Engineering and Management Field

– PhD THESIS –
-ABSTRACT-

RESEARCHES RELATED TO THE CIRCULAR ECONOMY

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– Cluj-Napoca –
2022

Contents

INTRODUCTION

The doctoral thesis with the title "RESEARCH ON THE CIRCULAR ECONOMY" has as its theme the circular economy, a notion interdependent with that of the product life cycle, forming an indissoluble doublet; this is a global concern considering that the life cycle is the essential element on which the circular economy can act to solve the issues facing the whole planet (rapid depletion of resources, pollution (by default and population health problems), short life cycles of products that lead to the rapid generation of waste, untreated waste, etc.), aspects that are becoming more aware in recent years.

The general objective of the paper

The study of the theoretical and practical aspects of the circular economy with a focus on the life cycle of the product, to outline a clear picture of the implementation of the circular economy at the level of Romania, to outline some conclusions and proposals regarding the possibilities of measuring circularity, to facilitate the transition to the circular economy in micro and macro plan.

Research Methodology

The part regarding the current state of the work was carried out by studying the specialized literature, more precisely by consulting relevant articles mainly from the Web of Science platform and other profile platforms such as ResearchGate, GoogleAcademic, and others, articles searched with the help of combinations of keywords folded on the documented topic. The research in the second part was carried out by combining the study of specialized literature with research methods such as the interview guide, questionnaire, or data analysis.

The structure and content of the thesis

The thesis begins with the introduction, after which it is structured into two parts; I. The current state of knowledge consists of 3 chapters and II. The personal contribution consists of 7 chapters, plus one of the conclusions. The first part of the thesis begins with the presentation of the current framework of the development of the circular economy concept, around which the entire content of the thesis is outlined. The issues discussed in the first chapter related to the emergence, definitions, principles, practices, and integration of the concept. The second chapter makes a short foray into the marketing sphere and presents aspects of the link between green marketing and the circular economy, the life cycle in classical marketing, and the marketing mix, both from classical and circular perspectives. The third chapter addresses another main topic of the thesis, the product life cycle from the circular perspective (stages, defining features, legislative initiatives, business models, and technologies in the context of the circular economy).

The second part aims to outline an overview of the circular economy in Romania and studies the circular economy from the stakeholders' perspective, thus, 5 types of research were implemented using tools such as the questionnaire, interview guide, and data analysis; this part begins with the presentation of the methodology used (chapter 4). The first study (chapter 5) is focused on educational institutions from the point of view of approaching the process of information, education, and dissemination of the circular economy. The second research (chapter 6) has as its subject the presentation of some models of good practices in the circular economy in Romania. The third research (chapter 7) studies the integration of circular practices in SMEs operating in the textile industry in Cluj county. The next chapter (8) studies aspects of the integration of the circular economy in the manufacturing industry at the level of Romania, the chapter is completed with a proposal for a circularity evaluation grid. Chapter five of the second part of the thesis (chapter 9) presents a comparative study of circular economy indicators specific to Europe, with a focus on Romania. In chapter ten, the framework of the transition to the circular economy is analyzed, and finally, a proposal for a single indicator for monitoring the evolution of the circular economy is presented, which will ultimately be reflected in the extension of the life cycle in the context of the circular economy. The paper is

completed with a conclusions chapter presenting the general conclusions, issues regarding the originality of the thesis, and future directions. Figure 1 shows the structure of the thesis:

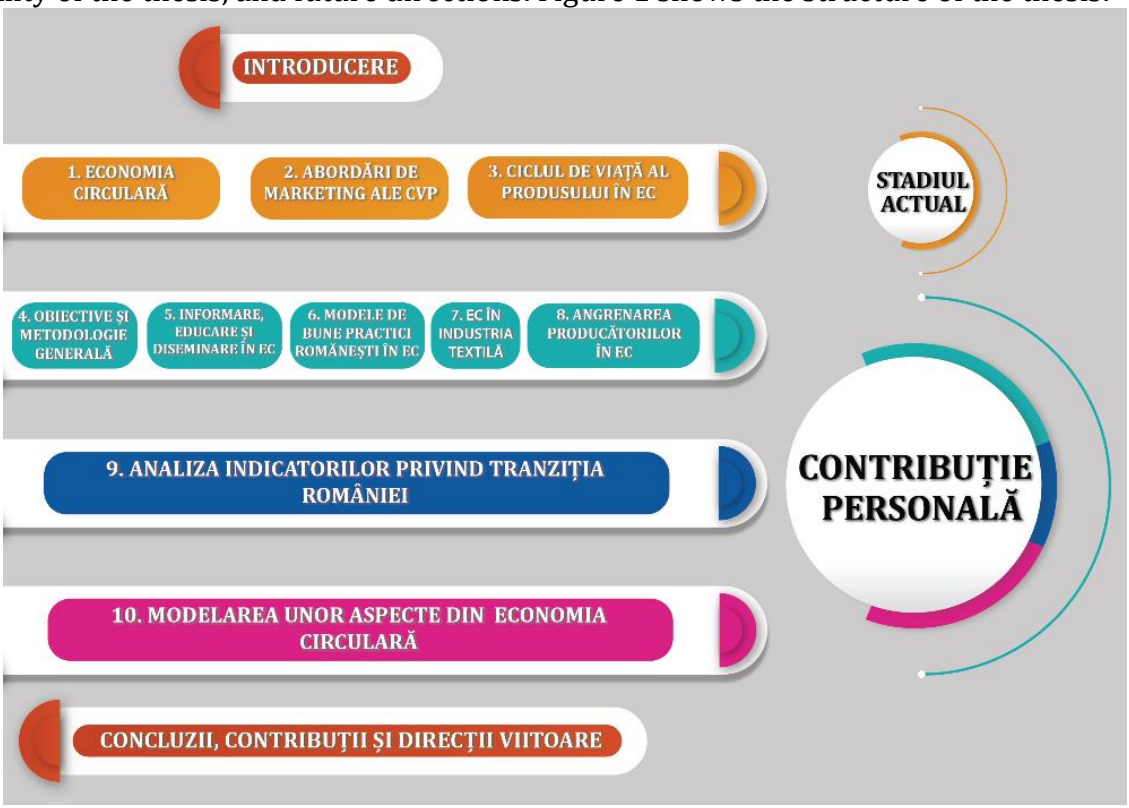


Figure 1. The thesis structure

CURRENT STATE OF KNOWLEDGE

1. CIRCULAR ECONOMY – CHRESTOMATION AND EVOLUTION

This chapter has as its main objective the outline of the concept of circular economy (CE), presenting the defining elements and the aspects it implies. At the beginning of this chapter, the origin and development of the circular economy are identified, this concept being the result of several schools of thought and representing the evolution of previous concepts such as cradle-to-cradle, the performing economy, biomimicry, industrial ecology, natural capitalism, the blue economy, the design regenerative, closed-loop supply chain and reverse logistics, these concepts having common features such as waste elimination, resource efficiency or loop closure, etc. [1]–[3]. Regarding the chronology of the development of the concept, CE does not have well-defined origins and is attributed to the years 1960-1970, with Ewart Boulding (1966), Meadows et al. (1972), and Walter Stahel and Reday Genevieve (1976) [4], [5]. The introduction of the term "Circular Economy" took place in 1990, and is done by Pearce and Turner [6].

Next, the main definitions of the circular economy are addressed, these being very large in number, there is no unanimously accepted one. Among the definitions discussed is the one given by the Ellen MacArthur Foundation (EMF), a world leader in the circular economy, considered a representative one, which defines the circular economy as "a regenerative and renewable industrial economy by intention and design"[1]. Another representative definition belongs to Kircherr and collaborators, whose definition equates the circular economy with "an economic system that replaces the concept of "end of life" with the reduction, reuse, recycling and recovery of materials in the production/distribution and consumption processes; It operates at the micro level (products, companies, consumers), medium level (eco-industrial parks) and macro level (city, region, nation and beyond), intending to achieve sustainable development, simultaneously creating environmental quality, prosperity and social equity, for the benefit of current and future generations", this definition addressing the relationship between the circular economy and sustainability, through the triple bottom line [7]–[9]. The principles of the circular economy, enunciated by the EMF consist of i) Circular design, avoiding negative externalities, ii) Keeping products and materials in use as long as possible, at the highest utility, and iii) Regenerating natural systems [10]–[12].

The paper then addresses the main strategies of the circular economy, the CE pillars or the 10 R's, arranged in descending order of circularity potential: Refuse, Rethink, Reduce, Reuse, Repair, Restore, Remanufacture, Refurbishment, Reorient, Recycle and Recover [7], [9], [13]–[16]. In the next sub-chapter, a brief foray into the development of the circular economy around the globe, with a footprint on the European Union (EU), is made, briefly listing the initiatives of the European Commission (EC) presented in the form of action plans, which establish proposals and measures throughout the life cycle of the product, for the transition to the circular economy; the first action plan at EU level was presented in 2015 [17]–[19]. The proposals, measures, legislation, and objectives set at the EU level represent standards to which Romania must also align, along with the other member states. Finally, the paper addresses the relationship between the circular economy, sustainable development, and sustainability. In this sense, the paper supports the fact that the circular economy is a condition, even an instrument of sustainable development, aiming to harmonize the three pillars of sustainable development, the environment, the economy, and society (triple-bottom-line), for the benefit of current generations and forthcoming [20]–[22]; also, sustainable development is a concept with macro implications, being a worldwide desire, and sustainability is a concept that is used in relation to businesses and organizations, but often sustainable development and sustainability are used interchangeably [23], [24]. For the adoption of the circular economy by as many stakeholders as possible, it is important to be aware of its benefits, thus, at the end of the first chapter, the paper summarizes the most important benefits of the three pillars of sustainable development:

i) in economic terms: obtaining competitive advantage, stimulation of economic growth, reduction of dependence on raw materials and reduction of costs with it, new business opportunities, etc.; ii) environment: reduction of greenhouse gas emissions, reduced pollution, conserved resources, elimination of waste, etc. iii) society: increasing the quality of life, new jobs, sustainable products, a healthier life, easier access to circular products, at lower prices, etc. In the context of EC impact, different authors highlight some negative effects, called rebound effects, and as an example we can recall the fact that remanufactured products or obtained through other EC strategies, having a lower price, will increase sales, and consumers can also buy other products by saving by purchasing a circular [25], [26].

2. LIFE CYCLE APPROACHES IN CLASSIC VERSUS CIRCULAR MARKETING

The second chapter has as its main objective the outline of the life cycle from the perspective of marketing, constituted in a comparative manner of classic and green marketing. The first sub-chapter addresses the relationship between the systemic circular economy and green marketing, emphasizing the common feature – the desire to achieve economic prosperity simultaneously with care for the environment mainly, and for society, as a result of the first 2; we can say that both are based on sustainable development. Next, the paper approaches the product life cycle from the perspective of marketing, summarizing the evolution of the concept and the main definitions. The product life cycle represents the period, from the product idea, until its exit from the market, a period divided into two parts: the innovation or development cycle (Idea generation, Selection, Concept creation, and testing, Strategy elaboration, Economic analysis, Design and creation, Pre-testing, Manufacturing) and the commercial life cycle (Launch, Growth, Maturity, and Decline) [27]–[30]. This concept dates back to the late 1800s. The next subchapter addresses the marketing mix, outlining the circular marketing mix by complementing the classic and green, this being an innovative contribution of the thesis; each element of the circular marketing mix takes into account the observance of the principles of the circular economy. The marketing mix for products consists of the 4Ps – product, price, placement, promotion, and in the case of services, 3Ps are added – personnel, processes, and physical evidence [32]–[36]. At the end of this chapter, the role of marketing in educating and directing consumer behavior toward circularity and sustainability is emphasized, as a major contribution of marketing in the transition to the circular economy [37]–[43], this fact emerges as the main conclusion of this chapter; the circular economy, through marketing communication, will persuade as many people as possible to choose sustainable products and adopt circular principles such as returning, reusing, or renting products. Another conclusion is that the product life cycle is considered a strategic tool, the recognition of the phase of the life cycle in which the product helps to adapt the elements of the mix accordingly to meet the business goal - profit, an objective which, in the circular economy, must be correlated with that of environmental protection and social equity.

