONOMY IMPLEMENTATION IN COMPANIES

Karolina KUŽMARSKYTĖ
Master thesis
Quality Management Master Programme
Faculty of Economics and Business Administration, Vilnius University
Supervisor prof. dr. Dalius Serafinas, Vilnius, 2023

99 pages, 8 figures, 14 tables, 4 annexes, and 185 references.

The aim is this Master thesis was to identify the relations between the use of life cycle assessment (LCA), material flow analysis (MFA) and the enhancement of dynamic business capabilities (DBCs) for the implementation of circular economy (CE) practices and related performance improvement in companies. Specific objectives of the work were:

1. To develop a conceptual research model by theoretically investigating the concepts of circular economy, life cycle analysis, material flow analysis, and dynamic business capabilities.
2. To establish a research methodology aimed at analysing how the use of LCA and MFA is associated to the implementation of circular economy practices in companies, based on a dynamic business capabilities framework.
3. To collect and analyse data determining how the use of LCA and MFA is associated to the implementation of circular economy practices in companies, based on a dynamic business capabilities framework.
4. To create a theoretical model defining the relations between the use of LCA and MFA and the implementation of circular economy practices in companies within a dynamic business capabilities framework.

The main methods used to achieve the objectives were: analysis and systematic review of scientific literature, semi-structured expert interviews, constant comparison analysis of qualitative data by applying theories related to DBCs, CE, and continuous improvement, as well as data synthesis and generalisation techniques.

Based on the results from 11 interviews with business consultants – experts and supporting evidence from the literature, a theoretical model defining the relations between life cycle assessment, material flow analysis, and dynamic business capabilities for circular

economy implementation in companies was developed. Key conclusions derived from the work are: 1) the use of LCA and MFA strengthens companies' capabilities to identify new business opportunities related to CE practice implementation through the analysis of internal company characteristics, and enhances the capabilities to plan and transform existing processes while taking the advantages of new improvement opportunities; 2) LCA and MFA enhanced DBCs enable companies to overcome barriers to the implementation of CE practices, covering aspects of strategic planning, business model governance, innovation, and collaboration, as well as organisational restructuring, technological upgrading, and knowledge integration; 3) in this context, more resource-efficient and circular design practices are commonly implemented in companies leading to improvements in related organizational performance; 4) companies' focus on long-term competitiveness in the market (attribute of strong DBCs) inclines them to the regular use of environmental assessment instruments (LCA and MFA) in order to better respond to changing market needs and regulations in the CE field.

The main results of the study were presented and discussed at the Lithuanian Innovation Centre, an organisation providing innovation support services for companies.

Keywords: circular economy, life cycle assessment, material flow analysis, dynamic business capabilities.

ANNEXES

Annex 1. The inventory of investigated circular economy performance indicators and assessment methods

Table 10. Circular economy performance indicators and assessment methods (compiled by the author)

Year	CE indicator	Scale	Sectorial focus	Life cycle approach	Sustainability direction	Type*	Primary source	Secondary source
2016	Circularity Calculator	Product	No	End of life	ENV	2	IDEAL&CO Explore (2016)	De Pascale et al. (2021); Kristensen & Mosgaard (2020)
2016	Material Reutilization Score	Product	No	End of life	ENV	1	Cradle to Cradle Products Innovation Institute (2016)	De Pascale et al. (2021); Kristensen & Mosgaard (2020)
2016	Eco-cost Value Ratio	Product	No	All	ECO	1	Scheepens et al. (2016)	De Pascale e et al. (2021); Kristensen & Mosgaard (2020), Saidani et al. (2019)
2016	Resource Duration Indicator	Product	No	Consumption, end of life	ENV	1	Franklin-Johnson et al. (2016)	De Oliveira et al. (2021); De Pascale et al. (2021); Kristensen & Mosgaard (2020), Saidani et al. (2019)
2016	End of Life Best Practice Indicators	Product	No	End of life	SOC, ECO, ENV	3	Jiménez-Rivero and García-Navarro (2016)	De Oliveira et al. (2021)
2016	PRP Circular e-Procurement Tool (PRP) and The ReNtryR© - module	Company	No	Production	ENV	2	Rendemint (2016)	De Oliveira et al. (2021)
2016	Recycling Index	Product	No	End of life	ENV	1	Van Shaink and Reuter (2016)	De Oliveira et al. (2021); De Pascale et al. (2021); Kristensen & Mosgaard (2020), Saidani et al. (2019)

