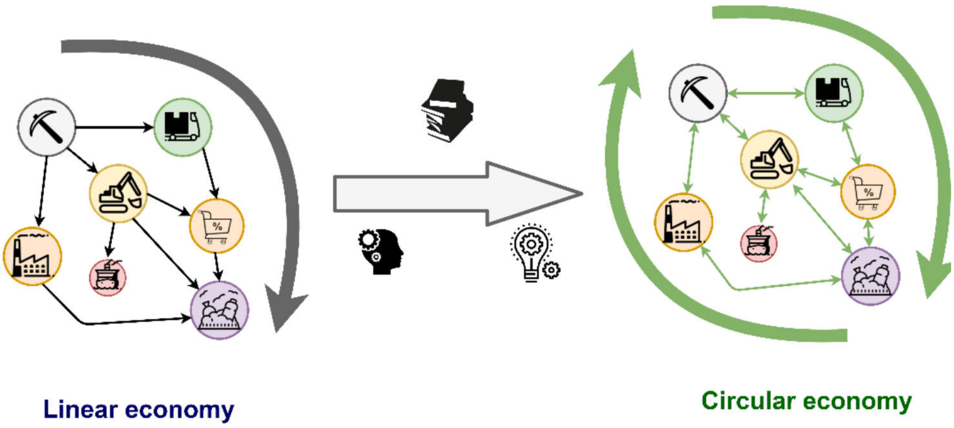
DEGREE PROJECT

Competitive Business framework design toward the circular economy

Kianoosh Amoorizi Varnamkhasti



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Business framework design toward the circular economy

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Acknowledgments

One of the great challenges in this world is knowing enough about a subject to think you are right but not enough about the subject to know you are wrong.

Neil Degrasse Tyson

I would first like to thank my thesis supervisor Prof. Yousef Ghorbani. His office door was always open whenever I ran into a difficult spot or had a question about my research or writing. Although he gave me the freedom to work, he steered me in the right direction whenever he thought I needed it. I am delighted that I had such a memorable experience to study and research under his supervision. I hope I have the chance to work with him again.

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Abstract

One of the main challenges the world is facing is resource management. Resources are not summarized in land resources and covers environmental resources (biodiversity) and human resources. Since most of them are non-reproducible or at least hard to restore, the ways they are extracted or used need to change. Otherwise, the current trend makes the future condition perilous.

The human population and their needs are continuously are growing while the resources are limited, and this limitation cause to bold the necessity of resource management. Many attempts have been made to make a fundamental change. While the most comprehensive one can be applying a concept of sustainable development and its sub-branch, circular economy. We are living in a world that was built on the linear economy concept. The concept consists of take, make, dispose. This manner was practical; however, resource scarcity forces us to change it and brought a new concept to the picture known as the circular economy concept. The circular economy means keeping the material and energy in the circuit. In other words, keep them more in the use phase or take-bake them to the production stage instead of sending them to landfills, which is the last station in the linear economy.

While this change is unavoidable, there is not any clear roadmap to follow. Many attempts have been made, but most are general, which lacks the practicality to apply. This study is started by scanning the available models for transforming business toward a more circular condition. Through the process, gaps in literature were found and tried to cover them by proposing a comprehensive framework. The framework incorporates the entire business ecosystem to change from the current linear situation to a circular one. The proposed framework has unique features such as a clear business ecosystem determination technique, quantitative criteria rather than qualitative ones. It also used the actual successful business records, businesses that had remarkable achievements in following circular economy concepts while staying profitable.

It starts from determining the business ecosystem's boundaries, then finding the critical points (gaps) that get the ecosystem far from circularity. The process is continued by resolving the found gaps based on actual records of successful business in the circular economy. At the

same time, this step needs to establishing a database of prosperous companies and finding patterns throughout their records. Then, the found patterns are customized and prioritize for the target ecosystem and apply. In the following, the proposed framework was used for the laptop ecosystem to validify the framework. In the laptop case, three different scenarios came up. Each one targets to solve some current issues in laptop industries that take them far from a sustainable condition. The first scenario is insisting on extending use by assigning some processing tasks to separate remote centers. This can make recycling and waste classification easier also help create better conditions for sharing the laptops or their parts. The second scenario is base on providing new standards to facilitate waste management and recycling. The last scenario targets issues in returning the end-of-life laptops and concerns relate to reverse logistics. The scenario suggests using the internet of things concept to satisfy the mentioned issues.

Chapter 1 Introduction

1.1 Background

These days by increasing the world population and the rise of the middle-class, we face higher demand for raw materials. While resources are limited and become depleted during time by extraction. Consequently, there was a need for an efficient solution to cope with this resource limitation. A fundamental solution is to increase efficiency and, on the other hand, decrease the demand for raw materials.

Sustainability or sustainable use of resources is the central solution that has been quoted recently. There is not a worldwide accepted definition for sustainability. However, it can be considered a stable interaction of population and the associated system's carrying capacity; considering that the system can be varied from a small farm to a city and Beyond that (Ben-Eli, 2018). A practical way toward sustainability is to design businesses in a direction that uses the resources more efficiently. In other words, keep the material in the use phase for a longer time and take them back to the production stage as more as possible, which knows as the circular economy concept (Bocken *et al.*, 2014). Nonetheless, the complexity of the businesses and the difficulty of changing their structure toward the CE concept requires a practical roadmap and framework; A comprehensive framework for redesigning them.

In between, Jackson (2009) recommends some approaches that can be summarized in three main one:

- Establish the limitation to protect the generation capacity of the earth's ecosystem;
- Modifying the businesses to make the long-term change in the demand profile; and
- Changing the social logic to affect the long-term trend of market demand, which directly influences resource consumption.

Thus, most proposed approaches to transferring toward sustainable development track one or more of the above recommendations. Later Bocken (2014), based on Jackson's (2009) works, describes an ideal system through six guild lines.

- A system that encourages to reduce and minimize material and energy consumption;

- A system that sets its main target to maximizing social and environmental benefits rather than the economic ones;
- A system that minimizes waste generation through different ways such as recycling, repairing, etc.;
- A function-oriented system rather than product-oriented. Means emphasize delivering the service even without the physical product or without the product's ownership transition;
- A system designed to provide humans with satisfying work experience and improve their creativity and skills; and
- A system was built on collaboration and synergy rather than a harmful competition environment.

Research on providing a straightforward way toward a sustainable system was sought through different areas, from changing social norms (Parajuly *et al.*, 2020) to technical innovation and devising new business models (Pieroni, 2019). Nevertheless, most of the efforts summarized the second recommendation and focused on modifying business models as a pivotal key to fit social and environmentally sustainable systems (Lüdeke-Freund, 2010; Foss and Saebi, 2016).

Some new concepts came up through these studies, such as the business ecosystem, which tried to look at businesses in a complex network rather than individual units. This concept provided an excellent base to look at the problem holistically and provide more practical solutions. Before that, most researchers assessed the businesses individually that led to delivering limited unpractical solutions. Based on the definition presented by Adner and Kapoor (2010), the business ecosystem is a complex value-oriented network of stakeholders with transactions in between. While, Stakeholders are groups of individuals who can influence or be influenced by the organization's actions (Freeman, 1984). Pfitzer and Kramer (2016) also proposed that the businesses' capacities are redefined through the business ecosystem to facilitate value generation for the whole ecosystem rather than a single business unit.

Every system needs to be evaluated, and it necessitates criteria and indicators. Applying transition methods toward more sustainable conditions is not exceptional and also requires these evaluations as well. Thus, many indicators were proposed that targeted different sustainability aspects, from environmental impact to resource preservation (EMF, 2016; Pauliuk, 2018a). One of the most well-known is life cycle assessment (LCA), which monitors the process's environmental impact (ISO 14040/14044, 2006). However, it is necessary to have more comprehensive indicators that evaluate all the aspects (Elia et al. 2017). Although some more wide-ranging indicators such as the material circularity indicator (EMF, 2016) emerged, a long way remains to have comprehensive ones that can evaluate more than one or few environmental, social, and economic impacts.

1.2 Problem statement

To fulfill the need for new circular business models (CBM), many frameworks have been introduced (Bocken *et al.*, 2014). However, most of them suffer two main weaknesses that are comprehensiveness and practicality.

Comprehensiveness: the problem of sustainable development is not limited to a specific field. It is a world matter which involves all aspect of our civilization. In fact, the comprehensive models should cover any areas from producing goods to providing services. But based on the fact that each of performed research has been done in a specific case, none of them have the needed comprehensiveness which expected (Mont, 2002; Pearce, 2009; Bocken *et al.*, 2014). The models are even sensitive to the system's size, which can vary from small to medium-size enterprises (SME) to large business ecosystems. Although some studies have been done on individual business units (Guldmann and Huulgaard, 2020), the ecosystem remains untouched.

A reason maybe is the lack of a clear understanding of the business ecosystem. The business ecosystem has not been presented by a clear definition and, consequently, any boundary-determining criterion. Although it is evident that it is impractical to provide an isolated group of connected business units as a business ecosystem, it still needs to have a limitation criterion to separate them from the rest; otherwise, it will encompass all the existence. Currently, it is somehow based on the researcher's opinion that where the ecosystem boundaries will be.

Practicality: frameworks should provide explicit instruction to apply and consider a correct view of business units in a network. Research on providing a framework to transform toward circular economy or sustainable development rarely has reached a clear and detailed framework. It can be caused by either the short history of the concept or the vast area of its coverage. To actualize the next step toward the circular economy and Sustainable Development, it's unavoidable to overcome this deficiency and introduce more practical frameworks to implement.

Given these points, although it's possible to find a framework that satisfies one of the mentioned deficiencies, the lack of a framework covering both parts is highly felt.

1.3 Thesis structure

This study is conducted in seven main chapters to provide a business model framework compatible with the Circular Economy concept. The **Introduction** chapter provides background information and explains existing problems. In the **Literature review**, firstly, the concepts and methods have been reviewed. Later in this chapter, the available business models are mentioned and tried to pinpoint their prominent features. **Methodology** focuses on generating a suitable model. In this chapter, more compatible models are selected. Later, some features are proposed for the parts that do not cover. The final step in this chapter is the combination part. In this part, all the available and suggested features and functions are arranged in a single business model framework. Further, the study is followed by a **Case study**. In case study chapter, the created business model framework is used for a specific case that is laptops here. Finally, in the **Result and discussion,** the outcomes are explained. The **EIT chapter** follows the chapter to look at the study in view of innovation. The document is finalized by **Conclusion and recommendation**. Figure 1 illustrate the structure of thesis in a straightforward way.

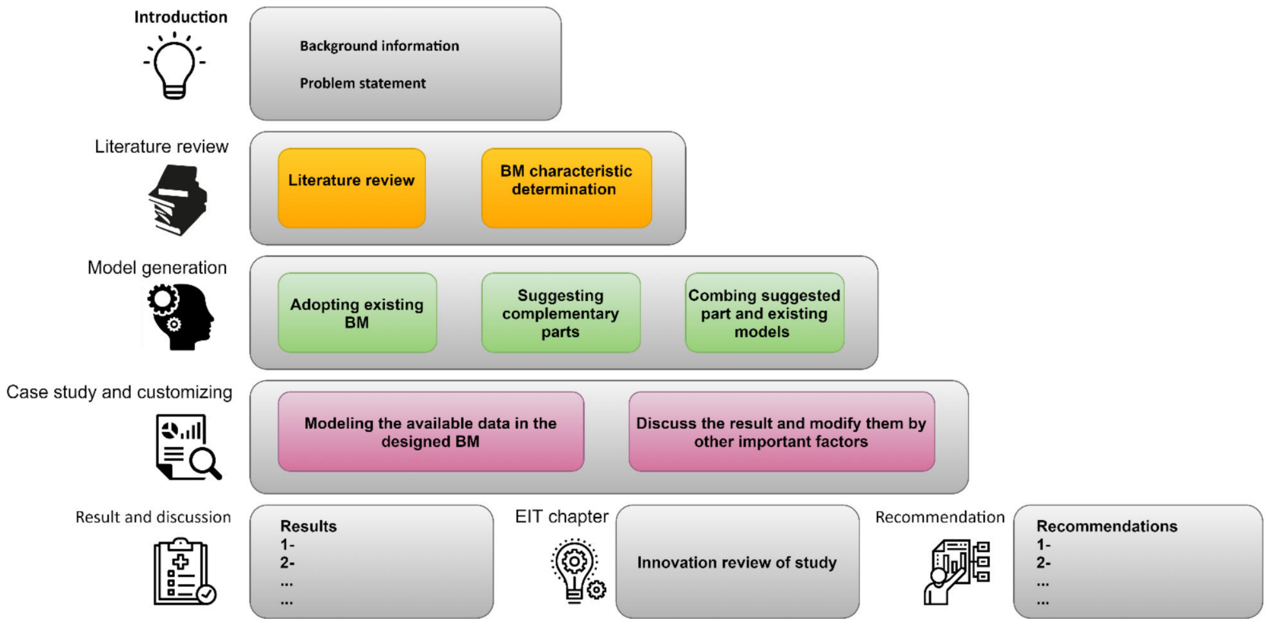


Figure 1. A schematic of the structure and content of the thesis

Chapter 2 Literature review

2.1 Circular economy and sustainable material-flow

By increasing population and their required needs, it is estimated by 2050; the earth will host around 9 billion people that need three times more resources compared to the current demand (Prosekov and Ivanova, 2018). Thus, the linear economic model, which traditionally follows the "take-make-dispose" step-by-step plan, will not be longer practical. Sempels and Hoffmann (2013) illustrated that 80% of used materials would end up within the landfill by time around six months with this linear approach. This linear economy model generates two distinct issues, depletion of resources and pollution/waste generation.

An alternative way has been required either by reducing the raw material needed for production or taking back the used material into the production stage (Figure 2). More importantly, environmental issues such as air, water, and soil pollution, biodiversity loss, greenhouse gases, and global warming intensify the need for new approaches (Jackson, 2009; Geissdoerfer *et al.*, 2017). To address these issues the circular economy and sustainable material-flow concepts emerged. It is not an entirely new concept (Boulding, 1966), but its perspective as a solution for the current linear economy model is recently developed. The concept became well-known by the attention of national and international organizations and gradually finds its present understanding (Commission, 2015; Lieder and Rashid, 2016). Notwithstanding, the importance of these two concepts Circular Economy and Sustainability, the conceptual relation between them still not clear (Geissdoerfer *et al.*, 2017).

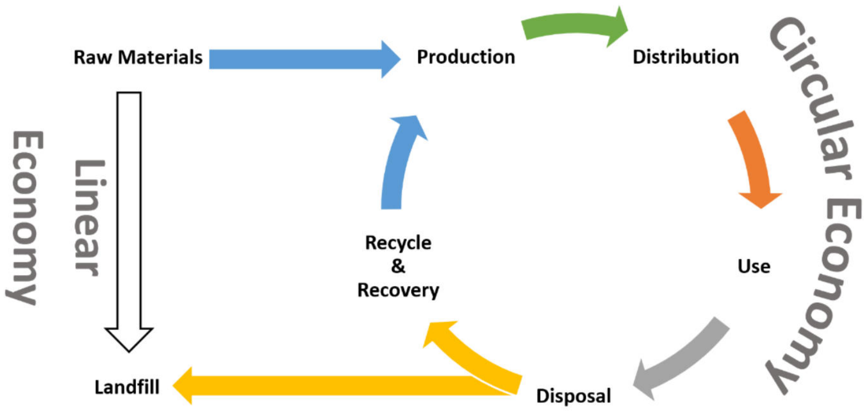


Figure 2. Circular economy vs linear economy

2.1.1 Sustainability

The sustainability concept has a long history background, but the recent perception and the way that we know it today dates back to not that long ago. The first official document that mentioned the concept of sustainable development is "The Stockholm Declaration on the Human Environment" which was the outcome of the United Nations Conference on the Environment, which was held in Stockholm in 1972 (Sohn, 1973). The concept later became a well-known concept when Norway's prime minister mentioned it in 1987 at the United Nations(UN) report (entitled 'Our Common Future') (UN, 1987). Based on the UN's report, sustainable development provides the current needs without jeopardizing the capacity of future generations to fulfill their requirements. The concept needs international and multidisciplinary effort to fully implement. Because, as long as poverty and inequity exist, the world is pregnant with ecological and other crises.

Reaching sustainable development relies on technological and management innovation and is highly influenced by cultural and social teachings (Parajuly *et al.*, 2020). For instance, in energy consumption patterns or shopping habits, the role of social and cultural values may be more important than other factors. Thus, sustainable development needs to promote living standards within the possible ecological boundaries (UN, 1987). But the proposed definition of sustainable development by the UN is so general and somehow unrealistic to measure. For instance, providing a clear perspective of future generation's needs and required resources is not easy to do. More importantly, the definition is not an appropriate tool for addressing the complexity of current systems. Thus, a more detailed road map was introduced as the millennium sustainable development goals (SDGs) project (Johnston, 2016). SDG consists of seventeen individual goals that targeted the gaps for sustainable development (Figure 3). These seventeen goals are almost cover all public concerns.

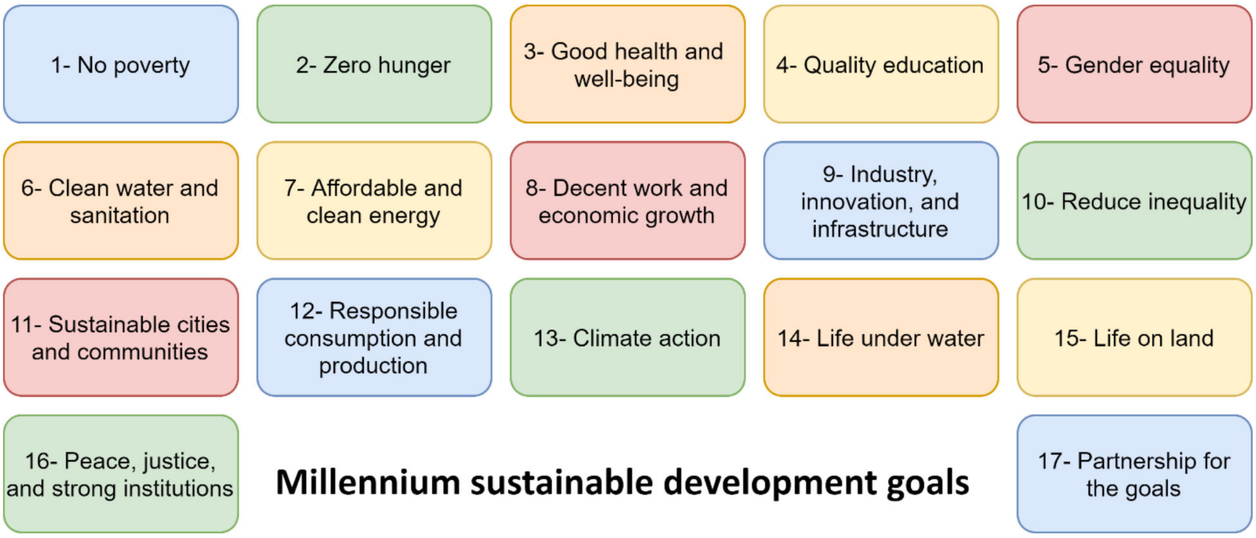


Figure 3. Millennium sustainable development goals

As it appears, the goals are so general and have a considerable overlapping. Accordingly, to meet them practically, another concept looks more practical to follow, known as the Triple Bottom Line concept (TBL). TBL is assessing all the issues in three main domains environmental, social, and economic aspects.

