

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

Marta NIKANOROVA

THE ASSESSMENT OF CIRCULAR ECONOMY IN THE CONTEXT OF SUSTAINABLE WELL-BEING

DOCTORAL DISSERTATION

SOCIAL SCIENCES,
ECONOMICS (S 004)

Vilnius, 2021

Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2016–2021.

Supervisor

Prof. Dr Jelena STANKEVIČIENĖ (Vilnius Gediminas Technical University, Economics – S 004).

The Dissertation Defense Council of Scientific Field of Economics of Vilnius Gediminas Technical University:

Chairman

Prof. Dr Manuela TVARONAVIČIENĖ (Vilnius Gediminas Technical University, Economics – S 004).

Members:

Prof. Dr Habil. Yuriy BILAN (Rzeszow University of Technology, Economics – S 004),

Assoc. Prof. Dr Viktorija SKVARCIANY (Vilnius Gediminas Technical University, Economics – S 004),

Prof. Dr Dalia ŠTREIMIKIENĖ (Kaunas University of Technology, Economics – S 004),

Assoc. Prof. Dr Asta VASILIAUSKAITĖ (Vilnius Gediminas Technical University, Economics – S 004).

The dissertation will be defended at the public meeting of the Dissertation Defense Council of Economics in the Senate Hall of Vilnius Gediminas Technical University at **9 a. m. on 30 August 2021.**

Address: Saulėtekio al. 11, LT-10223 Vilnius, Lithuania.

Tel.: +370 5 274 4956; fax +370 5 270 0112; e-mail: doktor@vilniustech.lt

A notification on the intend defending of the dissertation was send on 29 July 2021.

A copy of the doctoral dissertation is available for review at Vilnius Gediminas Technical University repository <http://dspace.vgtu.lt>, at the Library of Vilnius Gediminas Technical University (Saulėtekio al. 14, LT-10223 Vilnius, Lithuania) and at the library of the Lithuanian Center of Social Sciences (A. Goštauto st. 9, LT-01108 Vilnius, Lithuania).

Vilnius Gediminas Technical University book No 2021-039-M

doi:10.20334/2021-039-M

© Vilnius Gediminas Technical University, 2021

© Marta Nikanorova, 2021

marta.nikanorova@vilniustech.lt

VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Marta NIKANOROVA

ŽIEDINĖS EKONOMIKOS VERTINIMAS TVARIOS GEROVĖS KONTEKSTE

DAKTARO DISERTACIJA

SOCIALINIAI MOKSLAI,
EKONOMIKA (S 004)

Vilnius, 2021

Disertacija rengta 2016–2021 metais Vilniaus Gedimino technikos universitete.

Vadovas

prof. dr. Jelena STANKEVIČIENĖ (Vilniaus Gedimino technikos universitetas, ekonomika – S 004).

Vilniaus Gedimino technikos universiteto Ekonomikos mokslo krypties disertacijos gynimo taryba:

Pirmininkas

prof. dr. Manuela TVARONAVIČIENĖ (Vilniaus Gedimino technikos universitetas, ekonomika – S 004).

Nariai:

prof. habil. dr. Yuriy BILAN (Žešuvo technologijos universitetas, Lenkija, ekonomika – S 004),

doc. dr. Viktorija SKVARCIANY (Vilniaus Gedimino technikos universitetas, ekonomika – S 004),

prof. dr. Dalia ŠTREIMIKIENĖ (Kauno technologijos universitetas, ekonomika – S 004),

doc. dr. Asta VASILIAUSKAITĖ (Vilniaus Gedimino technikos universitetas, ekonomika – S 004).

Disertacija bus ginama viešame Ekonomikos mokslo krypties disertacijos gynimo tarybos posėdyje **2021 m. rugpjūčio 30 d. 9 val.** Vilniaus Gedimino technikos universiteto senato posėdžių salėje.

Adresas: Saulėtekio al. 11, LT-10223 Vilnius, Lietuva.

Tel.: (8 5) 274 4956; faksas (8 5) 270 0112; el. paštas doktor@vilniustech.lt

Pranešimai apie numatomą ginti disertaciją išsiųsti 2021 m. liepos 29 d.

Disertaciją galima peržiūrėti Vilniaus Gedimino Technikos universiteto talpykloje <http://dspace.vgtu.lt> ir Vilniaus Gedimino technikos universiteto bibliotekoje (Saulėtekio al. 14, LT-10223 Vilnius, Lietuva) ir Lietuvos socialinių mokslų centro bibliotekoje (Goštauto g. 9, LT-01108 Vilnius, Lietuva).

Abstract

The concept of Circular Economy (CE) is alternative to linear economy, which focuses on sustainability. The current industrial and business model does not include the global environmental challenges. Business could be one of the most significant participants to change this situation. The circular economy focuses on resource efficiency, “no waste” approach, social factors and promotes the co-existing of green economy together with environmental wealth. Circular economy leads to sustainable well-being based on the synergy of environmental, economic and social dimensions.

The dissertation analyses the aspects of circular economy based on environmental, economic and social dimensions and proposes the assessment model of circular economy in the context of sustainable well-being. The object of dissertation is circular economy of the country in the context of sustainable well-being.

The literature analysis of circular economy was performed, which formed the approach of circular economy and its connection to sustainable development formulating the assessment model of circular economy, which analyses the dimensions of circular economy in the context of sustainable well-being. The assessment model of circular economy is designed to evaluate the development of circular economy in the selected country or region. Moreover, the proposed model would allow to evaluate the dimensions of circular economy in the selected geographical area over the time to identify the problems of the sustainable development of circular economy.

The dissertation aims to analyse the theoretical approaches that form the approach of circular economy for the formulation of the assessment model of circular economy in the context of sustainable well-being that would be empirically tested on Baltic sea region.

The research work resolves following key tasks: to conduct a theoretical analysis of circular economy and form the approach based on the coherence of economic, environmental and social dimensions; to determine the concept of circular economy indicator's selection and based on it to select circular economy indicators in the context of well-being; to propose a selection system of circular economy indicators which will be used in assessment of circular economy; to develop the model for accessing circular economy in the context of well-being; based on the developed model of circular economy assessment empirically evaluate the development of circular economy in the context of sustainable well-being.

The dissertation consists of an introduction, three chapters and general conclusions.

Reziumė

Žiedinės ekonomikos (ŽE) samprata yra alternatyva linijinės ekonomikos sampratai, kurios tvarumas yra vienas svarbiausių tikslų. Dabartinis verslo modelis, veikiantis linijinės ekonomikos principu, neapima pasaulinių aplinkosaugos iššūkių. Verslas galėtų būti vienas iš reikšmingiausių dalyvių, keičiančių šią situaciją. Žiedinė ekonomika orientuota į išteklių efektyvumą, gamybą be atliekų, socialinius veiksnius ir skatina žaliosios ekonomikos egzistavimą kartu su aplinkos gerove. Žiedinė ekonomika lemia tvarią gerovę, pagrįstą aplinkos, ekonomikos ir socialinių aspektų sinergija.

Disertacijoje analizuojami žiedinės ekonomikos aspektai, pagrįsti aplinkos, ekonomikos ir socialiniais aspektais, ir siūlomas jos vertinimo modelis tvarios gerovės kontekste. Disertacijos objektas yra šalies žiedinė ekonomika tvarios gerovės kontekste.

Atlikus žiedinės ekonomikos literatūros analizę, buvo suformuota žiedinės ekonomikos koncepcija bei jos sąsaja su tvaria gerove, remiantis kuria buvo suformuluotas žiedinės ekonomikos vertinimo modelis leidžiantis išanalizuoti jos komponentus ir pagerinti žiedinės ekonomikos rodiklius tvarios gerovės kontekste. Žiedinės ekonomikos vertinimo modelis yra skirtas įvertinti žiedinės ekonomikos raidą pasirinktoje šalyje ar regione. Be to, siūlomas modelis leistų įvertinti žiedinės ekonomikos komponentus pasirinktoje geografinėje vietovėje per tam tikrą laiką, siekiant nustatyti jos tvarios raidos problemas.

Disertacija siekiama išanalizuoti teorinius požiūrius, kurie sudaro žiedinės ekonomikos koncepciją formuluojant žiedinės ekonomikos vertinimo modelį tvarios gerovės kontekste, kuris būtų empiriškai išbandytas Baltijos jūros regione.

Tyrimo metu sprendžiami šie pagrindiniai uždaviniai: atlikti teorinę žiedinės ekonomikos analizę ir suformuluoti koncepciją, pagrįstą ekonominių, aplinkos ir socialinių aspektų darna; nustatyti žiedinės ekonomikos rodiklių pasirinkimo sampratą ir ją remiantis pasirinkti žiedinės ekonomikos rodiklius tvarios gerovės kontekste; pasiūlyti žiedinės ekonomikos rodiklių atrankos sistemą, kuri bus naudojama vertinant žiedinę ekonomiką; sukurti žiedinės ekonomikos vertinimo modelį tvarios gerovės kontekste; remiantis sukurtu žiedinės ekonomikos vertinimo modeliu, empiriškai įvertinti žiedinės ekonomikos raidą tvarios gerovės kontekste.

Disertaciją sudaro įvadas, trys skyriai ir bendros išvados.

Notations

Abbreviations

CE –	Circular Economy;
DEA –	Data Envelopment Analysis;
EU –	European Union;
GDP –	Gross Domestic Product;
LFA –	Life Cycle Assessment;
MCA –	Material Cost Analysis;
MCDM –	Multi criteria Decision Methods;
MFA –	Material Flow Analysis;
MULTIMOORA –	Multi-Objective Optimization by Ratio Analysis;
ODA –	Official Development Assistance;
OECD –	Organisation for Economic Co-operation and Development;
R&D –	Research and Development;
SDG –	sustainable development goals;
SMEs –	small and medium sized companies;
TOPSIS –	Technique for Order of Preference by Similarity to Ideal Solution;
UN –	United Nations.

Contents

INTRODUCTION	1
Problem Formulation.....	1
Relevance of the Thesis.....	2
Research Object.....	3
Aim of the Thesis	3
Tasks of the Thesis.....	3
Research Methodology.....	3
Scientific Novelty of the Thesis	4
Practical Value of the Research Findings.....	5
Defended Statements.....	5
Approval of the Research Findings	6
The Structure of the Dissertation.....	6
1. THEORETICAL ANALYSIS OF CIRCULAR ECONOMY CONCEPT	9
1.1. The concept of Circular Economy.....	9
1.2. Circular Economy as a part of Sustainable Development leading to Sustainable Well-Being	22
1.3. Circular Economy as a key to Sustainable Well-Being.....	28
1.4. Alternative approaches to Circular Economy assessment	33
1.5. Conclusions of Chapter 1 and formulation of the objectives of the doctoral thesis	35

2. FORMATION OF CIRCULAR ECONOMY ASSESSMENT MODEL IN THE CONTEXT OF SUSTAINABLE WELL-BEING	37
2.1. Building of Circular Economy evaluation model.....	37
2.2. Environmental aspects of Circular Economy	39
2.3. Economic aspects of Circular Economy.....	50
2.4. Social aspects of Circular Economy.....	59
2.5. Integration of MCDM method TOPSIS into Circular Economy valuation system.....	68
2.6. Integration of MCDM method MULTIMOORA into Circular Economy valuation process	72
2.7. Conclusions of the Chapter 2	80
3. EMPIRICAL APPROBATION ON CIRCULAR ECONOMY ASSESSMENT IN BALTIC SEA REGION IN THE CONTEXT OF SUSTAINABLE WELL-BEING	81
3.1. Development of Circular Economy in the Baltic Sea Region	82
3.2. Assessment of Environmental dimension of Circular Economy	82
3.3. Assessment of Economic dimension of Circular Economy.....	90
3.4. Assessment of Social dimension of Circular Economy.....	97
3.5. Assessment of Circular Economy in the context of Sustainable Well-Being...	104
3.6. Overview of the results and discussion	111
3.7. Conclusions of the Chapter 3	113
GENERAL CONCLUSIONS	115
REFERENCES	119
LIST OF SCIENTIFIC PUBLICATIONS BY THE AUTHOR ON THE TOPIC OF THE DISSERTATION	133
SUMMARY IN LITHUANIAN	135
ANNEXES ¹	151
Annex A. Representation of Circular Economy concept in the context of Sustainable Well-Being	153
Annex B. Declaration of Academic Integrity	154
Annex C. The Coauthors Agreements to Present Publications for the Dissertation Defence.....	155
Annex D. Copies of scientific publications by the autor on the topic of the dissertation.....	158

¹ The annexes are supplied in the enclosed compact disc.

Introduction

Problem Formulation

Today the world is challenging the situation of inefficient use of resources and energy, inefficient waste management, faces the difficulties to decrease the pollution and maintain “green” environment. Circular economy model includes both economic and environmental welfare and sustainability principles shift from the value-added aspects to the core aspects. Business and industry all over the world should be aligned with the environment principle of the Earth, which is supported by circular economy and ensures the interconnectivity of economy with the environment and social aspects, based on the principle of sustainability. Sustainability leads to well-being, which is a vague term as focuses on the term “needs”. However, majority of the studies agrees that well-being concept is based on several dimensions which observe all the aspects of human life such as social well-being, economic well-being and environmental well-being.

Nowadays the integration of circular economy principles is necessary in order to allocate the resources and reduce the negative impact on the environment caused by consumption and production. However, the absence of the tool that would evaluate circular economy and clearly identify principles adjusted for selected region does not allow to determine the development of circular economy and its components. Established tool of circular economy evaluation would make

a significant impact on the development of circular economy determining the gaps for improvement. Moreover, a critical literature analysis indicated the following economic and research problems:

1. Circular Economy approach is not developed enough to create a standard concept, which would describe circular economy as a tool for sustainable development leading to sustainable well-being.
2. The lack of circular economy assessment tools and indicators does not allow to form and analyse circular economy approach and its components.
3. Existing methods of circular economy measurement does not allow evaluating the development of circular economy in the context of well-being for a specific country or region. Existing tools of circular economy measurement are adopted for a specific region only measuring the specific environmental aspect and can not be used without the changes for other country or region.

Relevance of the Thesis

The concept of circular economy is one of the recent economic models, seeking to ensure the sustainable well-being of the country or region and dealing with unified environmental problems causing the negative impact to economy and society. Circular economy approach has a lot of scientific outstanding issues: the components of circular economy, economic performance, environmental indicators, social indicators, and other retained in circular economy assessment of the European Union. Also, scientists are discussing the universal three-dimensional circular economy evaluation models which could be used for any type of region.

Circular economy would ensure resource efficiency in the EU to 3% per year, which is equivalent to 0.6 trillion per year by 2030. GDP confidently would grow about 7% each year, together with the positive impact on employment (European Commission, 2016). Many other programs have been launched to reduce the negative impact on the environment such as Horizon 2020, Horizon 2030 and long long-term vision for 2050 called “Long-term vision for a prosperous, modern, competitive and climate neutral economy by 2050 – A Clean Planet for All” (EC, 2018)

According to the interest of European Union to implement circular economy and encourage the country implement its components in their economies signals the necessity of universal tool that would be able to evaluate and rank circular economy over the European Union region with a possibility to analyse its components and compare among EU members.

Research Object

The object of the research is circular economy of the country in the context of sustainable well-being.

Aim of the Thesis

The aim of the thesis – after distinguishing indicators of circular economy, to develop a model for assessing circular economy in the context of sustainable well-being.

Tasks of the Thesis

In order to achieve the objective, the following problems had to be solved:

1. Theoretically justify the links between economic, environmental and social dimensions of the circular economy in the context of sustainable well-being.
2. To propose a guideline of the selection of circular economy indicators which will be used in circular economy assessment in the concordance with the components of sustainable well-being.
3. To collect circular economy indicators complying with the proposed guidelines of the selection indicators for circular economy assessment complying with sustainable well-being.
4. To propose a circular economy evaluation model in the context of sustainable well-being based on environmental, economic and social dimensions.
5. Based on the developed model, empirically evaluate circular economy in the context of sustainable well-being.

Research Methodology

To investigate the object, the following research methods are chosen:

1. Methods of collecting, grouping and systematizing primary and secondary sources, summarizing, comparative and logical analysis.
2. Select criteria and alternatives and determine the decision matrix using the ratio system method.

3. Criteria and alternatives are optimized according to the need for maximization and minimization, values are normalized using the ratio system method and prepared for the use of multi-criteria analysis methods.
4. Application of MULTIMOORA and TOPSIS multicriteria analysis methods for data processing of the model: determination of the maximum target reporting point using the MULTIMOORA method and determination of the Euclidean distance to the best hypothetical solution using the TOPSIS method.
5. Using the full multiplication form according to the MULTIMOORA method and the relative proximity coefficient according to the TOPSIS method to perform the ranking according to the development of the circular economy in the context of sustainable welfare. Using the principle of complementarity (triangulation) of methods to check the reliability of the conclusions, to compare the obtained results.
6. Approbation of results by the example of a country case analysis method.

Scientific Novelty of the Thesis

The aspects of scientific novelty on the assessment of circular economy in the context of sustainable well-being are as follows:

1. The concept of circular economy determined based on environmental, economic and social pillars that are complying with the sustainable well-being approach.
2. In the thesis introduced 10R circular economy strategies by EU have been supplemented with proposed indicators of economic pillar (6E) and Social pillar (6S) according to the goal of economic and social aspects of circular economy. 6E strategy identifies economic aspects of circular economy and describes the contribution of circular economy to the economic wealth of the country. 6S strategy identifies social aspects of circular economy which is an integral part of economic wealth of the country. 6E and 6S strategies fulfill the scientific gap of circular economy research by giving an advanced tool for analysis of circular economy from economic and social aspects perspective.
3. The system of indicators proposed needed for circular economy assessment. The indicators selected based on environmental, economic and social pillars of circular Economies and grouped according to the areas of targets.

4. The assessment model of circular economy in the context of sustainable well-being combines systems of circular economy indicators and multiple-criteria decision-making methods (MCDM) that allow to assess circular economy of a specific country or region, analyse the components of circular economy, identify the problems and compare the assessment of circular economy over the time.

Practical Value of the Research Findings

The findings of the thesis have important implications for practice:

1. The determined framework of circular economy enables practitioners, scientists, policy makers, institutions and government to acquire a better understanding of the complexity of circular economy approach, its pillars and targets it focuses for further its implementation and development.
2. The developed system of circular economy indicators selection identifies the areas of targets which would help to identify the issues of sustainable development of circular economy, which would help government to make effective policy decisions towards circular economy and stimulate the improvement of weak parts of the circular economy framework.
3. The assessment model of circular economy would help to develop the assessment of circular economy over the period has been set or by the implementation of new regulations issued by the government towards circular economy implementation.
4. The assessment model of circular economy could provide the guidelines for policy implications on the country or regional level related to strategic decisions of the government towards implementation of circular economy.

Defended Statements

1. By extending the model of circular economy by three dimensions: economic, environmental and social – ensures the compliance of circular economy model with sustainable well-being.
2. The problem of evaluating the development of the circular economy can be solved by applying the developed evaluation model, which integrates the indicators of the circular economy, grouped according to dimensions.
3. The framework of the proposed tools (MULTIMOORA and TOPSIS) is integrated into the circular economy development evaluation model and

allows to evaluate circular economy in the context of sustainable prosperity as a whole, as well as by dimensions or sub-groups of indicators.

4. The proposed model of circular economy assessment allows the integration of the circular economy into the country's economic model and promotes the spread of the circular economy.

Approval of the Research Findings

The dissertation research findings were disseminated among four publications in reviewed scientific journals and one publication in other editions focusing on the subject of the dissertation. The results were also presented at the conference on the subject at international level. The author has made two presentations at the international scientific conferences and scientific seminars:

- Nikanorova M. Analysis of economic and environmental welfare in the context of circular economy. Contemporary issues in business, management and education'2017 – Vilnius Gediminas Technical University;
- Nikanorova M. Analysis of Green Economy dimension in the context of Circular Economy: The case of Baltic Sea Region., Vytauto Didžiojo Universitetas 2018.

Four scientific presentations have been made at the scientific seminars for PhD students at the Faculty of Business Management (one each academic year during the period of 2016–2020). One scientific visit during doctoral studies have been made:

- Visit at the University of São Paulo, Brazil, 2019.

The Structure of the Dissertation

The structure of the dissertation is as follows: the introduction, three chapters of the dissertation, general conclusions, references, author's publications on the subject of the defended dissertation. The total scope of work is 161 pages, 15 numbered formulas are used, 26 pictures and 11 tables, 183 references are included in the dissertation.

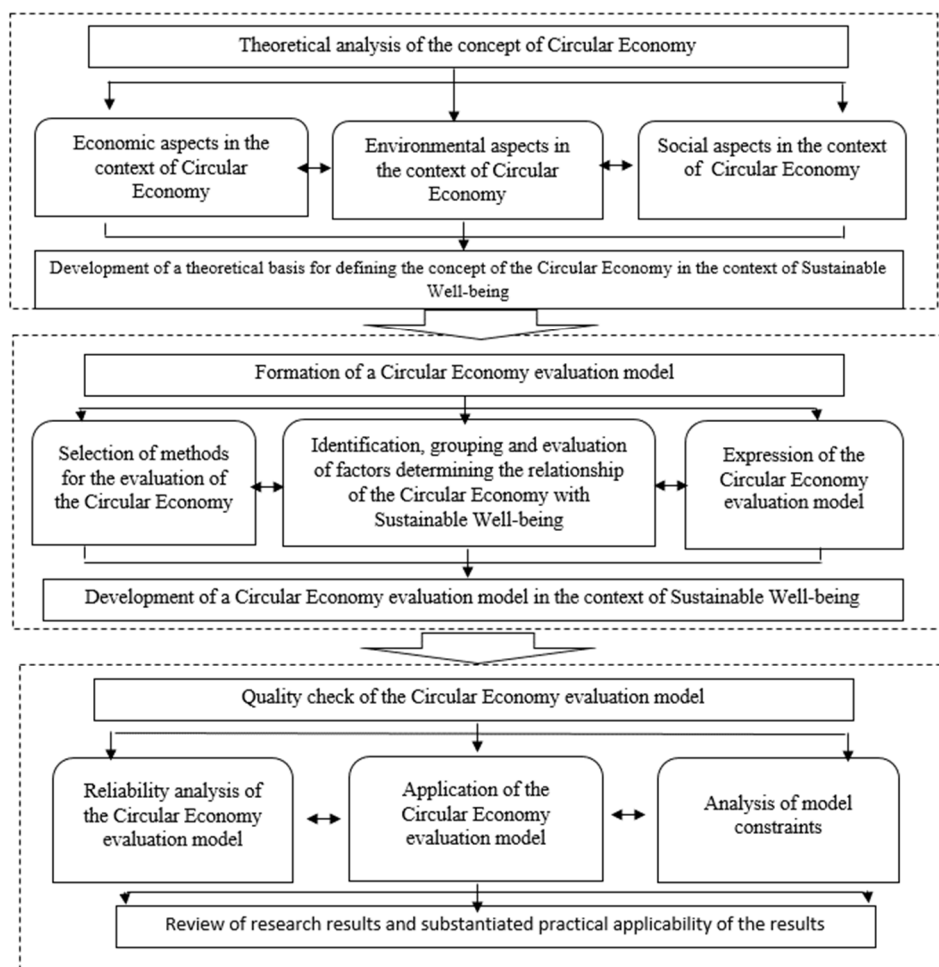


Fig. 0.1. Structure of dissertation (source: compiled by author)

Theoretical Analysis of Circular Economy Concept

This Chapter aims to determine the concept of circular economy and investigate the relationship with sustainable well-being. The components, aims and strategy of circular economy have been identified together with the need and possibility of the replacement of linear economy with circular economy analysing its benefits and barriers. Moreover the chapter shows the promotion and support of Circular Economy by European Union institutions bringing Environmental problems in the center of the attention.

The findings of Chapter 1 have been published in 3 scientific papers (Stankevičienė, Nikanorova 2017; Stankevičienė, Nikanorova; 2020; Nikanorova, *et al.*; 2020)

1.1. The concept of Circular Economy

The idea that the economy and environment are positively related goes in 1928, when W. Leontief has published an article “The Economy as a Circular Flow” (1928, 1991 translation), where the main idea of economics considers price theory and material. He suggested to include the material as a key important factor to economic’s theory after the establishing a positive correlation. Boulding (1966)

continues Leontief's idea and introduced the own point of view by representing the Earth as a closed economic system, where the economy and the environment have a circular relationship. The concept of circular economy was introduced by and Turner & Pearce (1990), where they have represented that the economics without environmental aspect is a linear and open-ended system, while closed loop system expressed by the interaction of economics and environment with a system for zero waste of material or recycling approach brings much more benefits.

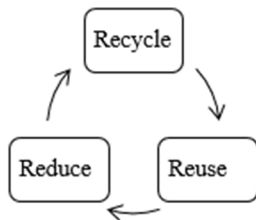
The fast technological progress, rapid industrialization and urbanization lead to the increasing production volumes and consumption. During the years it made a negative impact on the environment. Today the environment and reduction of waste are most common topics to discuss by the society. The regions and countries are establishing more and more regulations and laws to reduce the negative impact on the environment by involving recycling into economics. For example, Germany, Japan, China, United Kingdom, the Netherlands, Sweden and European Union have established several directives leading the economy towards the circular economy concept by introducing the framework of closed cycle waste management ensuring waste disposal, which moves towards recycling-based society. Some European Union countries have established "green" politics in their political decision making which encourages the movement towards circular economy. European Union has put a lot of efforts to move towards circular economy by the issued directive "European Resource Efficiency Platform (EREP) – Manifesto and Policy Recommendations" (European Commission, 2012). In this directive the society, including business, manufactures and labor to support the reduction of waste and increase resource efficiency by providing an action plan for transitioning to resource efficient Europe which includes the encourage to produce and use renewable energy, to manage the waste.

In 2005 (Zhu 2005) the third "social" dimension was added to the concept of circular economy. The third dimension would help to move from linear economy to circular as it promotes the resource efficiency in each level of product consumption – starting from the product creation and ending by its consumption and disposal. All three aspects lead to the overall well-being society promoting the resource allocation, redesigned industry focused on "zero" waste politics and reducing negative impacts on the environment made by production and consumption of products.

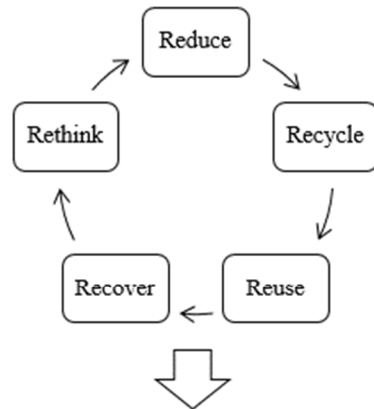
In 2007 (Zhu & Qiu 2007) the concept of circular economy was introduced by 3R principle: material use reduction, waste reuse and recycling of waste into the state of secondary raw materials. The idea of 3R principle is to reduce the use of natural resources and the waste generated which could be done by changing the design of the product, or changing the production process, which would let to reduce generated production waste. Parts of the production or generated waste of

some production stages could become a raw material for another product what would lead to the secondary use of the materials. According to Zhu & Qiu (2007), the circular economy is a sustainable economic growth model, which goal is to minimise inputs and waste, increase efficiency of the production and capacity of products usage.

3R principle of Circular Economy



5R principle of Circular Economy



7R principle of Circular Economy

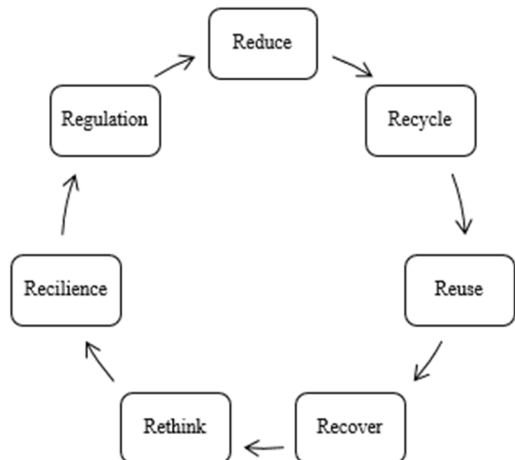


Fig 1.1. Development of the principles of circular economy
(source: compiled by author based on Xing *et al.* (2017))

The circular economy approach to agriculture was introduced by Li *et al.* (2011) according to which the benefits of agricultural development in the context

of circular economy were presented and compared to traditional agriculture. The main benefits of agricultural development in the context of circular economy were multi-industry and agricultural waste recycling. Dolinsky & Maier (2015) used a game theory analysis tool to make a simulation of shifting from linear economy system towards circular economy in easiest and the most feasible way.