2016	Building Circularity Indicators	Product	Yes	All	ECO, ENV	3	Verbene (2016)	De Oliveira et al. (2021); Saidani et al. (2019)
2017	Global Resource Indicator	Product	No	Production, end of life	ENV, SOC	1	Adibi et al. (2017)	De Pascale et al. (2021)
2017	Sustainable Circular Index	Company	No	All	SOC, ECO, ENV	3	Azevedo et al. (2017)	De Oliveira et al. (2021); De Pascale et al. (2021); Saidani et al. (2019)
2017	Input-Output Balance Sheet	Product	Yes	All	ECO, ENV	2	Capellini (2017)	De Oliveira et al. (2021)
2017	Circular Economy Indicator Prototype	Product	No	All	ENV	3	Cayzer et al. (2017)	De Oliveira et al. (2021); De Pascale et al. (2021); Kristensen & Mosgaard (2020)
2017	Circularity Index	Product	No	All	ENV	1	Cullen (2017)	De Oliveira et al. (2021); Saidani et al. (2019)
2017	Value-based Resource Efficiency Indicator	Product	No	Production	ECO	1	Di Maio et al. (2017)	De Pascale e et al. (2021); Kristensen & Mosgaard (2020), Saidani et al. (2019)
2017	End-of-life Indices (Design Methodology)	Product	No	End of life	ECO, ENV	3	Favi et al. (2017)	De Oliveira et al. (2021); De Pascale et al. (2021); Kristensen & Mosgaard (2020)
2017	Circular Economic Value	Product	No	Production, consumption	ENV	2	Fogarassy et al. (2017)	De Oliveira et al. (2021); Saidani et al. (2019)
2017	Synthetic Economic Environmental Indicator	Product	Yes	All	ECO, ENV	1	Fregonara et al. (2017)	De Pascale et al. (2021)
2017	Circular Economy Performance Indicator	Product	No	End of life	ENV	1	Huysman et al. (2017)	De Oliveira et al. (2021); De Pascale et al. (2021); Saidani et al. (2019)
2017	Minesite MFA Indicator	Company	No	All	ECO, ENV	1	Lèbre et al. (2017)	De Oliveira et al. (2021)

2017	Product-level Circularity Metric	Product	No	Production, end of life	ECO	1	Linder et al. (2017)	De Pascale e et al. (2021); Kristensen & Mosgaard (2020), Saidani et al. (2019)
2017	Recycling Desirability Index	Product	No	End of life	ENV	1	Mohamed Sultan et al. (2017)	De Oliveira et al. (2021); De Pascale et al. (2021); Kristensen & Mosgaard (2020)
2017	Circular Pathfinder	Company	No	Production	SOC, ECO, ENV	2	ResCoM (2017a)	De Oliveira et al. (2021); Saidani et al. (2019)
2017	Circularity Calculator	Product	No	Production, end of life	ECO, ENV	2	ResCoM (2017b)	De Oliveira et al. (2021); De Pascale et al. (2021); Saidani et al. (2019)
2017	Model of Expanded Zero Waste Practice	Company	No	End of life	SOC, ECO, ENV	2	Veleva et al. (2017)	Kristensen & Mosgaard (2020)
2017	Eco-efficient Value Creation	Product	No	End of life	ECO, ENV	3	Vogtlander et al. (2017)	Kristensen & Mosgaard (2020)
2017	Circularity Potential Indicator	Product	No	All	ENV	2	Saidani et al., (2017)	Saidani et al. (2019)
2017	Hybrid LCA Model	Product	No	All	ENV	1	Genovese et al., (2017)	Saidani et al. (2019)
2018	Product Recovery Multi-criteria Decision Tool	Product	No	End of life	SOC, ECO, ENV	2	Alamerew and Brissaud (2018)	De Oliveira et al. (2021); Kristensen & Mosgaard (2020)
2018	Material Efficiency in Supply Chains Spread sheets	Company	No	Production	ENV	3	Braun et al. (2018)	De Oliveira et al. (2021)
2018	Circular Gap	Both	No	All	ECO, ENV	2	Circle Economy (2018)	De Oliveira et al. (2021)
2018	Longevity and Circularity	Product	No	Consumption, end of life	ENV	2	Figge et al. (2018)	De Oliveira et al. (2021); De Pascale et al. (2021); Kristensen & Mosgaard (2020)