2.1.2 Triple bottom line

The term was introduced by a business writer John Elkington (1994), which considers issues concurrently in the economic, social, and environmental domains that is more practical for microeconomics applications (Elkington, 2013). Sustainability in the economic view is more straightforward than those two other domains (Cruz and Wakolbinger, 2008). Such that economic sustainability can be understood as cost reduction and optimization. While sustainability in the environmental part consists of more unclear factors, but usually refers to energy consumption, waste production, pollution/Carbon dioxide emission, toxic/harmful substance usage, etc. In the social view, the term becomes even more complex to define. In general, sustainable social development relays equitability for all humanity, respecting the right to standard life and ensuring the quality of life in a democratic framework (Gimenez, Sierra and Rodon, 2012).

Although these three are assessed separately, it is clear that the economy is defined in human societies, and human society is part of the larger domine, the environment. Thus, these three domains can be considered as subsectors, as shown in Figure 4.

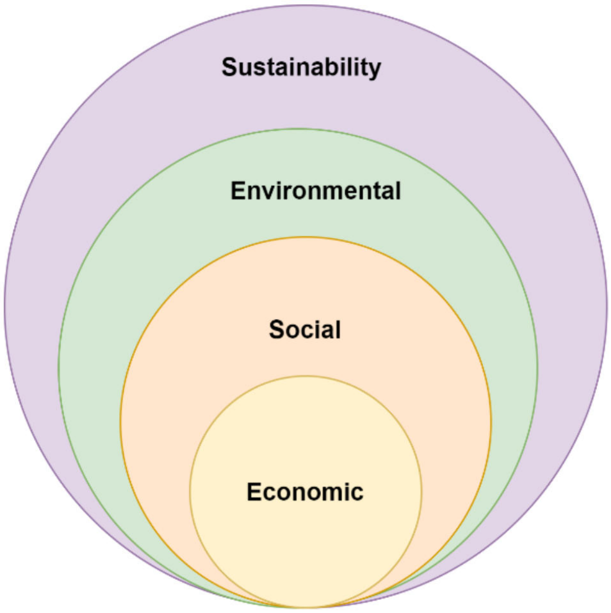


Figure 4. Triple Bottom Line concept

2.1.3 Circular economy concept

A possible way toward sustainable development is to design businesses to use the resources more efficiently. As mentioned in the abstract, the circular economy concept is defined as keeping the material and energy in the use phase for a longer time and take them back to the production stage as much as possible. The concept has a long history since Boulding's (1966) works. He proposed that the economy and environment can be in equilibrium if the earth is considered a closed-loop system with limited regenerative capacity. However, the present understanding of the concept is acquainted based on Pearce and Turner's (1990) works. They tried to contribute different features of a variety of concepts to make the idea of the close-loop. Its core concept stands on the circulating materials within the system such that the waste of a member is the feed for another member. This concept looks at waste as an abstract notion.

Through time, the concept became prominent globally to such an extent that many governmental attempts had been made to provide its infrastructures for its realization (e.g., the European circular economy package (Commission, 2015); and Chinese circular economy promotion Law (Lieder and Rashid, 2016)). These attempts are not limited to governments and international organizations; many private companies such as Renault, Google, and Unilever (Bocken et al., 2017) also felt the demand in the area and tried to provide some progress. These actions cause the attention of researchers to the topic as well or maybe vice versa. Such that since 2000 the number of researches in the field has been increased tremendously. Figure 5 shows the number of papers published since 2000 that contained "circular economy" among their keywords. McKinsey and Ellen MacArthur Foundation had a remarkable role in putting the concept under the spotlight through several comprehensive reports and seminars on the topic (Ellen MacArthur, 2012, 2015).

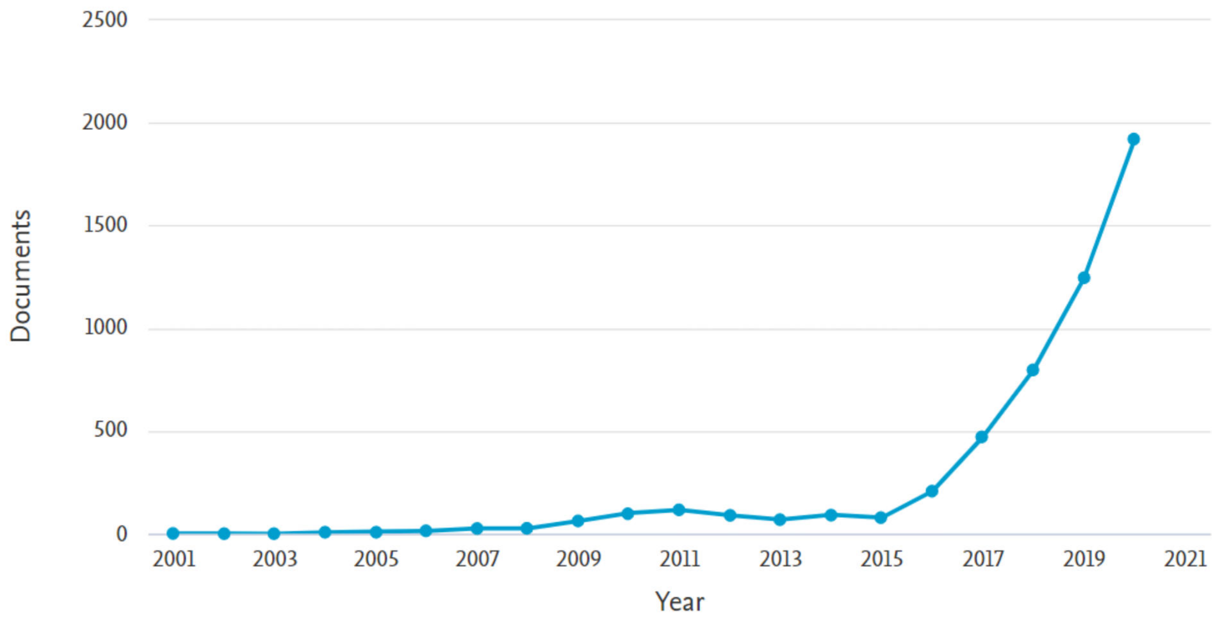


Figure 5. Number of published papers with "circular economy" as their keyword (Scopus, 2021)

Many detailed definitions have been proposed. One of the precise ones was stated by Kirchherr (2017). After reviewing 114 proposed definitions, he stated the circular economy as "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes". He provided two main practical solutions, recycling and reuse and emphasized that they should be applied in different stages from production to distribution and after use. Later, other terms such as remanufacturing and refurbishment emerged to pave the path toward the circular economy and made its contemporary understanding. Figure 6 clarifies the different terms in the Circular Economy context, how they define and connected.

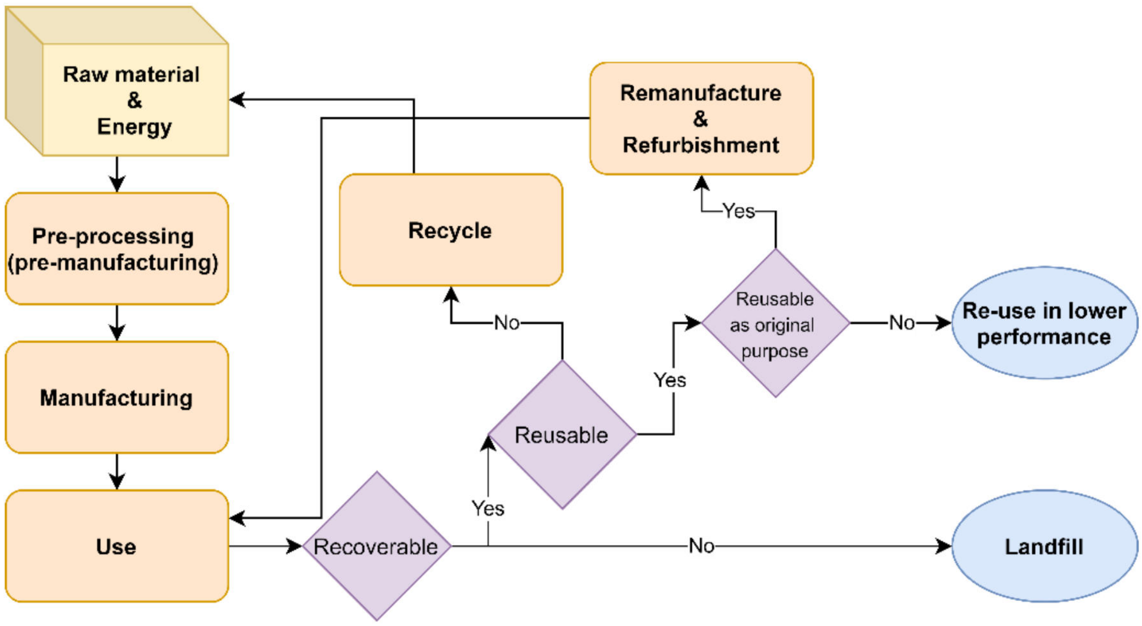


Figure 6. Circular economy schematic (Micro level)(modified after Zhang et al. 2013*).*

Although many researchers proposed different links between sustainability and circular economy, still no clear relationship has been provided for their connection. For instance, Läpple et al. (2013) proposed that circular economy is one of the conditions for a sustainable system. Bakker *et al.* (2019) mentioned that circular economy is the main solution to transportation toward a sustainable system. In between, in the European Union's instruction (European Commission, 2014), the circular economy is beneficial in them of sustainability. Still, there is not any conditionality to approve or substitute with an alternative approach. Nevertheless, some researchers defined the relationship differently, like what Allwood (2014) proposed. He considers a trade-off between circular economy and sustainability in a way that circular economy can even have a negative effect on reaching a sustainable system.

2.1.4 6Rs Theory

As mentioned in section 2.1.1, the primary way to reach a sustainable development is to use the resources efficiently and keep the material/energy circuit close. To accomplish this, several methods have been proposed; however, two became more prominent, 3Rs theory and its more detailed one 6Rs methodology. Both approaches mention that sustainability (or, in a specific view, circular economy) could be achieved by implementing these three (or six) actions. 3Rs consists of Reduce, Reuse, and Recycle, while in 6Rs theory, Recover, Redesign, and Remanufacture are added.

Although some of them, like recovery and recycle have close definitions, they are considered differently in the 6Rs method. Table 1 explains these six different of 6Rs theories.

Table 1. 6Rs methods

	COMPONENT	DEFINITION/EXPLANATION
1	**Reduce**	Refers to reducing resource usage (material/energy) in the manufacturing/premanufacturing phase. It also describes the actions taken to minimize waste and emission generation at the use phase.
2	**Reuse**	Refers to using the products after their first life cycle as a whole or components to minimize the need for virgin material to manufacture new ones. It also plays a significant role in reducing the needed energy for manufacturing.
3	**Recycling**	It is a well-known terminology that refers to recovering waste material to the usable ones that can be utilized in the production phase to substitute virgin material.
4	**Recovery**	The term of Recovery is described differently in different references. Jawahir and Bradley (2016) described it as a process that contains collecting end-of-life products, dismantling, sorting, and cleaning them in order to use them as new products.

5	**Redesign**	Refers to the process which modifies the product design to be more sustainable. It can contain changes, which lead to less virgin raw material in the production stage, providing the more recoverable and recyclable product and products that are more durable either physically or given market demand.
6	**Remanufacture**	The term applies to the series of actions that return used products to the condition which can be served as the new ones with the same functionality (Zhang, Badurdeen and Jawahir, 2013).

To illustrate how these 6Rs can be connected, Figure 6 modified to clarify the positioning of these components as Figure 7. It shows the Redesign gets information and feedback from the recycling and remanufacturing parts to modify the product's design and apply these changes into the production phase. In contrast, the Reduce is usually more dependent and using existing knowledge and technologies to deduce the material and energy usage in pre-manufacturing and manufacturing phase and a reduction on pollution and waste generation in mentioned phases and use phase as well. Mode detailed descriptions about these six components and their applications to modify business models toward a more sustainable condition are presented in the sections 2.1.6 and 2.2.4.

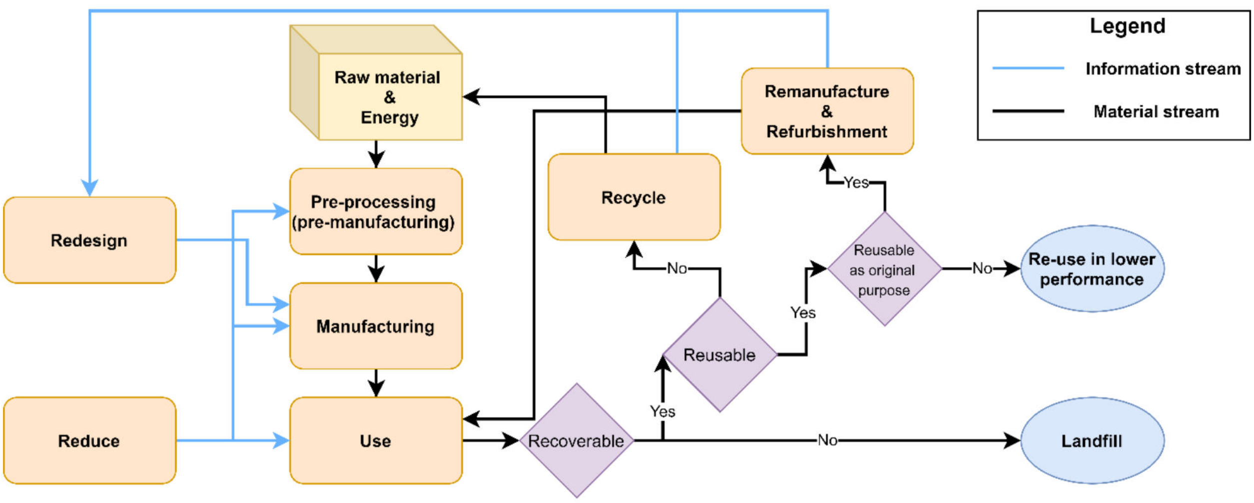


Figure 7. 6Rs methodology decision flow diagram.

2.1.5 Life cycle assessment

An essential need for any changes is a clear picture of the current situation compared to the desirable one. Change toward a circular economy is not excluded from this general rule. So, many criteria and indicators have been introduced to apply. Indicators such as Material Flow Analysis (MFA), Cost-Benefit Analysis (CBA), Environmental Impact Assessment (EIA), and Environmental Risk Assessment (ERA) (Finnveden *et al.*, 2009) (all presented in detail in section 2.2.4). But the most well-known is LCA that is a tool (indicator) to assess the environmental impact and resource use of a product (or service) through its whole life cycle from extraction of raw material to the landfill. It provides a better understanding and addresses environmental and, consequently, social and economic impacts. Specifically, LCA can help in following four different areas (ISO 14040/14044, 2006):

- Providing a better understanding of opportunities for improving the product's environmental performance at different points of its life cycle;
- Equip decision-makers, governmental, and non-governmental organizations for strategy planning, priority setting, and redesigning processes;
- Help to distinguish the system's weakness and selecting relevant indicators to target the point; and
- Assist in having a better marketing strategy by using LCA's strength, such as implementing ecolabelling or claiming to be more environmentally friendly.

A LCA study consists of four consecutive phases. Depending on the aim, the study can progress to a specific phase and does not necessarily cover all phases (ISO 14040/14044, 2006).

a) **Goal and scope clarification**

The LCA study's goal should set firstly to define the scope. However, based on the iterative nature of LCA studies, the scope is redefined during the process. Some features should be considered while setting the goal; the study's intended application, the reason for study, target audience, etc. Similar conditions should satisfy in scope design such as system boundaries, target product, data requirement, etc.

b) **Inventory analysis**

By determining the study's goal and scope, this phase tries to collect relevant data through an iterative process (**Error! Reference source not found.**), which also helps redefine the scope.

c) Impact evaluation or life cycle impact assessment (LCIA)

LCIA works with several indicators results for different impact categories, presenting the LCIA profile for the product system.

d) The interpretation

This interpretation accomplishes based on comprise results of previous phases. such as identifying significant issues based on LCIA results (detailed information is provided in**Error! Reference source not found.**, figure S2).

2.1.6 Business model in the circular economy

The business model has a long history as humans started to trade. At the same time, the current definition and its contemporary understanding are not that much old. It dates back to the 1990s when innovation revenue systems were proposed (Wirtz et al., 2010). So, the BM was emerged to convey the business ideas to the investors within a short time slot (Zott, Amit and Massa, 2011). During this time, the concept has become mature and more practical. Presently, it is mainly used for two purposes 1) system planning and analysis as well as communication tools 2) a tool for presenting business performance and competitive advantages (Geissdoerfer *et al.*, 2020). Consequently, many circular business models (CBMs) were proposed by the emerging circular economy concept. They cover different aspects of the circular economy concept and provide different solutions as well. Nevertheless, they can be categorized base on some of their shared feature. One of these classifications was presented by Geissdoerfer (Geissdoerfer *et al.*, 2018a,2018b, 2020). He proposed four distinct categories for CBMs (Figure 8) based on Bocken (2016) works as described below.

- **Cycling**: It refers to MBs that seek to circulate material and energy inside the system by recycling, reuse, remanufacturing, and refurbishment.

- **Extending**: It refers to the BMs that targeted stretching the life cycle of products via timeless and long-lasting design, a marketing approach that promotes long use period and regular maintenance and repair.
- **Intensifying**: BMs intensify product's use through different scenarios such as sharing economy (Hamari et al., 2016) and public use services (van de Velde, 1999).
- **Dematerializing**: BMs that meet customer needs by providing service/software instead of physical products. They reduce the use of material that comes for manufacturing. A well-known concept in this category is the product-service system (PSS) (Mont, 2002).