There are different definitions of circular economy proposed by scientists. According to Kirchherr *et al.* (2017), a circular economy describes an economic system that is based on 4R principles: reduce, reuse, recycle and recover which replace the 'end-of-life' concept in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond). 4R framework principles start from reduction and minimization of resource usage on each stage of product lifespan. The second stage of the framework is reusing of the resources excluding the waste. On the recycling stage the waste should be remanufactured, recycled or reused. On this stage the loop is being closed and recover of the materials should be discussed. However, Shen & Qi (2012) introduce 5R principles of circular economy by adding "Rethink" and "Repair", which stands for rethinking of towards the maintaining of environment and repair already damaged ecosystem. Li *et al.* (2015) support the idea of 5R principles of circular economy by "Rethink" principle which updated 4R principle. 5R principle of circular economy includes: Reduce, Reuse, Recycle, Recover and Rethink principles, where "Recover" stands for the practice to turn the waste into resources and "Rethink" stands for people taking into consideration the impact on the environment due to their activities as well as ensuring the compliance of all other Rs. As an example, solid waste that is found in landfill could be turned into electricity, which would be used for production or by households.

Teodor *et al.* (2020) see circular economy as opportunity for business and industry to reduce generated waste without any economic losses to any of stakeholders. "Reduce" means the decrease of inefficient use of non-renewable resources which leads to inefficient production and lost of economic benefits as a result. For example, the production cost could be lowered if the consumption of energy would be reduced in all or some production stages. This would lower the cost of production and would lead to greater economic benefits. "Reuse" – utilization or secondary use of the material or product. "Recycle" refers to the recycling of material, energy, data and etc. By the "Rethink" principle the social aspect of circular economy has been involved: rethinking the production stages to improve the processes and implement new eco-technologies or as well the control of all R principles to be followed.

Li & Xiao (2017) determine "producers-consumers-decomposers" as a circulation path in the industrial system and expressed doubts of the completion of 5R principles describing circular economy, explaining the need of "Resilience" to

be included. “Resilience” represents the capacity of recovering from the situation of shortage of waste of the resources.

Xing *et al.* (2017) propose 7R principle by adding “Resilience” and “Regulation”. “Regulation” supports social aspect of circular economy as stands for governmental control, management and adjustment. (Fig 1.1.) Government by the laws and regulations regarding circular economy, supports from non-profit sectors and media, proposals from trade associations form the positive way of thinking towards circular economy being formed by business, producers and consumers. The 7R approach involves all the stakeholders into circular economy such as: government, supply chain, non-profit organisations, producers and consumers. The practising of 7R would lead to economic growth by increasing the efficiency of production and reduction of costs, social progress and environmental wealth.

By the time the definition and principles of circular economy are being expanded by more focus areas, that is why more and more new principles have been added to circular economy approach. Reike *et al.* (2018) analysed 69 academic articles on proposing different R principles of circular economy. Different authors assign new Rs to the principles of circular economy or give new explanation of already existing R principles that implies the conceptualization of circular economy. 38 different “re-” words have been analysed by the Reike *et al.* (2018) in various combinations, as well the author analysed proposed principles of circular economy from 3R to 10R. This shows, that still, circular economy is not clearly defined academic discipline with determined features and focus areas. Also, it shows, circular economy is not the isolated discipline and acts as symbiosis between stakeholders, that gives the freedom of giving national meanings and define new terminology for circular economy principles. Moreover, circular economy includes various social principles showing the complex nature of its concept, which can be linked to global economy, national economy, supply chains, value chains, single businesses, single markets and specific product scale. Reike *et al.* (2018) and Potting *et al.* (2017) expand 7R principles of circular economy to 10R principles (Fig. 1.2), which are divided into the shortest loop (L1), medium long loop (L2) and long loop (L3). The shortest loop (L1) includes “Refuse”, “Reuse”, “Repair” and “Reduce” principles. In this case “Refuse” principle is applicable both to consumer and producer. From the consumer side – consumers may decide to buy products less and to use less, either refuse some products (for example some packaging are being refused). The decision of consumers may be influenced by the spread of information of circular economy approaches and ecological wealth. Producers may change the design of the products, refuse some not eco-friendly materials to avoid generated waste. The producers may be influenced by the government (regulations) and financial support (green investment, green fiscal policy, etc).

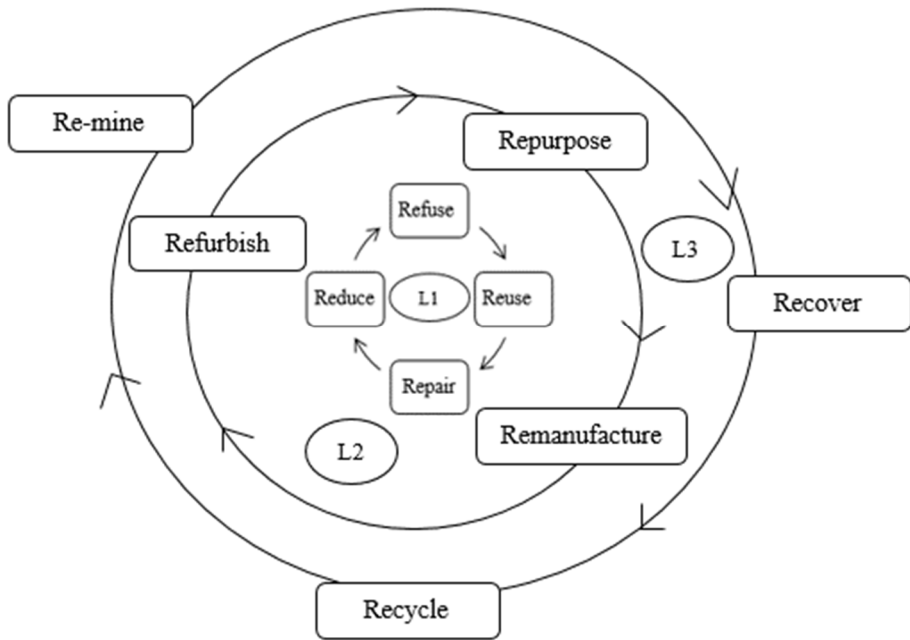


Fig 1.2. 10R principles of circular economy (source: compiled by author based on Reike *et al.* (2018) and Potting *et al.* (2017))

“Reduce” principle is linked to the elimination of production of waste. “Reuse” principle describes the need to return the product back to economy after the product has been initially used and is applicable both to producers and consumers. It may also represent “second hand” usage of the same product without the change of its purpose. “Repair” principle means the possibility the product can be fixed and brought back to live or by the customer or by the producer. The medium long loop (L2) includes “Refurbish”, “Remanufacture” and “Repurpose” and require more resources to be applied. “Refurbish” principle provides new features to the product, which is more complex, has many components requires additionally materials and resources to be upgraded. This gives the possibility to improve the quality of the product and safe it from the utilisation. “Remanufacture” principle applies once the multi-component product is being reviewed from the first production step, checking its structure and according to the need being replaces or repaired in the production process. “Repurpose” principle allows to change the purpose of the product. The longest loop (L3) is about effective waste management when such principles as “Re-mine”, “Recover” and “Recycle” are being implemented. “Recycling” requires eco-technological decisions and expensive equipment. This requires financial sources to be provided, thus, it is hard for each

producer to establish “Recycling” principle, as usually recycling decreases the quality of initial material and requires some decision of recycled product usage to be applied by the legislations. Also, higher energy inputs are being requires, which directly influence the price of the product. “Recover” principle of 10R is about the renewable energy source and reduction energy waste. “Re-mine” principles retrieves the materials after the landfilling phase.

With the different interpretation of the principles of circular economy a variety of its definitions have been proposed. Geissdoerfer *et al.* (2017) introduced the definition of circular economy as a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling. In addition to this, Stahel (2016) proposed the defined that a ‘circular economy’ would turn goods that are at the end of their service life into resources for others, closing loops in industrial ecosystems and minimizing waste. It would change economic logic because it replaces production with sufficiency: reuse what you can, recycle what cannot be reused, repair what is broken, remanufacture what cannot be repaired.

Giampietro (2019) agrees to identify circular economy as a model seeking to ultimately decouple global economic development from finite resource consumption supporting the idea of possibility increase economic productivity without the increasing the consumption of natural resources such as energy, water or minerals by recycling of product or components with the implementing of technological innovation. Zotti & Bigano (2019) as well agree regarding the confusion of circular economy meaning and identify the scientific debate of circular economy definition and propose the notion of economy’s circularity which is defined as a feature of the economy that consists in the presence of circular energy and matter flows within it, which co-works with circularity strategies (which allow its implementation, together with supporting initiatives). From the economic point of view this definition of circular economy allows to identify circularity as alternative production technology, where already used products and materials become usable again in the production and consumption. By this way circular production increases the capacity of non-circular production, which may influence the supply of the material. By this way the circular production should be increasing over the time.

Kirchherr *et al.* (2017) made an analysis of 114 definitions of circular economy, which states that, by time, the definition of circular economy is changing together with the concept of circular economy. As the concept of circular economy is relatively new and varies depending on practitioners, business, academic, etc., more and more definitions of circular economy include various R frameworks (reduction, reuse, recycling and etc.) and social gain (Blomsma & Brennan 2017).

It is important to relate the definition of circular economy to the initial aim of it presented by Ellen MacArthur Foundation (2013) and European Environment Agency (2016, 2018), stating that the initial aim of circular economy is maintenance of sustainable development based on three pillars: environmental, economic and social (WCED 1987). However, there are some discussions, stating that circular economy concept is based more on environmental benefits (Lieder & Rashid, 2016; Sauvé *et al.*, 2016), newly proposed R principles framework include socio-economic aspects.

Kirchherr *et al.* (2017) proposed the following definition of circular economy:

“A circular economy describes an economic system that is based on business models which replace the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the -micro level (products, companies, consumers), -meso level (eco-industrial parks) and -macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.”

By all these definitions circular economy is introduced as a model, where resources are extracted, transformed to the goods, distributed among consumers used and recycled in order to be returned back into the resource which can be ready for transformation into the good (Fig. 1.3). All these processes are integrated on –micro, –meso and –macro levels.

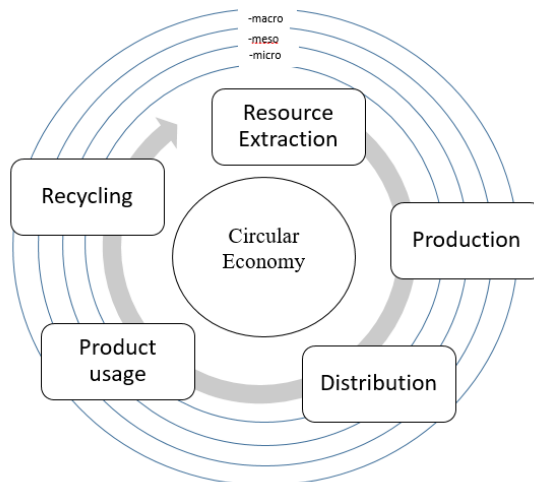


Fig 1.3. The general idea of circular economy according to the definition provided by Kirchherr (source: compiled by author based on Kirchherr (2017))

Many authors agree on the advantages of circular economy and possibilities of its implementation. One of the advantages of circular economy is resource allocation and reduction of resource use in production (Vermader 2008). With the development of economy, the industries are increasing amounts of production consuming more energy.

Circular economy encourages the switch from non-renewable energy sources to renewable “green” energy sources reducing pollution and energy waste. This leads to implementation of new “green” standarts in production and developing new technologies. According to Heck (2006), circular economy would lead to global well-being of the society. According to Su *et al.* (2013) circular economy should be implemented simultaneously on micro-, meso- and macro- levels and can be categorized into four areas: production, consumption, waste management and other support. Also, Raftowicz-Filipkiewicz (2016) supports the idea of simultaneous implementation of circular economy at all levels (Fig. 1.4). Once the circular economy can be assured on –micro level – product creation, production and consumption – it moves to –meso level, where circular economy works on regional level and eco-industrial parks could be created based on circular economy approach.

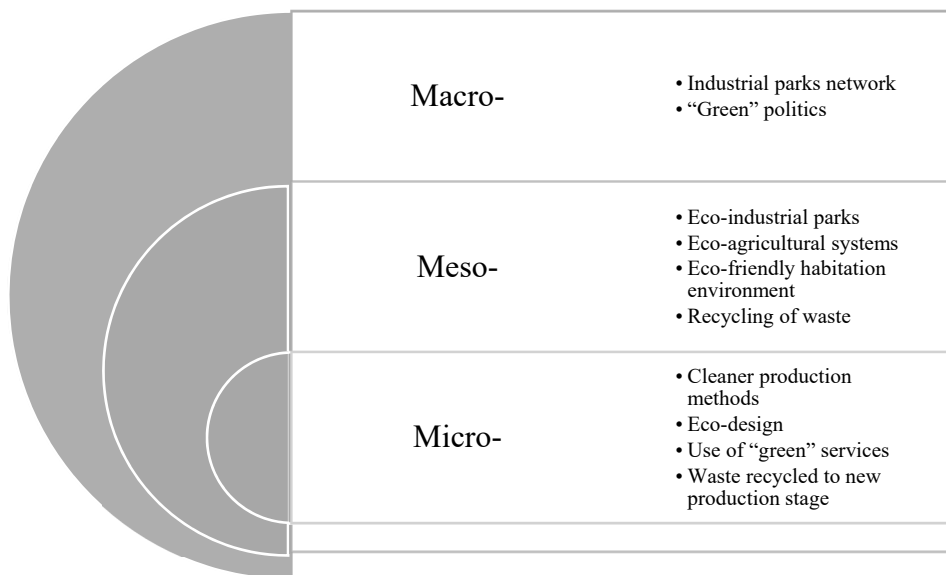


Fig. 1.4. Implementation of circular economy on micro-, meso- and macro- levels
(source: compiled by author based on Heshmati, 2015)

The next stage to move forward is –macro level, where circular economy can be implemented on national or global level. Engaged enablers in this case are consumers and business models. Development of circular economy requires new business models as well as use of new eco-friendly innovations and technologies to maintain zero waste approach and reduction of the resources used. Consumers should become the drivers for the circular economy development by demanding eco-friendly products and using responsibly. The main driver should become the behavior of consumers as the result of changed mindset towards eco-friendly consuming.

At micro-level the environmental-friendly production approach and eco-design of products are required to be applied. This will lead to the reduction of pollution, eco-design would give the advantage of full recycle of the product what will lead to efficient waste management from producer and consumer perspectives. At meso-level the eco-industrial parks and eco-agricultural systems are being created. This synergy allows easier process of material flow, supply chain, transition of technologies and innovation. Also, eco-industrial parks and eco-agricultural systems would lead to the rational usage of the resource and efficient control of the waste, in the result of which it would make a positive impact on the development of eco-friendly habitation environment. At macro-level, the “green” politics encourages to appear eco-cities, eco-regions and eco-communities. The synergy of eco-industrial parks would develop cooperative network of different industries including all sectors and levels of production. Heshmati (2015) has identified main aspects of implementing and developing circular economy:

- Land degradation,
- Deforestation,
- Water depletion,
- Air pollution,
- Loss of biodiversity,
- Generation of waste,
- Shortage of resources and energy to meet the growing demand.

According to Scheel (2016), in order to shift towards circular economy there is a need to promote eco-innovations, turn waste into materials that could be implemented into manufacture, reduce the pollution and save the tendency of economic growth. Pietro-Sandoval *et al.* (2018) determined four relevant components that are necessary to establish the concept of circular economy:

1. The recirculation of resources and energy, the minimization of resources demand and the recovery of value from waste;
2. A multi-level approach;
3. Achievement of sustainable development;
4. Close relationship with the way society innovates.

By the established components according to Pietro-Sandoval *et al.* (2018) circular economy is being treated as the way to reach sustainable development. Moreover, circular economy includes various principles connecting to environmental and social wealth and reaching economic benefits by turning the waste into resource, which in the linear economy harms the environment. However, to reach the circularity of the resources and “zero” waste there is a need of eco-technologies and financial resources to be allocated to eco-innovation research and new equipment are being used by industry.

Linear economy model which is widely used until nowadays in all over the world offers well-known “take-make-waste” concept, when the natural resources are being extracted by producers to produce a product which turns into the waste after consumption. In the future the economy may be at risk, as nowadays it is dependent on resources. While production and consumption each decade are rapidly growing, the shortage of resources will grow as well, what would cause a negative impact on the environment, society and economy itself. Circular economy model can solve this issue by allocation and protection of the resources. Circular economy approach aims to recover resources, economy and social capital. Garcia-Barragan *et al.* (2019) defines economic interpretation of circular economy, that the streams of materials maximize social welfare when present and future marginal benefits, accounting for durability, are equal to the marginal social costs of recycling, including the impact of scarcity of material resources and land-filling space. If the more functionality could be produced from the unit of the resources – more goods could be produced with a unit of material which would lead to higher productivity and efficiency that would positively impact economic benefit of circular economy. Thus, circular economy according to this model, which can be represented as a closed loop, waste which is gained after the consumption of a product should be turned again into the resource and returned to the production or recycled without residual have many positive benefits in the comparison to linear economy (Fig. 1.5). Linear economy in Figure 1.5 is represented as open-ended model where the last process is generation of waste after production or consumption.

Linear Economy turns into circular economy when waste is generating resource after recycling (Saraiva *et al.*, 2018). Waste can consist of biological and technological materials. Biological materials can be recycled and return back to the environment without harm or returned back to the production. Technological materials are being reused or recycled without harm to the environment (Grigoryan & Borodavkina 2017). However, in some cases, there still be a percent of non-recyclable waste which cannot be reused due to physical laws (De Almeida & Borsato 2019; Palacios 2021). Also, important resource is energy, which demand is growing rapidly, cannot be wasted – it should be converted or dissipated (Tseng *et al.*, 2018). Overall, non-recyclable waste should be rare issue and should

appear only if this is under the law of nature. However, soon it is impossible to receive absolute circular economy due to technological knowledge gap, thermodynamics laws and other barriers which can not allow a rapid spread of circular economy.

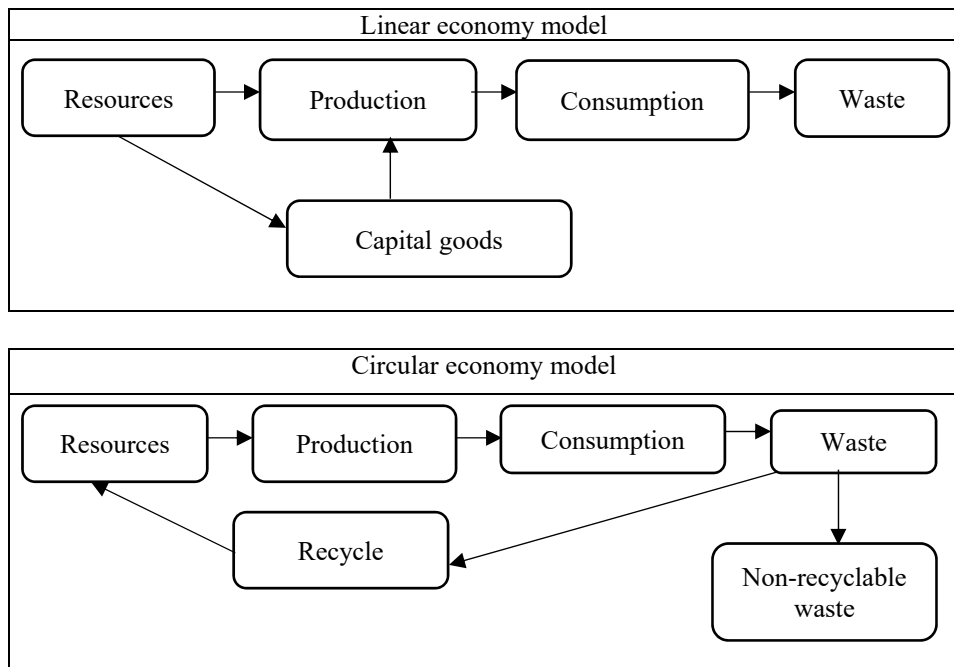


Fig. 1.5. Comparison of linear economy and circular economy processes
(source: compiled by author based on Busu & Busu, 2018)

The circular economy is quite new approach to be widely integrated in industry and business. Today many scientists are discussing about the establishing the measurements of circular economy and appropriate indicators to be analyzed because of diversity of different structure of economy, industries, socio-economic climate. The strategy of circular economy should be implemented on national level taking into consideration of socio-economic and environmental aspects of a particular country based on the principle of the global challenges. What is more, there are barriers to refuse “take-make-waste” approach of linear economy in short term perspective. According to Ritzén *et al.* (2017), it is possible to identify certain barriers:

1. Technological barriers – there is a need to extend the manufacturing cycle, to create technical and biological material cycles, improve recycling technologies to ensure “zero waste” concept. Moreover, the

industry and business need to overtake the recycling system and integrate it also to production cycle.

2. Legal barriers – legal requirements could become a barrier for materials recycling, waste management, replacement of certain materials and etc.
3. Economic barriers – the profit remains the aim of the business and positive return on investment is required to re-organize the company. To re-organize the production, business cycle, the company will require to take risk and face significant costs.
4. Change in mindset – There is a need to rely on new way thinking, to communicate with others in a chain and act according to mindset, to create a new value chain and refuse current paradigm.

There were more barriers presented by Ritzén *et al.* (2017) such as procurement, as the business would need to create new supply chains, to re-think about material flow, as today there is a limited volume of recycled and reused materials available in the market. Circular economy concept could be represented as a barrier because of its radicalism and complexity to be applied. In addition, customer behavior could be a barrier for circular economy. As business need to change the mindset towards sustainability, the consumers should follow this initiative and create a demand for such goods, re-think their values towards the recycled materials and quality of such goods. Furthermore, quite important barriers are lack of governmental support and collaboration barriers. As the companies should collaborate among themselves and follow the same circular economy approach. It would be impossible to implement circular economy approach to each business cycle element without the collaboration with other companies and motivation from the government side. Circular economy model, differently as linear economy model, includes recycling, material reuse processes and efficient resource use which lead to the development of eco-innovations and technologies, creation of jobs, increase “green” investment, changes habits of the society and contributes to the sustainable economic growth (Lahti *et al.*, 2018). In other words, circular economy is operating as natural ecosystem – if there is a natural waste – it could be returned to the environment, however all the materials what can be recycled and disposed – should be recycled and disposed to achieve “zero waste” target what is one of the key points of circular economy.

Chizaryfard *et al.* (2021) highlight, that still circular economy is being analysed mainly from ecological perspective and there is a gap in the analysis of circular economy as conceptual framework. Ferrante & Germani (2020) as well indicate, that circular economy apart ecological benefits can contribute to economic growth and includes socio-economic variables. This shows, that the conceptualization of circular economy is debated among policy-makers and businesses that

shows the necessity of clear concept of circular economy indicating all the components. Reike *et al.* (2018) in their work agree that circular economy conceptualizing needs to be cleared out, as by the time the concept of circular economy is developing by the scientists, which determine new focus areas.

To sum up, the circular economy describes an economic system based on business models, which are replacing “take-make-waste” concept by “take-make-reuse-dispose” concept implemented on micro-, meso- and macro- levels based on environmental, economic and social dimensions with the aim to accomplish sustainable development leading to sustainable well-being for current and future generations.

1.2. Circular Economy as a part of Sustainable Development leading to Sustainable Well-Being

The idea of sustainable development recent decades is popular not only among researchers but also among industry, business, policy makers. The sustainable development is being promoted using three dimensional pillars – economic, social and environmental - affecting the environment, economics and society. The principle of sustainable development is to meet the needs of present and ensure possibility for future generations to meet their needs by saving environment and resources (WCED 1987). Due to the growth of population, highly increased production and consumption, uncontrolled waste, economic growth, scarcity of resources, climate change and many other reasons – it is necessary to take an action in order to keep economic growth and at the same time protect environment, reduce harmful waste and safe resources. However, to reach the sustainable development is hardly possible by inefficient use of natural resources and reduction of value of natural capital by waste and pollution. Thus, to ensure the sustainable development there is a need for conceptualized approach according to which the resources would be kept in use as long as possible without the generation of waste and pollution (Alaerts *et al.*, 2019, Millar *et al.*, 2019).

The concept of circular economy including environmental well-being in the symbiosis with socio-economic activity comes as opposite to linear economy, where the use of resources is being turned into the waste and pollution after the manufacturing (Murray *et al.*, 2017). However, the circular economy concept finds its origins in the middle of 17th century, but as the closed-loop concept was presented in the middle of 20th century. The scientists and business have turned to circular economy mostly in the beginning of 21st century, while the economy and manufacture were growing rapidly and the scarcity of the resources became one of the major problems to solve. As the economy depends on the resources and

environment – it is hard to keep further economic growth without the reduction of the waste of resources and pollution.

Circular economy brings significant benefits not only for particular company or industry. It makes a contribution to whole society in general, improving ecology and promoting sustainable development. Efficient use of resources and zero waste may lower the need of resource extraction; by this, the problem of resource scarcity could be alleviated. In addition, by integrating “zero waste” strategy in value chain and business cycle would help to lower the pollution and improve ecological situation (EMF Ellen MacArthur Foundation 2013).

The definition of circular economy provided by Kirchherr *et al.* (2017) allows to identify sustainable development principles taken into focus area of circular economy (Fig. 1.6), such as creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.

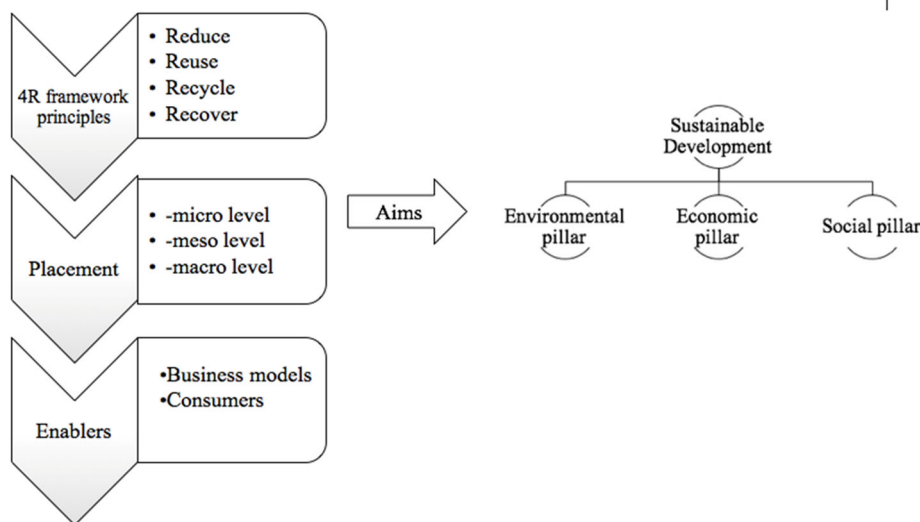


Fig. 1.6. The relationship of circular economy definition with sustainable development (source: compiled by author based on Kirchherr *et al.*, 2017)

According to Ghisellini *et al.* (2016), the circular economy is not only the approach of “zero waste” strategy. If circular economy would be considered only as an approach to efficient resource usage and appropriate waste management it could fail. Circular economy is about sustainable development including all the targets of sustainability: social, economic and environmental. Rodriguez-Anton (2020) identifies circular economy as a key tool leading to achieve sustainable development as it refers to health, education, eradication of poverty, reduction of inequalities, economic growth and allocation of natural resources.