3. PRODUCT LIFE CYCLE

This thesis chapter, the last of the first part, approaches the product life cycle from a circular perspective. The circular life cycle is a closed one, by connecting the last stage with the first stage, thus avoiding the displacement of new resources, keeping the resources in use for a long time by recirculating them as many times as possible [3], [44]–[47]. At the European level, these aspects are addressed through plans and legislative packages designed to support the transition to the circular economy [48]–[51]. The first subchapter presents the elements of the product's circular life cycle, which has 7 stages.

1) Raw material - must be, as far as possible, renewable or secondary raw material, obtained from waste or end-of-life materials recovered, and ultimately recycled; also, the raw material must have a low carbon footprint and allow it to be recycled as many times as possible.

2) Product design is one of the most important stages of the product because this is where the circularity of the product is integrated at each stage of the life cycle.

3) Production and manufacturing of products involve optimization and innovation for maximum efficiency of resources and processes, reduced consumption of raw materials, and low carbon footprint.

4) Product distribution involves logistics and transportation, which must be done with optimal resource consumption, minimal carbon footprint, and efficiency. The circularity of distribution requires, for example, smart packaging and innovative product return mechanisms made available to customers, also information technology can be an important factor in circularity.

5) The use and reuse of products and their components in the product consumption phase, including principles such as use, reuse, repair, and sharing of products, facilitating as long loops as possible, and extending the product life cycle.

6) The product and waste collection phase is an important one in closing the loop of the product life cycle and involves innovation to determine the highest possible rate of recovery of waste products.

7) Recycling is the outermost loop in EC, being the last preferred action, when other R's are no longer possible, to preserve resources and their value. Keeping resources in the economy as much as possible is a desire at the European level, addressed by the European Commission through action plans that aim to close the life cycle of the product, turning waste into resources.

Next, 5 types of circular businesses are presented; there are various criteria for their classification, but their list is not exhaustive.

1. Product as a service (Product service-system - PSS) is a representative model of circular business, with the principle of offering the product as a service. This model has high potential in terms of increasing resource productivity, conserving resources, recovering them from products at the end of their life cycle, extending the life cycle of products through reuse, recovery, recycling, and other practices offered by the circular economy and reducing the amount of waste generated [51]–[53].

2. Sharing platforms – platforms through which the products already owned are shared between people to satisfy the need, thus intensifying the use of the product, which leads to a decrease in the consumption of resources and the avoidance of environmental externalities [54].

3. Product life cycle extension – represents, as the title indicates – longer lifetimes for the products offered, which are designed for longer life cycles. To achieve this goal, the products have associated additional services such as repair. The extended warranty to extend the life cycle is reflected in the price of the product. One such example is the company Patagonia, a manufacturer of mountain equipment [55].

4. Resource recovery - consists of mechanisms that facilitate the recovery of resources and their return to the point of departure to reuse them, avoiding the displacement of new resources, by recirculating those already used, or by using the waste resulting from one activity, as an input in another activity [56]. For example, food waste from Walt Disney restaurants is used to produce biogas [57].

5. Circular suppliers – a model that involves the replacement of scarce resources with biodegradable, renewable, or recyclable raw materials. As an example, we can mention Genesis Bio partner, which produces renewable electrical and thermal energy, in cogeneration, using corn collected from a local source [58].

The next sub-chapter presents Industry 4.0 technologies as catalysts of the circular economy, by integrating them in different stages of the product life cycle and the supply chain. The technologies discussed are [59]–[68]:

Additive manufacturing (AM) - Technology that prints objects in a series of overlapping layers of material (plastic or metal) without cutting waste.

Augmented Reality (AR) - Combination of 3D elements with spatial context, integrated into a virtual form. It offers the possibility of real-time processing of image projections to test new products or improve processes.

Big Data & Analytics (BDA) - Tools with the ability to evaluate large volumes of data (text, images, etc.) to identify possible insights into consumer habits and preferences.

Cloud Manufacturing - Virtual platform in the form of a network, used to share resources.

Collaborative Robotics - Robots (mobile/fixed) that have automated operations and interact with human operators.

Cybersecurity - Systems that enable the protection of systems, equipment, networks, and users against illegal intrusions.

Internet of Things (IoT) - Computing system that allows the collection and exchange of data taken from electronic devices.

Simulations - Allows visualization of product design and processes. Used for virtual testing to obtain real solutions for further optimization and development.

Blockchain - System that keeps records of transactions in bitcoin or other cryptocurrencies, records that can be accessed on multiple computers that are connected in a network.

These technologies were analyzed concerning the ReSOLVE framework, developed by the EMF as a possible framework for implementing the circular economy within a company [61], [69]–[71]. Another aspect analyzed is the behavior of consumers to these technologies, the importance of which is given by the role of consumers in accepting and adopting circularity, both through the products/services chosen and through their behavior after the purchase [61], [68], [72]. The following table shows the two aspects discussed – the ReSOLVE framework and consumption behavior with the analyzed technologies.