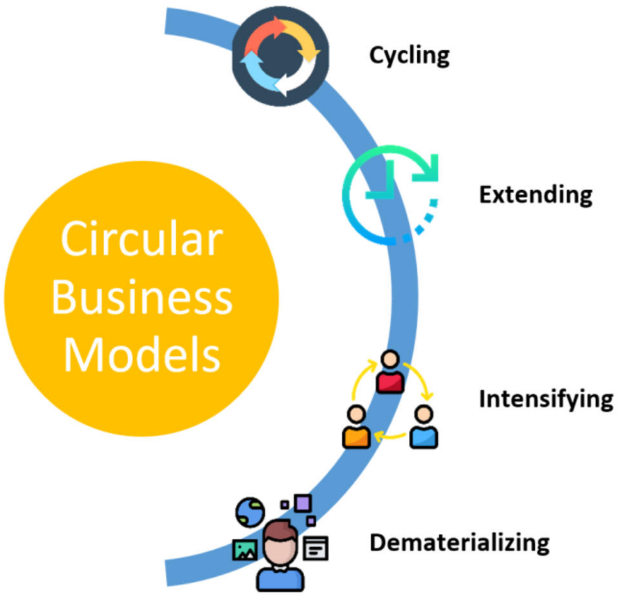


Figure 8. CBMs grouping created based on Geissdoerfer *et al.* (2020) *classification*

A more detailed classification is presented in the newly released British standard (British Standards Institution, 2017). It groups CBMs into seven types. 1) demand orientation ones 2) recovery and reuse the secondary raw material/byproduct 3) lifecycle extension and reuse 4) dematerialization 5) product service system PSS 6) Sharing economy 7) collaborative consumption.

2.2 Available circular business models and theories

The business model recognizes as the "design or architecture of the value creation, delivery, and capture mechanisms" (Teece, 2010). To put it simply, it explains how businesses work. Another complementary concept is business model innovation (BMI), which refers to any modification in BM to answer internal and external incentives to build a competitive advantage (Foss and Saebi, 2016; Geissdoerfer et al., 2018a&b; Pieroni et al., 2019). This part aims to present available CBMs and their modifications. From here onwards, it is mainly mentioned as BMI.

Since it is unrealistic to predict the effect of changes in a real system theoretically, Bocken et al. (2018) emphasized using the feedbacks of implementation to modifying the Business model innovation by the ongoing 'learning by doing' method; the lack that Pieroni et al. (2019) mentioned based on their studies. Bocken *et al.* (2014) also questioned the notion that reaching the circular economy has a single approach. Thus, Boons et al. (2013) presented a classification that categorizes business model innovations into three different classes. He claimed that any business model innovation would be fitted at least in one of them. 1) Organizational: This refers to the modification within an individual business unit. 2) Inter-organizational: It refers to the modifications that target business units' relations to create a shared value. 3) Societal: modifications that target interrelationships with other business units to create shared societal values.

Another classification proposed by Teece (2007) and modified by Pieroni et al. (2019), divides the business model innovation processes into three distinct phases presented below. Each suggested BMI can cover one or more phases, but the final value creation needs to cover the whole.

1. **Sensing**: Distinguishing opportunities and creating new BM ideas;
2. **Seizing**: using the emerged ideas to designing and testing new BM configuration; and
3. **Transforming**: Customized the BMI and renovate the Business model.

It is thought-provoking that only around 20% of proposed BMIs reach and cover the last transformation phase (Pieroni et al., 2019). Nonetheless, all of this 20% provide only some guideline manuals, and there is no computational framework that detailly steers BMs. Thus, there is a need to connect these separated islands to make a complete path toward a circular economy. In coming parts, methods which provide computational frameworks or at least practical and clear idea are presented.

2.2.1 People behavior changes toward the circular economy

As frequently mentioned, one of the three main aspects of sustainability and consequently circular economy is the social aspect and their interaction with core businesses (2.1.2). To address the gap, a first step is to change regular people's consumption behaviors toward sustainability terms such as recycling and reuse (Camacho-Otero et al., 2018). Martin et al. (2017) claim human behaviors root from two main sources, intrinsic attributes, and extrinsic ones. Intrinsic attributes (e.g., education, impulses, ideas, habits, values, and other mental attributes) while extrinsic attributes include social and cultural patterns, financial implications, and contextual variables such as infrastructure.

More than 80 distinct theories have been mentioned for human behavior changes (Darnton and Sustainable, 2008; Davis *et al.*, 2015). Turaga et al. (2010) presented two groups for pro-environmental behavior change theories, 1) moral and rational choice 2) economic interplay models. Further, Parajuly *et al.* (2020) added more items to these groups and suggested the following theories:

- Rational choice theories (e.g., the theory of planned behavior);
- Moral theories;
- Economic models;
- Nudging; and
- Community-based social marketing.

One of the most practical methods is using the nudging theory. Because it is easier to implement, and it covers a wider range of customer segments. In addition it is cheap and, more importantly, needs a shorter time to affect (Momsen and Stoerk, 2014; Ölander and Thøgersen, 2014), (Parajuly *et al.*, 2020). Nudging theory is based on the fact that humans do not always act logically and base on their knowledge. Their decision-making process can be irrational and biased (Thaler and Sunstein, 2008). To put it simply, a nudge is any small feature in the environment that attracts our attention and influences/changes our behaviors. It can be a nudge for good purposes or evil ones (Leonard, 2008). For example, they found that the order in which the food is displayed in schools' cafeterias influences what the students eat. So, it is possible to arrange the food in such a way that makes the students healthier, like putting the fruits in front of desserts. It can also be applied to pro-environmental behaviors. But firstly, the default options should be determined. The default option is simply what would happen if we do nothing. They are so sticky and need efforts to change. For instance, we order coke with fast foods by default. It developed from behavioral economics that declares (Carlsson and Johansson-Stenman, 2012): 1) Final results are not the single driver of individual behaviors; 2) Social patterns and circumstances are significant motivators; and 3) Cognitive limitations result in illogical choices. Nudge theory shows promising results in pro-environmental campaigns such as waste management in food (Kallbekken and Sælen, 2013) and plastic (Rivers et al., 2017) sectors and green energy promotion (Ebeling and Lotz, 2015).

2.2.2 Pattern-based business model design for disruptive technologies

One of the main challenges is to find a way for changing BMs to pass issues and generate higher value. Seeking new solutions has time-consuming, expensive, and sometimes impractical. Here patterns can be helpful to implement disruptive methods and technologies. Disruptive technologies/methodologies are those that have profound consequences on the business structure and value generation model (Bower and Christensen, 1995). These technologies can change the market share and remove former market leaders that either did not or lately implement the technology (Christensen, 1997). A good example happened in 1962 in the UK. Rolls-Royce presented its new business model. Since then, Rolls-Royce has no longer charged airlines for an engine's purchase. But they have to pay per hour of flight, while Rolls-Royce took responsibility for engine maintenance. This BM provided a continuous revenue stream and kept maintenance business in-house (Rolls-Royce, 2012).

The pattern terminology in business owes Alexander's (1977) work. He defined the term as that "Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice" (Christensen, 1997). To put it simply, patterns are solutions for frequent problems which documented in general form and used for similar problems with few changes. So they provide a shortcut to resolving the problems in different fields (Cloutier and Verma, 2006; Buschmann *et al.*, 2013). For instance, Gassmann (2014) provided a notable manual by publishing his book. He presented 55 universal business model patterns, widely used for new business ideas. They can cover different business aspects, from supply to customer, value generation, and financial model (Köster, 2014). He claims that each business model can be defined through some variables which can take different configuration options. A BM can be characterized based on its variable configuration, and each set of configuration options can be considered a pattern. To illustrate, consider the customer service as a business model variable of the BM element of customer relationship. The company can choose different configuration options for this variable such as "customer acquisition", "customer retention", "customer development," etc.(Gassmann et al., 2014; Gausemeier and Amshoff, 2014; Amshoff *et al.*, 2015).

This method of defining the businesses helps to have a more quantitative understanding of their BM and, consequently, extract existing patterns. By way of illustration, Figure 9 provides a table that shows different companies' profiles (companies 1 to 4). It presents that each company used which operational option for its defined variables. For instance, company 1 uses configurations 1 and 3 for its first business model variable. So, based on these kinds of tables, it's pretty easy to extract the patterns. As an illustration, Figure 9 shows a combination consisting of configuration options CO5 and CO7 mainly occurred in most successful businesses (company 1 to 4). Thus, they can consider as a pattern for variable 2. Because they come together and as a shared future in successful businesses.

Business variables	Configuration Options	Companies 1	2	3	4
BMV1	CO1	☑	☒	☒	☑
	CO2	☒	☒	☑	☑
	CO3	☑	☒	☑	☒
	CO4	☒	☒	☒	☒
BMV2	CO5	☑	☑	☑	☑
	CO6	☒	☒	☒	☒
	CO7	☒	☑	☑	☑
…	…	…	…	…	…
BMVn	COm	☒	☒	☒	☑

Business model pattern:
These arrangement of configuration options occurs in the different successful business models (Company 1,2,3, and4)

☑ the configuration option is used by the company
☒ the configuration option does not be used by the company
BMV: Business model variable
CO: Variable configuration option

Figure 9. Business model pattern-finding methodology (Modified after Köster, 2014*)*

Although some patterns have been extracted and documented, such as Gassmann's book (Gassmann et al., 2014), this fast changing area needs a more updated pattern to be practical. Therefore, the explained concept in Figure 9 can be used as an active method to find practical patterns.

To extract existing but Imperceptible patterns, one needs to determine the recurring combination of configuration options. A binary characteristic list (Figure 10) is created based on the occurrence table (Figure 9). Consequently, the similarity matrix can be determined for all the possible pairs of configuration options (Figure 10). High similarity values mean that two configuration options occur more in businesses together. Therefore, it reveals that they are frequently used together in successful businesses.

The matrix is transformed into its 2D expression map (Figure 11) via the multi-dimensional scaling method (Borg and Groenen, 2007) to make the patterns more visual (Amshoff *et al.*, 2015).

Business variables	Configuration Options	Companies							
		1	2	3	4	5	6	7	Sum
BMV1	CO1	1	0	0	1	1	0	1	4
	CO2	0	0	1	1	0	1	0	3
	CO3	1	0	1	0	0	0	0	2
	CO4	0	0	0	0	1	1	0	2
BMV2	CO5	1	1	1	1	0	1	0	5
	CO6	0	0	0	0	1	0	1	2
	CO7	0	1	1	1	1	0	1	5
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
BMVn	COm	0	0	0	1	1	0	0	2

$$
\begin{array}{c} \\ CO1 \\ CO2 \\ CO3 \\ CO4 \\ CO5 \\ CO6 \\ CO7 \end{array}
\begin{array}{c}
\begin{array}{ccccccc} CO1 & CO2 & CO3 & CO4 & CO5 & CO6 & CO7 \end{array} \\
\begin{bmatrix}
1 & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} & \alpha_{16} & \alpha_{17} \\
 & 1 & \alpha_{23} & \alpha_{24} & \alpha_{25} & \alpha_{26} & \alpha_{27} \\
 & & 1 & \alpha_{34} & \alpha_{35} & \alpha_{36} & \alpha_{37} \\
 & & & 1 & \alpha_{45} & \alpha_{46} & \alpha_{47} \\
 & & & & 1 & \alpha_{56} & \alpha_{57} \\
 & & & & & 1 & \alpha_{67} \\
 & & & & & & 1
\end{bmatrix}
\end{array}
$$

Similarity matrix

"1" the configuration option is used by the company
"0" the configuration option does not be used by the company
BMV: Business model variable
CO: Variable configuration option
α: matrix elements

Figure 10. Binary characteristic list and its similarity matrix

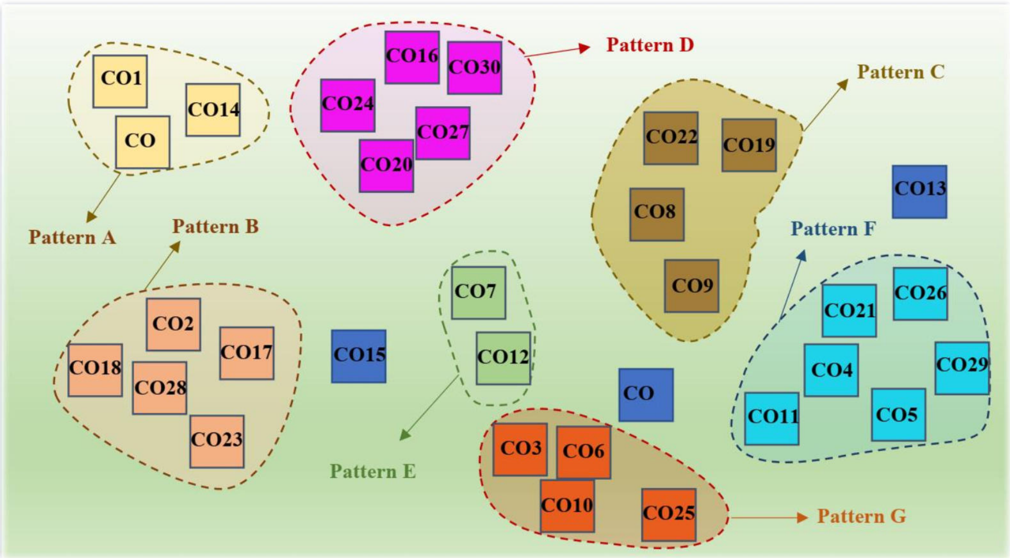


Figure 11. Pattern map (multi-dimensional scaling map)

2.2.3 Fuzzy cognitive map

As the size of a system increases, connections of the system's components and complexity increase as well. This complex network will be tough to define and monitor since all of the components are interconnected. Therefore, a change in one company or part can affect others directly and/or indirectly. Hence, it is necessary to provide a method or technic to show the links more transparent and have the ability to measure their interactions. Fuzzy cognitive map (FCM), which was introduced as a computational tool by Kosko (1986), is a practical solution in this case. It is a concept map based on a kind of fuzzy association between two different variables (components) defined within the concept map makes monitoring their interactions more transparent. As a matter of fact, it is a method of mapping the relationships between components to measure their impacts. Fuzzy cognitive map is highly used in different applications to indicate the complex relationships among variables and understand system dynamics (Gray et al., 2013). For instance, Trappey (2010) used Fuzzy cognitive map and genetic algorithms to assess a reverse logistic system's performance. Other applications from sustainable food consumption management into supply selection and strategic management in electronic devices are proposed in the literature (Gnoni *et al.*, 2017; Haeri and Rezaei, 2019; Morone et al., 2019).

The fuzzy concept means that there is not just white and black but also a gray range between them. Like the human brain working principle that cannot categorize cognitive information into two distinct categories with sharp borders. For instance, it's hard to say that who is old and who is not. But it's possible to have a range between the pretty aged to pretty young (Figure 12).

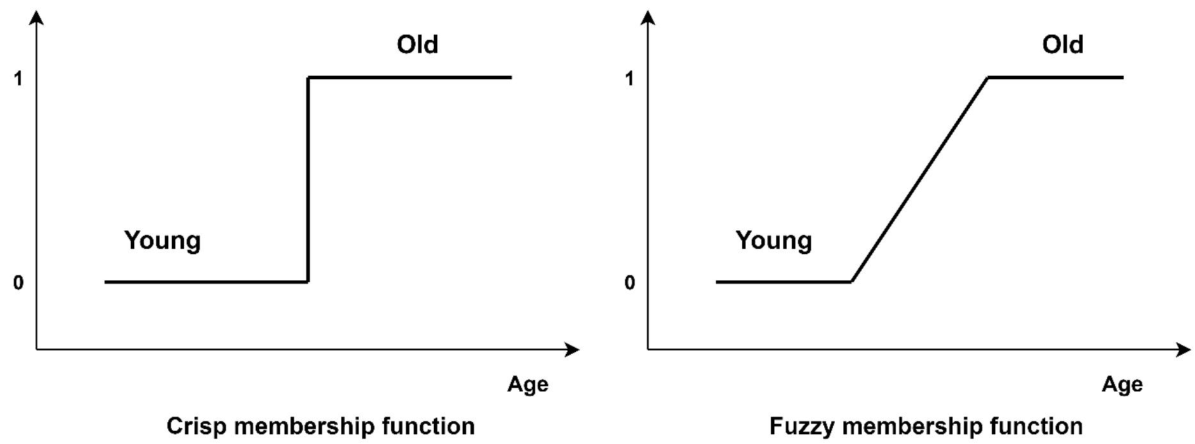


Figure 12. The visual description of the Fuzzy concept. Modified after Gray (2013)

A fuzzy cognitive map consists of two sets of components nods (elements or concepts) and edges (relationships). Nodes are representing different system components that interact with each other. The relationships, that are introduced by two main features in a fuzzy cognitive map. 1) the direction of the relationship (the way the arrow is pointing); 2) the degree of influence that one component can have on another, that is characterized positively or negatively in fuzzy scale between 0 to 1 (Papageorgiou and Stylios, 2008). Figure 13 provides a visual representation of a Fuzzy Cognitive Map with its nodes (C_n), edges (arrows), and weighted index (W_{nm}).

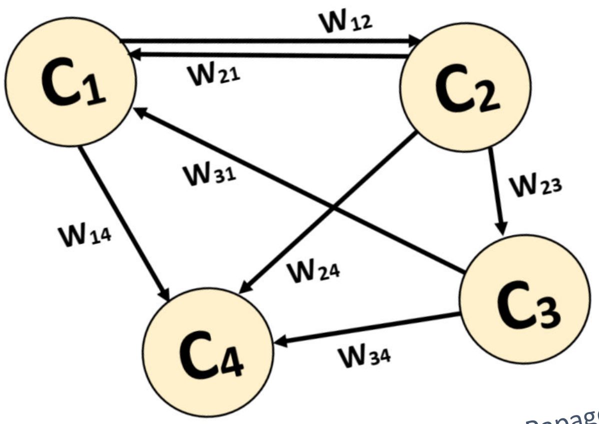


Figure 13. The visual description of an FCM modified after Papageorgiou and Stylios (2008)

So, based on this map, the system can quantitively be modeled, and the influence of changing any component on the whole system can be determined. Also, consider in many cases, there is no clear information for determining the weighting indexes. So, it is possible to convert some qualitative levels (High, Medium, and Low influence) into quantitative ones in a fuzzy range (0 to1)(Özesmi and Özesmi, 2004).

2.2.4 Methods to measure system circularity and sustainability

The necessity of any modification is a comprehensive understanding of the system's current condition to compare with the ideal condition and devise the appropriate action plan. The purpose needs some relevant criteria and standards. The story is the same for changing toward a circular economy as well. Based on the fact that sustainability is presented in three domains (section 2.1.2): economic, social, and environmental domine, the monitoring criteria should cover all.