More and more authors started linking the circular economy as a tool for sustainable development to reach, as linear economy emphasized economic dimension over other to reach economic benefits and growth despite the environmental impact. Technologies are developing, turnover of production and consumption increases over the time and can not be sullied by non-renewable resources if the resources are not being saved and efficiently used. By contrast, circular economy increases resource efficiency by the closed loop of resource usage and reduction of waste allow better balance between components of sustainable development (Ionascu & Ionascu 2018).

Implementation of circular economy to support sustainable development requires sustainable economy in order to be able provide “green” investments, which are not always economically better than economic investments supported by linear economy where the only economic benefit is being considered. This idea support Ghisellini *et al.* (2016) by saying that implementation of circular economy approach needs economic, politic and social support which will drive as a motivation to companies and investors act according to the principles of circular economy. Girard (2020) recognizes the complex values of circular economy including environmental, economic and social wealth and highlights the economic notions of circular economy indicating the long-term economic growth, which is reduced from the resource consumption and negative environmental impacts and increased in extending product life-cycle and production stages including R principles of circular economy. The idea of economic growth in circular economy is being switched from the resource consumption to resource saving making an accent on materials and generated waste recycling, reuse and remanufacture. To reach the economic benefit from these activities nowadays require much attention from government, society, businesses and scientists by investment in eco-innovation research and development.

Circular economy generates new values and profits by introduced closed loops, which reduce production cost, resource ineffective use and negative impact by the same time increase social benefits, stimulates employment and reduces the waste of capital. It can be stated that circular economy synergies and generates interdependency of environment, economic and social pillars (Fig. 1.7).

The conceptual relationship between circular economy and sustainable development has been proved by Millar *et al.* (2019), as linear economy which is used nowadays is concentrated on economic gain only, which leads to the resource scarcity, increasing prices due to it which leads to economic and social inequality in a long run. Circular economy concept fills this gap with environmental and social pillar that are preventing the negative outcomes of linear economy.

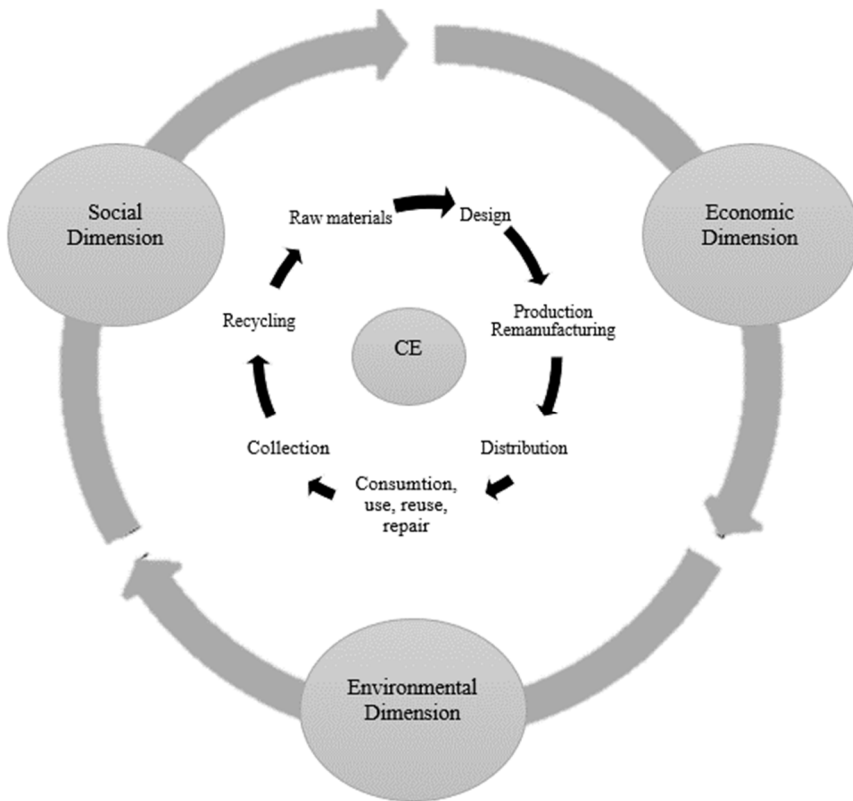


Fig. 1.7. The circular economy represented as a part of sustainable development (source: compiled by author based on Ionascu & Ionascu (2018), Girard (2020), Ghisellini *et al.* (2016))

Ladu *et al.* (2020) in the research represent simulation of “zero policy scenario” which shows a high value generated by circular economy activities leading to sustainable development. DeBoer *et al.* (2020) identify circular economy as pathway to sustainable development and stimulates the debate analysing the competitiveness of the companies implementing circular economy principles. D’Amato *et al.* (2020) see circular economy as a model that seeks to reach sustainable development, however identify, that the lack of social and financial support from the government and other stakeholders does not allow to be fully implemented. Entrepreneurs arguing, that it is not enough the idea of circular economy only to start creating the products related to circular economy, as this idea and possibilities should be integrated to all the pillars of circular economy leading to sustainable development. The customers should be educated about sustainability approach

which would form the demand for producers. Producers would see the expanding needs of customers in the relation of ecologically friendly decisions would try to fulfill customer needs accordingly. The full acceptance of sustainability principles by local communities discusses Piwowar (2020), indicating that successful implementation various models leading to sustainable development requires not only understanding the necessity of it by scientists, but as well changes in technologies, law, education programs financial stimulation and green fiscal policy. There is a need to create conditions for social and economic diversity engaging local communities into sustainability activities (Clube *et al.*, 2020).

Sustainability can not be measured directly. The assessment of sustainability depends on the characteristics that might be sustainable. The Sustainable Development Goals (SDG) were presented in the United Nations “2030 Agenda for Sustainable Development” (UN 2015) which represents sustainable development and could be applied to any country to assess the balance between three pillars: environmental, economic and social. The goal of sustainable development is a prosperous, high quality of life that is equitably shared and sustainable has been expressed by four key principles:

1. Improving people’s quality of life without increasing environmental degradation and without compromising resource availability;
2. Decoupling economic growth from environmental degradation;
3. Applying life-cycle analysis;
4. Avoiding the re-bounce effects, where efficiency gains are cancelled by resulting increases in consumption.

According to Gower & Schroeder (2016), circular economy approach could bring many important benefits, which are aligned with sustainable development goals, as circular economy may influence the cost savings, job creation, increasing productivity and resource efficiency, innovation and technology development. Circular economy approach is concentrated on technological aspects of sustainable business models rather than on social aspects. According to Skvarciany *et al.* (2021) circular economy acts as a contributor to sustainable development by considering all the dimensions of sustainability and implementation of circular economy directly impacts the country’s sustainability. Nowadays, circular economy is dealing with the maximization of material and energy efficiency, reduction of pollution and waste, creating value from waste by investigating the way of making renewable resources from non-renewable. However, there is a lack of socially oriented circular economy business models and practices regarding to ethics, consumer education, popularization of responsible consumption and eco-friendly business (Bocken & Short 2016). Also, Zaidi *et al.* (2019) agree that there is a need of public procurement policies to be implemented to stimulate circular economy among stakeholders as a tool to sustainable development. Small and medium

sized enterprises (SMEs) are being identified as a major engine towards sustainable development by Sebestova *et al.* (2020), which should demonstrate why consumers should buy ecologically friendly products, promoting recycling and reducing waste.

Sustainable growth promoted by circular economy can be understood as institutional arrangement of regenerating GDP into circular (sustainable) manner (Lin 2020). Moreover, the sustainable economic growth of circular economy affects unemployment growth, GDP growth, reduction of natural resources and effective their using, increased competitiveness among SMEs in a long run (Krysovatyy *et al.*, 2020). Sustainable growth is a dynamic process of mutually interacting socioeconomic and environmental activities. Sustainable growth from circular economy perspective is a long-term process which occurs from circular output increase by the reduction of generated waste.

Nowadays it is quite hard to implement circular economy on –macro or –meso levels due to the lack of technologies and innovations which would help in recycling and reuse of materials. The aim of circular economy implementation is to support sustainable development. Circular economy may maintain, protect and restore the environment, as well as keep efficient resource use and transition towards low carbon economy. Also, circular economy ensures stable development of the economy, which would be supported by eco-friendly mindset of all the participants. Moreover, circular economy may strengthen the society and develop human well-being by assuring the environmental quality, economic prosperity, development of new technologies, innovations and education. Circular economy has long-term perspective which allocates the resources and ensures its availability for future generations. What is more, circular economy requires innovative solutions to legislation, production and consumptions that are in line with sustainability concept. Once governmental regulations, supply and demand sides are interrelated and interacted in the terms of sustainable development – the circular economy can be reached.

To sum up, circular economy concept leads to sustainable development and can be aligned with sustainable development goals (SDG) that are based on environmental, economic and social wealth. The key principles of sustainable development are to improve quality of life avoiding a negative impact on the environment, gaining economic benefit from environmental degradation and maintaining economic and social wealth, that complies with the principles of circular economy.

1.3. Circular Economy as a key to Sustainable Well-Being

Sustainable development represents a consensus on the urgency to preserve the conditions that make life possible on the planet and ensure a future of well-being for humanity (Pla-Julian *et al.*, 2019). The general aim of sustainability is meeting the needs (WCED 1987), which is being reached by economic model promoting sustainability as main its approach. However, there is a lack of identification what exactly are those needs (Kjell 2011). Thus, human well-being is being the central issue for sustainability approach, recognizing, that humans are linked and embedded in nature, deriving specific and quantifiable benefits from the healthy functioning of these systems (Whiting *et al.*, 2018)

Sustainable development goals act as a direction towards sustainable well-being globally, as focus environmental, social and economic aspects of sustainability (Costanza *et al.*, 2016). Moreover, Constanza *et al.* (2016) have established the connection of sustainable development goals with sustainable well-being and states, that sustainable development goals can not be achieved once the principles of sustainable well-being are not taken in consideration initially. Sustainable development goals are leading to sustainable well-being offering sustainable and desirable future for current and future generations. Equity and human well-being or “ultimate ends” is presented as the sustainable development aim, which is described as a prosperous, high quality life that is sustainable and equitably shared. This goal is being reached through sustainability approach that is promoting to stay within planetary boundaries building a healthy economy and protecting capabilities for flourishing.

Many authors started using “well-being” term which replaces the term “needs”, as sustainable development includes not only the needs but the capabilities which may influence the human satisfaction (Kjell 2011; Helne & Hirvalammi 2015). The term of “human needs” are widely used by authors analysing sustainability approach (Raworth 2017; Uvarova *et al.*, 2020). “Capability” approach which is alternative to the “needs” approach can be found as well in the works of Oakley & Ward (2018). The hybrid of “need-capabilities” approach have been developed and the term “happiness” has been introduced in sustainability studies (Sachs 2016). Earlier, in 2005, Lyubomirsky *et al.*, proposed the term of “sustainable happiness”. The Stiglitz-Sen-Fitoussi commission (Stiglitz *et al.*, 2009), and the related OECD ‘Better Life Initiative’ have placed well-being indicator measurement in a systemic frame and promoted the term “well-being” as the “sustainable happiness” approach, which ensures the life satisfaction, capabilities and full-filments of needs on the constant basis in a long run.

Circular economy including environmental, social and economic aspects, acts as a tool to sustainable development by implementing sustainability approach

on on -micro, -meso and -macro levels aiming to reach sustainable well-being. Sustainable well-being is the outcome of a convergence of factors, including good human mental and physical health, greater equity and fairness, good social relationships and a flourishing natural environment (Constanza *et al.*, 2018). To reach sustainable development widely used economic model should promote well-being by valuing social capital and protect the natural capital. Linear economy model does not maintain well-being principles, as based on the concept to gain more economic benefit. Circular economy approach initially integrated well-being approach in its components which aims to generate economic benefits without negative impact on environment by effective resource and management.

Once sustainable development goals are being connected with sustainable well-being approach, circular economy, being treated as a tool to reach sustainable development reaches sustainable well-being as well (Fig. 1.8).

The circular economy gained its popularity in China as a strategy for economic development based on sustainability to reach sustainable well-being. China has implemented circular economy approach through governmental regulations in business and industries to keep the growth of economy by reducing the waste and pollution. However, China has been focused on environmental and economic dimensions of circular economy concept by the setting an ambitious development plan including reducing, reusing and recycling in the process of production, circulation and consumption. The absence of social dimension does not allow circular economy to align with sustainable development. Social dimension includes human well-being and human rights what is a part of sustainability concept (Haynes & Murray 2015).

Nowadays circular economy is mostly linked to environmental and industrial economics, while social dimension remains under discussions. According to Geissdoerfer *et al.* (2017) social wealth as a dimension of circular economy has a narrow coverage by authors. Usually job creation and unemployment factors are being mentioned as a part of social dimension of circular economy. However, changing lifestyles and consumption behavior and effective tax system are being included into social dimension (Webster 2015). However, there is a lack of conceptual integration of social factors into circular economy approach. According to Ghisellini *et al.* (2016), the lack of social factors in the concept of circular economy leads to the barrier of its development and integration.

Moreau *et al.* (2017) state that circular economy may ignore social equity, however, still the direct impact of circular economy on social pillar remains unknown yet. Social aspects should be aligned together with environmental and economic pillars. The circular economy can not be launched unless it is not being demanded. Once the demand for circular economy would be increased through the promotion and support from the government to business and consumers, the circular economy may develop.

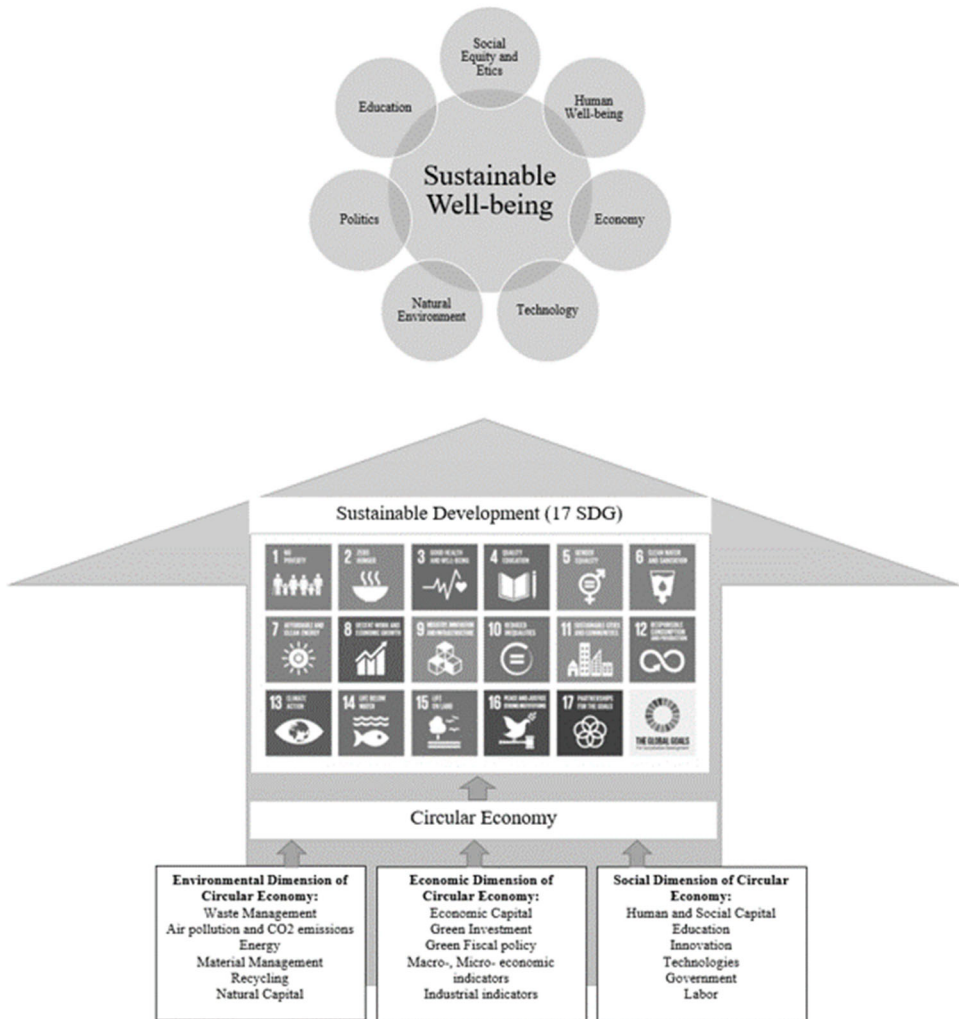


Fig. 1.8. Sustainable well-being as a sequence of circular economy (source: compiled by author based on Costanza *et al.*, 2016)

According to Lieder & Rashid (2016), circular economy may focus not only on production stage, but in the same time consider responsible consumption. This may be aligned to each product creation stage. This is why the promotion of responsible consumption is essential for launching the circular economy as the consumer becomes the main driver for circular business models. Thus, social pillar

becomes crucial in changing the consumers behavior and habits towards responsible consumption. Borrello *et al.* (2017) state that so far there is a lack of studies about consumers' willingness participate in the circular economy.

Circular economy can be described as interdisciplinary model including environmental, engineering, social and economic sciences together with social aspects of ethics, justice, common environmentally friendly norms, values and mindset. Sustainable development as a concepts was presented in UN Agenda for Sustainable Development in 2015 (UN, 2015), which is known as Agenda 2030. The Agenda presents 17 Sustainable Development goals and 169 targets. European Commission in 2010 launched a strategy for smart, sustainable and inclusive growth called as "Europe 2020" (EC 2010). It was the first document promoting the circular economy by highlighting the importance of sustainable enterprise and sustainable innovations. In 2013 European Commission issued Environment Action Programme (EAP, 2013) which provides the principles of circular economy:

1. Eco-innovations are acting as a key to prosperity and healthy environment.
2. Generated waste is equal to zero or can be re-used, recycled or makes a minimum impact which cannot be disposed do to the physical laws.
3. Natural resources are being used efficiently, biodiversity is protected, restored and valued.
4. Pollution and carbon growth is being sustainably managed.

On the basis of Environment Action Programme (EAP, 2013), all UN member states hasigned Frameworks for sustainable production and consumption being the part of sustainable development goals (12th goal) (UN, 2015). Furthermore, in 2018 European Commission issued an agenda ensuring the promotion, support and spread of eco-innovations called "Innovation Union" (EC, 2018) and "Resource efficient Europe" (EEA, 2018), which corresponds to the goals of circular economy. In 2015 European Commission presented Circular Economy Action Plan (EC 2019a), which is based on efficient use of resources, eco-innovations, sustainable use of materials, promoting ecological production and socially responsible enterprises, promoting "green" consumption and managing waste.

1. A common EU target for recycling 65% of municipal waste by 2035;
2. A common EU target for recycling 70% of packaging waste by 2030;
3. There are also recycling targets for specific packaging materials:
 - Paper and cardboard: 85 %;
 - Ferrous metals: 80 %;
 - Aluminium: 60 %;
 - Glass: 75 %;
 - Plastic: 55 %;
 - Wood: 30 %.

The Circular Economy Action Plan covers all the stages of product life-cycle – from its production to its consumption and waste management by implementing a market for secondary raw materials. The Circular Economy Action Plan also covers barriers of circular economy, material flow, sectors of implementation, promotion of innovations and investments. In 2018 European Union has published the results and progress of circular economy implementation in the agenda called “Measuring 2018”. According to the report, the major progress was noticed in recycling of industrial and organic waste. This results proves the luck of the tools methods to measure the Circular Economy progress as well as its complex concept including Environmental, Social and Economic dimensions as a single unit. In 2019 European Commission issued a new directive which is focused on Circular Economy goals to be reached by 2030 called “A long-term strategy for a European Circular Economy – setting the course for success” (EC, 2019).

The Concept of Circular Economy and the strategy of its implementation leads to the climate neutrality by investing into realistic technological solutions and aligning industrial, financial and research areas (EC, 2018). In 2017 (EC, 2019a) European Commission has provided a report on the implementation of the Circular Economy plan where it has been stated that Circular Economy is more tangible in comparison to other approaches that are solving problem of sustainability in the fields of reduction of CO₂ emissions, job creation, resource efficiency and productivity. At the moment European Commission is positive to continue developing goals for Circular Economy and issued a strategic long-term vision for 2050 called “Long-term vision for a prosperous, modern, competitive and climate neutral economy by 2050 – A Clean Planet for All” (EC, 2018). Circular economy highlights the resource management and prioritize environmental dimension, however, sustainable goals are being reached by eco-innovations, which require high intellectual human capital, investments, new business models and “green” consumption.

Environmental and economic dimensions of circular economy should create conditions for growing extension of life expectancy by reducing pollution and maintaining healthy environment. Development of innovations and technologies should improve medical treatment, make it available for everyone who needs the treatment by reducing cost and improving efficiency. Government should ensure promotion of investment in public health sector as the human capital brings benefits to circular economy. Government support and implementation of technologies development would help to decrease the number of long-standing illness people are facing. Economic capital, green investment, industrial and -micro, -macro indicators ensure the sustainable development of economic pillar towards Sustainable well-being. Environmental dimension deals with the main idea of circular economy – maintain zero waste and reduce negative impact of human activities to the environment. Environmental pillar includes the list of strategies which may

lead to this such as waste management, energy efficiency, reduction of pollution, recycling and material management to save the resources for this and future generations.

To sum up, sustainable development is the process of seeking the prosperous, high quality of life that is equitably shared and sustainable – sustainable well-being, that is being represented as the highest level of wealth to be distinguished. Circular Economy acts as a tool of sustainable development that aims to accomplish sustainable well-being.

1.4. Alternative approaches to Circular Economy assessment

Circular Economy is attractive due to being aligned with sustainable development. There are many discussions about circular economy, analysis its focus areas, principle and components, however there is a lack of representation of some empirical results assessing circular economy (Fonseca *et al.*, 2018). Literature review shows, that in general, circular economy is being measured by focusing a specific circular economy related aspect. Sassanelli *et al.* (2019), observed 45 articles related to circular economy assessment and identified the methods are mostly used: Data Envelopment Analysis (DEA), Input-Output, Design for X, Life Cycle Assessment (LFA), Multi criteria Decision Methods (MCDM), Material Flow Analysis (MFA) and Material Cost Analysis (MCA) (Fig. 1.9).

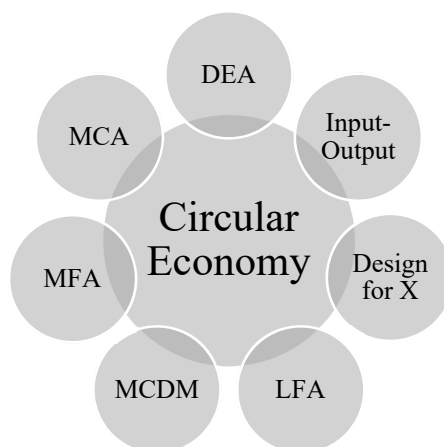


Fig. 1.9. Mostly used methods for Circular Economy analysis (source: compiled by author based on Sassanelli *et al.* (2019))

MCDM method TOPSIS has been selected by Shen *et al.* (2013) to evaluate green suppliers performance in the context of circular economy. The following criteria have been selected: pollution production, resource consumption, eco-design, green image, environmental management system, commitment of green supply chain management, usage of environmentally friendly technology and materials and staff environmental training. The result was represented as ranking for selection the supplier corresponding in the best ways to proposed criterias. Circular economy development levels have been measured in China using DEA method (Fan & Fang 2020). Authors agree on shortage of social indicators for circular economy evaluation, on the other hand the perception of circular economy in China turns to its environmental and economic pillars in most. In their research work authors agree that without social dimension integration in circular economy assessment model – partial circular economy development is being measured. Fan & Fang (2020) indicate the importance to measure all components of circular economy (environmental, economic and social) selecting R principles representing environmental dimension, while GDP, export share of circular materials, capital investment representing economic dimension and unemployment, living area, residents disposable income describing social dimension. However, due to Chinese peculiarities and concentration on environmental dimension social indicators have not been included in the measurement of circular economy of 31 Chinese regions. Thus, it can be said, that circular economy was measured in the context of environmental and economic dimensions.

Circular economy assessment model which would assess all the dimensions of circular economy is crucial to be developed as it can not be managed while can not be measured (Bilal *et al.*, 2020). According to Bilal *et al.* (2020), indicator system for circular economy is essential for successful implementation of circular economy. By developed indicator system reflecting the focus areas and dimensions of circular economy – decision makers could easily monitor the application of the transition towards circular economy and solve the issues in more effective way. Using indicator system wastewater treatment has been measured in the context of circular economy under 3R principles and expressed as the valuation starting as „very high“ to „very low“ (Kiselev *et al.*, 2019). In this case the assessment of environmental dimension has been performed in the context of circular economy and can not be treated as the measurement tool of circular economy whole concept. Indicator system has been used by Ūsas *et al.* (2021) to measure circular economy among European Union. MCDM methods have been selected to assess circular economy across European Union member states such as TOPSIS, PROMETHEE II and ELECTRE I. Environmental and economic indicator have been selected for circular economy assessment: circular material use rate, exports of recyclable raw materials, imports of recyclable raw materials, recycling rate of bio-waste, recycling rate of e-waste, the share of recycled packaging materials and

the share of recycled municipal waste. The results are being provided as ranking starting from 1 showing the best result up to 27 which is being evaluated by the lowest rank among 27 European Union member states. The ranking allows to evaluate circular economy on the country level and as well to compare the obtained result with the results of circular economy assessment of other countries by this identifying the level of development in the current situation.

Overview of the previous empirical researches of circular economy identifies the shortage of the assessment tools, which would measure circular economy including environmental, economic, social dimensions. Also, not much still circular economy is being measured on country level in regard of sustainable well-being. The assessment model of circular economy allowing to assess the development of circular economy on country level and compare to other countries practicing circular economy would bring a benefit for policy decision makers and scientists to making decisions and researches towards circular economy implementation.

1.5. Conclusions of Chapter 1 and formulation of the objectives of the doctoral thesis

1. The literature analysis suggests that the definition of circular economy should include all the aspects that circular economy covers including environmental, social and economic dimensions in the concordance with sustainable development principles. The definition of circular economy should be expressed as a unified definition describing the circular economy including environmental, social and economic aspects and contributing to sustainable well-being. The proposed definition of circular economy describes it as an economic system based on business models, which are replacing “take-make-waste” concept by “take-make-reuse-dispose” concept implemented on micro-, meso- and macro- levels based on environmental, economic and social dimensions with the aim to accomplish sustainable development leading to sustainable well-being for current and future generations
2. The synergy of circular economy and sustainable development has been identified and the aim of circular economy has been cleared out that aligns with the approach of sustainable well-being. Three pillars of sustainability approach formulated the core principles of circular economy leading to sustainable well-being. Environmental dimension ensures elimination of negative impact on environment due to economic activity, resource allocation and effective waste management.

Economic dimension ensures sustainable economic growth and generated economic benefits by turning the waste into resource. Social dimension of circular economy ensures the eco-friendly worldview of producers and consumers leading to responsible consumption, improved quality of life, human health, social capital.

3. The possibility of transition from linear economy to circular economy has been analysed and the main barriers and issues identified: technological barriers express the need to improve recycling technologies, extend the manufacturing cycle and include recycling system into production cycle; Legal barriers include the need to issue many legal requirements regarding the use of recycled materials and waste management; Economic barriers deals with the issue for business to remain profitable after implementation “zero waste” approach into production, as well as re-organisation of business models and face additional costs; Change of mindset deals with acceptance by the society “zero waste” approach and creation a new value chain which would replace linear economy concept. The literature analysis suggests circular economy as a promising model which could implement environmental aspects into the every stage of business life-cycle and ensure healthy economy of the country with integrated social aspects.
4. Circular economy principles are sorted by Euroean Union, which develops regulations towards the implementation of circular economy asects into the existing economy to reach environmental benefits and comply with the issued regulation of the reduction of negative impact on the environment such as pollution, waste and ineffective use of resources leading to the resources scarcity that makes a danger to the global economy.
5. Previous empirical researches on circular economy assessment topic have been analysed and identified the lack of concetualized assessment practises of the circular economy development among countries practising the imlementation of circular economy.