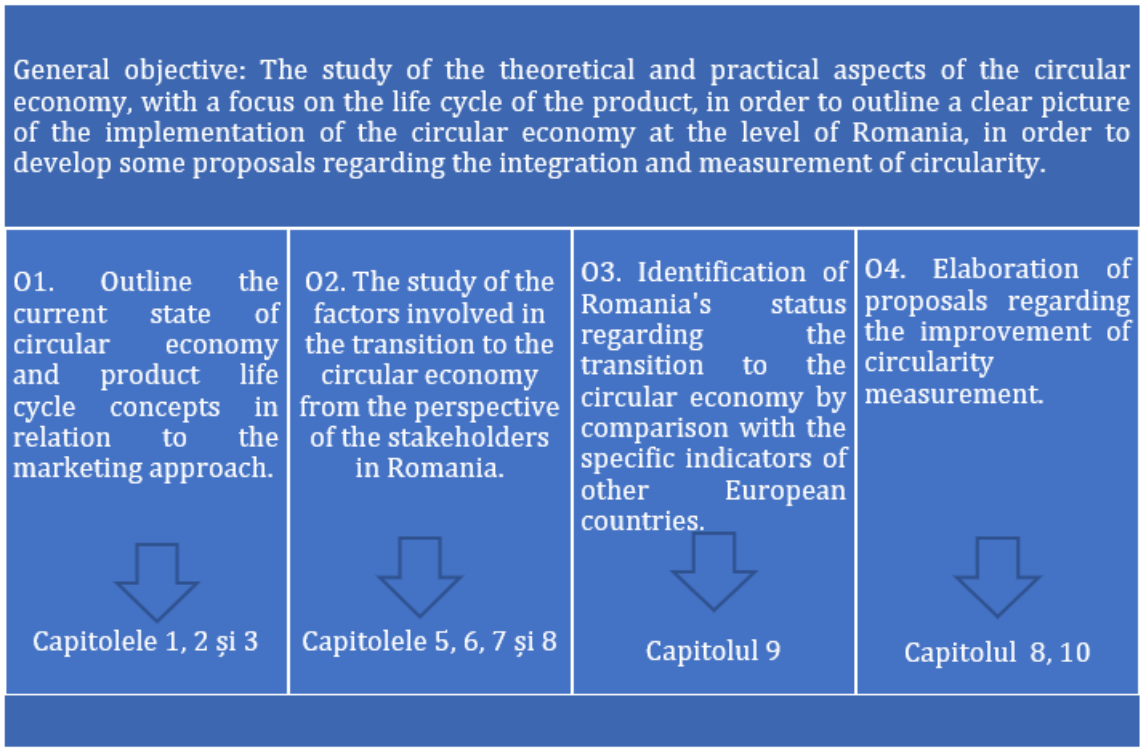
Technology	Economie circulară - ReSOLVE						Consumption		
	Regenerate	Sharing	Optimize	Loop	Virtualize	Schimb	Comportamentul consumatorilor privind		
							purchase	consumption	End of life
Additive manufacturing			x	x		x	x		
Augmented Reality			x		x				x
Big Data & Analytics		x	x	x			x	x	x
Cloud manufacturing		x	x		x			x	x
Collaborative Robotics	x		x			x			x
Cybersecurity		x	x				x		
Internet of Things (IoT)	x	x	x	x	x	x	x	x	x
Simulations	x		x		x				x

At the end of this chapter, we can conclude that closing the loop in the product life cycle and circularizing each of its elements represents the basic idea of CE, having derivative effects on the three pillars of sustainability. The negative changes facing society (e.g. materials crisis, high prices, etc.) force economic actors, but also society as a whole, to integrate circularity for sustainable development. The integration of I4.0 technologies is a key factor of the circular economy, acting at different stages of the life cycle as a catalyst; they also facilitate circular practices such as reuse, reconditioning, and recycling; influence circular behavior, and represent a decision-making tool.

II. PERSONAL CONTRIBUTION

4. OBJECTIVES AND GENERAL METHODOLOGY

The general objective of the thesis, mentioned in the introduction, has four subsumed objectives, from which the objectives corresponding to each chapter result, according to the figure below.



Regarding the general methodology of the thesis, the first four chapters consist of the bibliographic study of specialized literature, and the Web of Science platform was used, but also Google Scholar and Research Gate. The following chapters of the thesis consist of the design and implementation of qualitative research (Chap. 6), with an interview guide as a tool, and quantitative research (Chap. 5, 7, 8), with the questionnaire as the main tool. Chapter 10 combines a literature review with data analysis.

5. Study 1 – STUDY ON INFORMATION, EDUCATION AND DISSEMINATION PRACTICES WITHIN THE CIRCULAR ECONOMY

The first research in the second part of the thesis aims to study the approach of organizations in the educational sphere to information, education, and dissemination activities regarding the circular economy. The basis of this study is the fact that information is one of the factors of high importance in the process of adoption and transition to the circular economy. On the other hand, in the educational sphere, the education process taking place, or the training of pupils/students in the spirit of circularity will result in a responsible society. Innovation also takes place in the educational sphere, and as a result of research, innovation is another

condition of the circular economy. Open innovation, through partnerships between universities and companies, would not only help to successfully implement the circular economy, but would propagate positive effects for both parties involved [73], or a successful transition requires the collaboration of all parties involved.