Although many various criteria have been proposed, most of them are on material and energy streams, which mainly target the economic domain, lightly environmental, and rarely social (Elia et al., 2017). The reason is that quantifying economic and secondly environmental aspects is more practical than social ones. Elia (2017) presents a reasonable classification. He divided criteria into four distinct classes, each targeted a particular subject. He also noticed that they could be a single indicator or multiple indicators. **1)** Material Flow **2)** Energy Flow **3)** Land use & consumption **4)** Other lifecycle-based (The list of some of these criteria and their comparative advantage are presented in sections 2.2.4.1 to 2.2.4.3).

2.2.4.1 Indicators based on material and energy flow

The circularity in material/energy flow is summarized in using less as possible virgin raw material (energy) and return used one as much as possible. So, most of the indicators in this area targeted the mentioned definition. Some of the most common are listed in Table 2.

Table 2. Material and energy flow indicator of circular economy

	Method	Explanation	References
Material flow	**Water footprint**	Related to the amount of consumed water.	(Hoekstra *et al.*, 2011; Bai *et al.*, 2018)
	Material Inputs per Unit of Service	It determines all the material required for the production, distribution, use, redistribution, and disposal of a product/service, presented as the unit of product/service provided.	(Spangenberg *et al.*, 1999)
	Ecological Rucksack	The mass of material inputs minus the mass of the product.	(Angelakoglou and Gaidajis, 2015)
Energy flow	**Cumulative Energy Demand**	The total energy demanded to manufacture a product (or a service) over its entire life-cycle	(Huijbregts *et al.*, 2006)
	Embodied Energy	All direct/indirect energy flows required to produce a product (or a service).	(Brown and Herendeen, 1996)
	Emergy Analysis	It focuses on estimating the total quantity of energy - direct and indirect-required to produce a product or service estimated in units of only	(Angelakoglou and Gaidajis, 2015)

		one type of energy, usually solar energy.	
	Exergy analysis	It is based on the estimation of a single indicator defined as "the maximum amount of work which can be produced by a system or a flow of matter or energy as it comes to equilibrium with a reference environment"	(Rosen and Dincer, 2001)

In between, more complex indicators are introduced. Ellen MacArthur Foundation presented material circularity indicator (MCI)(EMF, 2016). It set of indicators that cover more aspects of the Circular Economy, such as reducing input and use of natural resources, Increasing the share of renewable and recyclables resources, Reducing valuable material losses, and increasing the value durability of products, etc. (Elia et al. 2017). The foundation also provided a *Circulytics* platform to help companies (Ellen Macarthur Foundation, 2017).

2.2.4.2 Environmental indicators

Although indicators are presented for the measurement of environmental impact, they lack some aspects. They only consider a specific impact, such as the greenhouse gas generation (ISO 14051, 2011)**;** Total restored product (Pauliuk, 2018b); Recycled content (Graedel *et al.*, 2011). However, Elia et al. (2017) mentioned LCA as the most comprehensive one. LCA is a well-known multiple indicator method that includes several impact categories related to human health, consequences on the ecosystem, and resources. Since it is a data and time-consuming procedure, it became impractical in many cases (section 2.1.5). Apart from that, for issues such as toxin material, there is no comprehensive reference globally to the best of my knowledge. All in all, the practical approach is to use the collection of aforementioned indicators as a composite environmental indicator.

2.2.4.3 Social indicators

As mentioned, there is no clear information to measure social impacts as well as data to show how the circular economy contributes to the wellbeing of the individuals/communities. So, defining an indicator will not be practical. However, some general codes and legislations will be helpful. Another approach is to monitor some social features such as employment rate as circular economy results (Padilla-Rivera *et al.*, 2021).

Although some research on social indicators has been done (Benoît *et al.*, 2010; Goedkoop et al., 2018), but Padilla-Rivera et al. (2020) did the most comprehensive one. He reviewed 60 papers that proposed social indicators to measure circular economy strategy's impacts and introduced an indicator that is mainly related to total job creation regardless of details such as quality of the job. A year later, he did more comprehensive research to find the relationship between social indicators proposed or mentioned in the literature with the circular economy. The list of 42 indicators such as employment, labor relations, occupational health and safety, and training and education was created and prioritized by using the Delphi fuzzy methodology. The final list sorted the indicators based on their importance and relativity to circular economy (Padilla-Rivera *et al.*, 2021) in five classes. Table 3 provides ten first indicators (Two in each class).

Table 3. Social indicators of circular economy

Classes	Indicators
Labor practices	Occupational health and safety
	Employment
Labor practices Human rights	Child labor
	Forced or compulsory labor
Society	Poverty
	Food security
Product responsibility	Consumer health and safety
	Fair trading relationships
Non categorized	Governance
	Corruption

A good approach is to connect these indicators into more general concepts such as sustainable development goals. It will be helpful to provide more understandable and easy to explain terms that can be digestible for any person (Padilla-Rivera *et al.*, 2021) (Figure 14). So this manner gives businesses and people with general knowledge points based on SDGs to target their businesses.

Figure 14. More related SDGs with selected indicators

To conclude, there is no comprehensive indicator or method to monitoring circularity. Subsequently, the practical way is to use a bunch of them. While, each indicator has its pros and cons and is designed to cover a specific. Therefore it's not useful to use a single set of indicator for all industries and different sets should be used to monitor the critical aspect of that different cases.

Chapter 3 Formulating the study

Any research rises from a need. So, to satisfy it, it is necessary to provide a clear perspective of the need, what the cause is, what the aim is, and what approach is needed to reach those aims. Therefore, this chapter illustrates all of the mentioned items separately in the following sections. It covers the gaps in previous research and defines the aim and objectives that should be met. Since the broadness of the topic, the limitation and research methodology of the study is stated.

3.1 Gaps in researches and less expressed cases

The circular economy and the present understanding of sustainable development are pretty new topics. Therefore, although studies have provided remarkable findings during this short period, many gaps remain to cover. The main one will be that almost all of them provided general hints and guidelines instead of determined a clear or specific roadmap or frameworks that can satisfy the complexity of businesses. The second important gap is the lack of a holistic view in guidelines. They look at businesses individually in the event that they are part of a bigger ecosystem which consist of several business. They are influence or be influenced by others. So, any suggested solutions should be provided based on business ecosystem.

3.2 Research questions

Based on section 3.1, the study can be conductive to answer the following research questions.

- How can a circularity of a business be evaluated?
- What is the current obstacle for that specific business which makes it far from circularity?
- How can a business ecosystem be defined quantitively?
- How can we make suggestions to improve their circularity?
- How can monitor the effect of changing in a player on the whole ecosystem?
- What is the right way to keep circular businesses in acceptable condition for the time?

3.3 Aim and objectives

Resource limitation and environmental damages illustrate a clear need to move toward having more sustainable businesses. Although many efforts have been made to achieve this aim, a long way with many gaps remains. The lack of a comprehensive and practical road map can be considered the central gap in between. However, the lack of qualitive assessments makes comparison impractical. More importantly, partially looking at the existing problem won't provide a comprehensive solution. Therefore, this master project will work on making quantitative assessments as well as providing a more holistic view by considering the business ecosystem instead of considering businesses isolated and out of context. Last but not least objective is to provide a roadmap and framework that defines the changes stepwise to make the following easier. The framework should cover the whole value chain, utilizes the business ecosystem concept, and provides clear and determined steps to follow. It should be evaluated by applying it for a real case such as the laptop's ecosystem to make its advantages and disadvantages more transparent.

3.4 Scope and limitation

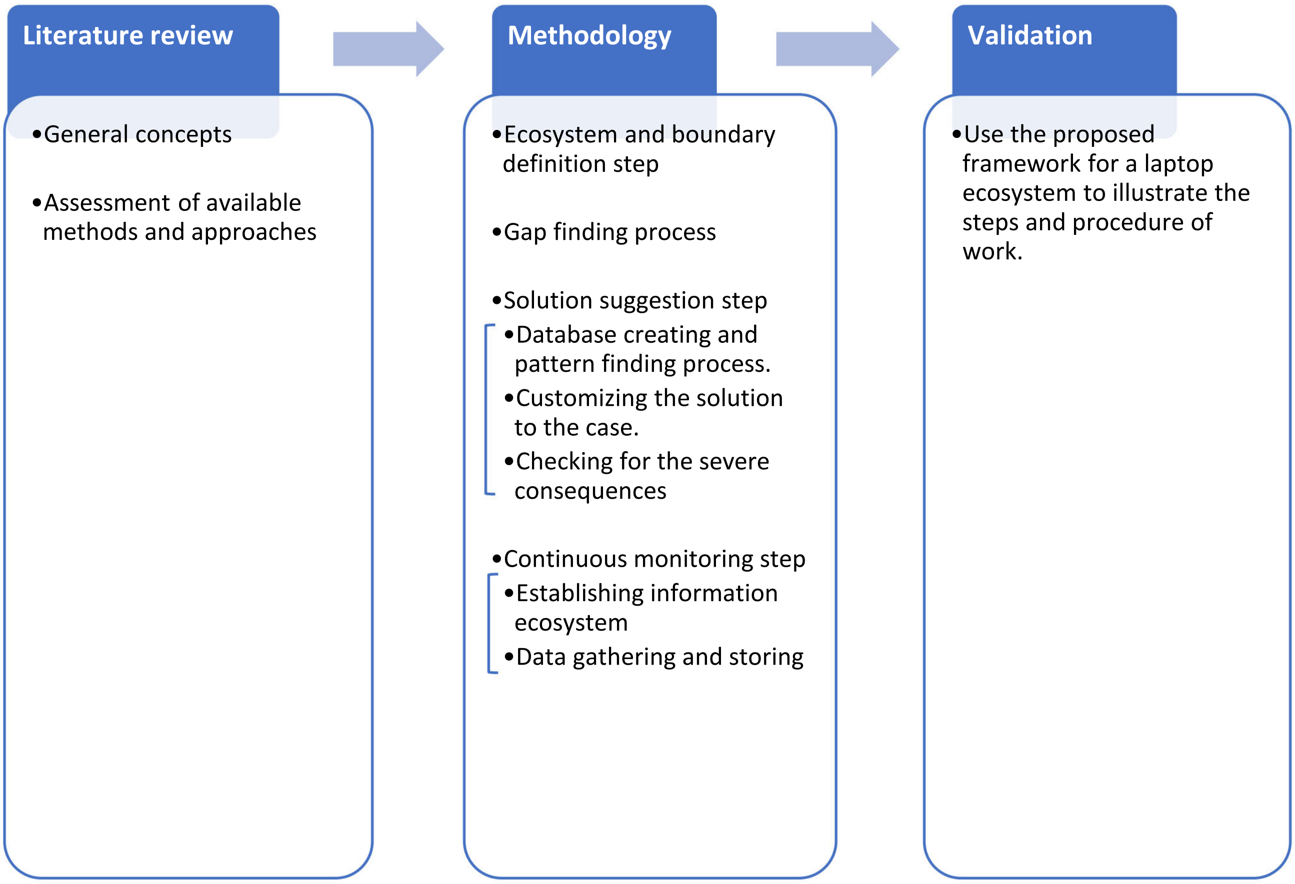
Such studies can be broad, which should be limited to fit in a master project structure. So, it is needed to provide more detailed targets which guild study. Table 4 provides a clear scope to differ the primary targets (green) from those that bound the content of this master thesis (yellow).

Table 4. Scope and limitation (green: primary aims/yellow: partially explained targets)

Business ecosystem			**Modification process**										**Continues controlling**	
Definition and general road map	Detailed criteria		problem finding				Data acquisition and database creation		Data analyzing and pattern finding methods		Solution selection		The overall setting, requirements, and suggested structures	Detailed design for different industries
	Material Energy	Environmental / Legal, Social	Material Energy		Environm-ntal, Legal Social		Structural, requirements, and action plan	Detailed scope customized for different industries	Structure and methods	Detailed design for different industries	General Structure	Detailed design for different industries		
			Roadmap and general structure	Specific criteria for various industries	Roadmap and general structure	Specific criteria for various industries								

3.5 Research approach

In order to cover the mentioned gaps, the study was performed in three main phases. It started with a literature review (Chapter 2) on the history of the concept, the definition of theories, and suggested solutions. In the second main phase (Chapter 4), based on available methods/models, a new framework is devised to design business models compatible with circular economy aims. The final main phase (Chapter 5) works on using the proposed framework to generate a circular business model for laptop industries. All the additional information and data are presented in the rest of the chapters and appendixes.


Literature review
•General concepts
•Assessment of available methods and approaches
Methodology
•Ecosystem and boundary definition step
•Gap finding process
•Solution suggestion step
•Database creating and pattern finding process.
•Customizing the solution to the case.
•Checking for the severe consequences
•Continuous monitoring step
•Establishing information ecosystem
•Data gathering and storing
Validation
•Use the proposed framework for a laptop ecosystem to illustrate the steps and procedure of work.

Chapter 4 Framework toward the circular economy

Through this chapter, a framework is developed and proposed for designing business models compatible with the circular economy concept. In section 4.1, a method is offered to determine the business ecosystem's boundaries. Section 4.2 presents a methodology to distinguish the critical points (gaps). Then in section 4.3, a combination of methods is stated to modify the detected gaps, which leads to different sets of solutions. The chapter will be continued by section 4.4, explaining available ways to prioritize suggested solutions (scenarios). Finally, in chapters 4.54.6, two necessary tools are defined, continuous monitoring and information ecosystem. The aforementioned procedure is shown in the Figure 15 below.

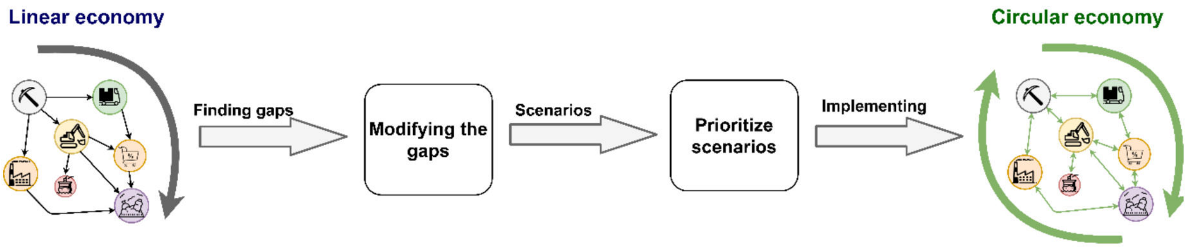


Figure 15. Simple sketch of the proposed framework

4.1 Defining business ecosystem

It is not realistic to consider a single business unite for sustainability assessment. Thus, a system of interconnected businesses should be studied, which is called the business ecosystem. A business ecosystem is an arrangement of business units (nodes) that have connections through different streams (material, energy, workforce, target market, information, etc.) and have interaction with each other (**Error! Reference source not found.**).

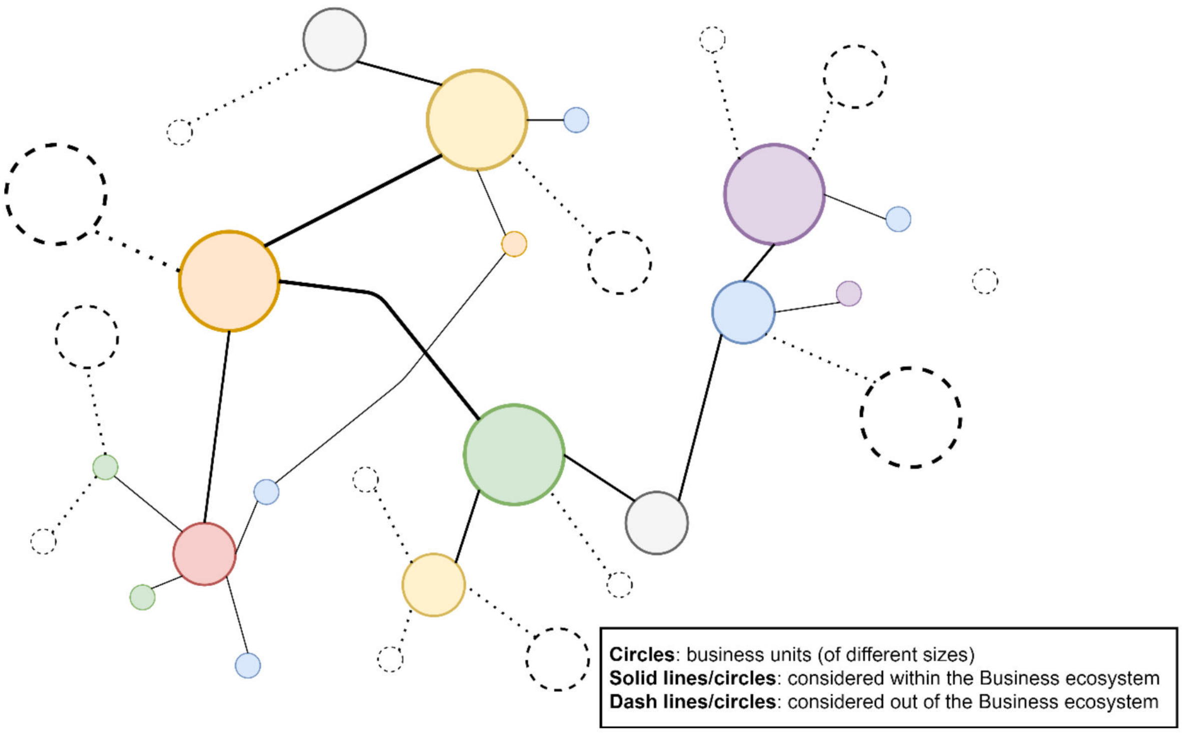


Figure 16. Schematic of a business ecosystem

Although the business ecosystem is a well-known concept, there is no clear definition for determining its boundaries. As a matter of fact, there is not any quantitative criteria to find which businesses should be considered in/out of the business ecosystem. Without these limitations, all the businesses will be involved in our business ecosystem, even if they have a tiny contribution or effect on the ecosystem's leading businesses. While two different approaches are proposed here to pull out the business ecosystem from the context: 1) Material flow circulation and 2) Product value chain. Each of these approaches can be used based on the available/required data and the target industry type.

4.1.1 Material circulating approach

Through the approach, the connected businesses are assessed based on the amount of material circulating between them. Those that have a certain percentage of entered material circulating between them are considered as a business ecosystem. So, the following steps can be considered.

4.1.1.1 Determining the major players

The starting point is to find the major players. It means based on the purpose of the study, the most significant and most influencing business units in the target industry are determined. For instance, the main players in the steel industry in the north part of Sweden can be considered steel producers (SSAB, …), Iron mines (Kiirunavaara, Malmberget, Kaunisvaara, earlier Tapuli, ...), and constructors. In literature, similar terminology is being used as an orchestrator (Gassmann et al., 2014; Palmié *et al.*, 2021).