Formation of Circular Economy assessment model in the context of Sustainable Well-Being

This Chapter investigates the formation of the strategy for collection of the indicators of circular economy, as well as the approach of systemizing and grouping the indicators according to the components of circular economy and areas of target. The chapter describes the methods used to form an evaluation tool based on MCDM methods. TOPSIS and MULTIMOORA methods have been characterized and applied in the formation of assessment model of circular economy. the selected indicators for circular economy assessment are characterized in detail and the model is presented.

The findings of chapter 2 have been published in scientific papers (Stankevičienė & Nikanorova 2017; Stankevičienė *et al.*, 2020; Nikanorova *et al.*, 2020; Nikanorova & Stankevičienė; 2020; Stankevičienė & Nikanorova 2020).

2.1. Building of Circular Economy evaluation model

The circular economy is based on three pillars: economic, environmental and social, but still the environmental pillar goals makes the core of circular economy

idea. Environmental goals allow us to stay within the planet, which leads to the creation of a sustainable living economy that safeguards opportunities for prosperity. The development of the economy, technology, the circular economy, the mindset and ethics of responsible consumption develop social equity and human well-being. Human well-being means a prosperous, high-quality life that is equal and sustainable. All these aspects of the circular economy create the conditions for sustainable development, which results in sustainable prosperity. Leviston *et al.* (2018) argue that there is an indirect link between man and ecosystems because human life depends on and is part of ecosystems. The relationship between the ecosystem and human well-being can be expressed in terms of security, basic products necessary for a good life, health and good social relations.

To assess the development of circular economy of the selected cities, countries or regions there is a need to indicate economic, environmental and social pillars which have relationship between each other – direct or indirect (Fig. 2.1).

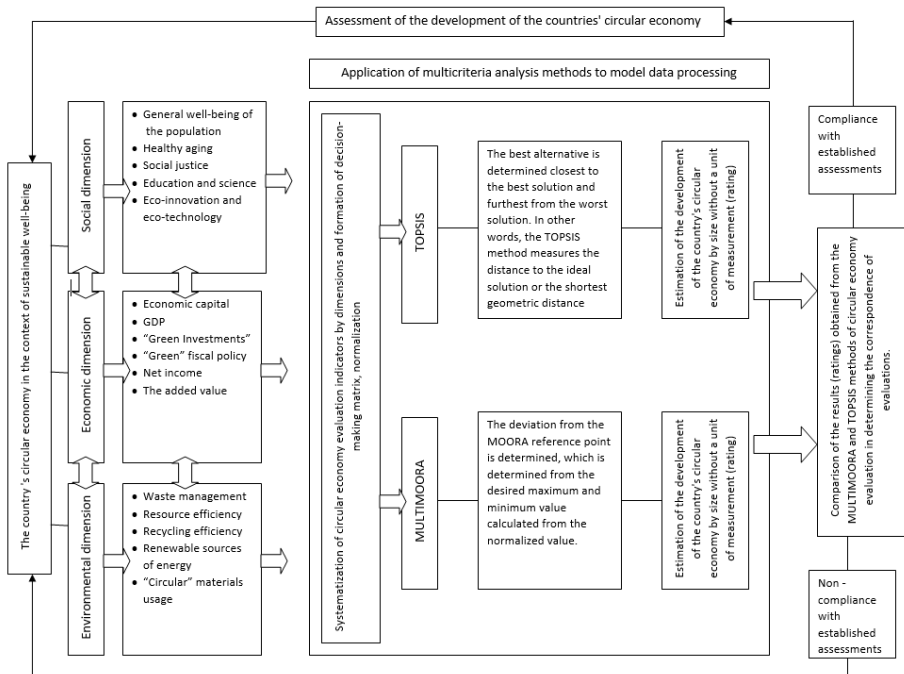


Fig. 2.1. Evaluation model of circular economy (source: compiled by author)

Environmental pillar is the core idea of circular economy which deals with nowadays environmental challenges such as waste management, resource efficiency, recycling, renewable energy and circular material usage. Environmental

pillar includes the concepts to save the resources, prevent resource scarcity and pollution, usage of recycled materials and be able to utilize waste generated.

Economic pillar ensures a sustainable economy of the city, country or region based on the “green” decision making. Economic pillar of circular economy includes development of “green” investments and fiscal policies, economic capital, economic macro-indicators. As well economic pillar seeks to create more job within “green” technologies, “green” patents and technological development. Social pillar leads towards healthy ageing, social justice and “green” decision made by governments towards circular economy, education and science support to help in the developing of “green” technologies. Social pillar leads to the general well-being of population which includes high living standards and satisfaction of the life including comfort, wealth and material goods.

Next step in the evaluation model of circular economy is collection of indicators which would assess environmental, social and economic pillars of circular economy. The development of circular economy could be assessed in cities, countries or regions in the selected period, which would be normalized using multi-criteria decision aid methods. MULTIMOORA and TOPSIS methods would be applied to receive the assessment of circular economy or any pillar separately what makes the evaluation model of circular economy able to represent not only assessment of circular economy, but any pillar separately with the possibility to compare all the components of the pillar in the period of time or between the selected geographical areas. Comparison of MULTIMOORA and TOPSIS results would show the correspondence of the evaluations. If the estimated results is corresponding – the assessment of circular economy could be finalized and results can be analyzed for the purpose they have been assessed. Once the results obtained by MULTIMOORA and TOPSIS methods are not corresponding – there is a need to return to the analysis of the circular economy dimensions and the collection of new indicators.

2.2. Environmental aspects of Circular Economy

Circular economy became a popular approach for policy makers, government and scientists to discuss about transition from linear economy to circular economy contributing to sustainable development. Today, in the times of economic growth and technological development, huge volumes of economy brought a negative impact on environment – the greenhouse effect, air, water and pollution, scarcity of materials and many others. Linear economy model helped society to build effective business models, which aimed to increase production and volumes. However, environmental problems became a very popular topic to discuss recent years, as many environmental changes we are facing now due to human activities.

Circular economy approach offers a decision how to keep economy healthy and reduce the harmful environmental activities. Circular economy offers new approach based on re-use, reduce and recycling of materials (Morseletto 2020). Circular economy promotes the idea of reducing waste and resources used, replacing them by recycled and re-used materials (Homrich *et al.*, 2018). China was one of the first countries who officially has started promoting circular economy concepts (Geng *et al.*, 2008; Li, *et al.*, 2007). However, circular economy concept was related to economic and environmental pillars in China making circular economy concept highly related to environment and less to social pillar (Geng *et al.*, 2012; Ghisellini *et al.*, 2016).

Lately, many authors discussed about the necessity of social pillar to be included in circular economy model as social pillar represent human well-being as the aim of circular economy. Circular economy corresponds to the sustainable development goals (Schroeder *et al.*, 2018) and includes environment, economic and social dimensions. According to Lewandowski (2016), many different size enterprises are becoming to implement the concepts of circular economy. European Union has introduced an action plan about circular economy implementation across the member states (EC, 2015). In 2018 European Commission has introduced key indicators for a monitoring circular economy development grouped in following classifications (EC, 2018):

1. Self-sufficiency for raw materials;
2. Green public procurement;
3. Waste generation;
4. Food waste;
5. Recycling rates;
6. Recycling / recovery for specific waste streams;
7. Contribution of recycled materials to raw materials demand;
8. Trade in recyclable raw materials;
9. Private investments, jobs and gross value added;
10. Patents related to recycling and secondary raw materials.

Mainly, the indicators suggested by EC (2018) are related to responsible production and consumption. Green public procurement, waste generation, food waste, recycling rates, recycling / recovery for specific waste streams relate to common EU target on waste management. Moreover, indicators to measure waste management are coming from earlier EU policy related to resource efficiency (EC, 2014). According to Repo *et al.* (2018), Bjørn *et al.* (2017), Morseletto (2020) studies on EU targets the can be classified according to area or object of targets in several groups:

- Recycling;
- Resource Efficiency;
- Waste reduction;

- Energy recovery;
- Water recovery;
- Emission reduction;
- Design.

Indicators proposed by EU for circular economy development monitoring can be grouped by the EU strategies, area of the target or object of the target. Potting *et al.* (2017) has introduced 10R Circular Economy strategies (Table 2.1).

Table 2.1. 10R Circular economy strategies of environmental pillar (source: Potting *et al.*, 2017)

R0	Refuse	R5	Refurbish
R1	Rethink	R6	Remanufacture
R2	Reduce	R7	Repurpose
R3	Reuse	R8	Recycle
R4	Repair	R9	Recovery

The strategies, represented in Table 2.1 are classified by circularity level, which means, that R0 has the lowest circularity level, while R9 has the highest circularity level. R0 “Refuse” strategy lets the product be unnecessary by abandoning its function or which can be easily replaced by different product. By R1 “Rethink” strategy the product is being used more intensively (multi-functional products), while R2 “Reduce” strategy increases efficiency of product manufacture or consuming fewer natural resources. R3 “Reuse” strategy offers to reuse the product by another customer, while the product is still in a good condition. R4 “Repair” strategy allows product to be modified or repaired, while R5 “Refurbish” strategy restores an old product up to date. R6 “Remanufacture” allows to use parts of discarded product in a new product with the same function, while R7 “Repurpose” strategy allows to use parts of discarded product or it part in a new product with different function. R8 “Recycle” strategy allows to process materials to obtain the same or lower quality. R9 “Recovery” strategy has the highest circularity level and allows incineration of material with energy recovery.

A successful implementation of the circular economy policy requires efforts at three different levels: micro-level, meso-level, and macro-level. The potential economic benefits from this monitoring and improvement system include more efficient materials and energy use, increased revenues from the sale of “wastes”, cost savings from lowered insurance costs and reduced environmental penalties and increased competitive capacity. The potential environmental benefits include the conservation of natural resources (especially non-renewable resources such as water, fossil fuels and minerals), reduced environmental impact through efficient energy and material use and less waste discharge, avoidance of toxic materials,

extended life cycle of landfill sites, and recovery of local ecosystem. The potential social benefits include improved social relations between industrial sectors and local societies, more employment opportunities from new recycling businesses, improved public environmental awareness and public health level.

Conceptual framework of relationship between environment, waste-to-energy supply chains and circular economy system shows the flow of materials including biological and technical nutrients exists within industrial economy. Both the economy and the environment should be maintained as a circular relationship for facing existing environmental problems and resource scarcity. In other words, the environment (e.g., freshwater production and waste production), energy and CO₂ emission should be linked together for establishing the circular economy system business model in an industrial system. The circular economy system should be based on the 5R principles, i.e., Reduction, Reuse, Recycling, Recovery and Reclamation. Studies on business strategies (Ellen Macarthur Foundation, 2013), public awareness (Liu 2009) analyses and case studies such as iron/steelmaking (Ma & Houser 2014) and printed circuit boards (Wen & Meng, 2015) industries have been carried out for promoting the circular economy system to decouple the economic growth from environmental degradation, and build a resource-saving society. It was noted that the use of technological and emergent innovative practices can improve the value of organizations and supply chains while reducing the environmental degradation caused by their economic growth. Under this vision, it is expected to allow policy makers to understand new techniques, thereby implementing energy policy, introducing green technology, attracting the interest of the public, and utilizing appropriate evaluation tools.

Environmental dimension of circular economy can be expressed as the range of practices used to build ecologically friendly environment and to insure the resource efficiency. Environmental dimension (Fig. 2.2) includes waste management, indicators of environment protection and resource efficiency indicators.

Waste management is useful in the controlling of waste reduction in -micro, -meso and -macro levels. The world of waste management is moving away from conventional landfill and recycling of both municipal and industrial waste towards integrated waste policy. Circular economy proposes a model where zero waste approach is proposed on each level: -micro, -meso and -macro levels. Sustainability outcomes, sustainable production, consumption behaviors and circular economy programs all underpin new standards in governance structures and waste policy intervention. Furthermore, environmental regulations, material cost and material scarcity are also creating an awareness of eco-design benefits in linking end of life waste materials as recycled/returned inputs to earlier production stages (Andrews-Speed 2013; EC 2011; UN 2015).

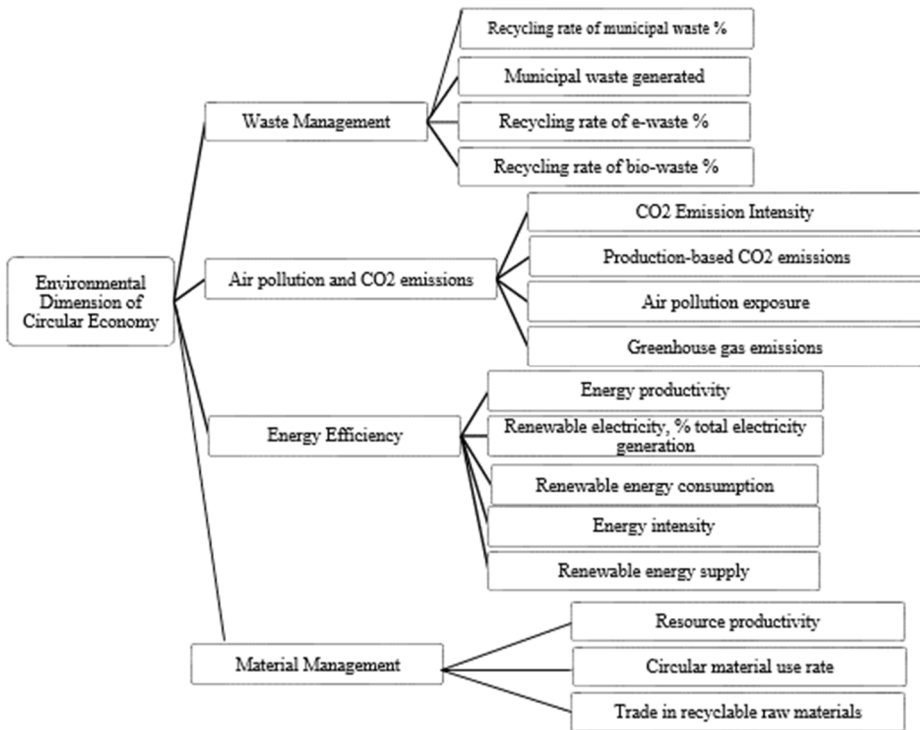


Fig. 2.2. Environmental dimension of circular economy (source: compiled by author)

In addition to this, air pollution and greenhouse gas emissions are being included in environmental pillar of circular economy, as air pollution one of green environment indicators. Air pollution causes many negative effects on the environment such as global warming, climate change, acid rains, smog effects, serious respiratory diseases and etc. Energy efficiency and material management are important indicators of environmental pillar of circular economy which ensures effective material use, recycling of disposals, ecologically friendly energy production and consumption.

The European Union contributes to global environmental, usage of “green” energy, resource efficiency challenges by implementing Horizon 2020 programme (European Commission, 2014). Horizon 2020 is the biggest EU research and innovation programme starting from 2014. Horizon 2020 includes energy efficiency problems, such as: reducing energy consumption, alternative fuels and mobile energy sources, low cost and low carbon electricity supply, new

knowledge and technologies. Also, Horizon 2020 includes smart, green, integrated transport and resource efficiency.

Environmental indicators are useful to measure the intensity of pollution and renewable energy usage. Today the scientists continue discussions regarding indicators system to evaluate environmental welfare and resource efficiency in the context of circular economy. Different proposals applied to particular countries economy and it is specific. While creation of the set of indicators, important is to pay attention on the specific of the economy of the selected region, to pay attention on the environmental challenges the region faces (Geng *et al.*, 2012; Su *et al.*, 2013).

As Circular Economy approach is to minimize pollution to zero, there is a need of new eco-innovative solutions to be implemented. Eco-innovative solutions are directly connected to the development of innovations, science and technology.

Environmental pillar of circular economy should include a complex set of indicators covering the targets and strategies set by European Union. The indicators could be classified by the area of target or circular economy strategies.

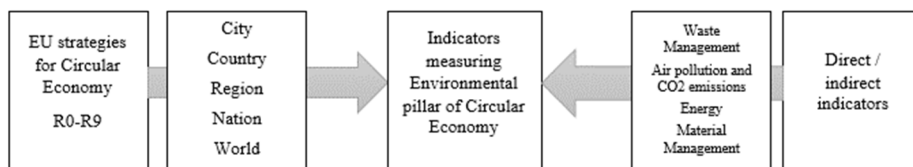


Fig. 2.3. Indicators selection strategy to assess environmental pillar of circular economy. (source: compiled by author based on Potting *et al.*, 2017; CE 2018)

All the factors influencing environmental dimension of circular economy are represented as direct and indirect indicators which are being grouped by the areas of target of circular economy (Fig. 2.3) European Union has released Circular Economy Action plan, according to which the strategies of circular economy are being discussed for European Union region with the implementation of circular economy strategies proposed by Potting *et al.* (2017). The proposed strategies of circular economy could be implemented in city, country, and region or be applied globally. Indicators of environmental pillar which complying with circular economy strategies are divided into four groups related to the areas of European Union targets for circular economy: waste management, air pollution and CO₂ emissions, energy and material management. Indicators could be collected by any area of target – city, country, region, nation, world. It is possible to collect indicators by districts within the city or any other area if indicators for the selected area are

available for the research. Collection of indicators, which are responding to circular economy areas of target and European Union implemented strategies for circular economy of the selected city, country or region could be included and identified as an indicator for circular economy measurement.

Indicators selected using proposed indicator selection strategy for environmental dimension of circular economy are represented in Table 2.2. The indicators have been selected based on the literature review which have been proposed by authors analysing Circular Economy.

Table 2.2. Indicators for assessment environmental dimension of circular economy proposed by previous research (source: compiled by author)

Area of target	Environmental Indicators	Proposed by authors in previous research:
Waste Management	Municipal waste generated	Wu <i>et al.</i> , 2014; Moraga <i>et al.</i> , 2019; Vuta <i>et al.</i> , 2019; Smol <i>et al.</i> 2017
	Recycling rate of municipal waste	Geng <i>et al.</i> , 2012; Su <i>et al.</i> , 2013; Moraga <i>et al.</i> , 2019; Vuta <i>et al.</i> , 2019; Smol <i>et al.</i> , 2017
	Recycling rate of e-waste	Moraga <i>et al.</i> , 2019; Vuta <i>et al.</i> , 2019; Smol <i>et al.</i> , 2017
	Recycling of bio waste	Geng <i>et al.</i> , 2012; Moraga <i>et al.</i> , 2019; Vuta <i>et al.</i> , 2019; Smol <i>et al.</i> , 2017
Air pollution and CO ₂ emissions	CO ₂ Emission Intensity	Li <i>et al.</i> , 2010; Martin <i>et al.</i> , 2018;
	Production-based CO ₂ emissions	Geng <i>et al.</i> , 2012; Kottner <i>et al.</i> , 2016
	Air pollution exposure	Su <i>et al.</i> , 2013; Van Schoubroeck <i>et al.</i> , 2018; Martin <i>et al.</i> , 2018
	Greenhouse gas emissions	Su <i>et al.</i> , 2013; Van Schoubroeck <i>et al.</i> , 2018; Martin <i>et al.</i> , 2018; Pauliuk, 2018; Vuta <i>et al.</i> , 2019
Energy	Renewable electricity, % total electricity generation	Li <i>et al.</i> , 2010; Van Schoubroeck <i>et al.</i> , 2018; Avdiushchenko & Zajac 2019
	Energy intensity	Li <i>et al.</i> , 2010; Van Schoubroeck <i>et al.</i> , 2018; Vuta <i>et al.</i> 2019

End of Table 2.2

Area of target	Environmental Indicators	Proposed by authors in previous research:
Energy	Energy productivity	Geng <i>et al.</i> , 2012; Qing <i>et al.</i> , 2011; Van Schoubroeck <i>et al.</i> , 2018; Kottner <i>et al.</i> , 2016; Vuta <i>et al.</i> , 2019
	Renewable energy consumption	Geng <i>et al.</i> , 2012; Guo-gang 2011; Van Schoubroeck <i>et al.</i> , 2018; Martin <i>et al.</i> , 2018
	Renewable energy supply	Geng <i>et al.</i> , 2012; Avdiushchenko & Zajac 2019
Material Management	Circular material use rate	Moraga <i>et al.</i> , 2019; Pauliuk, 2018
	Non-energy material productivity	Moraga <i>et al.</i> , 2019; Pauliuk, 2018
	Trade in recyclable raw materials	Moraga <i>et al.</i> , 2019

In Table 2.3 the indicators are classified into the group according to the area of targets of European Union for circular economy. Classified indicators correspond to the European Union strategies for circular economy. Indicators, representing macro-level have been selected to evaluate countries and regions.

Table 2.3. Indicators for assessment environmental pillar of circular economy (source: compiled by author)

Area of target	Environmental Indicators	Units of Measurement	Strategy
Waste Management	Municipal waste generated	numeric value	R2, R3
	Recycling rate of municipal waste	% (percentage)	R8
	Recycling rate of e-waste	% (percentage)	R8
	Recycling of bio waste	numeric value	R8
Air pollution and CO ₂ emissions	CO ₂ Emission Intensity	numeric value	R0, R2
	Production-based CO ₂ emissions	numeric value	R0, R1, R2
	Air pollution exposure	numeric value	R0, R1, R2
	Greenhouse gas emissions	numeric value	R0, R1, R2
Energy	Renewable electricity, % total electricity generation	% (percentage)	R4

End of Table 2.3

Area of target	Environmental Indicators	Units of Measurement	Strategy
Energy	Energy intensity	numeric value	R4
	Energy productivity	numeric value	R4
	Renewable energy consumption	% (percentage)	R9
	Renewable energy supply	% (percentage)	R9
Material Management	Circular material use rate	% (percentage)	R6,R7,R8,R9
	Non-energy material productivity	numeric value	R2, R3
	Trade in recyclable raw materials	numeric value	R8

Indicators are being classified into four groups: waste management, air pollution and CO₂ emissions, energy and material management. Waste management group of indicators is focused on the reduction of municipal waste generated and recycling of municipal, bio waste and e-waste what corresponds to one of the most important aspects of circular economy – zero waste approach. Municipal waste generated expressed as numeric value indicating kilograms per capita and can vary due to consumption patterns depending on applied policies of waste management and economic wealth. Recycling rate of municipal waste is measured in percentage rate indicating the amount of municipal waste being recycled including material recycling, composting and anaerobic digestion. E-waste is being considered as plenty of electronic equipment consisting of materials which are harmful to the environment and are causing the pollution and negative impacts on human health. More and more countries as well as European Union issue legislations to control and reduce e-waste. Due to the growth of technologies more and more electronic and electrical devices are being used by households and industries, thus there is a question of proper waste management of e-waste which appears once the devices are being thrown away after the use, are non-functional or obsolete. Many sectors are generating e-waste: IT, medicine, telecommunications, households, industries and etc. Recycling rate of e-waste is being calculated by multiplying the volumes of e-waste collected in all the sectors by the weight of recycled or prepared for re-use materials. Bio waste is a waste of organic materials including green, food, paper and bioplastics wastes. Recycling of bio waste indicator is represented as numeric value expressed in kilograms per capita, which has been obtained by recycled bio waste over the total population.

Air pollution and CO₂ emissions group measures CO₂ emissions intensity and production-based CO₂ emissions, including air pollution and greenhouse gas emissions – corresponds to air pollution reduction approach of circular economy.

CO₂ Emission Intensity indicator is represented as numeric value expressed in tones per capita. Due to the global warming and climate change CO₂ emissions is being the key driver towards the climate change. Reduction of CO₂ emission intensity nowadays has become one of the most important challenges. Year by year the planet average temperature grows up, influenced by the human activity. One of the major concerns is to stabilize CO₂ activities in two ways: reduce the production and consumption either to find out the technological solution which would let keep the consumption and production by the same way reducing gas emission. Production-based CO₂ emissions indicator expresses CO₂ emissions occurring within the industrial production of goods and services. Also, air pollution is important indicator as causes many risks to health globally. Air pollution has a significant impact on many respiratory and cardiovascular diseases in general and is one of the most negatively affecting pollutant. Air pollution includes many solid particles and gas causing by cars, factories, cities and etc. Air pollution indicator is measured as numeric value expressed by micrograms per cubic metre. Greenhouse gas emissions are emissions of seven gases such as carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃) which are causing greenhouse gas effect. Carbon dioxide (CO₂) is the largest contributor in greenhouse gas emissions that is why it has bigger negative impact on greenhouse gas effect. Human activity by burning fossil fuels causes greenhouse gas emissions which already are out of control globally. Greenhouse gas emissions which are out of control are not only the reason of global warming but as well cause many extreme weather events and rising sea level.

Energy group of indicators concentrates on the quantity of renewable energy produced and used in production or households – corresponds to the circular economy approach of green energy. Renewable electricity produced from renewable energy sources such as sun, water, wind or generated deep within the earth and etc. Electricity produced from renewable sources are more environmentally-friendly and does not cause heavy air pollution during all life-cycle than from fossil fuels. The more energy is being produced from renewable sources – the less negative impact would be done to the environment. Renewable energy indicator is expressed as the percentage of energy produced from renewable sources to total energy production. The higher the share of electricity generation from renewable resources the better progress of reducing pollution caused by production of electricity to the environment. Plenty of renewable resources that are used in the production of electricity would prevent from air pollution, however it requires accurate resource management to prevent water pollution if the energy is being produced by waves, or land pollution if geothermal sources have been used to

produce electricity. Energy intensity indicator measures the energy efficiency expressed by the ratio of energy used to Gross Domestic Product (GDP). Energy intensity indicator shows the conversion of energy into monetary output. High energy intensity shows a high price of conversion of the energy to GDP, while low energy intensity indicates low price of conversion of the energy into GDP. Energy intensity shows quantity of energy required to produce an output unit or activity. Energy intensity leads to use less energy for a unit output or activity – the less energy would be consumed in the production – the lower energy intensity would be. Energy productivity indicator measures the economic benefit gained from each unit of energy used and is calculated by dividing GDP by the available energy for a given period. Energy productivity aims to produce more and use less energy. Energy productivity leads to the energy efficiency which would reduce energy costs. Renewable energy consumption indicator shows the share of renewable energy in final energy consumption of the selected region. This indicator shows the consumption of renewable energy and give the opportunity to see the development of renewable energy use in the period of time. Renewable energy supply reduce the dependency on fossil fuels and supports turn to the potential renewable energy sources. Renewable energy supply indicator measures the share of renewable energy supply from the total energy supply. The development of green energy stimulates job creation in “green” technologies, development of technologies, energy efficiency and would ensure sustainable transition of energy sector to ecologically friendly “green” energy which would comply with circular economy ideas.

Material management group includes material management aspects as well as material circularity and recycling of materials. Circular material use rate expresses the share of material that is recovered and could be brought back to any production step or overall into economy in overall material use. Circular material use indicator is defined by the ratio of circular material use to the overall material use, which includes all the consumption of the materials both circular and non-circular use of materials. The higher the ratio is the higher is the use of circular materials. It means that more material substitutes are being integrated in the economy what reduces negative impacts on the environment and resource scarcity. Non-energy material productivity indicator measures the amount of economic output generated per unit of materials consumed such as biomass, construction and industrial minerals, metal, woods and other. Non-energy material productivity seeks to produce more and use less materials, or change materials with substitutes. Trade in recyclable materials measures the capacity of the country to deal with the waste of materials and amounts of the recyclable materials such as plastic, paper, iron, steel, copper and others being shipped. Trade in recyclable materials would encourage transition to circular economy and would lead to trade in technologies,

development of circular materials usage, as the recycled materials can be re-introduced into economy as substitutes or even new products.

Environmental pillar includes different aspects related to the protection and efficiency of natural resources and “green” environment. Environmental pillar has a connection with social and economic pillars of circular economy, as the development of any part of environmental pillar leads to the development of new technologies, creation of “green” patents, job creation in “green” technologies, decrease of serious diseases caused by the pollution, stimulation of “green” economy, as one of the aspects of circular economy is a formation of strong sustainable economy based on the environmentally friendly decision making.