The present research, of quantitative type, has as its instrument a questionnaire that includes 18 questions relevant to the purpose of the research. The results show that the majority of respondents believe that rewarding innovation, improving cooperation, and setting examples should represent the guidelines of institutions in the educational sphere regarding the CE approach. Also, most believe that the integration of the educational component on consumption and production folded on the circular economy (CPEC) in educational institutions and educational programs (schools and universities) can be addressed through the introduction into the curricula, as a transversal issue. The role of educational institutions in CPEC, according to the respondents, is to carry out the transfer of information and training in the spirit of CE and its promotion. The mobilization of interested parties in the circular economy can be achieved, from the perspective of the institutions participating in the research, through the system and personnel reform, partnerships, innovation, and the existence of replicable models. Curriculum adaptation and continuous staff training are ways to encourage the development of CPEC in vocational training. Most respondents believe that motivating decision-makers and stakeholders to create networks for CPEC must be a priority for decision-makers in the context of the CE transition.

In a conclusion, we can summarize the following: consumption and production folded on the circular economy (CPEC) can be encouraged in educational institutions through curriculum integration and system and staff reform; partnerships and innovation are, in the opinion of the majority of respondents, key factors in the context of the transition to the circular economy; the existence of replicable best practice models is also seen as a possible catalyst for circularity.

6. Study 2 – QUALITATIVE RESEARCH ON THE IMPLEMENTATION OF CIRCULARITY IN ROMANIAN COMPANIES - BEST PRACTICE MODELS

Chapter 6 is built around the main objective of mapping good practice models in our country, to identify their success factors and other related aspects. This qualitative research is based on both data analysis and an interview sheet and was carried out within the "Ernest Lupan" Institute for Research in Circular Economy and Environment (IRCEM) from Cluj-Napoca, of which the author of the thesis is part of almost 7 years. 5 business models and circular projects were analyzed and summarized in the following lines.

Katty Fashion SRL (Iași) has as its main object of activity the use of ecological materials (replacing cotton with hemp fibers) in the production of sustainable textiles and, at the same time, encouraging hemp crops in the region. The main factors involved or underlying the success of this organization are innovation, cooperation, partnerships, and the integration of the circular economy for sustainability by using sustainable raw materials from sustainable local sources and reducing the environmental impact of the textile industry through the activities undertaken.

Genesis-Bio partner SRL (Prahova) has as its main object of activity the production of electricity and thermal energy from organic waste and the production of an efficient organic fertilizer from waste. The main factors involved or underlying the success of this organization are Innovation, cooperation, using organic waste to obtain energy, and encouraging agriculture.

The Ecotic Association (Bucharest) has as its main activity the carrying out of activities to raise awareness of the population regarding sustainable development, with emphasis on the efficient management of WEEE, in the rural and urban environment. The main factors involved or underlying the success of this organization are innovation, information, education, dissemination of information related to the circular economy, supporting eco-education classes

in schools, presenting the disassembled content of electrical and electronic equipment, and facilitating the exchange of best practices between the interesting parts.

Green Group Holding (Buzău and Bucharest) has as its main activity the complete management of the waste cycle through a national integrated system. The main factors involved or underlying the success of this organization are innovation, carrying out awareness campaigns regarding the importance of recycling, smart collection and recycling of waste in Romania, cooperation and partnerships, traceability of waste, and incentives for citizens who use SIGUREC machines.

Food Waste Combat (Cluj) has as its main activity the fight against food waste by redistributing surplus food from different partners (Lidl, Kaufland, etc.) to disadvantaged categories. The main factors involved or underlying the success of this organization are: conducting awareness campaigns, building a network of partnerships to satisfy the food needs of people from disadvantaged categories, and avoiding food waste.

Analysis of these business models reveals several common factors underlying the success of the organizations studied, including awareness campaigns, innovation, and partnerships. All these circular examples are characterized by replicability. As we can see, within them, waste represents raw material for other activities, a fundamental principle of the circular economy.

7. Study 3 – RESEARCH ON THE CIRCULAR ECONOMY IN THE TEXTILE INDUSTRY OF CLUJ

The textile industry is one of the most necessary and at the same time among the most polluting industries in the world. Thus, the integration of the circular economy in the textile industry on a global scale would mean a significant decrease in pollution. Considering these, the main objective of the chapter consists in identifying the degree of familiarization of SMEs in the textile industry with the circular economy as a concept, and the circular practices are undertaken. The research is quantitative, in which the questionnaire was used as a research tool. The information obtained shows that all respondents know the concept of circular economy, associating it with protecting the environment by transforming waste into resources. Half of the responding organizations collaborate with specific departments to integrate the circular economy into their work, and in two-thirds of the organizations, environmental protection is regulated by procedures. As for the barriers to their transition to CE, half believe that they are technological and economic, and the rest believe that they are political and legal. Most respondents believe that by integrating circular principles, revenues and cost reduction will be positively influenced. More than two-thirds of respondents believe that recycling is good and useful. In most of the responding organizations. Waste is transferred to a specific collection center, and this together with maintenance services and the use of local raw materials in production represent the activities carried out in the spirit of the circular economy.

8. Study 4 – QUANTITATIVE RESEARCH ON THE ENGAGEMENT OF PRODUCERS IN THE CIRCULAR ECONOMY

The manufacturing industry faces current environmental concerns (resource depletion, materials crisis, etc.), which are addressed by regulations on resource consumption and other issues, intended to direct them towards EC [74]. This industry has a high impact on product circularity. The objective of this chapter is to highlight the perspective of manufacturing companies on the integration of the circular economy at their level. The study is a quantitative one, with the questionnaire as an instrument, the implementation of which was based on the accessibility.