4.1.1.2 Measuring the circuit load

Through this approach, the circulating load is calculating. Circulating load is the material that circulates between ecosystem players (businesses). Therefore, the material which inputs and outputs the ecosystem should be calculated. Subsequently, each business is considered a pointe that lets materials transfer into or out of the ecosystem. Based on the circulating load that is the material that does not leave the ecosystem and circulate. However, consider that in some cases, because the system is almost 100 percent linear, it has to consider the landfill inside the ecosystem otherwise it will not have any circulating load. Then the circuit load is determined, and the percentage of circuit load per total input material is computed. This ratio that is called the ecosystem material ratio (Equation 1), has to reach a specific amount; otherwise, the connected business units should be added to the circuit. Consider that although a higher ratio is more desirable, in some conditions, such as food industries, a high ratio may need to add many business units in the circuit, making assessment impractical.

Equation 1. Ecosystem material ratio

$$Ecosystem\ material\ Ratio:$$

$$\frac{\sum(material\ inputs\ to\ Business\ units)}{Circuit\ load = \sum(Material\ streams\ within\ ecosystem\ from\ resource\ to\ landfill)}$$

The ideal ratio for each case is different. But the practical way to define the suitable ratio is progressive design. Progressive design is started from a base such as 30% material and increase it step by step to the extent that the high ratio is reached, but the number of business units is manageable.

4.1.2 Value chain approach

In many cases, the main connection stream between businesses is not material flow. So, there is a need to devise a substitute approach. Therefore, the concept of value chain can come to the picture in such cases. The value chain is a term introduced by Harvard business school professor Michael Porter (1985). It is defined as interconnected operating activities that businesses do while converting raw materials into finished goods. Here, based on the concept, business units that add the most value to the specific product (or their component) are considered within the ecosystem. Take into account that through this approach, the product is the pivotal element to determine the ecosystem. For instance, consider the battery of the laptop as the central product which we are going to determine its ecosystem around. It consists of mining activities (metal extraction), transportations, process plants, electronic factories, laptop manufacturers, recycling companies, etc. this approach gives more freedom to defining business ecosystem boundaries compare to the first material circulating approach.

4.1.3 Complementary steps

To help to find a better connection map, two additional steps are designed. The use of them depends on both available data and network complexity. In order of illustration, in some business networks that consist of many business units, finding the clusters to look at them as the even smaller ecosystem is a better option for assessing the entire ecosystem. Apart from that, the effects that these connections can cause is another matter. Monitoring of these effects and influences can become complex due to a high number of connections. So, a mathematical method to monitor these interconnections' effect can be useful tools in complex and large ecosystems.

4.1.3.1 Network cluster finding

The method is highly used in the IT sector. A good example can be a complex network of people in your social network account. They are a network of people who have connections to you and themselves as well. But with a closer look, may you find different clusters in them. Clusters such as your high school friends, your gym friend, your colleague, etc. However, it is not easy to find this kind of cluster on an industrial scale and needs to use the precise technique. Newman (2004) presented the clustering method for the weighted networks, which can be used for our purpose by considering the material flow (or energy, information) as the weights. So, in the complex networks of businesses, firstly, the network is clustered into different groups (Figure 17). Then by using the methods which mention in sections 4.1.1 and 4.1.2, the boundaries will be adjusted.

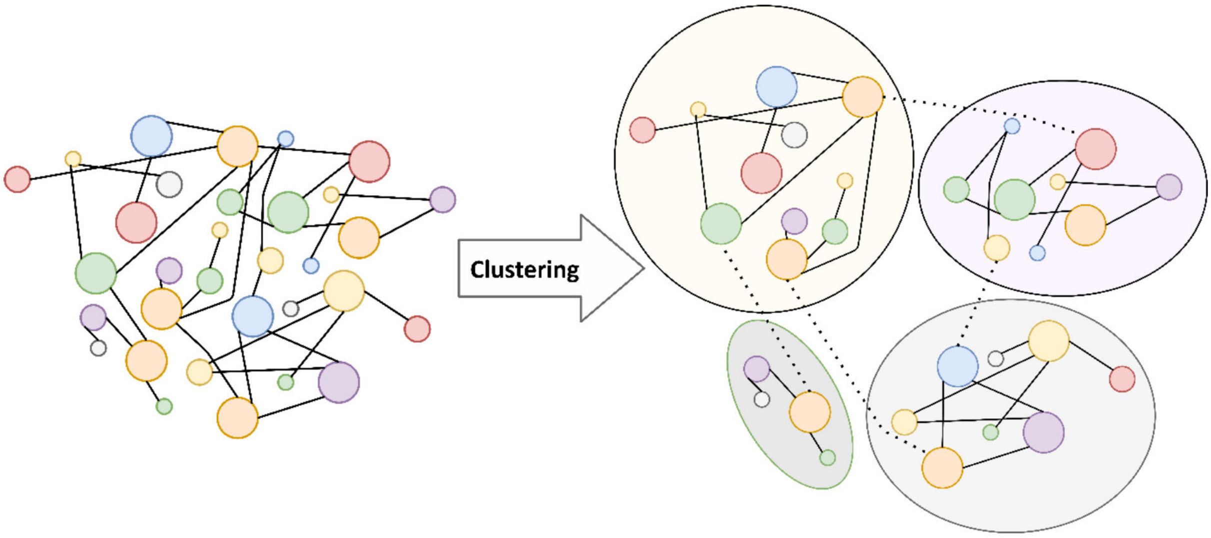


Figure 17. Schematic of clustering

4.1.3.2 Application of fuzzy cognitive map

Another complementary option is using the fuzzy cognitive map, which has been used in similar conditions (Gnoni *et al.*, 2017). In complex networks of businesses in which the influence of different business units on others is not summarized in material/energy flow, FCM can be helpful. A good example is the environmental issues caused by businesses. Even though they do not have considerable material flow with others, but they caused essential matters. The problem that can be caused by social impacts has the same story as well. Fuzzy cognitive mapping can be used as a complementary step to sections 4.1.1 and 4.1.2. It is useful when some players in the business ecosystem can be connected to the other players in ways different than material/energy paths. These alternative connections can be environmental, social, and legal issues.

4.2 Gap finding

After the definition of business ecosystem boundaries and determining the inside and outside units, the assessment will be started. In the ecosystem, some critical point exists which take the system far from sustainability and circular economy compatibility which we call gaps. The gaps can exist in three main economic, social, and environmental domains illustrated in Figure 18 (section 2.1.2).

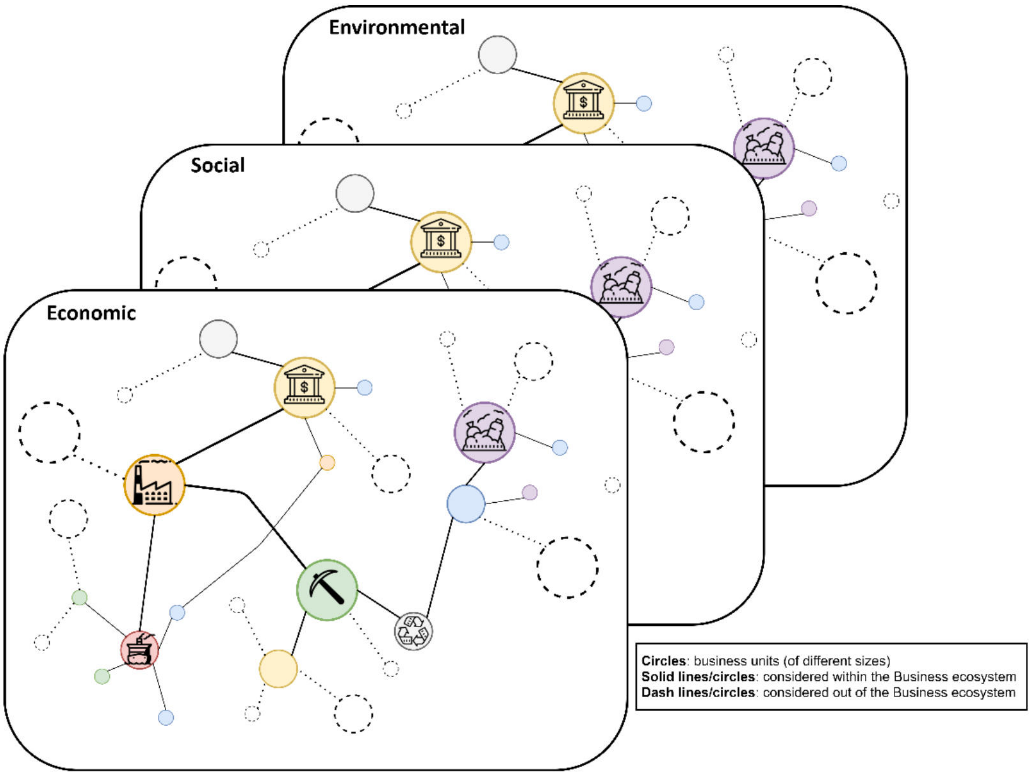


Figure 18. Business ecosystem covering three economy, social, and environmental domains

Criteria and indicators are needed to distinguish the gaps. But firstly, it is possible to classify them into two different categories. **1) Material/Energy leakage points**: the points that face a high percentage of losing material/energy out of the ecosystem. **2) Non-material critical points**: Points that caused environmental, social, or legal issues. For instance, a business unit releases toxic materials through the environment more than the local/international standard. Or a business unit that causes some social issue such as using child labor.

Based on the aforementioned classifications, two sets of indicators are presented, material/energy indicators and social/environmental indicators. They are sets of different indicators in each category. According to the intended industry, some of them can be selected and used. Therefore, it is not necessary to use all of them for each case, and it depends on available data and the target industry conditions. Note that environmental and social issues can cover different matters that may depend on the region. Therefore, established standards can be considered as environmental and social indicators (Standards such as the amount of arsenic released on air). Table 5 provides some of the most common indicators. However, still, there is some other indicator that can assess both aforementioned categories, such as LCA (section 2.1.5).

Table 5. Some of the material/energy and environmental/social indicatosrs are summarized from Pauliuk (2018a)*,* Elia et al. (2017)*, and* EMF (2016)

Material energy indicators	Environmental and social
Material input per unit of service	Water footprint
Material flow analysis	Ecosystem damage potential
Increase service per material stock	Ecological rucksack
Increase recycled content	Sustainable environmental performance indicator
Cumulative energy demand	Ecological footprint
Substance flow analysis	Environmental performance strategy map
More value-added per resource input	All environmental and social standards should consider as indicators based on the target industry and region
Linear Flow Index	
Embodied energy	
Emergy analysis	
Exergy analysis	
Material Circularity Indicator	

4.3 Modify the gaps (single node design)

Each node (business unit) that is related to the gaps should be modified (redesign). This modification consists of three steps; 1) detection, 2) customization 3) ecosystem check. The process is applied iteratively to all of the gaps, which were distinguished individually. The overall process is illustrated in Figure 19, which will be explained in detail by the following subsections.

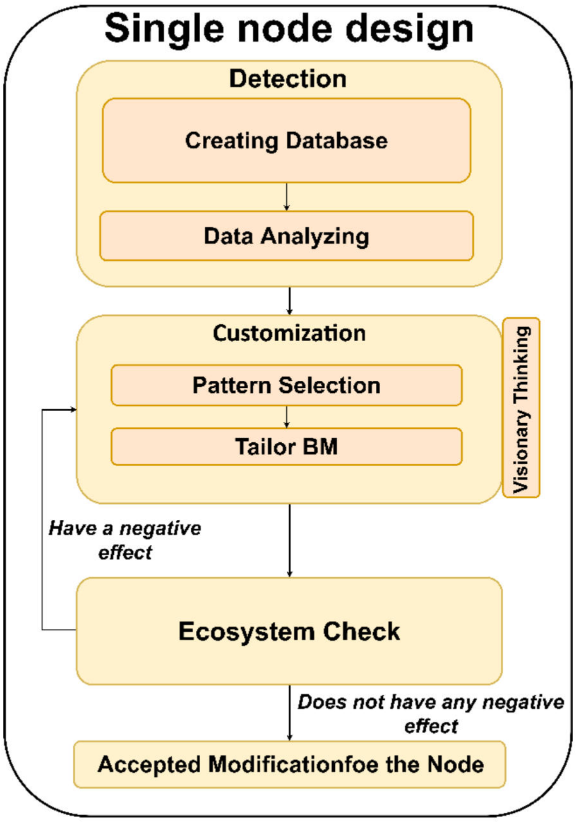


Figure 19. Schematic of the single node design process

4.3.1 Detection

The detection step is tried to scan for new circular BMIs in similar sectors and use them to provide a database. There are some public databases that can be used to monitor businesses that had innovation toward the circular economy. The two main ones are 1) Ellen MacArthur database[1] 2) circle economy database[2]. Consequently, the extracted businesses will be analyzed to classifying them into distinct variables for the pattern-finding method presented in section 2.2.2. Accordingly, the extracted patterns and subsequently their suggested business models are categorized in four main circular economy business models; namely cycling / extending/ intensifying/ dematerializing. A detailed description is provided in section 2.1.6. So finally, at the end of this step, we will have some suggested BMIs for our case.

[1] www.ellenmacarthurfoundation.org/case-studies
[2] www.circle-lab.com/knowledge-hub/all-content

4.3.2 Customization

Based on the target case, the more applicable patterns/solutions are selected. For instance, maybe in the electronic device sector, sharing was found as one of the circular business model innovations. It can be based on successful cases such as sharing washing machines, shared central vacuum systems, etc. However, consider this sharing pattern/solution is not applicable in laptop or mobile cases because nobody wants to share his laptop or mobile.

Subsequently, the selected patterns/solutions need to customize for the target case. Many factors should be considered to tailor the pattern for the case. Factors can vary from simple ones, such as the size of a business, to more complex ones like the main value generation route of a product or company. By visionary thinking, three domains of innovation in the pattern should be customized 1) Technological innovation, 2) Novel methodology, and 3) Social education/awareness.

The next step is needed to determine how the pattern and its changes should be applied to the business. Geissdoerfer *et al.* (2020) classified all the applying methodologies into four different main categories. To show differences between these four categories, it is necessary to state that each business has a main core business that targeted the primary process of the company and all the main activities of the company defined on its scope. The implementation process can target this core business or not. Also, the change can happen out of the company and then add to the company as an external part. Therefore, based on these alternatives, four different categories can consider for applying the change; **CBM transformation:** The core business model is changed into a more circular one. **Circular start-up:** When there is no business model, and a new circular business model emerges to fulfill the gap and meet the desired purpose. **CBM diversification:** The existing core business is not changed; however, a new circular business model is created and added to the current business. **CBM acquisition:** An existing circular business model is acquired and added to the current business. . Figure 20 illustrates the classification.

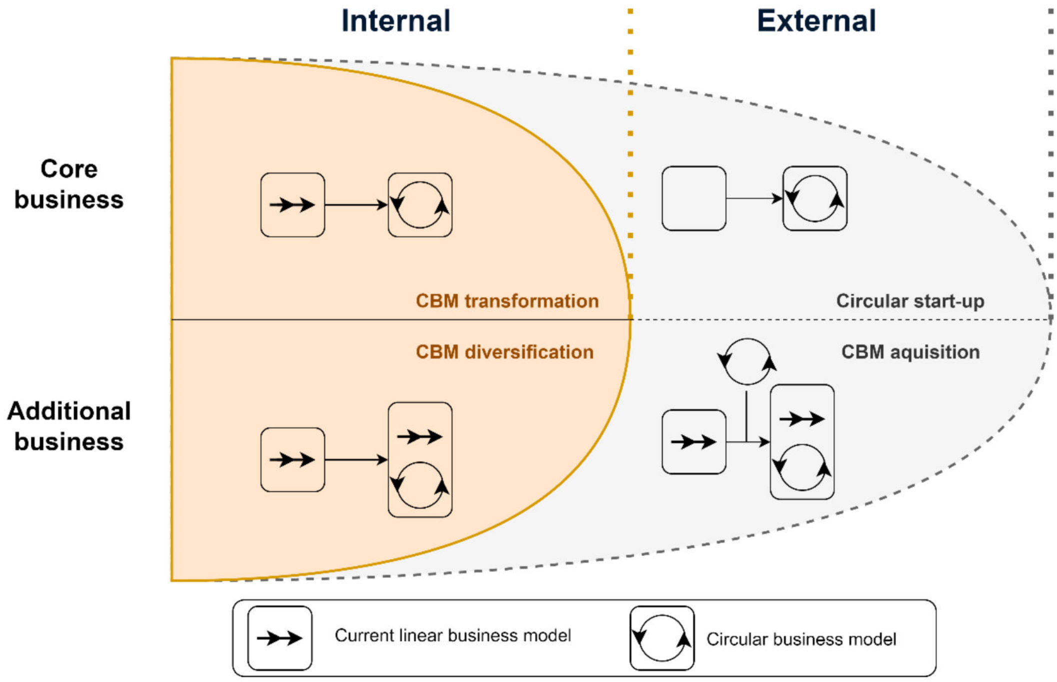


Figure 20. Implementing methods for CBMIs (*modified based on* Geissdoerfer *et al.*, 2020)

4.3.3 Ecosystem check

After modifying each business node, it seems necessary to check the overall influence of that modification on the whole ecosystem to ensure that the change does not negatively affect the other parts. Although it is an obvious need, the complexity of business networks (business ecosystem) makes it challenging. One of the solutions that can be useful is FCM (section 2.2.3). So, at this step, using FCM tries to assess the effects of modified nods in the business network. Changes that lead to an overall negative impact on the ecosystem should be reconsidered in the last step (section 4.3.2) to find an alternative solution. This iterative manner is necessary to reach the best scenarios. Gnoni *et al.* (2017) did a similar good study to monitoring the different phenomena in electronic equipment circular economy by using FCM. This gap-finding process (section 4.2) for different nodes is an iterative process that can scan all the business units.

4.4 Scenario selection

After reaching solutions to modify the gaps, it is most probable that some scenario shows up. Actually, each gap can lead to more than one solution or circular business model innovation. Therefore, different combinations of them (solutions) can be applied to salve all the found gaps. Consider two gaps are identified. Then each gap has two different chooses for circular business model innovations. Consequently, the whole ecosystem will be faced with four different alternatives (combination) or scenarios to change. Then because only one scenario can apply, they should be prioritized.

In order to prioritize the scenarios, different criteria can be used based on the available data. Apart from that, the assessment should be done in two main views 1) material and energy 2) social and environmental. So in material and energy, if data is available, the scenarios will be assessed based on the material circularity indicator (EMF, 2016); otherwise, the simple indicators were mentioned in section 2.2.4.1 can be used based on the available data and the industries features. But the social and environmental view is a highly inspector-oriented area that differs from industry to industry and case to case. However, the mentioned indicator in sections 2.2.4.2 and 2.2.4.3 are the base tools for us in this step. All the aforementioned algorithm is shown in Figure 21.