2.3. Economic aspects of Circular Economy

Implementation of circular economy requires synergy of economic, environmental and social dimensions on all three levels (-micro, -meso, -macro). To achieve the implementation of circular economy there is a need of legislation be shifted towards eco-innovations, production and consumption eco-innovative standards be implemented. In the case legislation, production and consumption are interrelated and interacted – the circular economy could be applied (Scheel 2016). Regulation and policy may influence consumer behavior of environmental practices, while it will encourage producers to develop innovative solutions to reduce production waste, be in the line of “green” production (Kalmykova *et al.*, 2016), while policy deterrents should support inefficient consumption taxes, production pollution taxes, subsidies for eco-innovation and eco-technology development, low-interest rate and promotion of the investment into environmental and social drivers (Nordenstam *et al.*, 2017). It can be stated that the green investment, green fiscal policy and technological development towards eco-innovation should be promoted and developed.

Economic pillar of circular Economy seeks economic development to benefit business, society and environment. Moreover, economic pillar should ensure a sustainable development of economy supported by the idea of the circular economy which highlights green economy, macro-economics and industry (Fig.2.4.). Green economy aims to reduce negative impact on the environment and ecology by saving resources but seeks sustainable economic growth and development by avoiding environmental damage. Green economy has a strong connection with politics and governmental decisions toward circular economy:

- Climate change;
- Material Management;
- Reduction of pollution;

- Protection and recovery of the environment;
- Natural disaster prevention.

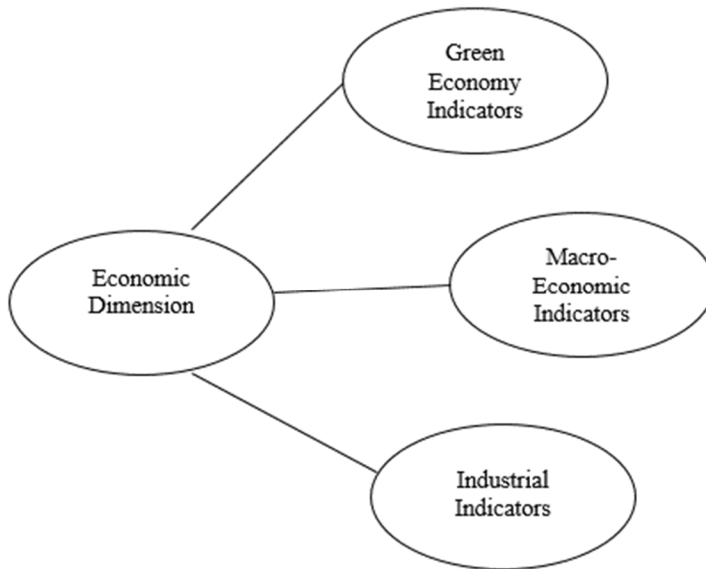


Fig. 2.4. Economic dimension of circular economy (source: compiled by author)

Green economy supports sustainable production and consumption and supports shift towards circular economy, as well as forming and promoting “green” thinking of stakeholders. What is more sustainable economy becomes one of major support of environmental pillar development by financial support, investment into eco-technologies and eco-innovations, new job creation. The idea of green economy leads towards sustainable well-being and sustainable growth.

Macroeconomics represents economy of the selected country or region as a whole including analysis of its structure, performance and behavior. Macroeconomics represents long-term economic growth and macroeconomic models forms economic policies and strategies. Circular economy focuses on long-term results that is why macroeconomic factors are being significant factors forming circular economy policies. Furthermore, the performance of industrial sector is important factor of economic pillar of circular economy, which would have many intersections with environmental pillar regarding resource management, energy efficiency, zero waste approaches.

The strategies, represented in Table 2.4 could classify economic indicators according to the aspect they are belonging to. Six strategies are represented by the identifications E0-E5 which are proposed to use in the classification of economic

pillar indicators. Economic pillar of circular economy focuses on six main strategies (Table 2.4) that circular economy considers seeking sustainable growth and development of economy. E0 entrepreneurial economy strategy focuses entrepreneurs that are being the main force of economic growth.

Table 2.4. 6E circular economy strategies of economic pillar
(source: compiled by author)

E0	Entrepreneurial economy
E1	Eco-Industrial economy
E2	Environmental economy
E3	Eco-innovation economy
E4	Eco-investments
E5	Economic sustainability

Entrepreneurs as key players would identify, create and seek opportunities of product or technologies increasing the market and competition. Moreover, this is closely related with social aspects such as overall ideology in the context of circular economy. E1 eco-industrial economy acts as economic framework for industries in the context of circular economy approach – reduce negative impact on environment and ecology by maintaining the same level of production or even growing production on the same time promoting ecologically friendly consumption. E2 environmental economy strategy ensures environmental protection and zero waste approach corresponding to circular economy. This strategy would have a close connection to Environmental pillar of circular economy. E3 eco-innovation economy strategy would support the development of eco-innovations as well as promote resource-efficient economy. Eco-innovation economy strategy would connect eco-innovations, industry and government. E4 eco-investments strategy would promote green investments and would help to form environmentally friendly way of thinking of stakeholders by supporting circular economy. Eco-investment strategy would help in the transition towards circular economy by supporting environmentally friendly substitutes which may help to refuse of pollution and waste generating materials. E5 economic sustainability strategy would support decisions seeking long-term sustainable economic growth avoiding of negative impact on society or environment. Economic sustainability strategy would have strong relationship with both environmental and social pillars by providing the preferred standards of living level, growing personal income and by the same time supporting environmentally friendly decisions. Economic sustainability strategy would support green technologies turning waste into recover resources or any type of re-usable materials that can be brought back to the economy and benefit from it.

Economic pillar of circular economy should include a complex set of indicators covering the targets and strategies proposed. The indicators could be classified by the area of target or economic strategies of circular economy.

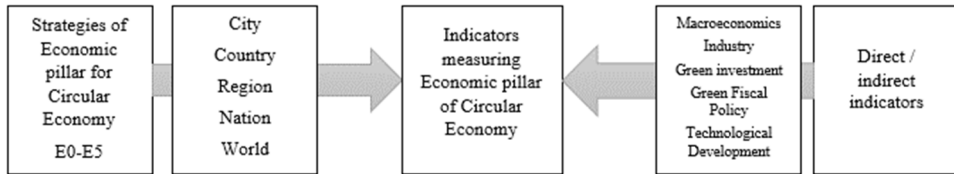


Fig 2.5. Indicators selection strategy to assess economic pillar of circular economy (source: compiled by author)

All the factors influencing economic dimension of circular economy are represented as direct and indirect indicators which are being grouped by the areas of target of circular economy (Fig. 2.5). Direct and indirect indicators for assessment of economic dimension have been selected according to the definition and principles (6E) of circular economy with the correlation of proposed strategies of economic dimension for circular economy and targets. Indicators of economic dimension are divided into following groups related to the areas of targets for circular economy: macroeconomics, industry, green investment, green fiscal policy and technological development. Indicators could be collected by any area of target – city, country, region, nation, world. It is possible to collect indicators by districts within the city or any other area if indicators for the area are available for the research.

Indicators for assessment Economic dimension of circular economy proposed by previous researches are represented in Table 2.5.

Indicators of economic pillar of circular economy could be divided into three groups: microeconomic indicators, industrial indicators and green economy indicators (Fig. 2.6). Macroeconomic group of indicators represents the growth of the economy of the selected geographical area. Also macroeconomic indicators show the output of economy. Real GDP represents all products and services produced within a settled period of time and adjusted for inflation. Real GDP provides insights for long-term economic performance. Annual GDP growth represents the change of GDP over the years. GDP volume allows the comparison over the time and enable to judge economic growth. Real GDP and GDP annual growth represent the “health” of the economy, as includes the value of all goods and services produced within the country during a period of time.

Table 2.5. Indicators for assessment economic dimension of circular economy proposed by previous research (source: compiled by author)

Area of target	Economic Indicators	Proposed by authors in previous research:
Macro-economic Indicators	Real GDP	Li <i>et al.</i> , 2010; Qing <i>et al.</i> , 2011; Wu <i>et al.</i> , 2014; Guo-gang 2011; Avdiushchenko & Zajac 2019
	Central government debt, total (% of GDP)	Milios 2021
	Investment by Institutional sectors (% of GDP)	Moraga <i>et al.</i> , 2019
	GDP growth (% annual)	Guo-gang 2011
Industrial Indicators	Employment in industry (% total employment)	Guo-gang 2011; Moraga <i>et al.</i> , 2019; Smol <i>et al.</i> 2017
	Green Patents	Kottner <i>et al.</i> , 2016; Moraga <i>et al.</i> , 2019; Smol <i>et al.</i> 2017
	Exports of products from eco-industries (% of total exports)	Moraga <i>et al.</i> , 2019
Green Investment	Net Official Development Assistance (% of GNI)	Moraga <i>et al.</i> , 2019
	Environmentally-related Official Development Assistance	Wu <i>et al.</i> , 2014; Kottner <i>et al.</i> , 2016; Smol <i>et al.</i> 2017
Green Fiscal Policy	Energy related tax % of total environmental tax	Vence & Perez 2021; Milios 2021; Shen & Qi 2012
	Total environmental tax % of GDP	Vence & Perez 2021; Milios 2021; Shen & Qi 2012
	Total environmental tax revenues	Vence & Perez 2021; Milios 2021; Shen & Qi 2012
Technological Development	Government investment in Environmental and Energy Research and Development (GBAORD)	Kottner <i>et al.</i> , 2016; Moraga <i>et al.</i> , 2019; Smol <i>et al.</i> 2017
	Global Innovation Index	Kottner <i>et al.</i> , 2016; Smol <i>et al.</i> 2017; Smol <i>et al.</i> 2017
	Eco-innovation inputs	Kottner <i>et al.</i> , 2016; Smol <i>et al.</i> 2017
	Eco-innovation outputs	Kottner <i>et al.</i> , 2016; Smol <i>et al.</i> 2017

GDP reacts to the economic growth or recession that is why GDP is selected as an indicator to show the development of the economy in the specific period of time. Circular economy requires a sustainable economy of the country, as strong economy could ensure the growing support of the environmental dimension.

Investment by institutional sectors shows the investment for total economy, government, business and households. The indicator shows the share of GDP for government, business and household sectors. The indicator covers all sectors of economy, represents the share of GDP is being used for gross investment and is a part of European sustainable development goals. Central government debt indicator expresses the gross overall government debt as a percentage of GDP. This is one of the key indicators to express economic sustainability of government sector.

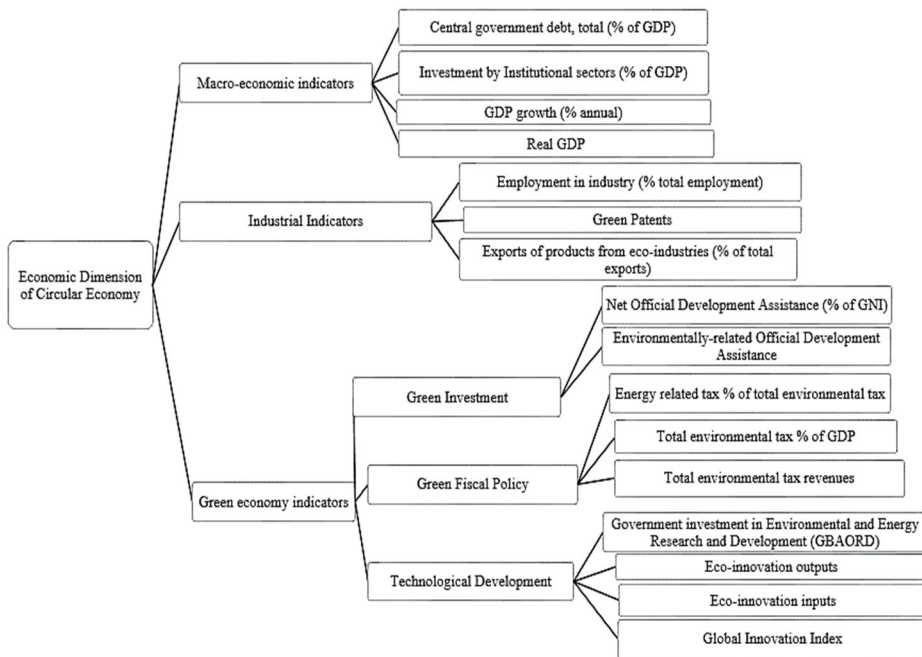


Fig 2.6. Economic dimension of circular economy (source: compiled by author)

Industrial indicators represent industry from economic perspective. Employment in industry indicator identifies persons of working ages engaged in any activity to produce goods or services. The industry consists of mining, quarrying, manufacturing, construction and public utilities. By the development of the economy labor force is shifting from agriculture to industry and services what can help to analyze the stage of the development of industry from economic perspective.

Green patent indicators shows how the green innovations have been applied within the industry. Green innovations develop economic opportunities and policy responses in the context of circular economy. Patent data could measure the results of innovation policies which are being used in the industry and shows the development of green technologies. Patents as the protection of green invention applied in the industry would come closer to the transition towards circular economy. Exports of products from eco-industries indicator measures the volume of the trade of circular materials. This indicator identifies an amount of circular materials being exported that means the need and the development of circular economy within the geographic area.

Green economy indicators could be divided in three groups: green investment, green fiscal policy and technological development. Official Development Assistance (ODA) consists of grants or loans that are undertaken by the official sector with the purpose of promoting economic development and welfare (United Nations, 2019). According to Nordenstam *et al.* (2017), the promotion of green investment considering well-being more than economic interest should be implemented by the policy owners. Also regulation and policy deterrents are promoting the clean production and pollution taxes. The European Union contributes to global environmental, usage of “green” energy, resource efficiency and minimization of pollution challenges by implementing Horizon 2020 programme. Horizon 2020 is the biggest EU research and innovation programme starting from 2014. Horizon 2020 includes energy efficiency problems, such as: reducing energy consumption, alternative fuels and mobile energy sources, low cost and low carbon electricity supply, reduction of air pollution, development of new knowledge and technologies (European Commission 2014). Environmentally-related Official Development Assistance indicator allocated environmentally-related sectors and measures the share of environmentally-related or “green” Official Development Assistance (ODA) to the total ODA. ODA is a vital support of the development of green technologies and the transition towards Circular Economy implementing low-carbon, climate resilient and environmentally sustainable policies. In this case environmentally related Official Development Assistance indicator expresses interdependence of all circular economy pillars. Official Development Assistance (ODA) targets the global and local finance for environmentally-friendly activities such as greenhouse emission reduction, biodiversity protection and prevention of climate change.

Green fiscal policy indicators include tools for environmental protection using governmental spending, taxation and transfer payments to influence aggregate demand affecting the total output produced. Green fiscal policy seeks to reach economic and price stability, full employment, effective resource allocation that aligns with the environmental pillar of circular economy, encourages green investments and sustainable growth of the economy. Environmentally related taxes

are taxes whose tax base is a physical unit (or a proxy of it) of something that has a proven, specific negative impact on the environment and include:

1. Energy products for transport and stationary purposes
2. Motor vehicles and transport;
3. Waste management;
4. Ozone-depleting substances
5. Other taxes.

Energy related tax indicator represents the share of the energy related environmental tax to total environmental tax encouraging production of energy using renewable energy sources. Energy related tax one of the strongest regulation which participates in price formation. Total environmental tax as a part of GDP shows the tax collection relatively to GDP. It is an important tool for government to influence prices for goods and services. Total environmental tax revenues indicator represents the collections by the government which have been set to reduce any harmful behavior towards the environment. The principle of environmental taxation leads to the transition to circular economy encouraging reduction of any kind of harmful activities to the environment. Tax systems built on the concepts of circular economy could boost the economic growth and green technology development.

The development of eco-innovations and technologies are one of the key drivers for implementation of circular economy. The more policy deterrents support Innovation, the more progress could lead to zero waste approach of producers and consumers. The core of the Global Innovation Index Report consists of a ranking of world economies' innovation capabilities and results. Recognizing the key role of innovation as a driver of economic growth and prosperity, and the need for a broad horizontal vision of innovation applicable to developed and emerging economies, the Global Innovation Index includes indicators that go beyond the traditional measures of innovation such as the level of research and development. Global Innovation Index represents innovation trends and able to rank economy by innovation performance. Eco-innovation output/input is calculated based on three indicators: government investments in environmental and energy research and development, green early stage investments and total research and development personnel. Eco-innovation outputs shows the results of eco-innovation activities such as issuing new green patents, eco-innovation scientific researches, eco-innovation popularization within the stakeholders. Eco-innovation inputs represent any investment to support eco-innovation activities. Eco-innovation inputs indicator includes government outlays as a percentage of GDP to environmental and energy research and development (R&D), attracting more personnel to R&D and green investments to support the development of green technologies and eco-innovation.

Indicators of economic pillar should be aligned with the proposed strategies for economic pillar. As represented in Table 2.6 indicators may be grouped according to the area of target and respond to the strategies of economic pillar. The indicator may respond to several strategies and correlate with environmental and social pillars. Macroeconomic indicators have different units of measurement and respond to eco-industrial economy, economic sustainability, environmental economy, eco-investments and entrepreneurial economy strategies. Industrial indicators mostly respond to entrepreneurial economy, eco-industrial economy and environmental economy strategies. Green investment indicators are aligned with entrepreneurial economy, environmental economy and eco-investments strategies. Green fiscal policy indicators are corresponding to eco-industrial economy and environmental economy strategies. Technological development indicators are linked to environmental economy and eco-innovation economy strategies.

Table 2.6. Indicators for assessment economic pillar of circular economy
(source: compiled by author)

Area of target	Economic Indicators	Units of Measurement	Strategy
Macro-economic Indicators	Real GDP	numeric value	E1, E5
	Central government debt, total (% of GDP)	% (percentage)	E5
	Investment by Institutional sectors (% of GDP)	% (percentage)	E2, E4
	GDP growth (% annual)	% (percentage)	E0, E5
Industrial Indicators	Employment in industry (% total employment)	% (percentage)	E0, E1
	Green Patents	numeric value	E1, E2
	Exports of products from eco-industries (% of total exports)	% (percentage)	E0, E1, E2
Green Investment	Net Official Development Assistance (% of GNI)	% (percentage)	E0, E4
	Environmentally-related Official Development Assistance	numeric value	E2, E4
Green Fiscal Policy	Energy related tax % of total environmental tax	% (percentage)	E1, E2
	Total environmental tax % of GDP	% (percentage)	E1, E2
	Total environmental tax revenues	numeric value	E1, E2

End of Table 2.6

Area of target	Economic Indicators	Units of Measurement	Strategy
Technological Development	Government investment in Environmental and Energy Research and Development (GBAORD)	numeric value	E2, E3
	Global Innovation Index	numeric value	E3
	Eco-innovation inputs	numeric value	E2, E3
	Eco-innovation outputs	numeric value	E2, E3

Economic pillar of circular economy intersects businesses, households and environmental activities leading to circular economy goals. By promoting environmentally friendly activities in the context of circular economy, economic pillar ensures sustainable economic growth and remain business profitable to build strong economy to be able support environmentally friendly activities. Profit, planet and people are three main cores that economic pillar relies on. However, economic pillar regulates fiscal policies to promote circular economy approach within stakeholders and support environmental and social pillars.

2.4. Social aspects of Circular Economy

Naturally, the social aspects of sustainability are intertwined with the environmental and economic aspects. A large part of a person’s social wellbeing is dependent on their economic status – how fulfilling their job is or whether they make enough money to support their lifestyle. The environment also has an effect on social wellbeing – recreation often involves use of environmental resources and the physical environment in which we live is important. However, the social aspects are more than just the indirect effects of environmental or economic sustainability. Sustainable development is about places that allow people to provide for their social needs.

Social well-being is a concept that has received a lot of attention in recent times. There is a number of different ideas as to what constitutes social well-being. Although this is not an exhaustive list, however it is considered that social well-being is influenced by the following (Costanza *et al.*, 2016):

- Health;
- Personal relationships;
- Safety;

- Standard of living;
- Material affluence;
- Equality;
- Freedom;
- Achievements;
- Community connectedness;
- Future security;
- Environment and services.

The concept of social sustainability is more than just providing for our social well-being – it is about sustaining a high level of social well-being in the long-term (Stiglitz *et al.*, 2009). There are a number of social factors that are key to sustaining social well-being in the long-term including:

- Equity;
- Understanding;
- Diversity;
- Inclusion;
- Quality of life;
- Opportunity;
- Individual empowerment.

It is important that we consider how these aspects are maintained as changes in the social environment occur in the future. Social sustainability is based on the concept that a decision or project promotes the betterment of society. In general, future generations should have the same or greater quality of life benefits as the current generation do. This concept also encompasses many things such as human rights, environmental law, and public involvement & participation. Failing to put emphasis on the social part of decision or action can result in the slow collapse of the spheres of sustainability (and society as well). The sustainable development system that is focused on the maintenance of human-environment interaction balance, its theoretical research and the use of the acquired knowledge for making political and economic decisions could give the necessary directions to the solution of acute social and environmental challenges in different countries around the world.

The strategies, represented in Table 2.7 could classify social indicators according to the aspect they are belonging to. Six strategies are represented by the identifications 6S which are proposed to use in the classification of social pillar indicators. Social pillar of circular economy focuses on six main strategies (Table 2.7) that circular economy considers seeking sustainable growth and development of economy.

Table 2.7. 6S Circular economy strategies of social pillar
(source: compiled by author)

S0	Social Justice
S1	Satisfaction with Health
S2	Social Well-being and Healthy ageing
S3	Science, education and technology
S4	Satisfaction with financial wealth
S5	Satisfaction with Environment

S0 “Social Justice” strategy acts as intermediary between concepts of fairness between individuals in society and equal distribution of wealth, opportunities and social privileges in a society. S1 “Satisfaction” with “Health” strategy observes the personal satisfaction with health care system and equal availability of medical treatment to meet personal health care needs. S2 “Social well-being” and “Healthy ageing” strategy focuses on the satisfaction with quality of life including health, personal development, work, financial wealth, society and other aspects influencing psychological comfort. Moreover, well-being in older age extends the satisfaction with quality of life after retirement. S3 “Science, education and technology” strategy promotes ecologically friendly research and development involving population into science and technology and spread the benefits of eco-innovation to increase quality of life. S4 “Satisfaction with financial wealth” strategy represents financial wealth of population including personal income, reducing poverty rates and promoting the equality. Financial wealth provides the possibility to improve life quality. S5 “Satisfaction with environment” strategy ensures recognition of government environmental policies and local environmental condition. Social pillar strategies intersect with economic and environmental strategies in the context of circular economy. Life satisfaction of the population includes almost all aspects of life that the population is facing. That is why circular economy concept is being built on three components which cannot function without each other.

Social pillar of circular economy should include a complex set of indicators covering the targets and strategies proposed. The indicators could be classified by the area of target or social strategies of circular economy.

All the factors influencing social dimension of circular economy are represented as direct and indirect indicators which are being grouped by the areas of target of circular economy being aligned with the roosed 6S strategy (Fig. 2.7).

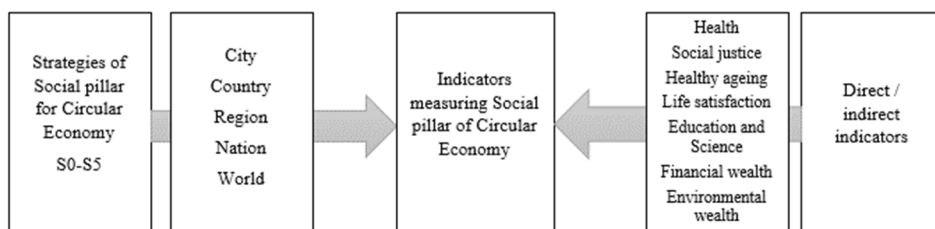


Fig 2.7. Indicators selection strategy to assess social pillar of circular economy (source: compiled by author)

Indicators of social pillar are divided into following groups related to the areas of targets for circular economy: health, social justice, healthy ageing, life satisfaction, education and science, financial wealth and environmental wealth. Indicators could be collected by any area of target – city, country, region, nation, world. It is possible to collect indicators by districts within the city or any other area if indicators for the area are available for the research.

Indicators for assessment social dimension of circular economy proposed by previous research represented in Table 2.8.

Table 2.8. Indicators for assessment social dimension of circular economy proposed by previous research (source: compiled by author)

Area of target	Social Indicators	Proposed by authors in previous research:
Health	Healthy life years and life expectancy at birth, by sex	D'Adamo <i>et al.</i> , 2020; Van Schoubroeck <i>et al.</i> , 2018; Pauliuk 2018; Vuta <i>et al.</i> , 2019; Avdiushchenko & Zajac 2019
	Unmet need for medical treatment, by income	Martin <i>et al.</i> , 2018; Vuta <i>et al.</i> 2019
	People having a long-standing illness or health problem	D'Adamo <i>et al.</i> , 2020; Martin <i>et al.</i> , 2018; Vuta <i>et al.</i> , 2019
	Health expenditure, total (% of GDP)	Martin <i>et al.</i> , 2018; Vuta <i>et al.</i> 2019
Social Justice	Corruption Perceptions Index	Van Schoubroeck <i>et al.</i> , 2018; Vuta <i>et al.</i> , 2019
	Political stability and absence of violence	Van Schoubroeck <i>et al.</i> , 2018; Vuta <i>et al.</i> 2019

End of Table 2.8

Area of target	Social Indicators	Proposed by authors in previous research:
	Regulatory Quality	Van Schoubroeck <i>et al.</i> , 2018; Vuta <i>et al.</i> 2019
	Government Effectiveness	Van Schoubroeck <i>et al.</i> , 2018
Well-being and Healthy ageing	Participation rate in education and training (55–74 years)	D'Adamo <i>et al.</i> , 2020; Vuta <i>et al.</i> , 2019; Avdiushchenko & Zajac 2019
	Employment of older workers % (55–64 years)	Guo-gang 2011; Pauliuk 2018; Vuta <i>et al.</i> , 2019; Avdiushchenko & Zajac 2019
	Self-perceived health (as “very good” and “good”) %	Van Schoubroeck <i>et al.</i> , 2018
	Human development index (HDI)	Van Schoubroeck <i>et al.</i> , 2018; Pauliuk 2018; Vuta <i>et al.</i> , 2019
Education, Science and Technology	% of population involved in science and technology	Kottner <i>et al.</i> , 2016
	Total REsearch & Development expenditure	Kottner <i>et al.</i> , 2016; Vuta <i>et al.</i> 2019; Avdiushchenko & Zajac 2019
	Expenditures on Education	Qing <i>et al.</i> , 2011
	Eco-Innovation activities	Van Schoubroeck <i>et al.</i> , 2018
Financial Wealth	Long-term unemployment rate	Li <i>et al.</i> , 2010; Pauliuk 2018; Avdiushchenko & Zajac 2019
	Employment rate, by sex, age group 20–64%	Li <i>et al.</i> , 2010; Vuta <i>et al.</i> 2019
	Employment rate, by highest level of education attained	Guo-gang 2011; Kottner <i>et al.</i> , 2016; Avdiushchenko & Zajac 2019
	Household saving rate	Li <i>et al.</i> , 2010
	At-risk-of-poverty rate	Van Schoubroeck <i>et al.</i> , 2018; Pauliuk 2018; Avdiushchenko & Zajac 2019
	Inequality of income distribution	Van Schoubroeck <i>et al.</i> , 2018
Environmental Wealth	Pollution, grime or other environmental problems	Su <i>et al.</i> , 2013; Kottner <i>et al.</i> , 2016
	Exposure to air pollution	Su <i>et al.</i> , 2013; Kottner <i>et al.</i> , 2016
	Renewable energy consumption by households	Guo-gang 2011

Indicators of social pillar of circular economy (Fig. 2.8) could be divided into six groups: health, social justice, well-being and healthy ageing, education, science and technology, financial wealth and environmental wealth. Health indicators analyze and summarize information about health system performance and overall health of population. Health indicators could provide information in various forms depending on the research goals. Health indicators could be collected by the geographic area, different age groups or any other targets. Healthy life years and life expectancy at birth indicate the average number of years that members of population live healthy. Many studies, researches and resources are being focused to extend healthy life years of the population by reducing the occasion of serious diseases which make a significant impact on the health of population leading to disability or mortality. Unmet need for medical treatment indicator measures availability of medical treatment to meet the need of specific health care service. Many reasons can be analyzed the delay in medical treatment needed – low income, as medical treatment costs more than the member of population can afford, or distance which would become the reason the medical treatment was not received on time, or timeliness which makes medical treatment unavailable due to waiting lists.