The results show that the most important economic opportunities are Generating new revenue streams, Improving CSR reputation, and Reducing the cost of raw materials. From a social point of view, Improving knowledge in the circular economy and Reuse, maintenance and

easy repair of products are the main opportunities perceived by most respondents. From a technical point of view, these are Designed and manufactured for reuse, maintenance, repair, reconditioning, remanufacturing, and recycling of the product and Use of more efficient manufacturing processes. Circular businesses present the following opportunities in the opinion of most respondents: Recovery of useful materials from end-of-life products, Stimulation of product return, Industrial symbiosis (use of production waste in the manufacture of other products and Carrying out repairs, remanufacturing, renovation, modernization, and resale by third parties. The legislative challenges are represented most by Lack of knowledge of legislative requirements, Lack of understanding of legislative requirements, and Undecided national circular economy legislative requirements. From the point of view of most respondents, the campaign's promotion of consumption and circular economic practices is a social catalyst for the transition to the circular economy. From an economic point of view, important catalysts are represented by Funding of research for the optimization of circular products, Fiscal incentives ale for repair, renovation, improvement, and resale, and Eliminating the taxation of circular products.

Another important part of the work under the aspect of own contribution is found further in this chapter. This consists of a proposal for a grid for evaluating the circularity of an organization, a grid structure on the stages of the product life cycle, and stages previously mentioned in the section of the third chapter. As a result of the data obtained, correlated with the specialized literature in the field, a possible tool for evaluating the circularity of a company's life cycle can take the form of an evaluation grid, similar to the model proposed by Kotler for evaluating the marketing activity of company companies [75]. Circularity at the micro level, regarding products and companies, is of high importance, directly impacting the circularity at the meso and macro levels. In the specialized literature, most studies conclude the lack of a universally used framework for evaluating the circularity of an organization [76]–[81]. The proposed grid also requires an in-depth analysis of individual processes, for a clear and objective picture. The grid represents a table of circularity in which the weak points and those requiring improvement are represented by the questions where the score is 0. The level of circularity is according to the score obtained and can be consulted in the following table, which includes five levels of circularity, each corresponding to a certain range of points, like this: Very high 70 – 83 p, High 50-75, Medium 30 – 50, Weak 15 - 30, Not at all <15.

9. Study 5 – COMPARATIVE ANALYSIS OF CE INDICATORS AT EUROPEAN LEVEL FOCUSING ON ROMANIA

This section of the thesis aims to outline Romania's situation in the transition to the circular economy. The objective is achieved by analyzing the indicators specific to the circular economy, available on Eurostat - the official website of the European Commission. The indicators related to Romania are analyzed in a comparative manner, with those corresponding to the other member states of Europe, in order to obtain a more complete overview. The indicators specific to the circular economy are structured into 4 categories, covering the entire life cycle of the product, as follows: 1. Production and consumption; 2. Waste management; 3. Secondary raw materials and 3. Competitiveness and innovation. The following table presents an enlightening synthesis of the analysis.

Circular economy indicators		Values related to Romania	European	Circular economy indicators	Values related to Romania
PRODUCTION	Autosuficienţa UE privind materiile prime în 2018 [%]	N/A	Extracţie : - calcar 94.9% Procesare : - fluorspar şi indiu – 100%	N/A	N/A

	Achiziții publice verzi		Date indisponibile			
	Generare deșeuri	Generare deșeuri municipale în 2020 [kg/locuitor]	287	505	834 Austria	287 România
		Deșeuri generate pe unitate PIB în 2019 [Kg la mia de euro]	128	66	646 Estonia	27 Luxemburg
		Deșeuri generate pe consum de materiale casnice în 2018	4.8%	12.7%	29.7% Estonia	4.8% România, Letonia
	Deșeuri alimentare în 2018		Date indisponibile	69 milioane de tone	Date indisponibile	
WASTE MANAGEMENT	Rata de reciclare a tuturor deșeurilor în 2018		29 %	55 %	82 % Slovenia	23 % Bulgaria
	Deșeuri municipale generate / tratate în 2019 [kg/locuitor]		280 / 258	502/493	844 /844 Danemarca	280 / 258 România
	Rata de reciclare a deșeurilor municipale în 2020 [%]		13.7%	47.8%	68.3% Germania	10.5% Malta
	Rata de reciclare a deșeurilor de ambalaje în 2019 [%]		44.6%	64.4%	83.5% Belgia	33.7 % Ungaria
	Reciclare ambalaje pe tipuri de materiale în 2019 [%]	plastic	31.1%	40.6%	69.6% Lituania	15.4 % Malta
		lemn	24.8%	31.1%	91.1% Portugalia	2.9% Croația
		metale	49.6%	77.4%	129.3 % Cipru	19% Malta
		sticlă	42.9%	75.4%	100% Belgia	28.7% Ungaria
		hârtie și carton	68.3%	82%	115.9% Slovacia	45.5% Malta
	Rata reciclării deșeurilor electonice în 2018 [%]		25% (2016)	38.9%	83.4% Croația	24.7% Islanda
	Rata reciclării deșeurilor biologice în 2020 [kg/cap de locuitor]		18	90	186 Luxemburg	0 Malta
	Rata recuperării deșeurilor minerale din construcții și demolări în 2018 [%]		74%	88%	100% Olanda, Malta, Irlanda	24% Bulgaria
SECONDARY RAW MATERIALS	Rata de reciclare la sfârșitul ciclului de viață în 2019 [%]		N/A	Plumb 75% Fier 31.5% Molib-den 30%	N/A	N/A
	Rata de utilizare a materialului circular în 2020 [%]		1.3%	12.8%	30.9% Olanda	1.3% România
COMPET ITIVENE	Investiție brută în bunuri corporale - procent din produsul intern brut (PIB) la prețuri actuale în 2019 [%]		0.17%	0.12%	0.23% Croația	0.02% Grecia

	Persoane angajate în 2019 [%]	1.55%	1.76%	2.81% Croaţia	1.01% Belgia
	Valoarea adăugată la costul factorului în 2019 [%]	0.76%	0.99%	1.74% Croaţia	0.4% Grecia
	Patente anuale privind reciclarea şi materialele secundare în UE în 2019	5.5	295.32	85.7 Germania	1 - Slovenia Ungaria LuxembourgLituania

The results of the analysis allow us to conclude on Romania's specific indicators, that they indicate the early stage of our country's transition towards circularity, their values, in many aspects, being among the lowest in Europe. Another conclusion that emerges from the table above is that reporting is characterized by significant delays in reporting and presenting data (in the current year 2022 some indicators correspond to 2018), or this must be remedied because the formulation of measures and interventions based on their values are not adapted to the real context. The indicator values show an advanced transition towards circularity in the case of Germany and the Netherlands.