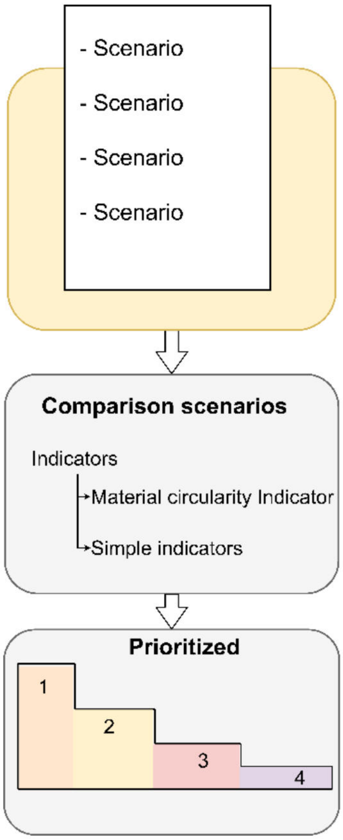


Figure 21. Scenario selection algorithm

4.5 Continuous monitoring

After all gap modifications and scenario selection/implementation, the ecosystem should be acceptable to the circular economy concept. However, this acceptability won't be long-lasting and due to different reasons, it can change. The reasons can be 1) the ongoing changes and progress in all parts of the ecosystem (Technology, social concerns, environmental concerns, etc.), or 2) it can be the fact that all systems naturally tend to go in the way to increase their entropy.

So, the necessity of a continuous monitoring system emerges. This monitoring needs its tools and infrastructures, such as the continuous/semicontinuous gathering data system for all the processes. The monitoring responsibility can assign one of the leading players in the ecosystem (orchestrators) or, much better to assign to an external organization that the leading players in the ecosystem establish. It highly depends on the conditions; for instance, in a small ecosystem that a main player dominantly influences, it looks reasonable that the main player be responsible for it.

The core of this continuous monitoring is indicators. Indicators which detailed discussed in section 2.2.4. However, the available data can be different from what is used before reaching the acceptable situation (before implementing the framework). Because, after reaching the circular condition and providing the infrastructures for measuring and gathering data for continuous monitoring, you will access more detailed data classified and stored. These data sets form a virtual concept explained in section 4.6 and is one of the main components of the framework.

4.6 Information ecosystem

The information ecosystem is responsible for gathering and classifying the data. It consists of three main parts, 1) measuring gathering part, 2) organizing and standardization part, and 3) storing part or database. The information ecosystem plays as the central component of the business ecosystem. It consists of both physical and virtual parts that connect all aspects of the business ecosystem. Data can vary from very detailed data such as product performance to general ones like factories' CO_2 emissions. There are many different ways to get this data, from stored written documents to electronic installed sensors to technologies like the internet of things.

This information ecosystem as it mentioned consist of three parts as following:

- Measuring and gathering part:
  The first part of this information ecosystem is to acquiring data. The data can be obtained directly by some sensors or some records that gather through different processes such as the number of soled products or salaries of employees. However, in any case, they should be measured and gathered. This measuring process depends on the nature of data while gathering more or the same can be the same for both kinds. It can be done by transferring the measured data to digital records and record them.
- organizing and standardization:
  Data will gather from different parts of different businesses in the ecosystem. Therefore, they should first be classified and secondly standardized. Standardizing process means that da same kind of data should follow the same of expressing way

and formatting. A simple example can be that all the temperatures should be presented in Fahrenheit. A more complicated example can be the fact which kind of water streams are considered as wasted water. After this classification and standardizing, data can be comparable.

- Databasing

  All the classified and standardized data need to be store in order to be available for further needs. Therefore, data is available whenever any of the players or the controlling organization (section 4.5) needs access for subsequent analysis.

Figure 22 Schematize the overall process in the information ecosystem.

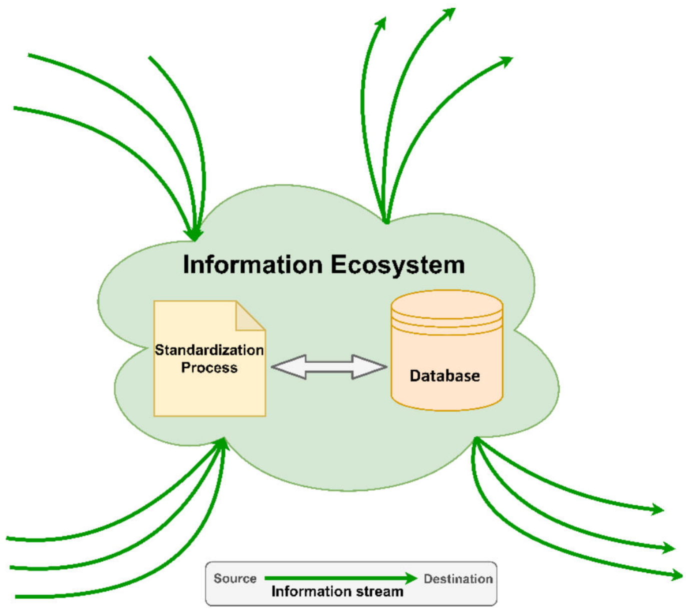


Figure 22. Information ecosystem schematic

Figure 23 shows all aforementioned steps as a framework modifying business models toward the circular economy. A responsible organization should start the whole process to implement the framework. So, the legislations are needed to be ratified in order to act as incentives or inhibitors. This legislation provides financial profits for the companies who follow them. Hence, either companies will start making consortiums and asking external consultant companies to govern them through the changing process, or even the consultant companies proposed their proposal to the companies, and then the consortiums will be established.

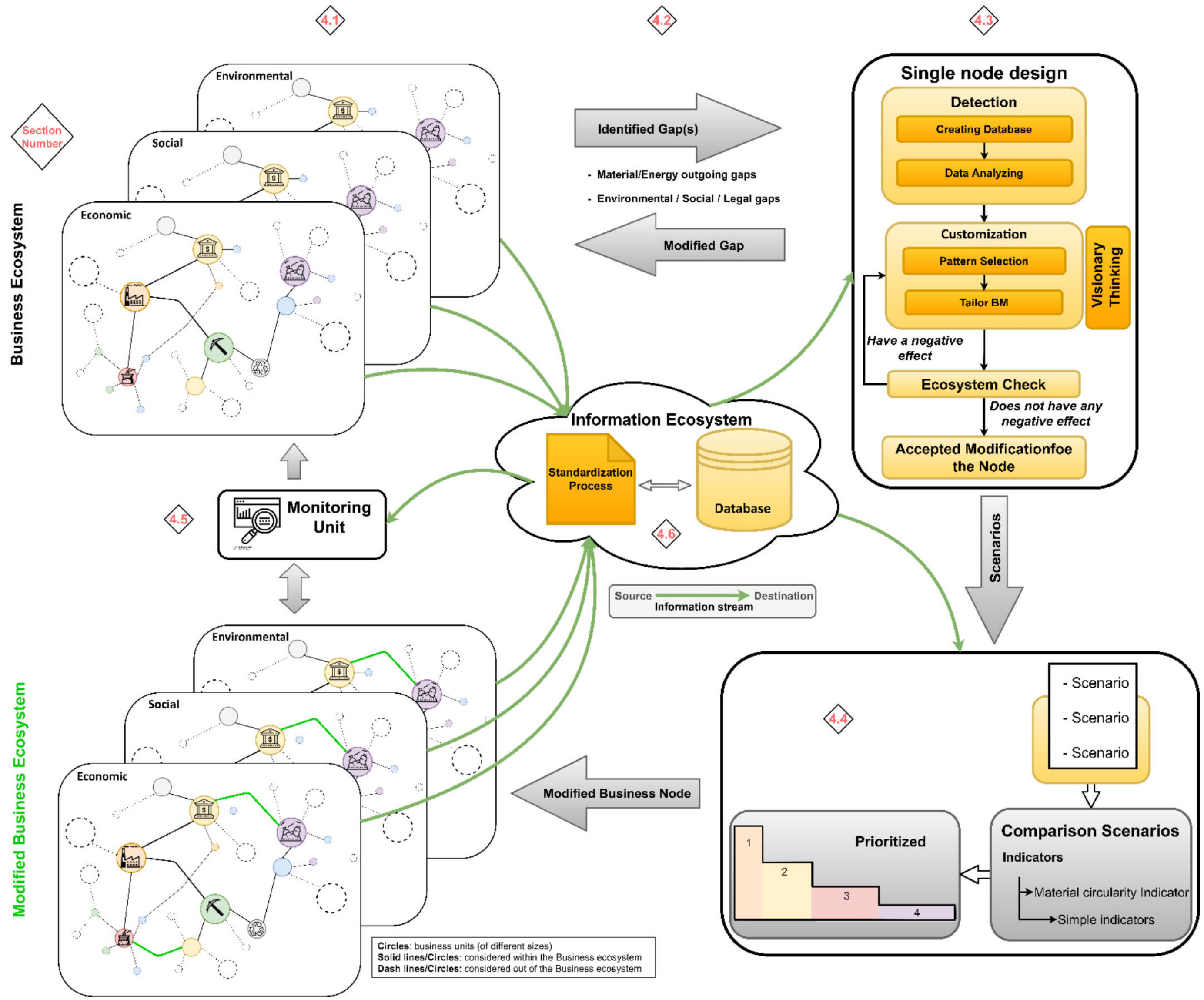


Figure 23. Business design framework toward the circular economy

Chapter 5 Case study

Throughout this chapter, the business ecosystem around a laptop is considered as a case to follow the designed framework. The purpose is to modify the ecosystem to a more circular condition by proposing different business model innovations. As a pre-requirement, the data (database) is needed in order to feed indicators in different framework's steps. Although these data cover various categories (such as material input/output, CO2 emission, pollution emission, hazardous material release, employees' condition), they highly rely on the kind of industry and vary from case to case. Indicators are also classified into two main categories as mentioned in section 4.1; tangible (material, energy stream) and intangible (such as legal, social, environmental concerns).

As mentioned, making a complete database is a crucial step in using the framework. However, providing a comprehensive database is beyond a master project. Moreover, the laptop ecosystem is a complex network that makes the situation more complicated. Despite all the cases mentioned, but because the German partner requested to focus on the laptop due to using it for some more significant project on their side, the case study is accomplished on the laptop's ecosystem. Although they started to provide some of the required data through their project, the Corona pandemic forced them to stop most of their process. So, the promised data was not generated to hand in our project.

Therefore, the lack of data was compensated by simplifying the steps and get more general scenarios. It is indisputable that for more specific scenarios the detailed information is needed.

5.1 Ecosystem determination

In the first step, the ecosystem should be defined. As mentioned in section 4.1, two ways can be used based on the case and available data. Here the value chain method is used to provide a simple map of the laptop ecosystem. All parts from material extraction to part-makers and laptop producers are societies that need detailed data for deep investigation. So here, they summarized separately in one representative company due to available data.

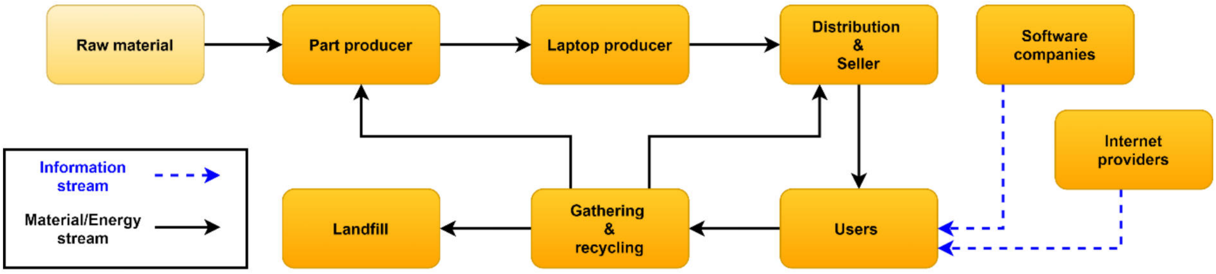


Figure 24. laptop ecosystem schematic

To reach the above ecosystem (Figure 24), the following criteria are utilized.

Assessing the material stream: the primary connection in the ecosystem is the material stream that works perfectly in this case to determine the leading players (based on available data).

Value chain: value chain criterion shows results mainly the same as the material stream in the laptop case unless two players which are attached to the ecosystem without any significant material stream contribution; the software developers and internet providers.

Social and legal concerns: some social and legal matters such as privacy and data protection are essential in the laptop case; however, they didn't make any change because their players are already added in the value chain approach.

5.2 Gap detection

In the second step, gaps should be determined. Section 4.2 illustrates the ways which can be used for the purpose. Probably many gaps exist in the economic, social, and environmental domine. But again, due to the lack of data and complexity of the system, gaps are determined based on qualitative data rather than quantitative ones. Based on qualitative information, the four following gaps can be considered:

1) Packing and distributing between laptop producers and sellers (stream 3, Figure 24) caused lots of plastic and cardboard waste (Tencati *et al.*, 2016).

2) Gathering and reverse logistics of used and end-of-life laptops are inefficient and weak processes (Safdar *et al.*, 2020).
3) Due to their complexity in dismantling and composition, recycling laptops is a time, energy, and labor-intensive process. It is also a low efficient operation as well (Webster, 2013). Recycling laptops can be a nightmare since A) they can consist of more than forty different elements (Van Eygen *et al.*, 2016; Coughlan et al., 2018), and B) it's so hard to sort their parts based on their component to send them to different routes for recycling. Especially for the rare elements, which are expensive while a tiny portion in total (Lixandru *et al.*, 2017). Consider that all laptops consist of printed circuit boards (PCBs) that 99% look like each other, but they can have different compositions based on the attached components.
4) The reuse of dismantled parts in new products or old ones is inefficient due to fast-changing laptop design (given changes in technology and shape). So in this versatile market, it will be hard to find a match for a part (Sundin *et al.*, 2020).

5.3 Gap modification

This step consists of three main subsections. Firstly, it is needed to create a database. The database should cover the booming business in view of circular economy concept in similar or close sector. For instance, here for laptops, the similar sector can be electronic equipment. Secondly, patterns should be extracted from listed information in the database, like what is explained in section 2.2.2. two primary online sources provide information on successful circular economy businesses (Ellen MacArthur database[3] and Circle Economy database[4]). Pieroni *et al.* (2021) classified the data in some general sectors that one is electrical equipment. They consequently extracted patterns as well. Here for this step, their work is used to save time. Table 6 summarizes the more relevant pattern. It shows the patterns and suggested solutions based on successful cases that are mentioned as well. The table listed all patterns, but each pattern is related to a specific gas which is listed in the first column.

[3] www.ellenmacarthurfoundation.org/case-studies
[4] www.circle-lab.com/knowledge-hub/all-content

Table 6. defined patterns for electronic equipment (produces by Pieroni *et al.*, 2021*)*

Gap	Pattern name	Pattern or solution description	Cases	Benefits for resource decoupling
2	Incentivized buy-back of electronic appliances and devices	- Manufacturers or partners incentivize customers to return end- of-use devices or appliances through a convenient system. - Incentives to the customer to increase the rate of return can occur in different formats (e.g., a discount offered on a new product for surrendering the old one).	• Snew • Circular Clockwork	Increased product longevity.
2	Access to electronic appliances and devices in customizable time-based contracts	- Manufacturers or integrators offer solutions that enable easier access to or use of devices/appliances by customers. - Contracts are long-term (e.g., lease agreements with a minimum time of 36 months), with simpler benefits, usually not including life-care services. - Devices are collected back in the end-of-use, as the ownership is maintained with the provider.	• Logic Vending - Access to coffee machines	Intensified product usage.
1 & 2	Electronic appliances and devices as through- life care services in pre-configured packages (subscriptions)	- Manufacturers offer solutions that enable the use of devices, including life-care services (e.g., maintenance, repair) for a temporary period agreed on a formal contract (e.g., lease agreement). - During the period of the agreement, the customers are able to benefit from the products without limit.	• Gerrard Street I - Headphones as through life care service	Intensified product usage and increased product longevity.

2 & 3	Function as a service (e.g. washing as a service, coffee brewing as a service) in pre-configured packages (subscriptions)	- Electronic devices and appliances manufacturers offer services based on functionalities of the product (e.g., washing, coffee brewing). - They charge according to the use with a rate agreed in subscription agreements (e.g. pay-per-cup of coffee) and provide a comprehensive solution (e.g., device/appliance, installation, maintenance, upgrades, consumable management, and replenishment). - The ownership of the devices/appliances is usually not transferred to the customer. The product returns to the manufacturer at the end of use. - Benefits for Circular Economy: manufacturer is stimulated to use the minimum amount of resources and energy to reduce costs and increase its operational margin.	• Bundles - Washing as a service • Bundles - Coffee brewing as a service	Displace more resource-intensive systems.
4	Peer-to-peer electronic appliances and devices lending, renting, sharing or trading services based on commissions	- This offering is based on solutions that enable sequential users to temporally access or use devices and appliances. These users could be from the same organization (in the same or different regions) or from different organizations. - Usually, digital and physical platforms to enable the customer to access the solution are established and coordinated by the manufacturer or controlled by an integrator with expertise in logistics and digital technologies (e.g. marketplaces).	• Fat Lama - peer to peer electronic appliances lending and renting	Displace more resource intensive systems and intensified product usage.

	- Transactions can occur in a peer-to-peer or peer-to-integrator format, usually on a rental or pay-per-use format. - Different transactional arrangements are possible: one example is to charge commissions per rental or per-use from the companies renting out devices.	

Then based on suggested patterns, tries to customize solutions to fill the gaps. The process goes through visionary thinking that covers three technological innovations (technical solution), novel methodology (management solution), and social education/awareness (social help or support). By considering the discovered patterns for gaps 1 and 2, the solutions are mainly around dematerialization strategy, and for gaps 3 and 4 are around intensifying use strategy (specifically on sharing and PSS). So based on the above patterns and visionary thinking, the following solutions are proposed (Table 7).

Table 7. Scenarios

	scenario	Explanation
1	**Dematerialization & sharing**	A business model is based on separating previous business into two parts, a shared part and an individual part that works together.
2	**Digitalization scenario**	A new function (using the concept of the internet of things) is added to the current business model in order to extend the use of continuous monitoring which increases the data which can be used for maintenance and recycling.

5.3.1 Dematerialization (digitalization) & sharing solution

By considering the issues which led to the gaps, a business model around dematerialization is proposed. The associated issues should be listed to provide a clear overview of the needs that should cover by the suggested business model innovation. These issues are the part of the aforementioned gaps (section 5.2), which are explained in detail as below:

1- ***Hard to dismantle the laptops.*** Due to the ongoing process toward making laptops smaller and lighter, all producers design their products so compact. They try to use all the spaces and fit all components tightly together—this concept behind designing causes the difficulty in dismantling process and make it a costly and time-consuming process.