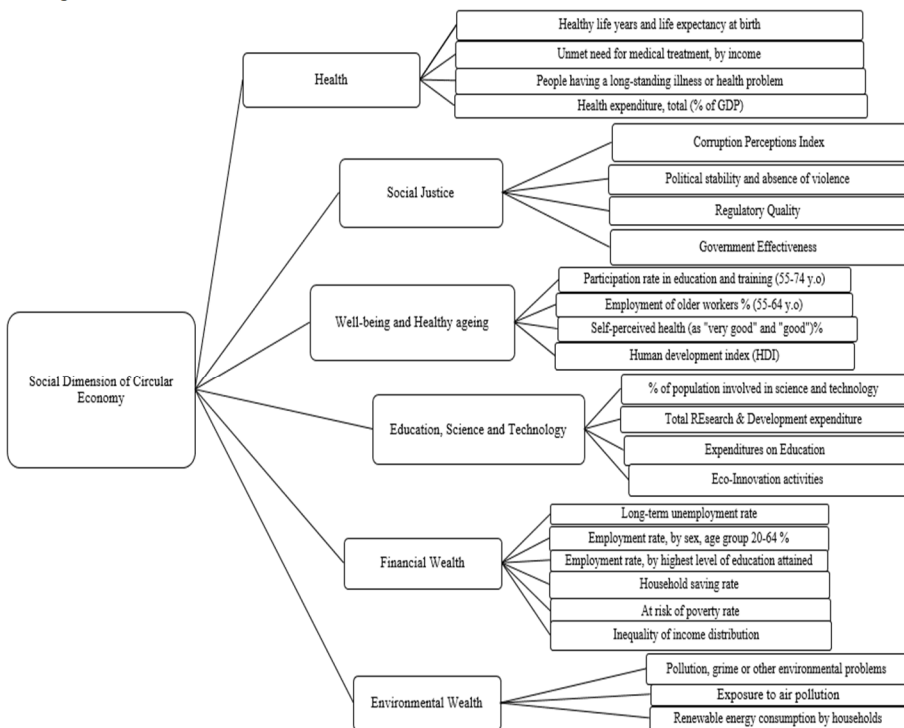


Fig. 2.8. Social aspects of circular economy (source: compiled by author)

People having a long-standing illness or health problem indicator shows the percentage of population facing chronic morbidity or disability. Health expenditure, total (% of GDP) indicator measures the expenditures of a budget to the health care system as a share of GDP and shows the importance of the health sector in the whole economy.

Social justice group of indicators ensures that members of the population fulfill their roles in the society and receive the benefits from the society such as social insurance, public health, public education, jurisdiction, and other public sector services. Corruption Perceptions Index (CPI) indicator ensures the financial transparency and prevents from abuse of entrusted power for private gain. The indicator has quite significant impact on the trust to the government or authorities. Political stability and absence of violence indicator measures the perception of the population of government instability. Political instability negatively impacts on economic and social aspects which in long-term will negatively affect macroeconomic performance. Regulatory quality indicator measures the ability of the government formulate and implement policies and regulations in the support of private sector development. Government effectiveness indicator represents the quality of public services in order to improve the quality of provided public services and maintain the quality high constantly.

Well-being and Healthy ageing group of indicators represent the overall satisfaction of life including all the social benefits and services population may need to use. The idea of healthy ageing to extend the expectancy of life without the reduction of healthy life. Participation rate in education and training (55–74 years old) indicator shows the availability of education and training for the population in the age of 55–74 (or older) years old in order to be involved in the labor market and technological development or be satisfied with the quality of life. Employment of older workers indicator identifies the percentage of workers older than 55 years old. This indicator represents healthy ageing idea that by the ageing member of population should be satisfied with the quality of life, would have possibility participate in the labor market. Self-perceived health indicator would identify the share of population identifying their health as “very good” or “good”. Human development index (HDI) measures the achievement of key aspects of human development such as healthy life, being educated and have a high standard of living.

Education, science and technology group of indicators analyzes the availability and the development of education and science, promoting the research and expenditures on education, R&D and eco-innovation activities. Percentage of population involved in science and activity indicates the capacity of science to solve problems that are related to the shift towards Circular economy such as human resource development, new technology creation for sustainable development and providing human welfare with less consumption of resources. Total R&D expenditure indicator shows the gross domestic spending on R&D in the economy

in the period of time regardless the source of funds. Also, the expenditures on education indicator represents the amount of governmental budget allocated in different educational activities. Governmental expenditure on health and education improves labor productivity, what has a connection with environmental and economic pillars of circular economy. eco-innovation activities indicator ensures the implementation of resource efficiency actions, implementation of circular materials and sustainable products, promoting eco-innovation outputs.

Financial wealth group of indicators analyze the financial position of the population by considering labor market and overall economic situation as personal income is influencing the quality of living. Long term unemployment rate indicator shows the situation in the labor market and identifies unemployment for 12 month or more, what negatively impacts all the pillars of circular economy. In addition to this employment rate indicator expressed as a percentage of total population shows the available labor resources, while employment rate by highest level of education attained represents available labor resources with the higher education, as higher education leads to better personal income, quality of living, while population with higher education boosts the spread of technology, R&D and science. The household saving rate indicator defines the gross saving rate as gross saving divided by gross disposable income. At risk of poverty rate indicator identifies the percentage of population whose income is comparatively low and is below at risk of poverty threshold that negatively impacts on their life satisfaction. Inequality of income distribution indicator shows unevenly distribution of the income within the population which leads to the huge gap in the quality of living and life satisfaction.

Environmental wealth group of indicators evaluates the satisfaction of the population with the environment. Pollution, grime or other environmental problems indicator represents the satisfaction with the environment within the population. Exposure to air pollution indicator measures the satisfaction with air pollution which can be expressed directly by the population or indirectly by the increased number of respiratory diseases. Renewable energy consumption by household's indicator shows the spread of renewable energy among households for energy use for various purposes: heating, lighting and usage of electrical appliances. The more households are being involved in the use of renewable energy the less fossil fuels would be used in the energy production that would lead to the environmentally friendly consumption in the concordance of circular economy concept.

Indicators of social pillar should be aligned with the proposed strategies for social pillar. As represented in Table 2.9. indicators may be grouped according to the area of target and respond to the strategies of economic pillar. The indicator may respond to several strategies and correlate with environmental and economic pillars.

Health indicators have different units of measurement and respond to satisfaction with health and social well-being and healthy ageing strategies. Social justice indicators respond to social justice strategy. Well-being and healthy ageing indicators are aligned with science, satisfaction and technology, satisfaction with health and social well-being and healthy ageing strategies.

Table 2.9. Indicators for assessment social pillar of circular economy (source: made by author)

Area of target	Social Indicators	Units of Measurement	Strategy
Health	Healthy life years and life expectancy at birth, by sex	numeric value	S1, S2
	Unmet need for medical treatment, by income	numeric value	S1
	People having a long-standing illness or health problem	% (percentage)	S1
	Health expenditure, total (% of GDP)	% (percentage)	S1
Social Justice	Corruption Perceptions Index	numeric value	S0
	Political stability and absence of violence	numeric value	S0
	Regulatory Quality	numeric value	S0
	Government Effectiveness	numeric value	S0
Well-being and Healthy ageing	Participation rate in education and training (55–74 years)	% (percentage)	S2, S3
	Employment of older workers % (55–64 years)	% (percentage)	S2
	Self-perceived health (as “very good” and “good”) %	% (percentage)	S1, S2
	Human development index (HDI)	numeric value	S1, S2
Education, Science and Technology	% of population involved in science and technology	% (percentage)	S3
	Total REsearch & Development expenditure	% (percentage)	S3
	Expenditures on Education	% (percentage)	S3
	Eco-Innovation activities	% (percentage)	S3

End of Table 2.9

Area of target	Social Indicators	Units of Measurement	Strategy
Financial Wealth	Long-term unemployment rate	% (percentage)	S4
	Employment rate, by sex, age group 20–64%	% (percentage)	S4
	Employment rate, by highest level of education attained	% (percentage)	S3, S4
	Household saving rate	% (percentage)	S4
	At-risk-of-poverty rate	% (percentage)	S4, S0
	Inequality of income distribution	% (percentage)	S0, S4
Environmental Wealth	Pollution, grime or other environmental problems	numeric value	S1, S5
	Exposure to air pollution	numeric value	S1, S5
	Renewable energy consumption by households	% (percentage)	S5

Education, science and technology indicators are corresponding to science, satisfaction and technology strategy. Financial wealth indicators are linked to social justice, science, satisfaction and technology and satisfaction with financial wealth strategies. Environmental wealth indicators are corresponding to satisfaction with health and satisfaction with environment strategies.

Close relationship between social processes and the environment regarding the resource consumption for production of public goods within the framework of the economic subsystem, as well as the waste and pollution endangering ecosystem's ability to reproduce the necessary resources for human existence in an appropriate quantity and quality, are clearly shown in the offered model.

2.5. Integration of MCDM method TOPSIS into Circular Economy valuation system

Multi-criteria decision aid (MCDA) is simply a process of decision-making where criteria could be found out. This method attracts by using a well-structured framework to evaluate a criteria by the setting weights, ranks to the criteria in order to establish an importance of all the criteria in the solving problem of decision-making. In fact, Multi-criteria decision methods (MCDM) do not necessary will provide the only one right solution to the problem. It happens so, that using MCDM

method a decision maker would be well oriented between the different alternatives, so it leads to the choice of decision maker between the provided possible solutions by the method.

MCDM methods selected for valuation of circular economy have an ability to analyse, systemize and group different circular economy indicators from environmental, economic and social dimensions despite the units of measurement, which gives the advantages over other methods used for circular economy analysis and assessment. Moreover, MCDM methods could provide the evaluation of the object selected and comparison of the result among other analysed objects. In addition to this, MCDM methods do not require difficult mathematical calculations, deals with the different value of indicators meaning of maximization and minimization. As circular economy is multi componential approach MCDM methods have been selected to access circular economy which gives the possibility to systemize and group indicators, find out the best and worse solution and rank the selected countries according to the level of circular economy developed.

MCDM could provide the best decision between the possible alternatives or the final solution could be grouped by the several groups of preference, by ranking or classifying them (Cheng 2006). By the implementing MCDM methods, the decision maker would always have the choice of the most suitable solution of the problem, would gather all the possible outcomes of the alternatives as it is represented in Fig. 2.10, which represents the structure of MCDM problem, where $A = \{A^1, A^2, \dots, A^i, \dots, A^n\}$ is the set of alternatives and $Q = \{1, 2, \dots, j, \dots, q\}$ is the set of criteria. On the basis of this, MCDA methods helps the decision makers to be well oriented in the possible alternative impacts on the decision. Methods of MCDM could be differ as well in the such cases as the choice of criteria, weights estimation, mathematical tools, so it is important to choose the right method before the evaluating the alternatives.

		Alternatives					
		A^1	A^2	...	A^i	...	A^n
Criteria	1						
	2						
	...						
	j						
	...						
	q						

Fig. 2.10. The structure of MCDA problem (source: Cheng 2006)

MCDM has a wide range of the advantages. It helps to find possible solutions of the problems, could help to classify the solutions to the acceptable and not acceptable. What is more, MCDM helps to develop a whole framework for decision making, which would be based on logic and mathematically proved. What is more, MCDM could help to identify relevant and non-relevant data to the problem solving that would be evaluated. Evaluation and comparison of the alternatives – one of the basic parts of MCDM. All this led to the obtaining of the right decision, evaluation of the problem from the different edges, taking in the account all possible alternatives and outcomes (Montis *et al.*, 2000).

To sum up, MCDM helps a lot to make the decisions in the own opinion of the decision maker. It helps to develop criterion, that are evaluated, weighted that shows the importance of each in the decision, as well the final result that shows the evaluation of the all possible outcomes of the alternatives.

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) belongs to MCDM group and is one of the most popular methods is being used in different scientific fields. The basic idea of the method is that the best alternative would be the closest to the best solution and far away from the worst solution (Hwang & Yoon 1981). In other words, TOPSIS method measures the distance to the ideal solution, or the shortest geometric distance (Sarkar 2013). What is more, the TOPSIS method includes weights for criterion, requires a set of alternatives and normalization for the TOPSIS method.

TOPSIS method is widely used in different scientific fields. For example, TOPSIS was used to assess the sustainability of government bond funds (Bilbao-Terol *et al.*, 2014), Sustainability reporting in energy companies (Ergüden & Çatlıoğlu 2016). Also, TOPSIS method was used to establish the efficiency ranking method in the case of Indian bank (Chitnis & Vaidya 2016), to prioritize critical success factors in pharmaceutical industry (Mehralian *et al.*, 2016) and used to evaluate ecological-economic efficiency of green technology innovation in strategic emerging industries (Sun *et al.*, 2018).

According to the literature review, it is not enough to apply a single index or indicator to measure country's environmental, economic or social welfare in the context of circular economy. A wide range of different indicators and measurements needed to be analyzed. That is why, TOPSIS method was selected to evaluate the development of circular economy of a country. All indicators are well-organized and systemized and on the basis of complex evaluation are represented by the “best” scores or high scores, that shows a closeness to the right decision and “bad” scores or low scores, which show in opposite way – which show the distance to the wrong decision.

The beginning of applying TOPSIS method starts with the decision matrix preparation, assuming that there are n evaluation indicators, and evaluation indicator sets have m subsets, the evaluation value of indicator j in subset i is a_{ij} . Decision matrix (Byun, Lee 2005) (2.1):

$$A = (a_{ij})_{m \cdot n} = \begin{bmatrix} a_{11} & \cdots & a_{n1} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{m \cdot n} \end{bmatrix}, \quad (2.1)$$

where: element a_{mn} represents the value of the alternative.

The second step is TOPSIS normalization (Byun, Lee 2005) (2.2):

$$r_{ij} = \frac{r_{ij}}{\sqrt{\sum_{j=1}^n r_{ij}^2}}, \quad (2.2)$$

where: $i = 1, \dots, m; j = 1, \dots, n$.

As TOPSIS can analyze data with different numeric values (r_{ij}), to systemize it there is a need for normalization. Once the data is normalized, each criterion should be multiplied by the weight. There are different types how to establish the weight for TOPSIS method, but for this particular case the equal weight was selected for each criterion to create an equality of the importance of each criterion. Each criterion should be multiplied by the establish weight (Byun, Lee 2005) (2.3):

$$ij = w_{ij} \cdot r_{ij}, \quad (2.3)$$

where: $i = 1, \dots, m; j = 1, \dots, n$.

TOPSIS method includes two categories of the solution as well – the best hypothetical solution V^* (2.4) and the worst hypothetical solution V^- (2.5), (Podvieszko 2011):

$$V^* = \{V_1^*, V_2^*, \dots, V_m^*\} = \left\{ \left(\max_j \omega_i r_{ij}^{\sim} / i \in I_1 \right), \left(\left(\min_j \omega_i r_{ij}^{\sim} / i \in I_2 \right) \right) \right\}; \quad (2.4)$$

$$V^- = \{V_1^-, V_2^-, \dots, V_m^-\} = \left\{ \left(\min_j \omega_i r_{ij}^{\sim} / i \in I_1 \right), \left(\left(\max_j \omega_i r_{ij}^{\sim} / i \in I_2 \right) \right) \right\}, \quad (2.5)$$

where: I_1 is the set of indices of the maximizing criteria; I_2 is the set of indices of the minimizing criteria.

By the estimating the best hypothetical solution, that is represented by V^* and the worst hypothetical solution, that is represented by V^- , there is a need to

analyze the data after the multiplying weight by normalized data. By the estimation the best and the worst hypothetical solutions should take in account whether the criterion are minimizing or maximizing.

The Euclidean distance to the best and the worst hypothetical solutions is calculated as follows (Byun, Lee 2005) (2.6), (2.7):

$$D_j^* = \sqrt{\sum_{i=1}^m (\omega_i r_{ij} - V_i^*)^2}; \quad (2.6)$$

$$D_j^- = \sqrt{\sum_{i=1}^m (\omega_i r_{ij} - V_i^-)^2}. \quad (2.7)$$

And the cumulative criterion of the method C_j^* for each alternative j is calculated as follows, (Byun, Lee 2005) (2.8):

$$C_j^i = \frac{D_j^-}{D_j^* + D_j^-}. \quad (2.8)$$

Cumulative criterion of the method C_j^* shows the best alternative (Pavić & Novoselac 2013), which distance to the best hypothetical solution is shorter and shows the worst alternative, which distance to the worst hypothetical solution is the smallest.

2.6. Integration of MCDM method MULTIMOORA into Circular Economy valuation process

The MOORA method first introduced by Brauers (2004) is such a multi-objective optimization technique that can be successfully applied to solve various types of complex decision making problems.

Several authors used MULTIMOORA method in the various research. For example, Baležentis *et al.* (2012) analysed the personnel selection implementing MULTIMOORA method, also, earlier, Baležentis *et al.* (2011a) offered to evaluate structural indicators of the country targeting the Europe strategy for 2020, in 2010 the evaluation of Lithuania in European Union was represented (Baležentis *et al.*, 2011). MULTIMOORA method was used by Brauers & Zavadskas (2013) in evaluation of the preparation for the economic aim for 2020 of the countries of European Union. Brauers *et al.* (2013) offers MULTIMOORA method in evaluation of construction enterprises, Baležentis & Baležentis (2011) used MULTIMOORA in assessment of the efficiency of transport sector in Lithuania. Also,

MULTIMOORA was used in evaluation of risk assessment tools for various industries such as, robot selection evaluation by MULTIMOORA introduced by (Liu, 2014). Brauers *et al.* (2012) adopted MULTIMOORA for the evaluation of performance of Lithuanian commercial banks, also, Brauers *et al.* (2012) introduced economic ranking of European Union countries using MULTIMOORA.

MULTIMOORA method is widely used in many fields to solve a variety of problems. MULTIMOORA method has been used for the assessment of the risk of occupational accidents in steel industry by Fattahi & Khalilzadeh (2018), residential house element and material selection by Zavadskas *et al.* (2017), ranking and selecting the best performance appraisal method for organisations by Maghsoodi *et al.* (2018), selection of optimal mining method by Liang *et al.* (2019), pharmacological therapy selection by Eghabali-Zarch *et al.* (2018), selecting project-critical path by Dorfeshan *et al.* (2018).

To sum up, MULTIMOORA is widely used by researches in different study fields. The method is flexible, can be easily adopted to the analysis of several factors effecting the objective, can solve multi-criteria questions, can rank the objectives according the selected indicators. The method does not require difficult mathematical calculations, can be easily implemented in the case of existing different indicators, which value differs in the meaning of maximization and minimization. What is more, method deals with the criterion having different units of measurement, what is important in circular economy assessment, as many indicators are represented as rates, numeric vlues, ages, currency.

The method starts with a matrix of responses of different alternatives on different objectives. A table (a matrix) assembles the data with vertically numerous objectives, criteria (a weaker form of objectives) or indicators and horizontally alternative solutions like projects (Table 2.10). The data originate from statistics, desk research, or from simulated figures. In this way, alternatives, solutions or projects enter the response matrix as rows. Concerning projects information has to be as intensive as possible.

Table 2.10. Matrix of responses (source: Brauers & Zavadskas 2012)

	Obj. 1	Obj. 2	...	Obj. i	...	Obj. n
Alternative 1	X_{11}	X_{21}	...	X_{i1}	...	X_{n1}
Alternative 2	X_{12}	X_{22}	...	X_{i2}	...	X_{n2}
...	$X_{1...}$	$X_{2...}$	...	$X_{i...}$	...	$X_{n...}$
Alternative j	X_{1j}	X_{2j}	...	X_{ij}	...	X_{nj}
...	$X_{1...}$	$X_{2...}$	...	$X_{i...}$	...	$X_{n...}$
Alternative m	X_{1m}	X_{2m}	...	X_{im}	...	X_{nm}

The question remains how to find and how to decide on the choice of the objectives. One decision maker like a captain of industry will focus on his own objectives. Once agreement reached about alternatives and objectives, a decision must be taken how to read the response matrix, either horizontally or vertically. The Ratio System which forms the basis of the MOORA method follows the vertical reading of the matrix. Fig. 2.11 shows the exact relation between the two methods of MOORA and MULTIMOORA.

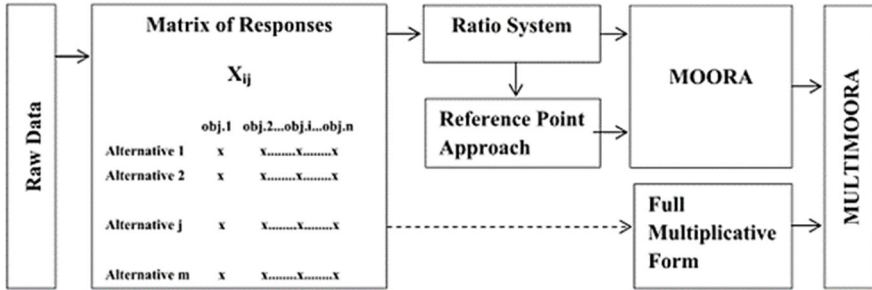


Fig 2.11. Relation between MOORA and MULTIMOORA methods
(source: Brauers & Zavadskas 2012)

To start implementing the method, there is a need to enter the data to a matrix of responses (Brauers & Zavadskas 2012) (2.9):

$$X_{ij} = \begin{bmatrix} X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{m1} & \cdots & X_{mn} \end{bmatrix}, \quad (2.9)$$

where: X_{ij} – the response of alternative j on objective or attribute i ; $i = 1, 2, \dots, n$ – is the number of objectives; $j = 1, 2, \dots, m$ – is the number of alternatives.

With internal normalization, MOORA method does not use weights of objective or attribute (i). The MOORA method consists of two components: the ratio system and the reference point approach

MOORA goes for a ratio system in which each response of an alternative on an objective is compared to a denominator, which is representative for all alternatives concerning that objective. For this denominator the square root of the sum of squares of each alternative per objective is chosen. Brauers & Zavadskas (2010) proved that this is the most robust choice (10):

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{j=1}^m x_{ij}^2}}, \quad (2.10)$$

with x_{ij} = response of alternative j on objective i ; $j = 1, 2, \dots, m$; m the number of alternatives; $i = 1, 2, \dots, n$; n the number of objectives; x_{ij}^* = a dimensionless number representing the normalized response of alternative j on objective i .

Dimensionless numbers, having no specific unit of measurement, are obtained for instance by deduction, multiplication or division. The normalized responses of the alternatives on the objectives belong to the interval $[0; 1]$. However, sometimes the interval could be $[-1; 1]$. Indeed, for instance in the case of productivity growth some sectors, regions or countries may show a decrease instead of an increase in productivity, i.e., a negative dimensionless number. For optimization these responses are added in case of maximization and subtracted in case of minimization (Brauers & Zavadskas 2012) (2.11):

$$y_j^* = \sum_{i=1}^{i=g} x_{ij}^* - \sum_{i=g+1}^{i=n} x_{ij}^*, \quad (2.11)$$

with $i = 1, 2, \dots, g$ as the objectives to be maximized; $i = g + 1, g + 2, \dots, n$ as the objectives to be minimized; y_j^* = the normalized assessment of alternative j with respect to all objectives. An ordinal ranking of the y_j shows the final preference.

The second part of MOORA the Reference Point Theory starts from the already normalized ratios as defined in the MOORA method, namely formula (11). Preference is given to a reference point possessing as co-ordinates the dominating co-ordinates per attribute of the candidate alternatives and which is designated as the Maximal Objective Reference Point. This approach is called realistic and non-subjective as the co-ordinates, which are selected for the reference point, are realized in one of the candidate alternatives according the formula (Brauers & Zavadskas 2012) (2.12).

$$\min_j \left\{ \max_i |r_i - x_{ij}^*| \right\}, \quad (2.12)$$

with $|r_i - x_{ij}^*|$ the absolute value if x_{ij} is larger than r_i for instance by minimization. The min-max metric is the best choice between all the possible metrics of reference point theory (Brauers & Zavadskas 2012).

For the Reference Point Approach the place of the significance coefficient would be calculated as shows formula (Brauers & Zavadskas 2012) (2.13):

$$|s_i r_i - s_i x_{ij}^*|. \quad (2.13)$$

Brauers (2004) described the three parts of MULTIMOORA:

1. The Ratio System Approach, producing dimensionless ratios;
2. The Reference Point Approach, but still based on scores;
3. The Full Multiplicative Form.

MULTIMOORA is composed of MOORA and of the Full Multiplicative Form of Multiple Objectives. The following n -power form for multi-objectives is called from now on a Full-Multiplicative Form in order to distinguish it from the above mentioned mixed forms (Brauers & Zavadskas 2012) (2.14):

$$U_j = \prod_{i=1}^n x_{ij}, \quad (2.14)$$

where: $j = 1, 2, \dots, m$; m the number of alternatives; $i = 1, 2, \dots, n$; n the number of objectives; x_{ij} – the response of alternative j on objective i ; U_j – the overall utility of alternative j .

The overall utilities (U_j), obtained by multiplication of difference units of measurement, become dimensionless.

How is it possible to combine a minimization problem with the maximization of other objectives? Therefore, the objectives to be minimized are denominators in the formula (Brauers & Zavadskas 2012) (2.15):

$$U'_j = \frac{A_j}{B_j}, \quad (2.15)$$

where: $A_j = \prod_{j=1}^g x_{ij}$, $j = 1, 2, \dots, m$; m the number of alternatives; i – the number

objectives to be maximized; $B_j = \prod_{j=g+1}^n x_{ij}$, $n - i$ – the number of objectives to

be minimized; U' the utility of alternative j with objectives to be maximized and objectives to be minimized.

The overall utilities (U_j), obtained by multiplication of different units of measurement, become dimensionless. The outcome of this presentation is nonlinear, which presents an advantage, as the utility function of human behavior toward several objectives has to be considered as nonlinear. Following mathematical logic in the Full Multiplicative Form multiplication and division are harmoniously linked to each other, like addition and subtraction in the ratio system.

MULTIMOORA is a popular method to assess many multiple objectives problems in many fields. MULTIMOORA method has been used in the implementation of EU energy policy priorities in the Baltic Sea Region (Siksnelyte, *et al.*, 2019). Also, MULTIMOORA has been used in calculation of semi-human development index (Omrani, *et al.*, 2020), robot evaluation and selection (Liu, *et al.*, 2019), innovative ability of universities (Dong, *et al.*, 2019) assessment of progress towards “Europe 2020” strategy targets (Fedajev, *et al.*, 2020), financial system sustainability assessment model creation (Stankevičienė, & Nikanorova, 2019).

Another MCDM method TOPSIS, as well as MULTIMOORA method, can solve multi objective problems, which include different units of measurement. TOPSIS method finds out the shortest distance of the alternative to the ideal solution and ranks it as the best one (Zavadskas *et al.* 2016). TOPSIS method is widely used in many fields: assessing EURO 2020 strategy (Ture *et al.*, 2019), evaluating strategies for sustainable energy planning (Solangi *et al.*, 2019), risk assessment for sustainable engineering projects (Koulinas, *et al.*, 2019), product design concept evaluation (Tiwari *et al.*, 2019), measuring the maturity of carbon market in China (Liu *et al.*, 2019a), measurement of regional green economy sustainable development ability (Wang *et al.*, 2019).