10. Study 6 - MODELING SOME ASPECTS REGARDING THE MEASUREMENT OF CIRCULARITY

Chapter 10 presents the study with number 6 of the paper, having as its main objective the evaluation of the European framework after which the transition to the circular economy is monitored, in order to develop proposals for its improvement. The study takes place in 4 steps: i) Analysis of circular economy indicators; ii) Identifying the deficiencies of the European monitoring system; iii) Proposing measures to improve the monitoring system; iiii) Elaboration of a comprehensive circularity index proposal.

The main conclusions that the analysis highlights are:

- the monitoring framework corresponds to an initiation stage of the transition, and is still being developed;
- the limitation to monitoring the material resources of the soil, will have to be overcome with the transition to a new stage of the transition;
- the need to optimize the information collection time;
- the need to overlap the system of indicators for sustainability with that for circularity;
- reducing the consumption of raw materials should also target the raw materials used to generate the energy needed to transform the raw materials through all the activities associated with the economy;
- the circularity analysis must also include indicators of energy, water, air, human and biological resources;
- the input of non-renewable raw materials used to generate the energy needed to transform raw materials into products is not taken into account, also missing the time factor.

The analysis outlined the need for a complete indicator, capable of assessing progress at every moment and at every scale (product, product group, organization, company, region, country). Starting from this need, and based on the definition of the general efficiency of the economy (as a circular economy system and based on the three pillars of the circular economy mentioned above) treated in the work A New, Consonant Approach of Circular Economy Based on the Conservation of the Fundamental Scalars of Physics [82], the following calculation formula of an index called "Efficiency (in) the circular economy" was proposed.

$$\mathbf{EF_{CE} = M_v.C_v / A_{ec},\ [kg^* currency\ /J^*s]}, \quad (1)$$

Where:

$\mathbf{M_v}$ is the total mass of virgin materials entering an economic process plus the mass of non-renewable materials used to generate the energy used to transform the mass:

$$M_v = M_{tot\,v} + M_{tot\,nr} \quad [kg]; \quad (2)$$

C_v is the commercial value of the process output [currency] and
A_{ec} is defined as a general economic action, based on activities related to the manufacture of products; it is defined as the product of (Er (renewable energy - from renewable sources) + Enr (non-renewable energy - from non-renewable sources)) and Tt (a period in which the measured mass is transformed):

$$A_{ec} = (E_r + E_{nr}) * T_t \quad [J * s] \quad (3)$$

Relationship (1) above applies to each phase (which may itself be a closed or open loop) of transformation (extraction, material manufacture, component and product manufacturing, preparation for reuse and recycling, use/reuse, and recycling and regeneration).
The Time factor in the relationship can be used to harmonize these frequencies of extraction of substances, conversion into desired materials, manufacturing, preparation for reuse and recycling, and recycling/regeneration), as it follows the accumulation and dissipation of matter stocks (as matter/materials are conservable). The same virgin, preservable mass connects all phases in a regenerative cycle.

11. General discussions and final conclusions

11.1. General conclusions

The increasing awareness of the need to integrate the circular economy at different levels to achieve the desired to achieve a sustainable development, has facilitated the development of CE both theoretically and practically. At the European level, the transition to CE has been addressed since 2015, through an ambitious plan of proposals, measures and laws, valid for all EU countries.

The circular economy is an umbrella concept, and at the same time, a tool of sustainable development, created with the aim of counteracting the effects of the linear economic model, represented by the depletion of resources and a crisis of materials, environmental degradation, stored waste, high carbon emissions, pollution, things which negatively affects not only the economic sector and the environment, but also the quality of life.

The aspects mentioned above have the impact of increasing the circularity of the supply, by orienting the producers towards circularity, so, taking into account the law of demand and supply, it is necessary to direct attention to the circularization of the demand, a fact for which the main role is that of marketing. Marketing, through its functions and power, plays a key role in the circular economy; the circular marketing mix, by appropriately adapting its elements to circularity, can facilitate the acceptance and adoption of the circular economy through its power to educate and motivate consumers to accept circular products, however, the role of marketing is not limited only to these, being a much more widely but insufficiently explored in the literature and in business. Circular marketing is a key tool of CE, through which sustainable competitive advantage can be achieved in business, harmonizing the 3 dimensions of sustainable development (profit, people, planet).

The life cycle of the product represents the central point of the circular economy, forming, together with it, an indissoluble doublet. Extending the life cycle of products is addressed by the definition of the CE concept. The use of I4.0 technologies offers a new perspective on the value chain of the life cycle, facilitating its expansion, even by influencing circular behavior. Another catalyst of the transition to the circular economy is circular business models, which, when addressed, positively impact the meso and macro level, thus also representing an engine of the transition.

The research carried out in the second part of the thesis is intended to outline the perspective on the transition to the circular economy of different stakeholders, highlighting the

success factors, barriers, advantages and challenges perceived by them, of an economic, social, technological and legislative order; also, the thesis tries to outline an image of Romania's transition to circularity, also addressing the monitoring framework.

Institutions in the educational sphere represent a category of actors of the circular economy with a significant impact on circularity, which resides in their potential for information, education and dissemination in the CE spirit.

The analyzed business models represent starting examples in terms of the integration of circular principles in organizations. These were analyzed in 2018, and mapped on the European Commission website through IRCEM. From the author's experience, the number of circular businesses is increasing in Romania, a promising fact for achieving the transition to the circular economy.