2018	Circularity Assessment Model	Company	No	End of life	ECO, ENV	2	Giacomelli et al. (2018)	De Oliveira et al. (2021)
2018	Evaluation Index System of CE for PCFs	Company	No	All	ENV	3	Liang et al. (2018)	De Oliveira et al. (2021)
2018	Effective Disassembly Time	Product	No	End of life	ECO	1	Marconi et al. (2018) Mandolini et al. (2018)	De Pascale et al. (2021); Kristensen & Mosgaard (2020)
2018	Sustainability Indicators in CE	Product	No	All	ENV	3	Mesa et al. (2018)	Kristensen & Mosgaard (2020)
2018	Sustainability Performance Indicators	Product	No	End of life	SOC, ECO, ENV	3	Mesa et al. (2018)	De Oliveira et al. (2021); De Pascale et al. (2021)
2018	Circular Economy Measurement Scale	Company	No	Production, end of life	ENV	2	Nuñez-Cacho et al. (2018)	De Oliveira et al. (2021)
2018	Systems Indicators for Circular Economy Dashboard	Both	No	All	SOC, ECO, ENV	3	Pauliuk (2018)	De Oliveira et al. (2021)
2018	Economic-Environmental Remanufacturing	Product	No	End of life	ECO, ENV	2	van Loon and van Wassenhove (2018)	De Oliveira et al. (2021); Kristensen & Mosgaard (2020)
2018	Ease of Disassembly Metric	Product	No	End of life	ECO	1	Vanegas et al. (2018)	De Pascale et al. (2021); Kristensen & Mosgaard (2020)
2018	Material and Energy Circularity Indicators	Company	No	Production, end of life	ENV	3	Zore et al. (2018)	De Oliveira et al. (2021)
2019	Mathematical Model to Assess Sustainable Design and End-of-life Options	Product	No	Production, end of life	SOC, ECO, ENV	2	Ameli et al. (2019)	Kristensen & Mosgaard (2020)

2019	Design Method for End-of-use Product Value Recovery	Product	No	End of life	ECO	2	Cong et al. (2019)	De Pascale et al. (2021); Kristensen & Mosgaard (2020)
2019	Circularity Check	Both	No	All	ECO, ENV	2	Ecopreneur (2019)	De Oliveira et al. (2021)
2019	Circularity Measurement Toolkit	Company	No	All	ECO, ENV	2	Garza-Reyes et al. (2019)	De Oliveira et al. (2021)
2019	Circular Economy Benefit Indicators	Company	No	End of life	ENV	3	Huysveld et al. (2019)	De Oliveira et al. (2021)
2019	Typology for Quality Properties	Company	No	Production	ENV	2	Iacovidou et al. (2019)	Kristensen & Mosgaard (2020)
2019	Assessment of Circular Economy Strategies at the Product Level	Product	No	All	ENV	2	Niero and Kalbar (2019)	De Oliveira et al. (2021); Kristensen & Mosgaard (2020)
2019	Environmental Sustainability of Food Packaging indicators	Product	Yes	All	ENV	3	Pauer et al. (2019)	De Oliveira et al. (2021)
2019	Circularity of Material Quality	Product	No	Production, end of life	ENV	2	Steinmann et al. (2019)	De Oliveira et al. (2021)
2020	Multi-Criteria Evaluation Method of Product-Level Circularity Strategies	Product	No	End of life	SOC, ECO, ENV	3	Alamerew et al. (2020)	De Oliveira et al. (2021)
2020	Product Circularity Improvement Program	Product	No	All	ECO	2	Circularity IQ and KPMG (2020)	De Oliveira et al. (2021)
2020	Circulytics	Company	No	All	ECO, ENV	2	EMF (2020)	De Oliveira et al. (2021)

2020	Circular Business Model Set of Indicators based on Sustainability	Both	No	All	SOC, ECO, ENV	3	Rossi et al. (2020)	De Oliveira et al. (2021)
2020	Circularity Transition Indicators	Company	No	All	ECO, ENV	3	WBCSD (2020)	De Oliveira et al. (2021)
*1) single quantitative indicator 2) analytical tool 3) composite indicator set								