The creation of assessment model of circular economy could be divided in several steps as represented in Table 2.10. The creation of assessment model of circular economy starts with the data collection corresponding to the settled areas of targets and strategies in the selected geographic area and period of time.

Table 2.10. Stages of assessment model creation of circular economy (source: compiled by author)

Stages	Sequence of process
Data collection	Data were collected using the following databases: – European Statistical Database – Eurostat (2020), – Organization for Economic Co-operation and Development (2020), – European Commission (2020), – United Nations database (2020).
Scope of the study	Evaluation of the countries' circular economy on the basis of economic, environmental and social dimensions and comparison of the development of the circular economy in 2014–2019 period.
Step I – selection and systematization of indicators	The indicators of the circular economy evaluation are classified into groups according to dimensions and systematized into a decision-making matrix.

Continued Table 2.10

Stages	Sequence of process	
Step II – normalization of the decision-making matrix	The decision-making matrix is normalized	The formula applies: $x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{j=1}^m x_{ij}^2}}.$
Step III – Ideally better and ideally worst alternatives are identified	The maximum and minimum values are found using the TOPSIS method.	The formula applies: $V^+ = \{V_1^+, V_2^+, \dots, V_m^+\} = \left\{ (\max_j \omega_i r_{ij}^- / i \in I_1), ((\min_j \omega_i r_{ij}^- / i \in I_2)) \right\}$ $V^- = \{V_1^-, V_2^-, \dots, V_m^-\} = \left\{ (\min_j \omega_i r_{ij}^- / i \in I_1), ((\max_j \omega_i r_{ij}^- / i \in I_2)) \right\}$
	The maximum and minimum values are found using the MULTIMOORA method.	The formula applies: $y_j^i = \sum_{i=1}^{i=g} x_{ij}^* - \sum_{i=g+1}^{i=n} x_{ij}^*$
Step IV – is determination of the best alternative	The distance of each alternative from the ideally best alternative is sought, the distance calculation in Euclidean space according to the TOPSIS method is used.	The formula applies: $D_j^* = \sqrt{\sum_{i=1}^m (\omega_i r_{ij}^- - V_i^+)^2}.$
	The values of the normalized indicators are used to find the maximum target point using the MULTIMOORA method.	The formula applies: $\min_j \left\{ \max_i \left r_i - x_{ij}^* \right \right\}.$
Step V – is the identification of the ideal worst-case alternative	The distance of each alternative from the ideally worst alternative is sought, the distance calculation in Euclidean space according to the TOPSIS method is used.	The formula applies: $D_j^- = \sqrt{\sum_{i=1}^m (\omega_i r_{ij}^- - V_i^-)^2}$
	Determining the target reporting point using the MULTIMOORA method	The formula applies: $\left s_i r_i - s_i x_{ij}^* \right $

End of Table 2.10

Stages	Sequence of process	
Step VI – calculation of relative distance of each alternative and total usefulness of the alternatives	Calculate the relative distance of each alternative from the ideal worst-case alternative according to the TOPSIS method	The formula applies: $C_j^i = \frac{D_j^-}{D_j^* + D_j^-}$
	The total usefulness of the alternative is expressed in terms of the MULTI-MOORA method, which has no unit of measurement.	The formula applies: $U_j = \prod_{i=1}^n x_{ij},$
Step VII – final ranking of alternatives	Alternatives are ranked using TOPSIS and MULTIMOORA methods from the best developing country in the context of the circular economy to the worst in the context of the developing country's circular economy.	
Step VIII – comparison of the obtained results	The determined results of the countries' circular economy development rankings are compared between the results obtained between TOPSIS and MULTIMOORA, where the reliability of the model is checked. Slightly different results indicate the reliability of the model.	

The step I of the creation of assessment model of circular economy collects the indicator of environmental, social and economic pillars (Table A1), group them according to the areas of targets and systemized into a decision-making matrix, which would be normalized as shown in Step II according to TOPSIS and MULTIMOORA methods. Systemized indicators has been equally weighted (Chen *et al.*, 2012; Chen & Yang 2011; Lin *et al.*, 2008; Su *et al.*, 2013). The attributes have the same weights, which is proposed in some studies, as the characteristics of experts should be examined which might result in poor accuracy, especially for the situation that the number of alternatives and attributes is extremely large. Equal criteria weights are still the most popular in weighting methods. According to the Step III the ideally better and ideally worst alternatives are identified using TOPSIS and MULTIMOORA methods and the best alternative is being determined by step IV. Step V calculates the ideal worst-case alternative which is used by TOPSIS and MULTIMOORA methods to finalize the ranking of alternatives. Step VI calculates the relative distance of each alternative from the ideal worst-case alternative according to the TOPSIS method and the total usefulness of the alternative is expressed in terms of the MULTI-MOORA method, which has no unit of measurement. The final ranking of the alternatives is represented in Step VII using TOPSIS and MULTIMOORA methods from the

best developing country in the context of the circular economy to the worst in the context of the developing country's circular economy. The reliability of the model which is represented in Step VIII is being checked by comparison of TOPSIS and MULTIMOORA results. In the case of huge discrepancies there is a need to return to the step I and check the accurateness of the indicators selection.

2.7. Conclusions of the Chapter 2

1. The assessment model of circular economy would be based on the economic, environmental and social pillars, which would comply with sustainable well-being approach which would help to analyse circular economy as a whole economy with identification of the issues in its development.
2. The strategy for selection of environmental indicators has been proposed based on EU 10R strategy for circular economy implementation. The indicators are systemized and grouped based on area of targets of environmental pillar of circular economy such as waste management, air pollution and CO₂ emissions, energy, material management.
3. The strategy for selection of economic indicators has been introduced based on 6E strategy proposed by the author based on literature analysis aligned with sustainable well-being. The indicators are systemized and grouped based on area of targets of economic pillar of circular economy such as macroeconomics, industry, green investment, green fiscal policy and technological development.
4. The strategy for selection of social indicators has been introduced based on 6S strategy proposed by the author based on literature analysis aligned with sustainable well-being. The indicators are systemized and grouped based on area of targets of social pillar of circular economy which are health, social justice, healthy ageing, life satisfaction, education and science, financial and environmental wealth.
5. MCDM methods TOPSIS and MULTIMOORA are described as applicable for accessing circular economy and used to evaluate a complex criterion by giving a possibility to systemize, analyze and group indicators with different units of measurement, that have maximizing or minimizing values. The model would let to evaluate circular economy in the selected geographical area and provide analytical insights about each component of circular economy. The model would let to evaluate the development of circular economy over the time and compare the evaluation of different countries or regions.

Empirical approbation on Circular Economy assessment in Baltic Sea Region in the context of Sustainable Well-Being

This Chapter presents an approbation of circular economy assessment model in the context of sustainable well-being applied to the case of Baltic Sea Region. The overview presented with the calculation of circular economy and its components: environmental, social and economic pillars. The model is applied following the sequence of steps provided in the previous chapters. The model has been applied to Baltic Sea Region, however can be applied to any European Union or other geographic area, country or region. The model would evaluate the development of circular economy in the region and areas which need the improvement.

The findings of Chapter 3 have been published in scientific papers (Stankevičienė & Nikanorova 2017; Stankevičienė *et al.*, 2020; Nikanorova *et al.*, 2020; Nikanorova & Stankevičienė, 2020; Stankevičienė & Nikanorova 2020).

3.1. Development of Circular Economy in the Baltic Sea Region

Baltic Sea Region was represented by European Council in 2009 (European Commission 2009) by the framework, according to which there is implemented a strategy for improving environmental condition, transport and energy interconnections as well as facilitating the development of competitive markets across borders and common networks for research and innovation. The European Union Strategy for the Baltic Sea Region (EUSBSR) is the first macro-regional strategy in Europe. It aims at reinforcing cooperation within this large region in order to face several challenges by working together as well as promoting a more balanced development in the area. The aim of the strategy is to bring together the initiatives in different sectors (growth, sustainable development etc.) as well as promoting cooperation between stakeholders in Baltic Sea Region. Moreover, it aims to create joint projects and processes regarding the saving of Baltic Sea by maintaining clear water in the sea, rich and healthy wildlife, clean and safe shipping; connecting the Region by improving transport conditions, energy markets, cooperation in fighting cross-border crime; and increasing prosperity by creating the single market. This in effect, will contribute to the implementation of EUROPE 2020 Strategy (EC 2019, EC 2017), improving global competitiveness of the Baltic Sea Region and solving issues regarding climate change. The Strategy also promotes flagships in the Baltic Sea Region. These flagships have a macro-regional impact and start from joint initiatives involving partnership from different countries. Also, EUSBSR helps to promote a sustainable development of the region. The EU member states involved in the EUSBSR are Sweden, Denmark, Estonia, Finland, Germany, Latvia, Lithuania and Poland.

Data was collected using the following databases: European Statistical Database – Eurostat (2014–2019), United Nation database (2014–2019), Organization for Economic Co-Operation and development (2014–2019), European Commission (2014–2019).

3.2. Assessment of Environmental dimension of Circular Economy

The environmental dimension has been assessed according to the sequence of the steps represented in the Chapter 2 using indicators determined by the area of targets of Environmental dimension and EU strategies (10R).

Baltic Sea Region countries were analyzed and evaluated their Environmental welfare in the context of circular economy using MULTIMOORA and TOPSIS

methods in the period of 2014–2019: Sweden, Denmark, Estonia, Finland, Germany, Latvia, Lithuania and Poland. According to MULTIMOORA results in 2014 (Fig. 3.1), the highest results had Sweden (rank 1), Denmark (rank 2) and Finland, Germany, Latvia (rank 3) got the same evaluation results and places in the third position. Lithuania (rank 6) and Poland (rank 7) are places on fourth and fifth position and Estonia (rank 8) takes the last place in the ranking. According to TOPSIS results in 2014, the highest results had Sweden (0.587), Germany (0.583) and Denmark (0.563). Finland (0.488), Lithuania (0.423) and Latvia (0.405) places in the middle of the rating. Estonia (0.403) is placed on the seventh position out of eight countries, while Poland (0.305) takes the last place in the ranking. To compare to MULTIMOORA results, Sweden ranked as a country with the best environmental welfare. TOPSIS places Denmark on the third place comparing to MULTIMOORA results, however the numerical value does not have a big difference. However, the ranking group from 1–3 ranking places are concordant by both methods. 4–6 ranking places including Finland, Lithuania, Latvia are in concordance with both methods. Estonia has been ranked the country with the weakest environmental welfare according to MULTIMOORA method, however TOPSIS method placed Estonia on the seventh position and Poland on the eight. Both methods agree that Poland and Estonia are countries with the weakest environmental welfare in 2014.

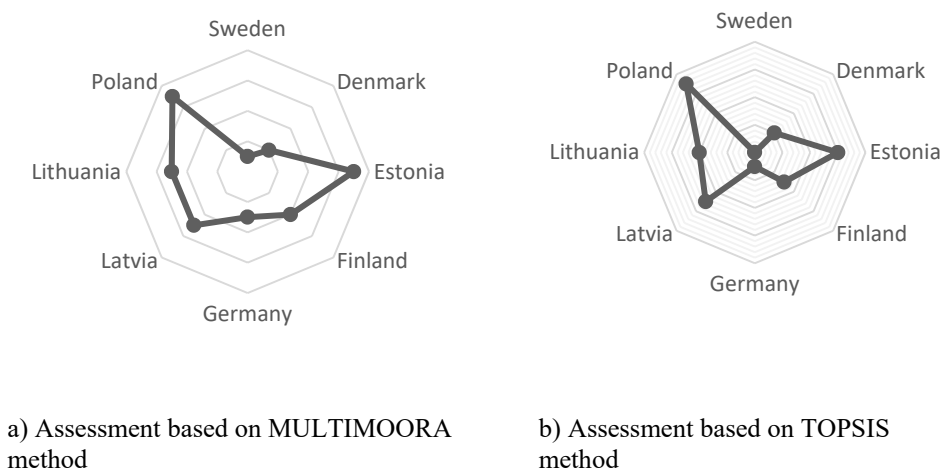


Fig. 3.1. Environmental pillar evaluation of Baltic Sea Region in 2014
(source: compiled by author)

According to MULTIMOORA results in 2015 (Fig. 3.2), the highest results had Sweden (rank 1), Denmark (rank 2) and Germany (rank 3). Finland and Latvia

both ranked 4 and Lithuania (rank 6) what holds these countries in the middle of ranking. Poland (rank 7) and Estonia (rank 8) take the last places in the ranking. According to TOPSIS results in 2015, the highest results had Germany (0.591), Sweden (0.570) and Denmark (0.539). Finland (0.489), Lithuania (0.410) and Estonia (0.401) places in the middle of the rating. Latvia (0.397) is placed on the seventh position out of eight countries, while Poland (0.311) takes the last place in the ranking. The ranking group from 1–3 ranking places are concordant by both methods, however, to compare to MULTIMOORA method results, Sweden which is ranked as first takes the second position according to TOPSIS method. Both methods agree that Poland and Estonia are countries with the weakest environmental welfare in 2015, the same as in 2014.

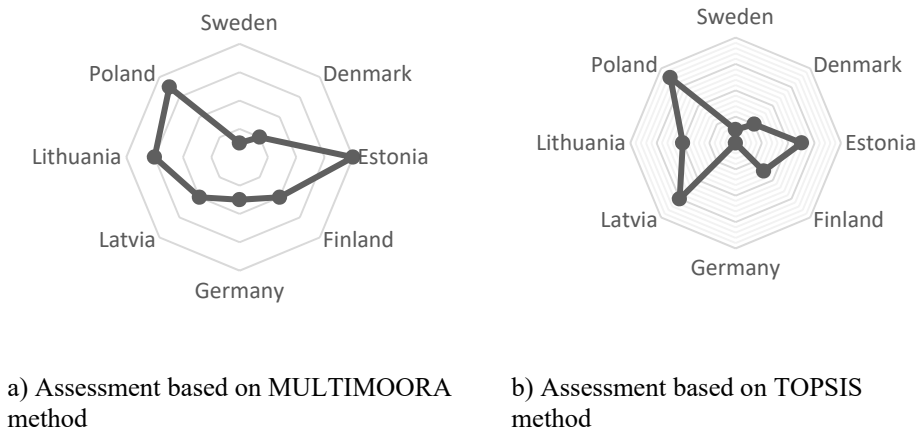
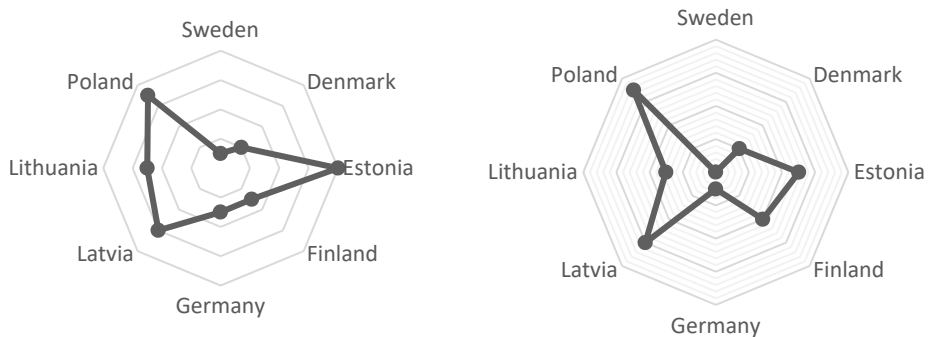


Fig. 3.2. Environmental pillar evaluation of Baltic Sea Region in 2015
(source: compiled by author)

According to MULTIMOORA results in 2016 (Fig. 3.3), the highest results had Sweden (rank 1), Denmark (rank 2) and Germany with Finland (rank 3). Lithuania (rank 5) and Latvia (rank 6) hold their positions in the middle of ranking. Poland (rank 7) and Estonia (rank 8) take the last places in the ranking. According to TOPSIS results in 2016, the highest results had Sweden (0.611), Germany (0.575) and Denmark (0.524). Lithuania (0.496), Finland (0.472), and Estonia (0.434) place their positions in the middle of the rating. Latvia (0.420) is placed on the seventh position out of eight countries, while Poland (0.307) takes the last place in the ranking. The ranking group from 1–3 ranking places are concordant by both methods and Sweden is ranked the first by both methods. Both methods agree as well that Latvia, Poland and Estonia are countries with the weakest environmental welfare in 2016.



a) Assessment based on MULTIMOORA method b) Assessment based on TOPSIS method

Fig. 3.3. Environmental pillar evaluation of Baltic Sea Region in 2016
(source: made by author)

According to MULTIMOORA results in 2017 (Fig. 3.4), the highest results had Denmark (rank 1), Sweden (rank 2) and Latvia (rank 3). Latvia, to compare to 2016, has the biggest shift towards the leading positions (from rank 6 to rank 3) and overcomes Germany (rank 4). Finland (rank 5) and Lithuania (rank 6) hold their positions in the middle of ranking. Poland (rank 7) and Estonia (rank 8) take the last places in the ranking. According to TOPSIS results in 2017, the highest results had Germany (0.578), Sweden (0.570) and Denmark (0.547). The difference in the results of Sweden and Germany is such a minimum (0.008) that it can be said, that they both take the highest place in ranking using TOPSIS method in 2017. Finland (0.486), Lithuania (0.461), and Estonia (0.430) place their positions in the middle of the rating. Latvia (0.428) is placed on the seventh position out of eight countries, while Poland (0.307) takes the last place in the ranking. The ranking group from 1–3 ranking places has difference regarding to Latvia results. According to MULTIMOORA results Latvia jumped by three ranking positions on the top, while according to TOPSIS method Latvia remains on the same position as in previous year – on the seventh position out of eight countries. This difference comes from the differences in the calculations used by the methods and the improvement of the country in Environmental sector. According to the indicators collected – Latvia increased the results of municipal waste and e-waste recycling. Both methods agree that Poland and Estonia are countries with the weakest Environmental welfare and are in the group of 6–8 ranked countries in 2017.

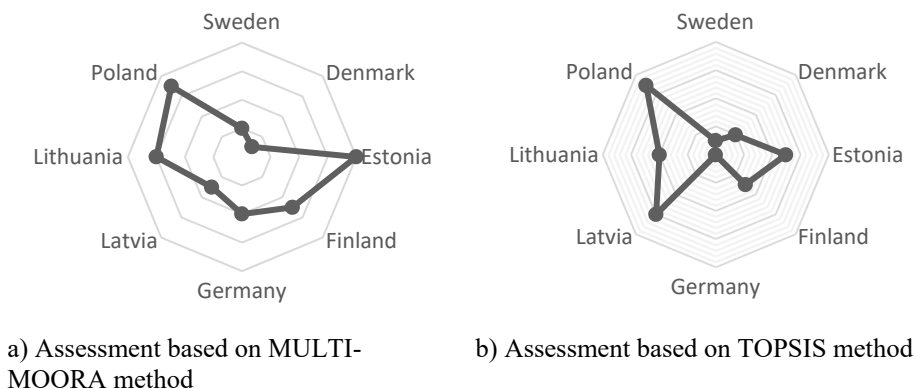


Fig. 3.4. Environmental pillar evaluation of Baltic Sea Region in 2017
(source: compiled by author)

According to MULTIMOORA results in 2018 (Fig. 3.5), the highest results had Denmark (rank 1), Sweden (rank 2) and Germany with Latvia (rank 3). Finland (rank 5) and Lithuania (rank 6) what holds these countries in the middle of ranking. Poland (rank 7) and Estonia (rank 8) take the last places in the ranking.

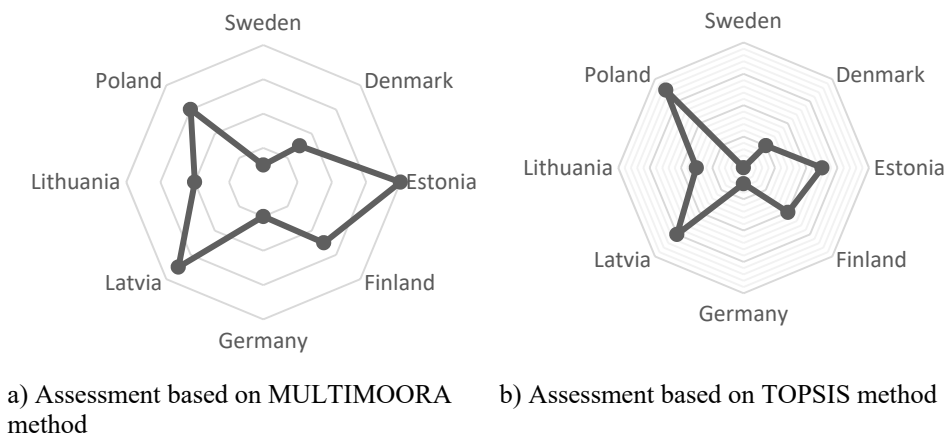


Fig. 3.5. Environmental pillar evaluation of Baltic Sea Region in 2018
(source: compiled by author)

According to TOPSIS results in 2018, the highest results had Sweden (0.604), Germany (0.577) and Denmark (0.529). Lithuania (0.466), Finland (0.460) and Estonia (0.416) places in the middle of the rating. Latvia (0.409) is

placed on the seventh position out of eight countries, while Poland (0.291) takes the last place in the ranking. The ranking group from 1–3 ranking places are concordant by both methods, however, to compare to MULTIMOORA method results, Latvia remains on the third ranking place as in 2017. According to both methods, Finland and Lithuania are being placed in the middle of the ranking. Both methods agree that Poland and Estonia are countries with the weakest environmental welfare and are in the group of 6–8 ranked countries in 2018.

According to MULTIMOORA results in 2019 (Fig. 3.6), the highest results had Denmark (rank 1), Sweden (rank 2) and Germany (rank 3). Latvia (rank 4), Finland (rank 5) and Lithuania (rank 6) what holds these countries in the middle of ranking. Poland (rank 7) and Estonia (rank 8) take the last places in the ranking. According to TOPSIS results in 2019, the highest results had Sweden (0.598), Germany (0.581) and Denmark (0.531). Lithuania (0.477), Finland (0.466) and Estonia (0.420) places in the middle of the rating. Latvia (0.399) is placed on the seventh position out of eight countries, while Poland (0.332) takes the last place in the ranking. The ranking group from 1–3 ranking places are concordant by both methods. According to both methods, Finland and Lithuania are being placed in the middle of the ranking and are in the group of 4–6 ranking. Both methods agree that Poland and Estonia are countries with the weakest environmental welfare and are in the group of 6–8 ranked countries in 2019.

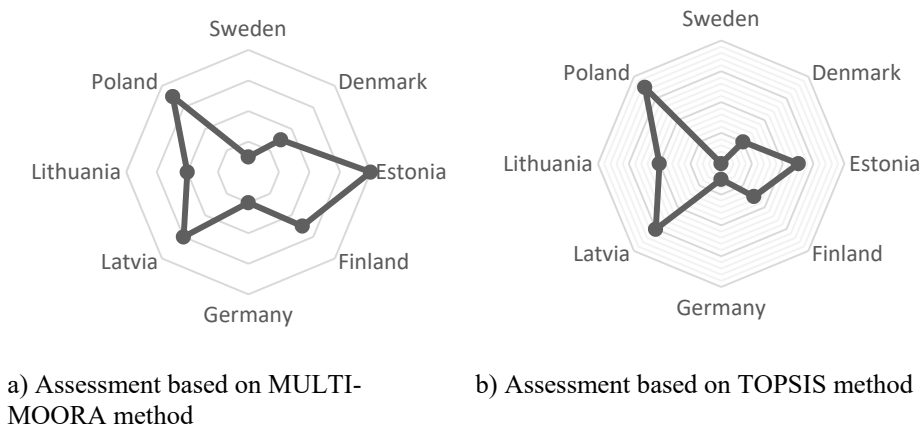


Fig. 3.6. Environmental pillar evaluation of Baltic Sea Region in 2019
(source: compiled by author)

The development of environmental pillar of circular economy from 2014 to 2019 year according to MULTIMOORA method is represented in Figure 3.7. Sweden results of environmental welfare have decreased from 2014 to 2019 year,

even Denmark overtook the leading position of Sweden in 2018–2019 years. Otherwise, Denmark improved the results of Environmental welfare and could overcome Sweden. Estonia is the only one country which remains on the same environmental welfare during 2014–2019 and takes weakest position according to MULTIMOORA results. Germany, Latvia and Poland did not make any improvements in their results of environmental welfare from 2014 to 2019 year. Finland's result decreased over the time, while Lithuania has improved its result of environmental welfare by 2019. Finland dropped down from third ranking point in 2014 to fifth ranking point in 2019. Lithuania did not make the shift in the ranking, however it improved its personal result.

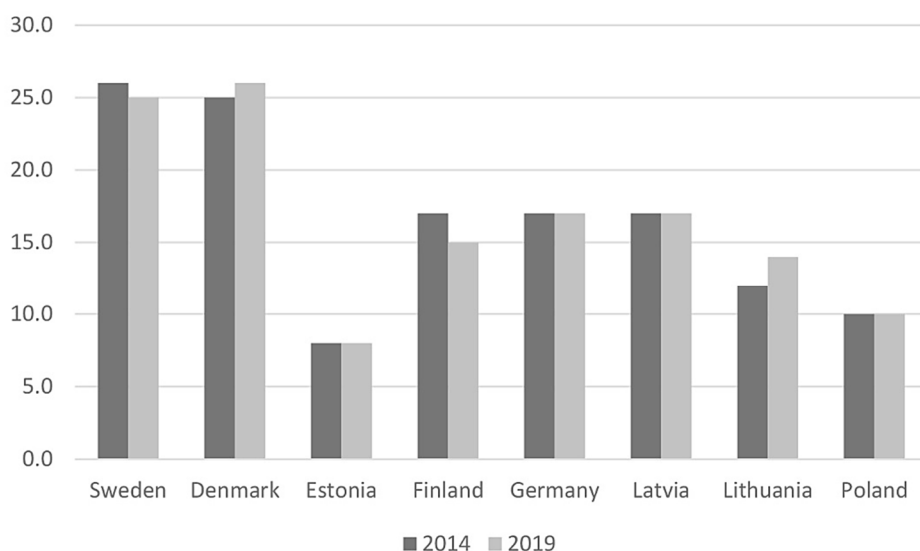


Fig. 3.7. Development of environmental pillar in Baltic Sea Region from 2014 to 2019 represented by MULTIMOORA method (source: compiled by author)

The development of environmental pillar of circular economy from 2014 to 2019 year according to TOPSIS method is represented in Figure 3.8. Sweden results of environmental welfare have decreased from 2014 to 2019 year, the same decrease in the results to compare to the development of MULTIMOORA method results of Sweden. Denmark has decreased the result according to the development of the results by TOPSIS method, however, to compare to MULTIMOORA method results, Denmark improved the results of environmental welfare. Estonia, Germany, Latvia and Poland made slightly differences in their results of Environmental welfare from 2014 to 2019 year. To compare to the development of

MULTIMOORA method results, these countries as well did not make a big difference in the results from 2014 to 2019 year. Finland's result decreased over the time, while Lithuania has improved its result of environmental welfare by 2019, what is proved by MULTIMOORA results development over the same period.