2- ***Hard reverse logistic.*** People do not show an acceptable contribution in returning their end-of-life laptops. Firstly, they don't have enough incentive to spend their time and money for returning. And secondly, they do not feel interested in giving their assets that had their data to those they don't know. Also, there is no pricing strategy for secondhand laptops. This lack of a pricing system causes people to feel that they cannot sell their laptops at their right price even if they sold them higher than their actual value.

3- ***Lack of compatibility of dismantled parts.*** One of the main issues is that because of the diversity of laptops, it is hard to supply one type/model of laptop with the part from another type/model. It is much easier for home computers because most of their components have a standard size and connecting port type.

4- ***Short life cycle.*** Ongoing technological change from one side and advertising new products from another side cause the fake need for change in customers faster than before. So, it decreases laptops' life cycle tremendously compared to the last, while they can work perfectly to meet the customers' real needs.

In order to meet the aforementioned reasons, and based on visionary thinking and considering the similar cases mentioned in Table 6, a business model is suggested, under the title of "Remote Process Center" (RPC). Use remote computers instead of having very powerful laptops; By this way, laptops can be very simple and light. Therefore, companies only should work on the design attraction of their products and provide them with very simple hardware. These laptops connect to the network (high-speed Internet connection which is possible in near future, at least in developed countries by technologies such as 5G or satellite affordable internet access) and use that network for their connection to the processing centers (each laptop producer can have its own processing centers) and use the specific hardware which owner ordered when he bought the laptop. So, each customer can promote its system's condition by asking the processing center to change his account. His assigned hardware will be change, or he will be connected to another hardware without removing the previous hardware. Similarly, the previous hardware can assign to another customer who does not need that much advanced performance—besides, considering that the processing centers are equipped with standard hardware in size and acceptable ports, which can easily dismantle and change. By applying RPC, the following outcomes can be achieved:

- The lower change will happen for laptop production;
- People can keep laptops for a longer time, and whenever they need more powerful laptops, they can easily change their account specifications in the processing center;
- Processing centers can be managed for reuse and recycle easier. Because of their standard equipment; and
- Because the laptops will be designed simpler, they can be dissembled and recycle easier.

This step needs to precisely customize the new BM (Remote process center scenario) implementation process in the form of one of four strategies mentioned in section 4.3.2. So, by considering the four strategies, CBM diversification is more suitable for the purpose because we need core business of laptop production while RPC should add it. Also, because there hasn't been any appropriate center before, the CBM acquisition is not practical. Figure 25 illustrates the new structure of the business ecosystem after the implementation of RPC.

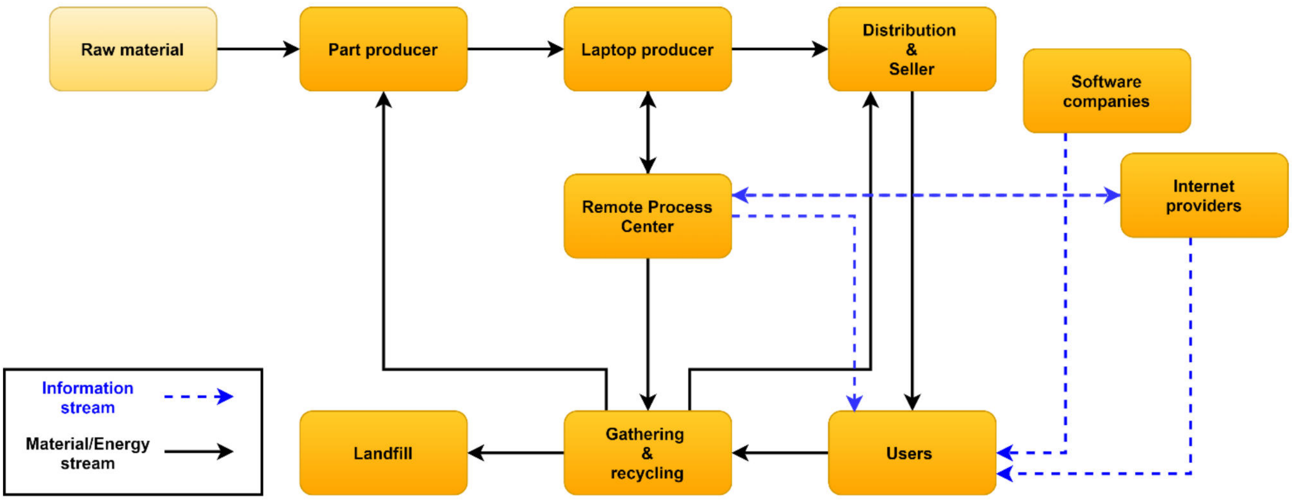


Figure 25. Laptop ecosystem with RPC implementation

Implementing RPC can cause concern about storing personal data. It is reasonable that people do not tend to keep their personal data in places that others can access. Although the cloud storage providers try to persuade them that the data will be secure from any threat. So, two vital actions need to take. Firstly, the more proactive contribution from software developers to make storing more safe and secure. Secondly, the legislation which makes users more comfortable storing their data in clouds is needed to ratify. Although any laptop has in the RPC project still has a small hard drive for essential data. Basic software such as operating systems (Windows, Macintosh, etc.). This small storage can also be used for some confidential personal data.

5.3.1.1 Ecosystem check

As a following step, it is necessary to check the influence of the changes in the ecosystem. Are these changes (implementing the RPC) caused negative consequences on other players in the ecosystem or the entire ecosystem? One of the adverse effects is the need for investing and improving internet infrastructures. Like any other development, this development needs energy, funding, and resources, leading to waste generation and environmental damage. However, because this improvement in internet infrastructure is an unavoidable phenomenon and undoubtedly will happen with or without implementing RPC, the implementation of RPC will not cause any adverse effect and can happen.

However, as illustrated in section 4.3.3, Fuzzy cognitive mapping can be used to assess the effect of change in one component on the whole ecosystem. Therefore, the method is used to clarify the effect of using a remote process center scenario. The main variable of the ecosystem is determined based on the collaboration of expertise, so they are not definite set and can vary slightly from person to person. Nevertheless, because this is just an illustration of how Fuzzy cognitive map can be used in the framework, the following variables (Table 1) are considered.

Table 8. Used variables in Fuzzy cognitive map for remote process center scenario

Variable	Explanation
Raw material production	The amount of raw material that is used.
Number of users of standard laptops	It is a representative of standard laptops which is produced. (Usual laptop: the currently available laptop, not those that design for use in conjunction with remote process center)
Number of produced parts	The number of produced parts which are used in laptops and computers
Used energy and material for distribution and selling	The energy (fuel, electricity, etc.) and materials (plastic, paper, etc.) are used in the distribution and selling process.
Amount of material goes to landfill	The amount of material that is unrecyclable/ non-reusable or hard to recycle/reuse. They are considered to be destined to landfill.
Amount of material gathered and recycled	It is representative of the end-of-life material which can gather and recycle.
Needed internet speed	The broadband (speed) of the Internet network that is needed.
Number of users in remote process center	It is representative of the users who use simple laptops linked to remote process centers.
amount of released pollution and wasted energy	The total released pollution and wasted energy which related to different processes.
Environmental damage	The relative effect of laptop ecosystem on the environment in the adverse direction
Public awareness	The awareness of people regarding the effects that linear economy can have on the environment. This awareness will affect their preference and can change their actions.

The connections between these variables should be determined with different weight factors. The weight factors show their influence on each other. These weight factors are measured in two steps, 1) based on detailed studies performed on determining the relationship between different variables (for instance, the study shows that the regular 3-hour workout in a week decreases the risk of heart attacks 30%) 2) for the rest of the variables, which there is no precise scientific study behind, Seeking the opinion of experts is the way. For this purpose, some methods such as Delphi technique (Linstone et al., 1975) can be used.

Since the affirmation steps are beyond our scope, and fuzzy cognitive mapping is used here as an illustration of its application, the determination of weight factors is simplified.

The weight factors are explained and tried to consider by reasonable relative values. So, the relation is classified into two main categories:

1) **Direct relation**, those that have a direct ascending or descending relationship. In a way, with the increase of the first variable, the second one also increases and vice versa.

2) **Reverse relation**, the relation that with the increase of the first one, the second one will decrease and vice versa.

Additionally, each direct or reverse relation has different levels, varying from very high to low. The levers are valued linearly, as shown in Table 9. The next step is necessary to assign different levels to the defined relations in Table 8. In this step, the best option is to use a more reliable method such as the Delphi method. While here is tried to use different rational justifications and available information in the literature (Table 10). In the following, some are explained to make the method and selected values more clear. Still, consider it is just the demonstration of how the FCM is used in this framework, and reliable results need more accurate data, which is suggested in the recommendation chapter.

- Number of users of standard laptops VS Number of produced parts: Since there is no significant reuse in laptop manufacturing, any laptop should use new parts, which leads to having a high direct relation between them. It means that as the production of standard laptops increases, at the same rate, the need for parts increases.

- Number of users in remote process center VS Number of produced parts: In this case, there is no clear information since the idea is needed to implement at first. Consequently, only because the remote process center makes the reuse process pretty easier can the medium direct relation be selected. Consider the Delphi technique will be an excellent option for this.

- Amount of material gathered and recycled VS Raw material production: Van Eygen *et al.* (2016) shown that if the laptops are recycled, they will provide 39% of all materials and 85% of metals for production. So, the weighted factor for this relation is considered high but reverse relation (-0.75).

- Amount of material gathered and recycled VS Amount of material goes to landfill: The same concept as the previous relationship based on Van Eygen *et al.* (2016) findings applies to this one.

- For those relations with no apparent association exist, such as the effect of public awareness, consider the lowest weighted factor (0.25). Since it is reasonable that the relation should exist but the amount is needed further investigation.

- Amount of material goes to landfill VS Environmental damage: regarding this relation, although there is no clear number, it is reasonable that the amount of material that goes to landfill is highly influencing the environment in a negative way.

Note that the relation associated with the remote process center, as mentioned previously, needs to be implemented to measure otherwise use methods such as the Delphi technique. So, their weight factors are applied compared to the similar relation in standard laptops. They are selected by considering the aims and purpose of the remote processing center (RPC) in facilitating the recycling and extending use of products. For instance, since the RPC make recycling, extending use, and sharing strategy easier, its reliance on produced part should be lower than the standard laptops. Therefore, the relation between *Number of users in remote process center* & *Number of produced parts*, is selected medium (0.5) while the same relation for standard laptops is considered very high (1.0).

Table 9. relative weight factors

Reverse relation (-)					**Direct relation (+)**			
Very high	High	Medium	Low		Low	Medium	High	Very high
-1	-0.75	-0.50	-0.25		0.25	0.50	0.75	1

Table 10. Weight factors in laptop ecosystem (the cells are colored based on values)

	Raw material production	Number of users of standard laptops	Number of produced parts	Used energy and material for distribution and selling	Amount of material goes to landfill	Amount of material gathered and recycled	Needed internet speed	Number of users in remote process center	Amount of released pollution and wasted energy	Public awareness	Environmental damage
Raw material production									0.75		
Number of users of standard laptops			1	0.75		0.25	0.25		0.5		
Number of produced parts	0.75								0.75		
Used energy and material for distribution and selling					0.5				0.5		
Amount of material goes to landfill											0.75
Amount of material gathered and recycled	-0.75				-0.75						
Needed internet speed	0.25								0.25		
Number of users in remote process center			0.5			0.75	0.75		0.25		
Amount of released pollution and wasted energy											0.75
Public awareness		-0.25						0.25			
Environmental damage										0.25	

Therefore, based on the selected weight factors and their connection, a fuzzy cognitive map can be designed as Figure 26. The Mental modeler software[5] that Michigan State University designed has been got help for this part of the study. It is a free and famous online software for fuzzy cognitive mapping.

According to the Figure 26, it appears that some variable only affects others. In contrast, they are not be affected by any other. These variables are known as drivers, which provide good leverage to change the system. However, it is hard to have drivers (variables that only dives

[5] www.mentalmodeler.com

others and not be influenced by them). So the other definition emerged, which shows how much a variable is affected by others as “Indegree”(the number of income arrows per number of arrows goes out, Figure 26). While the level of which variable will affect others is shown by “Outdegree”. Therefore, “Number of users of standard laptop”, “Number of users in remote process center” and “Public awareness” are most influence other than being influenced. However, Public awareness influence two other and therefore may it can be considered as one of the semi-drivers.

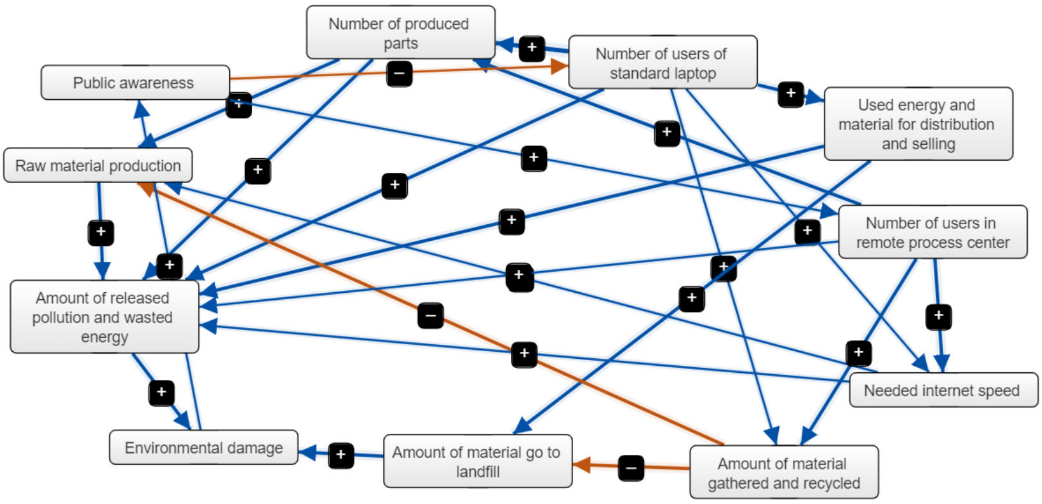


Figure 26. Fuzzy cognitive map of remote process center scenario (Mental modeler software)

Then according to the model, the consequences of the selected scenario (use remote process center) can be assessed. Two different option is considered 1) increase 100% of the use of standard laptops 2) increase 100% use of remote process center. The effects of these two different options are shown in Figure 27. The figure shows how much difference these two options make. The amount of material that goes to landfills is dramatically decreased by using remote process center strategy while continuing using current standard laptops can make more trash to bury. The same story for the environmental damage, raw material production, used energy, and so on.

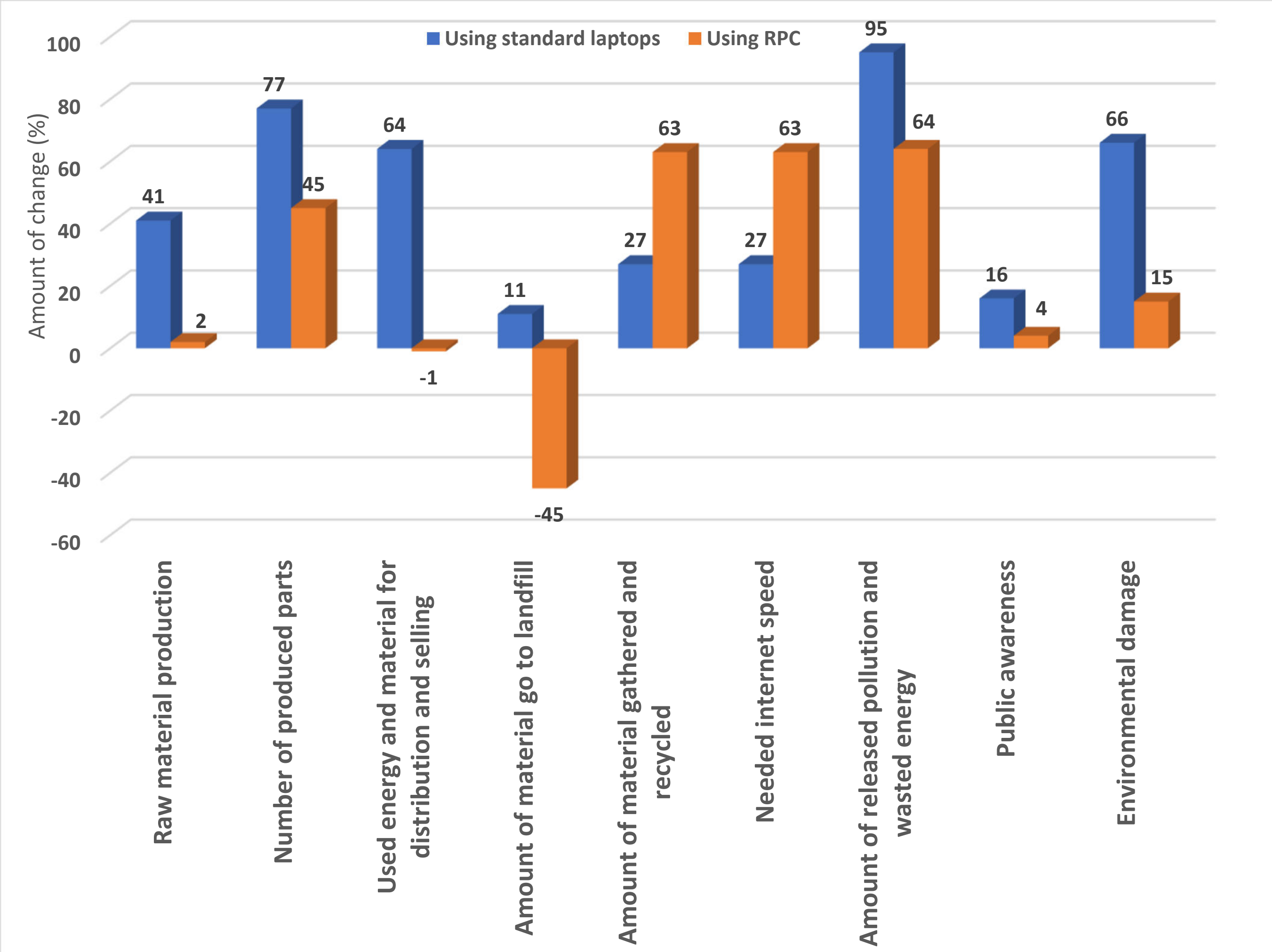


Figure 27. comparison between using standard laptops and remote process center strategy (RPC)

Therefore, the ecosystem check shows the consequences of this scenario are entirely acceptable and do not show the adverse impact. However, the precision of the method should be increased by gathering more accurate data. In between processes such as the Delphi technique could be the acceptable and practical method to focus on. Through such practices, the weight factors and the structure of the network will be finalized by a group of experts in a reciprocating manner. Undoubtedly, the outcome of the process is not the same for all practices and varies from group to group. But it is still acceptable in lack of statistical data. Indeed, it is pretty evident that many other effects can be found by more detailed investigation.