The study on the integration of CE in the Cluj textile industry reveals the initial phase in which they are regarding the integration of the principles of the circular economy.

The research carried out at the level of the manufacturing companies confirms aspects recorded in the specialized literature, for example, the reduction of the cost of raw materials is an advantage caused by the orientation towards circularity. Another aspect is represented by the legislative challenges on the way to circularity for companies. This research is completed with a proposal for an organization's circularity assessment grid, whose items analyze the integration of circularity aspects in each stage of the life cycle.

The analysis of circular economy indicators shows the early stage of our country's transition to circularity. By the values of the related indicators, it is near the bottom of the list, or at the tail of the list in some respects. As for the monitoring system, it needs constant improvements and updates. In this last study, the paper proposes an indicator for measuring circularity, developed on the basis of the observations derived from the thorough analysis of the current system of indicators.

The research carried out shows a series of common factors involved in a successful transition, such as innovation, partnerships between stakeholders of the circular economy, the transformation of waste into resources, the promotion of sustainable consumption, etc.

The final conclusions of the thesis present a list of directions, measures and actions for the adoption of circularity valid at the organization level, a list which is then extrapolated to the macro level and mentions key points to be addressed in the case of Romania.

11.2. Originality, innovative contributions of the thesis and limits of the research

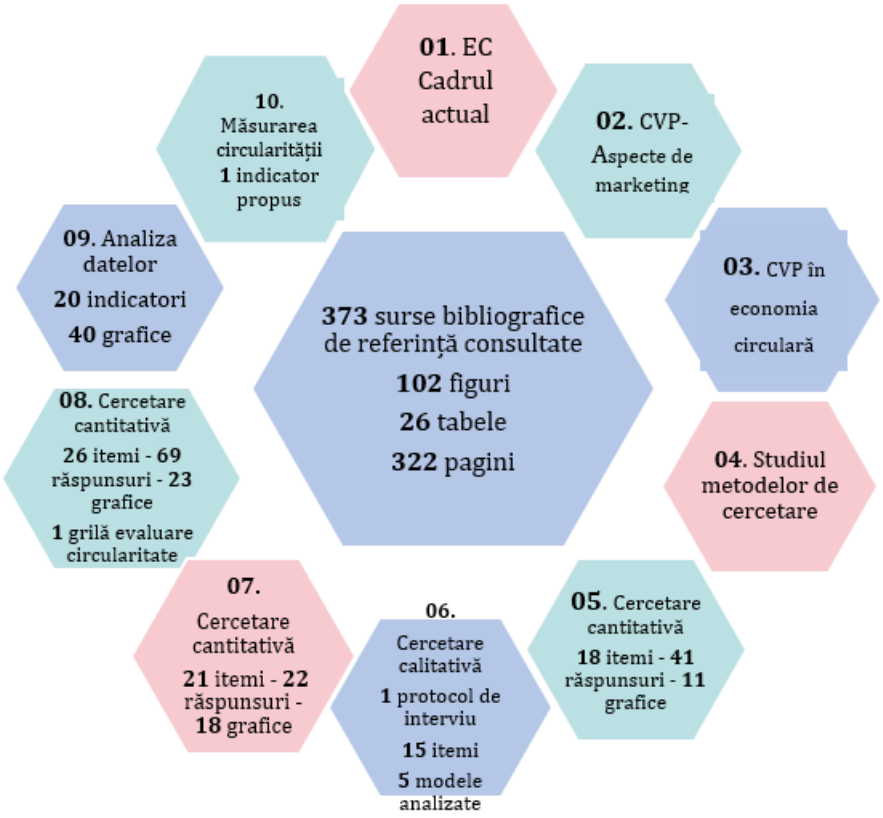
My contribution from the first part of the thesis (the current state of knowledge) materialized theoretically through the study of specialized literature to achieve the synthesis of knowledge and the definition of the conceptual framework regarding the aspects involved in the two basic concepts in this doctoral thesis, the circular economy and the product life cycle and the marketing perspective on the two concepts - chapters 1, 2 and 3, and the originality of this part resides in the way they are correlated. Also as a contribution, 3 definitions of the three previously mentioned concepts were developed. As an innovative contribution, I laid the foundations of a circular marketing, customized for the principles of the circular economy; we also addressed the outline of circular marketing mix characteristics, analyzing the circular implications of each element of the extended marketing mix – the 7Ps (product, price, placement, promotion, personnel, processes, physical evidence/evidence).

The contribution related to the second part consists in carrying out research, involving activities such as designing research, creating research tools, implementing them, processing results, analyzing data and interpreting them in accordance with the objectives of the work.

The main and innovative contribution of the thesis consists in the development of a unitary circularity indicator, integrating the fundamental scalars that describe economy, mass, energy, time and, respectively, value.

Another important own contribution consists in proposing and developing a grid model for evaluating the circularity of a production organization according to the life cycle, the exploration and refinement of the model being the subject of future research.

The following image shows the main numerical coordinates of the thesis.



11.3. Future research directions

D1: Design and implementation of descriptive research, extended to representative samples for Romania, regarding aspects of the circular economy in different fields.

D2: Involvement of stakeholders from certain fields that adhere to the principles of the circular economy, on the ROCESP platform - "ROMANIAN STAKEHOLDER PLATFORM FOR THE CIRCULAR ECONOMY", for collaboration in order to innovate, exchange experience and ideas to facilitate the transition to a circular economy from the micro level with important results and at the macro level, in certain sectors and fields.

D3: Realization of a practical guide regarding the description of the steps to follow in the process of orientation and transition to the circular economy of an organization, by activity sector.

D4: Pretesting the grid for evaluating the circularity of organizations in view of its refinement and improvement.

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