Annex 2. Types of categorizations of DBCs applied in previous research within circular economy topic

Table 11. Categorization of DBCs by Prieto-Sandoval et al. (2018)

Category of DBCs	Identified capabilities
Sensing	• Access to stakeholders' information • Research and development
Seizing	• Improvement of the business models • Ability to create a "green" culture • Ability to train and increase workers' ability to propose improvements • Capability to transform obsolete jobs into new employment
Transforming	• Leader's vision and environmental awareness • Capacity to design and reconfigure sustainable business models • Knowledge management and development

Table 12. Categorization of DBCs by Santa-Maria et al. (2020)

Category of DBCs	Identified micro foundations	Identified practices (i.e., skills, processes, procedures, and activities)
Sensing	External sensitivity	• Understanding the needs of customers and key stakeholders • Being open for external expert support • Leverage developments of exogenous science and technology
	Adopting holistic perspectives	• Adopting a lifecycle perspective • Adopting a systemic perspective
	Knowledge creation	• Undertaking R&D activities
	Use of sustainability-oriented instruments	• Implementing environmental management tools (e.g., LCA, ISO14000, and Sustainability Reporting) • Guidance from sustainability frameworks (e.g., SDGs, FSSD, C2C, Doughnut, and Biomimicry)
Seizing	Delineating sustainable solutions and business models	• Ideating and developing value propositions with environmental and/or social impact • Designing and implementing the (sustainable/circular) business model • Generating business model architectures that can transform socio-technical systems
	Stakeholder engagement & collaboration	• Engaging strategic partners in collaboration and co-creation • Engaging customers early in the innovation process • Engaging an interdisciplinary team to participate in the innovation process
	Supporting a sustainability & innovation culture	• Articulating a clear and ambitious sustainability vision • Developing a sustainability strategy and culture • Developing and supporting an innovation and continuous improvement culture • Educating workers in sustainability and empowering them to propose innovations

Continuation of Table 12

Transforming	Co-specialization of assets	• Prioritizing strategic fit of resources and capabilities
	Organizational flexibility	• Implementing experiments/pilots to validate, learn, and adapt quickly • Build decentralized (sustainability oriented) innovation teams and allow flexible organizational structures
	Trust-building communication	• Having a fact-based consistent and transparent external communication
	Ecosystem orchestration	• Skills to integrate stakeholders and coordinate partners in the business ecosystem
	Leadership and change management capabilities	• Commitment and support from top management (key role of leadership) • Proficiency at organizational change management • Implementing specific sustainable and circular KPI's

Table 13. Categorization of DBCs by Khan et al. (2020)

Category of DBCs	**Indicators**
Sensing	• Identification of customer needs • Tracking new market trends • Analysing competitors' actions • Observing technological developments • Organizing brainstorming sessions • Involving customers / suppliers in the product development process • Undertaking R&D to create new knowledge for developing new products / processes • Undertaking R&D to try out new ideas having strategic / operational implication • Assessing potential environmental impacts of products / processes / services • Networking with public organizations / industrial associations / universities / others
Seizing	• Formulation of a strategy • Finding strategic partners • Planning investments • Capital budgeting • Planning requisite human resources • Redesigning / transforming business models • Restructuring of governance structure • Collaboration to acquire requisite knowledge / skills • Collaboration to acquire requisite raw materials / resources • Interdepartmental cooperation
Transforming	• Merger with or acquisition of another organization • Changed organizational structure • Made slight modifications in existing technology / machinery • Introduced new or significantly improved technology • Acquisition of a new manufacturing plant • Organized training to employees • Acquisition of existing know-how • Adopted new business practices for organizing procedures • Adopted new methods of organizing external relations • Adopted new or significantly improved logistics

Annex 3. Operationalisation and encoding logic of interview data

Table 14. Operationalisation and encoding logic of interview data (compiled by author)