5.3.2 Digitalization scenario

Digitalization by using the internet of things concept (IoT). To answer gap 2 (gathering and reverse logistic) and gap 4 (reuse of dismantled parts) based on visionary thinking, the idea of the internet of things can be practical. But because it's somehow a new concept, there is not that much industrial case in our records. There are two potential advantages for the laptop case. Firstly, they have access to the internet (at least in most cases); secondly, their suitable hardware generates and shares needed data. However, an external infrastructure is required to set standards for data, provides an action plan for gathering and users' data, as well as have executive arms to manage and facilitate the reverse logistic and pricing system. A profitable strategy can be merging this external infrastructure with organizations responsible for the information ecosystem. A more detailed plan can be sought in further studies. However, to get more familiar with the benefits of applying the concept, it is suggested to read the works of Rudolf *et al.* (2020), which is a part of the mother project of this thesis.

5.3.2.1 Ecosystem check

Many legal and social issues are related to applying IoT, especially for laptops (and smartphones). The generated data has legal value and so needs to have acceptance of beneficiaries which include users, laptop producers, etc. So, the consequences of using this generated data lead to fewer contributions from companies. These companies fear the reaction of their customer regarding tracking their data. As the connection of a device increases, the ways that data can leak or stole (hacked) will increase. The mother project of the current study at Braunschweiger University focuses on this issue and how the legal concerns can be fulfilled. Therefore, to get more about it, it is highly recommended to follow their ongoing research.

5.4 Scenario check and Actions after optimation process

Previous parts of the framework led to different scenarios to solve the defined gaps. However, these scenarios should be prioritized in order to provide a better guideline for decision-makers. While, the prioritizing process demands quantitative data, which is beyond the study's scope and has not been accessible for it.

After implementing the selected scenario or scenarios, the ecosystem should be reached to acceptable sustainability. But as mentioned, this acceptability won't be long-lasting and needs continuous monitoring (section 4.5). This constant monitoring requires some external organizations. One responsible for the information ecosystem, and the second one, the organization, continually monitors all parts of the ecosystem to check their commitment to sustainable development criteria. A vital point here is the fact that how they should be funded. There is no clear way in the beginning steps unless legislation which works as incentives and inhibitor. For instance, the European Union ratifies legislation for increasing the share of recycled products in cars. They were released on the title of waste law available on their website(*Waste law*, 2020). These legislations provide financial gains for the companies who follow them. Consequently, either companies in the ecosystem will build a consortium and ask external consultant companies to direct them through the changing process, or even the consultant companies offered their proposal to the companies, and then the consortiums will be established.

Although there are other ways to funding the process, such as using one of the leading players, they have two primary defects. 1) Make big players more influential in decision-making. 2) In the beginning, it is hard to establish a consortium for funding since still no clear definition of ecosystem boundaries.

Chapter 6 Critical reflection and Discussion

Nevertheless, the framework is made of different parts that some came from other author's works; the overall structure and many critical parts are designed and modified through this study. Accordingly, it can provide a comprehensive view of the business ecosystems and guide them from A to Z, which other methods lack.

The proposed framework satisfies the lacks of current solutions. It assesses ecosystems instead of a single business. It means that instead of modifying a single business unite regardless of its interactions, look at businesses on an integrated scale as an ecosystem. Therefore, more practical solution will appear which considers the connection interconnection of different business units in the ecosystem. Hence unlike the previous frameworks, the proposed framework can suggest changes that target the structure of an ecosystem.

Another key difference is the ecosystem definition. The framework provides a quantitative definition of ecosystem boundaries. It suggests different ways based on the available data and target industry to close ecosystem boundaries and focus on the demarcated area. It is a crucial feature since otherwise, it is not practical to assess the ecosystem by its open boundaries.

Available frameworks provide general guild lines which need efforts to customize for each case. In contrast, the suggested framework is designed to stepwise guild businesses throughout the changing process. So, in each step, all the requirements and actions are explained, which makes it straightforward to use for the players.

Although the framework offers a detailed roadmap to follow, it keeps rooms open for the users to contribute. It can happen either by selecting indicators and using the databases they prefer or rearranging the ecosystem structure. At the same time, the core of solution-making is patterns extracted from similar successful businesses in a similar market. Consequently, the framework suggests more practical solutions compared to others. It means that the suggested solutions have some actual successful experiment although not precisely in targeted case.

Chapter 5 shows that although the patterns can provide some hints to follow, the main works remain for visionary thinking, forming the final plan. Solutions not should only be narrowed to what was exist and experienced in different industries since it somehow destroys the role of innovation. So, professional and innovative experts are needed—people who have a technical view on the subject as well as general knowledge of management and innovation in order to get hints from the suggested patterns but recommend the new scenario for change. This approach tries to fill the gap between the theoretical and practical parts caused by non-technical persons who usually designed these kinds of frameworks.

The laptop case-study shows that although detailed data plays a crucial role, the framework can be used on different levels based on data accuracy. Actually, the lack of precise data shows more effect on the gap finding process than the solution suggestion part, which shows less independence to the data accuracy. Therefore, the framework can use in conceptual studies, which is not that much access to accurate data.

Also, the study reveals that new legislation can be one of the significant critical points for the starting step; when there is no internal duty description and even the internal structure for the ecosystem. Therefore, without the help of legislations, it is hard to start a change and persuade the partners (ecosystem players) to be involved. These kinds of legislation that act as incentives and inhibitors also will facilitate data acquisition. The data that companies do not tend to share and know them as their valuable assets.

Chapter 7 EIT chapter

The current dominant consumption culture is a linear economy. It relies on take, make, and dispose; the approach starts from extracting raw materials, making products, using them, and finally dispose of them in a landfill. However, this approach has worked yet; it will not be practical anymore. The resources are not unlimited, and throwing them out as waste will destroy the environment as well. Therefore, the circular economy concept came into the picture to take back used materials into the production stage. It will reduce the need for virgin raw material and decrease the amount of abandoned waste throw nature. Additionally, recycling the raw material and taking them back to the production stage can save much energy. Although the circular economy looks fantastic, changing this linear economy to a circular one is not a straightforward path.

This study arranged a framework to help companies towards this change. How to produce environment-friendly and making more money simultaneously by using strategies such as sharing, recycling, digitalization, and so on. These strategies and many others that suggest in the framework will be a key to consume less material and energy, which is consequent to lower need for energy, virgin raw material and lower waste production. All these advantages are also targeted by sustainable development goals (SDGs) in Agenda 2030 (Johnston, 2016). They especially in line with some of them, such as SDG 12th (Responsible consumption and production), SDG 9th (Industry, Innovation, and Infrastructure). To look more precisely, the primary outcome of applying the framework can be categorized into few pivotal items in Table 11.

Table 11. Outcomes of applying the framework

	items	Explanation
1	**Make less waste**	By keeping material more in the circuit, it is evident that less material will reach the landfill. It is achievable through efficient scenarios such as using recycled materials, making more durable products, extending the use of products.

2	**Less energy is needed**	Using recycled material or used devices, acts as a shortcut that passes some steps in the raw material value chain. For instance, producing aluminum as second metal (producing it by recycling) will save 95% energy compared to producing from bauxite ore (primary aluminum ore) ((Kuchariková et al., 2016)).
3	**Keep critical material in the useable phase**	The shortage of some raw materials can significantly influence industries. For instance, the European Union releases the list of its critical material every five years to insist on their importance for Europe (Blengini *et al.*, 2020). Therefore, by rearranging from linear to the circular economy, industries' reliance on shortage of these critical materials will be minimized. They will have a close loop that circulates this critical material inside Europe. Therefore, they won't be that vulnerable to this shortage as they were in the linear economy.
4	**Reduce the release of hazardous and toxin substances**	Extraction and process of raw material consumed energy and chemical substances. This study also helps decrease the emission of hazardous and toxin material through nature via different ways such as reducing raw material production. Therefore, according to the EU's action plan for the circular economy (EU, 2021) and Sweden's national strategy for transitioning to a circular economy(Sweden-Government, 2019), the framework is precisely in line with the aims that Sweden and the EU are seeking.
5	**Keeping nature intact**	Keeping material in the circuit causes less virgin raw material to substitute, which leads to less pollution and destruction of nature, by avoiding resource losses and downcycling of basic raw materials contained in the waste stream.

6	**Reduce the release of toxin substance**	This study also helps to decrease the emission of toxin material through nature via different ways such as reducing raw material production. Therefore, according to the EU's action plan for the circular economy (EU, 2021) and Sweden's national strategy for transitioning to a circular economy(Sweden-Government, 2019), the framework is precisely in line with the aims that Sweden and the EU are seeking.

Chapter 8 Conclusions and Recommendations

The necessity of more sustainable conditions compelled us to change our businesses to a more circular setup, and the proposed framework is a tiny step. The proposed framework uses quantitative indicators and records of other successful circular businesses to suggest and modify the business ecosystems. It can be considered a step toward the circular economy since it makes a more quantitative road map and helps companies change easier compared to existing approaches. Nevertheless, the proposed framework or any other approaches are only tools that need support to implement. Ratifying the appropriate legislation and increasing public awareness regarding the necessity of change toward a circular economy are keys to facilitating such using frameworks. There are many obstacles in between, and Policymakers should consider that. For instance, one of the main obstacles is the worries that people have about their data security and valuable information. So, the legislation should also cover these legal issues as well. Apart from that, the connection between businesses passes political borders, emphasizing the necessity of worldwide collaboration and effort. The local solution will not be comprehensive and effective enough.

All in all, although the proposed framework was a starting point, the study can be followed to cover the missed parts. These parts may look small, while they play a critical role in reaching the result. Therefore, a more holistic study can pursue the following areas.

- Classifying indicators based on the target business and industry: Using indicators becomes easier for businesses if classified based on their required data and targeting the area. Therefore, the more relevant indicators are used, which provides a straightforward way toward applying.

- Providing more detailed indicators for intangible subjects: Although there are no quantitative indicators for social and legal subjects, even semi- quantitative indicators can make comparison easier. Thus, creating and classifying indicators for these non-tangible areas, will be one of the recommendations to follow in the subsequent studies.

- Large scale case study: Implementing the framework on a simple but detailed documented business ecosystem can clarify the lack of framework and provide significant help to tune it.

- Structural change: The structure of any business ecosystem can change, but the way that shows which structure will be the optimum case needs to define in a separate comprehensive study.

- Database creation: Although some databases are available for the circular economy, the lack of more practical databases is felt. The classification of cases and the standardizing of the records are essentials to consider.

- Extend the solutions: Providing detailed business plans and action plans for three suggested scenarios for the laptop industry.

- Case study on the Delphi technique: Use the Delphi technique to determine the most acceptable weight factors in the fuzzy cognitive mapping method to illustrate its lack and modify the process of finding the weight factor.

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Chapter 10 Appendices

Appendix A:

Through this appendix, the supplementary figures regarding calculating the life cycle analysis are presented. The first figure shows the procedures of inventory analysis in a graphical view. At the same time, the second figure provides an overall view of the connection between interpretation and other parts of LCA. It shows how the interpretation can change other parts of the LCA procedure, such as goal and scope definition.

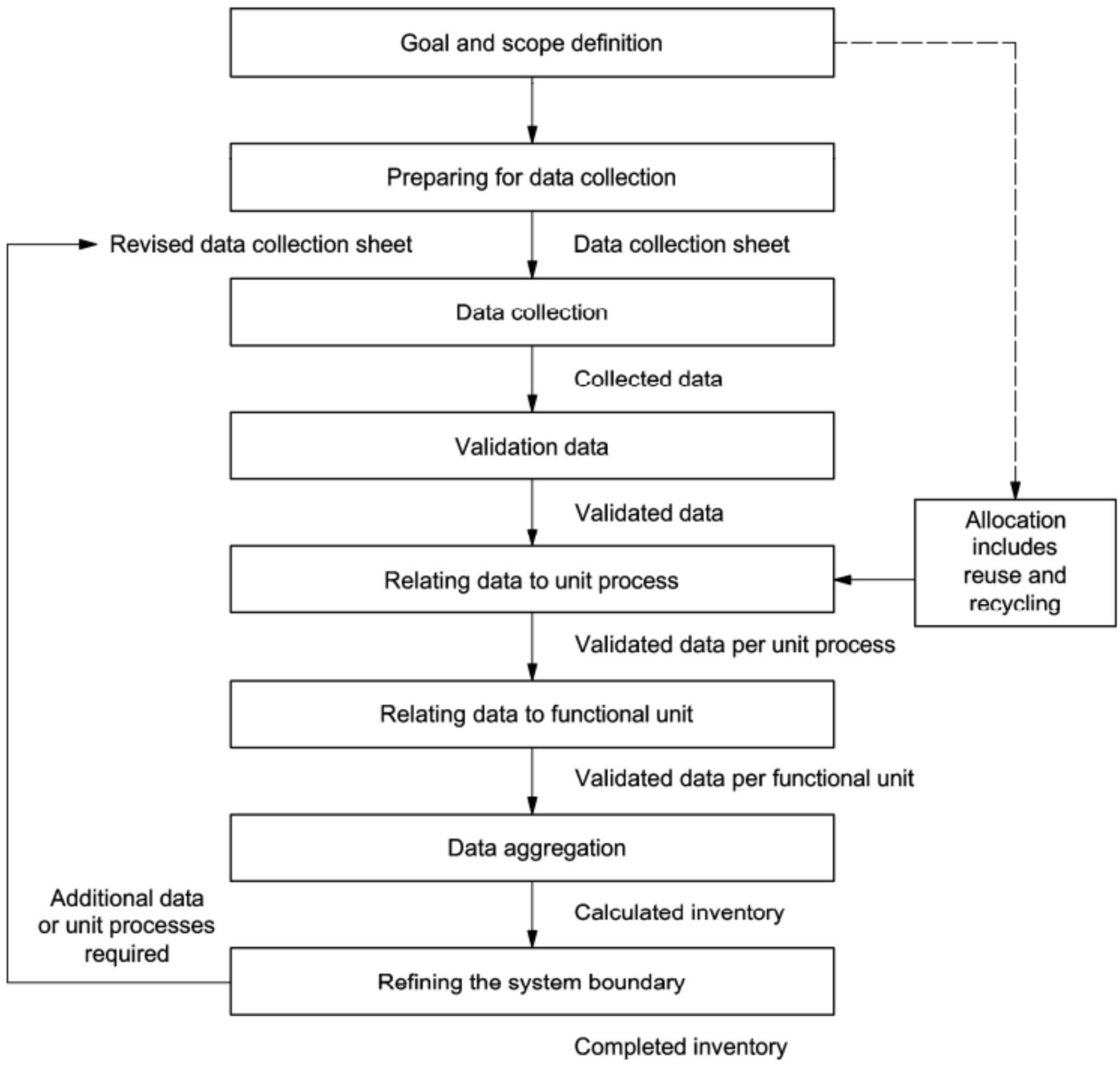

Figure S 1. Simplified procedures for inventory analysis (ISO 14051, 2011)

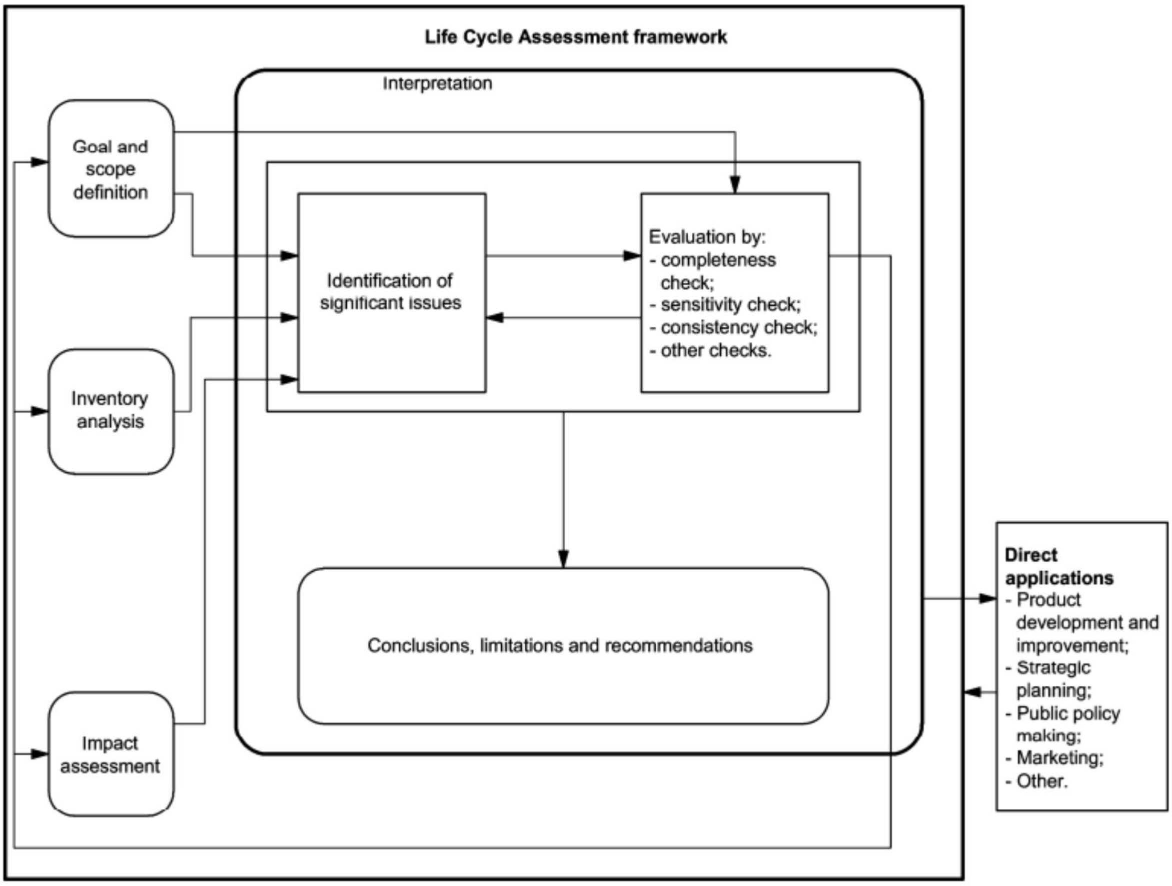

Figure S 2. Relationships between elements within the interpretation phase with the other phases of LCA (ISO 14051, 2011)