Variable	**Key notions describing the variable (coding)**	**Sources**
The use of LCA	• Purposeful LCA implementation based on ISO 14040:2006 standard procedures • Computation of LCA calculations for a material, component, product, or a project using existing software programmes (e.g., SimaPro, GaBi, etc.)	International Organization for Standardization (2006a) Ormazabal et al. (2014)
The use of MFA	• Purposeful MFA implementation – calculations of physical flows of natural resources and materials into, through and out of a given system (i.e., company or its process), based on a mass balancing principle	OECD (2008)
DBCs	Sensing: • Identification of customer needs • Tracking new market trends • Analysing competitors' actions • Observing technological developments • Organizing brainstorming sessions • Involving customers/suppliers in the product development process • Undertaking R&D to create new knowledge for developing new products/processes • Undertaking R&D to try out new ideas having strategic/operational implication • Assessing potential environmental impacts of products/processes/services • Networking with public organizations/industrial associations/universities/others Seizing: • Formulation of a strategy • Finding strategic partners • Planning investments • Capital budgeting • Planning requisite human resources • Redesigning/transforming business models • Restructuring of governance structure • Collaboration to acquire requisite knowledge/skills • Collaboration to acquire requisite raw materials/resources • Interdepartmental cooperation Transforming: • Merger with or acquisition of another organization • Changed organizational structure • Made slight modifications in existing technology/machinery • Introduced new or significantly improved technology • Acquisition of a new manufacturing plant • Organized training to employees • Acquisition of existing know-how • Adopted new business practices for organizing procedures • Adopted new methods of organizing external relations • Adopted new or significantly improved logistics	Khan et al. (2020b)

Continuation of Table 14

Implementation of CE practices	• Designing and producing products to be easily repaired/refurbished • Designing and producing products to be easily biodegradable/recyclable • Designing and producing products with recycled/renewable inputs • Utilizing biodegradable/recyclable packaging • Using closed loops in the production • Increasing material and energy efficiency of processes • Transferring/selling by-products to other organizations • Providing repairing/refurbishing services to customers • Collecting end-of-life products • Reusing by-products/recycled materials from other organizations	Khan et al. (2020b)
Change in CE related organizational performance	• Reduced energy consumption/increased energy use efficiency • Reduced waste generation • Decreased material consumption/increased material use efficiency • Decreased manufacturing/operational costs • Improved quality of products/services • Increased capability to introduce innovative products/services	Khan et al. (2020b)

Annex 4. Confirmation of dissemination of work results

LIETUVOS
INOVACIJŲ
CENTRAS

2023-01-06
Vilnius

Dėl pristatyto tyrimo „GYVAVIMO CIKLO VERTINIMO, MEDŽIAGŲ SRAUTŲ ANALIZĖS IR DINAMINIŲ VERSLO GEBĖJIMŲ RYŠIAI ĮGYVENDINANT ŽIEDINĖS EKONOMIKOS PRAKTIKAS ĮMONĖSE" rezultatų

2023 m. sausio 5 d. Karolinos Kužmarskytės pristatyti tyrimo rezultatai pasižymi aktualumu atspindint vieną iš dvigubos pramonės transformacijos elementų – perėjimą prie klimatui neutralios ir žiedinės ekonomikos. Šios transformacijos metu įmonėms svarbu ne tik išlikti konkurencingoje rinkoje, bet ir gebėti prisitaikyti prie vis griežtėjančių reguliacinių reikalavimų ar naujai besiformuojančių klientų poreikių. Todėl pristatytas požiūris į įmonių gebėjimus tikslingai išnaudoti aplinkosauginius matavimo instrumentus (LCA ir MFA) ir turimus vidinius resursus formuojant naujus vertės pasiūlymus yra matomas kaip diskusiją apie rinkoje pastebimus pokyčius praturtinantis argumentas.

Tyrimo rezultatai taip pat vertingi nagrinėjant inovacijų skatinimo įmonėse klausimą. Matoma, kad žiedinių ir aplinkai palankių inovacijų kūrimui ir diegimui didelę reikšmę turi įmonių gebėjimas įsivertinti vidinių procesų poveikį aplinkai ir ieškoti tvaresnių technologijų, produktų ar žaliavų alternatyvų. Ši įžvalga formuoja poreikį peržiūrėti ir atnaujinti verslo paramos organizacijų teikiamas paslaugas, siekiant kuo geriau atliepti verslo poreikius dvigubos transformacijos metu.

Direktorius Dr. Mantas Vilys

Mokslininkų g. 6A, LT-08412 Vilnius, tel. (8 ~ 5) 235 61 16, faks. (8 ~ 5) 213 27 81 | lic@lic.lt
Duomenys kaupiami ir saugomi Juridinių asmenų registre, kodas 110066875 www.lic.lt