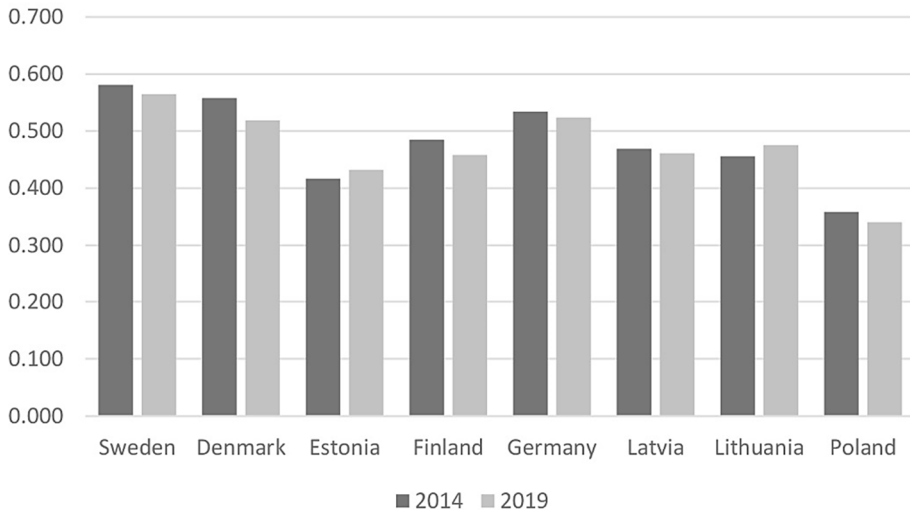


Fig. 3.8. Development of environmental pillar in Baltic Sea Region from 2014 to 2019 year represented by TOPSIS method (source: compiled by author)

Baltic Sea Region	MULTIMORA method		TOPSIS method	
	2014	2019	2014	2019
Sweden	▲ 1	▲ 2	▲ 1	▲ 1
Denmark	▲ 2	▲ 1	▲ 2	▲ 3
Estonia	▼ 8	▼ 8	▼ 7	▼ 7
Finland	▲ 3	▲ 5	▲ 4	▼ 6
Germany	▲ 3	▲ 3	▲ 3	▲ 2
Latvia	▲ 3	▲ 3	▲ 5	▲ 5
Lithuania	▼ 6	▼ 6	▼ 6	▲ 4
Poland	▼ 7	▼ 7	▼ 8	▼ 8

Fig. 3.9. Development of environmental pillar of circular economy assessed using MULTIMOORA and TOPSIS methods in Baltic Sea Region from 2014 to 2019 year (source: compiled by author)

The development over the time of environmental pillar of Circular Economy is presented in Figure 3.9. The figure shows the decrease or increase of the results from 2014 to 2019 year by method.

The figure shows the decrease or increase of the results of environmental pillar assessment the development over the time of environmental pillar of Circular Economy is presented in Figure 3.9. The figure shows the decrease or increase of the results from 2014 to 2019 year by method.

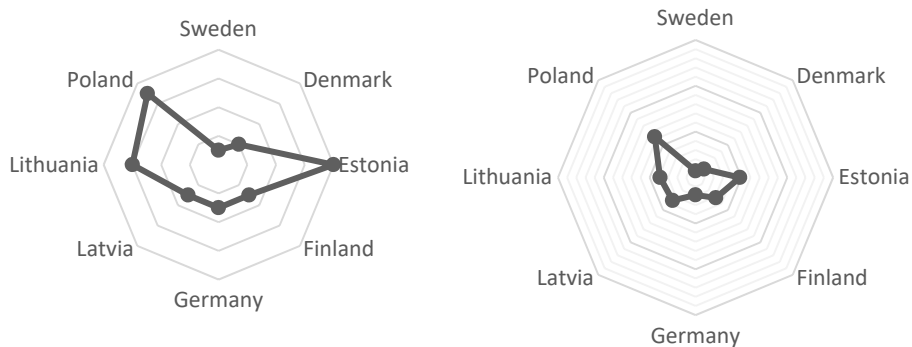
by method. According to the Figure 3.9, Estonia, Lithuania and Poland did not make a significant improve according to MULTIMOORA and TOPSIS methods, while Sweden, Germany and Denmark ensures leading positions in the ranking.

3.3. Assessment of Economic dimension of Circular Economy

The economic dimension has been assessed according to the sequence of the steps represented in the Chapter 2 using indicators determined by the area of targets of Economic dimension and strategies (6E).

According to MULTIMOORA results in 2014 (Fig. 3.10), the highest results had Sweden (rank 1), Denmark (rank 2) and Finland, Germany, Latvia (rank 3) got the same evaluation results and places in the third position. Lithuania (rank 6) and Poland (rank 7) are places on fourth and fifth position and Estonia (rank 8) takes the last place in the ranking. According to TOPSIS results in 2014, the highest results had Sweden (0.581), Denmark (0.558) and Germany (rank 0.534). Finland (0.485), Latvia (0.469) and Lithuania (rank 0.455) places in the middle of the rating. Estonia (0.417) is placed on the seventh position out of eight countries, while Poland (0.359) takes the last place in the ranking.

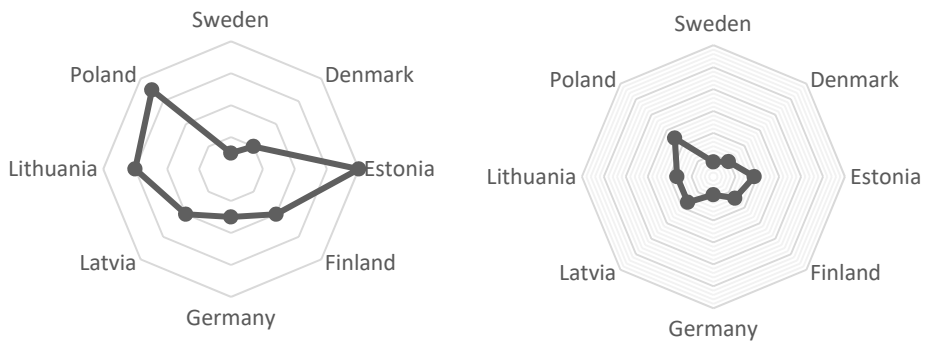
To compare to MULTIMOORA results, Sweden ranked as a country with the best Economic welfare. The ranking group from 1–3 ranking places are concordant by both methods. Estonia has been ranked the country with the weakest economic welfare according to MULTIMOORA method, however TOPSIS method placed Estonia on the seventh position and Poland on the eight. Both methods agree that Poland and Estonia are countries with the weakest economic welfare in 2014.



a) Assessment based on MULTIMOORA method b) Assessment based on TOPSIS method

Fig. 3.10. Economic pillar evaluation of Baltic Sea Region in 2014
(source: compiled by author)

According to MULTIMOORA results in 2015 (Fig. 3.11), the highest results had Sweden (rank 1), Denmark (rank 2) Germany (rank 3). Latvia and Finland ranked fourth, Lithuania (rank 6) are placed in the middle of the ranking by MULTIMOORA method. Poland (rank 7) places on seventh and Estonia (rank 8) places on eighth position what is the last place in the ranking. According to TOPSIS results in 2015, the highest results had Sweden (0.581), Denmark (0.558) and Germany (rank 0.534). Finland (0.485), Latvia (0.469) and Lithuania (rank 0.455) places in the middle of the rating. Estonia (0.417) is placed on the seventh position out of eight countries, while Poland (0.359) takes the last place in the ranking. To compare to MULTIMOORA results, Sweden ranked as a country with the best economic welfare. The ranking group from 1–3 ranking places are concordant by both methods. Estonia has been ranked the country with the weakest economic welfare according to MULTIMOORA method.



a) Assessment based on MULTIMOORA method b) Assessment based on TOPSIS method

Fig. 3.11. Economic pillar evaluation of Baltic Sea Region in 2015
(source: compiled by author)

According to MULTIMOORA results in 2016 (Fig. 3.12), the highest results had Sweden (rank 1), Denmark (rank 2), Finland (rank 3) and Germany (rank 3). Lithuania (rank 5) are placed in the middle of the ranking by MULTIMOORA method. Poland (rank 7) places on seventh and Estonia (rank 8) places on eighth position what is the last place in the ranking. According to TOPSIS results in 2016, the highest results had Sweden (0.578), Denmark (0.531) and Germany (rank 0.524). Lithuania (0.508), Finland (0.472) and Estonia (0.469) place in the middle of the rating. Latvia (0.447) is placed on the seventh position out of eight countries, while Poland (0.369) takes the last place in the ranking. To compare to MULTIMOORA results, Sweden ranked as a country with the best economic welfare. The ranking group from 1–3 ranking places are concordant by both methods. Poland has been ranked as the country with the weakest economic welfare according to both methods.

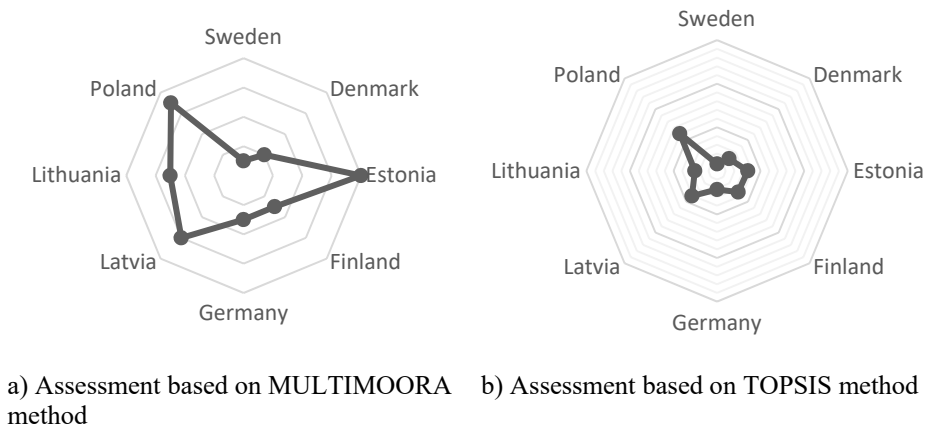
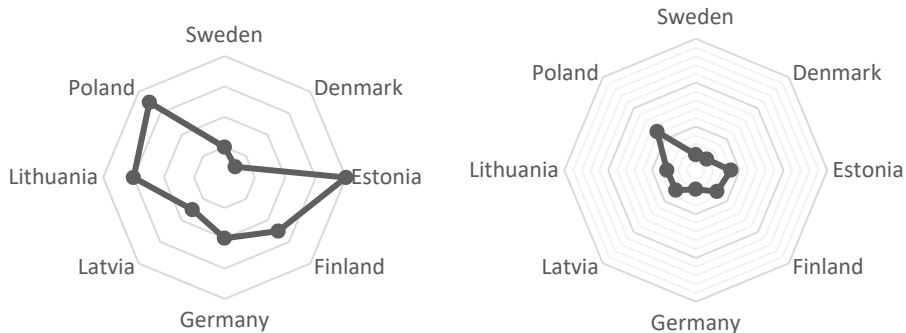


Fig. 3.12. Economic pillar evaluation of Baltic Sea Region in 2016
(source: compiled by author)

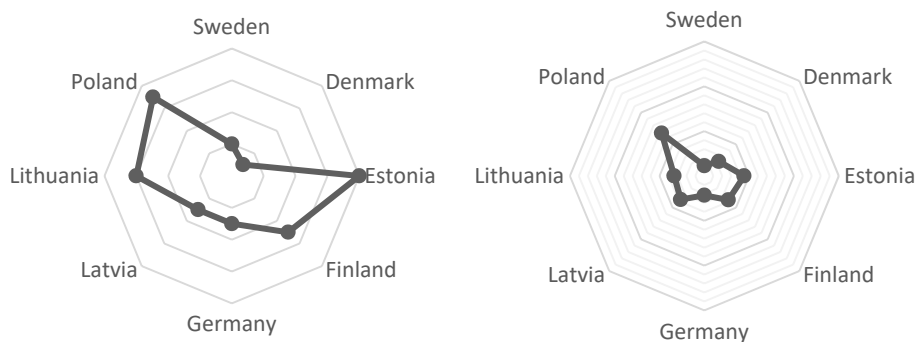
According to MULTIMOORA results in 2017 (Fig. 3.13), the highest results had Sweden (rank 1), Denmark (rank 2), Finland (rank 3) and Germany (rank 3). Lithuania (rank 5) are placed in the middle of the ranking by MULTIMOORA method. Poland (rank 7) places on seventh and Estonia (rank 8) places on eighth position what is the last place in the ranking. According to TOPSIS results in 2016, the highest results had Sweden (0.578), Denmark (0.531) and Germany (rank 0.524). Lithuania (0.508), Finland (0.472) and Estonia (0.469) place in the middle of the rating. Latvia (0.447) is placed on the seventh position out of eight countries, while Poland (0.369) takes the last place in the ranking. To compare to MULTIMOORA results, Sweden ranked as a country with the best economic welfare. The ranking group from 1-3 ranking places are concordant by both methods. Poland has been ranked as the country with the weakest economic welfare according to both methods.



a) Assessment based on MULTIMOORA method b) Assessment based on TOPSIS method

Fig. 3.13. Economic pillar evaluation of Baltic Sea Region in 2017
(source: compiled by author)

According to MULTIMOORA results in 2018 (Fig. 3.14), the highest results had, Denmark (rank 1), Sweden (rank 2), Latvia (rank 3) and Germany (rank 3). Finland (rank 5), Lithuania (rank 6) are placed in the middle of the ranking by MULTIMOORA method. Poland (rank 7) places on seventh and Estonia (rank 8) places on eighth position what is the last place in the ranking.



a) Assessment based on MULTIMOORA method b) Assessment based on TOPSIS method

Fig. 3.14. Economic pillar evaluation of Baltic Sea Region in 2018
(source: compiled by author)

According to TOPSIS results in 2018, the highest results had Sweden (0.565), Germany (rank 0.524) and Denmark (0.519). Lithuania (0.475), Finland (0.458) and Estonia (0.432) place in the middle of the rating. Latvia (0.461) is placed on the seventh position out of eight countries, while Poland (0.340) takes the last place in the ranking. The ranking group from 1-3 ranking places are concordant by both methods. Latvia has been assessed differently by TOPSIS method and placed on seventh place, while MULTIMOORA method has placed Latvia on the third place in the ranking.

According to MULTIMOORA results in 2019 (Fig. 3.15), the highest results had, Denmark (rank 1), Sweden (rank 2), and Germany (rank 3). Latvia (rank 4), Finland (rank 5), Lithuania (rank 6) are placed in the middle of the ranking by MULTIMOORA method. Poland (rank 7) places on seventh and Estonia (rank 8) places on eighth position what is the last place in the ranking. According to TOPSIS results in 2019, the highest results had Sweden (0.573), Germany (rank 0.551) and Denmark (0.513). Lithuania (0.455), Finland (0.428) and Estonia (0.422) place in the middle of the rating. Latvia (0.401) is placed on the seventh position out of eight countries, while Poland (0.356) takes the last place in the ranking. The ranking group from 1-3 ranking places are concordant by both methods. Poland has been ranked as the country with the weakest Economic welfare according to both methods.

The development of economic pillar of circular economy in the period of 2014–2019 years according to MULTIMOORA method is represented in Figure 3.16. Sweden results of economic welfare have increased from 2014 to 2019 year, mostly than any other country. Denmark and Lithuania improved the results of economic welfare slightly. Estonia, Germany, Latvia and Poland are the countries which remain on the same Economic welfare level from 2014 to 2019 year according to MULTIMOORA method results. Finland's result decreased over the time.

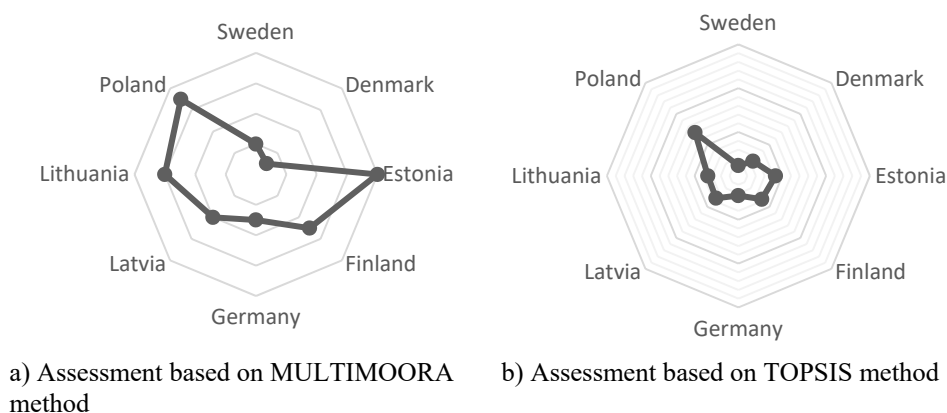


Fig. 3.15. Economic pillar evaluation of Baltic Sea Region in 2019
(source: compiled by author)

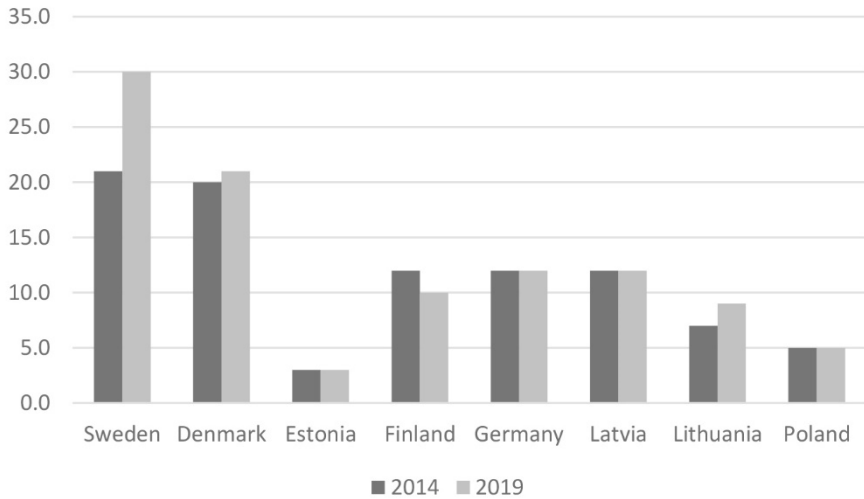


Fig. 3.16. Development of economic pillar in Baltic Sea Region from 2014 to 2019 year represented by MULTIMOORA method (source: compiled by author)

The development of economic pillar of circular economy from 2014 to 2019 year according to TOPSIS method is represented in Figure 3.17.

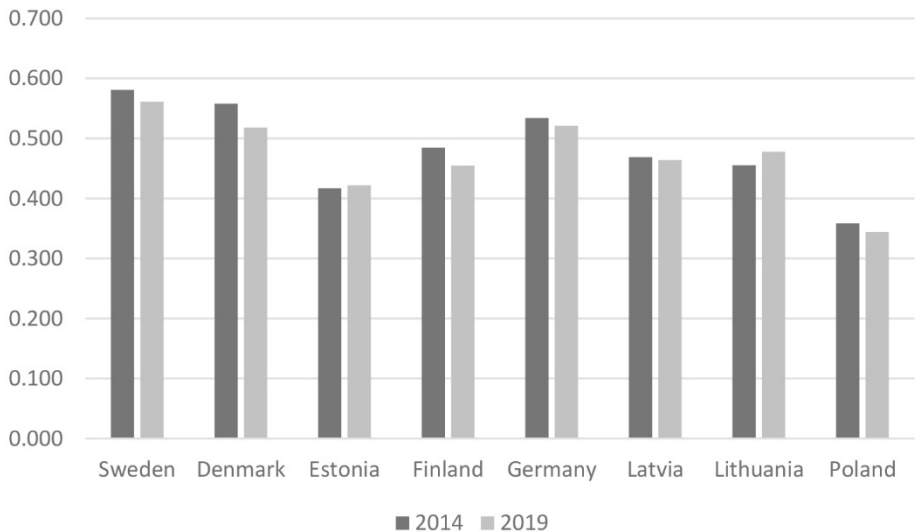


Fig. 3.17. Development of economic pillar in baltic sea region from 2014 to 2019 year represented by TOPSIS method (source: compiled by author)

In general, there is no significant changes in the result of Economic welfare and countries keep the same level of economic welfare according to TOPSIS method from 2014 to 2019 year.

Baltic Sea Region	MULTIMOORA method		TOPSIS method	
	2014	2019	2014	2019
Sweden	 1	 1	 1	 1
Denmark	 2	 2	 2	 3
Estonia	 8	 8	 7	 6
Finland	 3	 5	 4	 5
Germany	 3	 3	 3	 2
Latvia	 3	 4	 5	 7
Lithuania	 6	 6	 6	 4
Poland	 7	 7	 8	 8

Fig. 3.18. Development of economic pillar of circular economy assessed using MULTIMOORA and TOPSIS methods in Baltic Sea Region from 2014 to 2019 year (source: compiled by author)

The development over the time of economic pillar of circular economy is presented in Fig. 3.18. The figure shows the decrease or increase of the results from 2014 to 2019 year by method. According to the Figure 3.18, Estonia, Lithuania and Poland did not make a significant improve according to MULTIMOORA and TOPSIS methods, while Sweden, Germany and Denmark ensures leading positions in the ranking. Latvia and Finland mostly remain in the middle of ranking.

3.4. Assessment of Social dimension of Circular Economy

The social dimension has been assessed according to the sequeance of the steps represented in the Chapter 2 using indicators determined by the area of targets of Social dimension (6S).

According to MULTIMOORA results in 2014 (Fig. 3.19), the highest results had Sweden (rank 1), Germany (rank 2) and Estonia (rank 3). Finland (rank 4), Poland (rank 5) and Denmark (rank 6) are placed in the middle of the ranking.

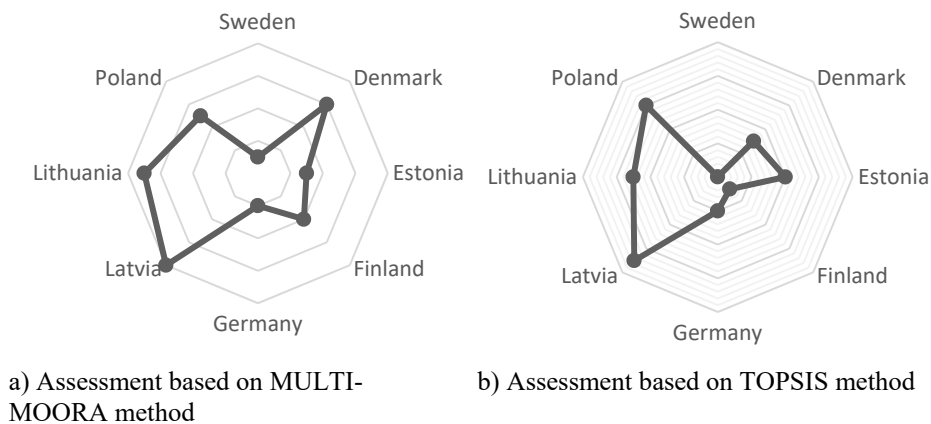


Fig. 3.19. Social pillar evaluation of Baltic Sea Region in 2014
(source: compiled by author)

Lithuania (rank 7) and Latvia (rank 8) take the last places in the ranking. According to TOPSIS results in 2014, the highest results had Sweden (0.888), Finland (0.651) and Germany (0.605). Denmark (0.601), Estonia (0.529) and Lithuania (0.444) are placed in the middle of the rating. Poland (0.388) is placed on the seventh position out of eight countries, while Latvia (0.197) takes the last place in the ranking. To compare to MULTIMOORA method results, Sweden ranked as a country with the best social welfare. MULTIMOORA method places Estonia on the third place comparing to TOPSIS method results, while TOPSIS method places Estonia in the middle of rating. Lithuania and Denmark take the middle position in the ranking by both MULTIMOORA and TOPSIS methods. Both methods agree that Latvia is a country with the weakest social welfare in 2014.

According to MULTIMOORA results in 2015 (Fig. 3.20), the highest results had Sweden (rank 1), Denmark (rank 2) and Germany (rank 3). To compare to MULTIMOORA method results in 2014, Denmark has shifted from sixth position to the second position. Estonia (rank 4), Finland (rank 5) and Poland (rank 6) are placed in the middle of the ranking. Lithuania (rank 7) and Latvia (rank 8) take the last places in the ranking. According to TOPSIS results in 2015, the highest results had Sweden (0.886), Denmark (0.693) and Finland (0.648). Germany (0.598), Estonia (0.540) and Lithuania (0.437) are placed in the middle of the rating. Poland (0.341) is placed on the seventh position out of eight countries, while Latvia (0.218) takes the last place in the ranking. To compare to MULTIMOORA results, Sweden and Denmark ranked as countries with the best social welfare. Both methods agree that Latvia is a country with the weakest social welfare in 2015, as well as in 2014.

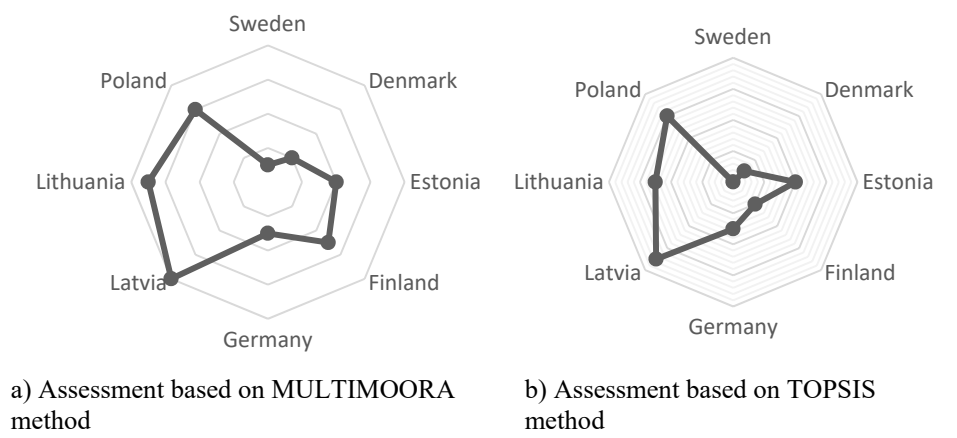


Fig. 3.20. Social pillar evaluation of Baltic Sea Region in 2015
(source: compiled by author)

According to MULTIMOORA results in 2016 (Fig. 3.21), the highest results had Sweden (rank 1), Denmark (rank 2) and Germany (rank 3). To compare to MULTIMOORA method results in 2015, same countries took the leading position in the ranking. Estonia (rank 4), Poland (rank 5) and Finland (rank 6) are placed in the middle of the ranking. Finland according to MULTIMOORA method results in 2014 shifted down from fourth position to sixth in the ranking. Lithuania (rank 7) and Latvia (rank 8) take the last places in the ranking.

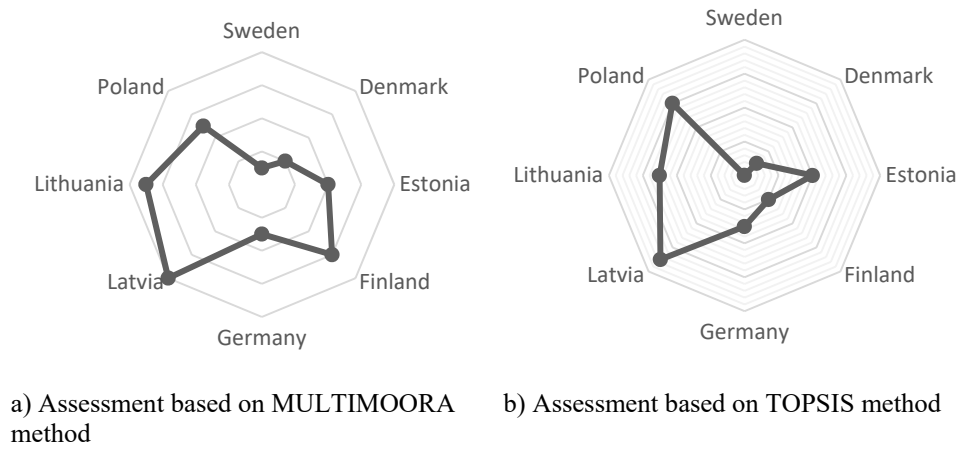


Fig. 3.21. Social pillar evaluation of Baltic Sea Region in 2016
(source: compiled by author)

According to TOPSIS results in 2016, the highest results had Sweden (0.921), Denmark (0.716) and Finland (0.628). To compare to TOPSIS method results in 2015, same countries took the leading position in the ranking in 2015. Germany (0.590), Estonia (0.504) and Lithuania (0.453) are placed in the middle of the rating. Poland (0.336) is placed on the seventh position out of eight countries, while Latvia (0.236) takes the last place in the ranking. To compare to MULTIMOORA results, Sweden and Denmark ranked as countries with the best social welfare, as in 2015. Both methods agree that Latvia is a country with the weakest social welfare in 2016, as well as in 2015–2014.

According to MULTIMOORA results in 2017 (Fig. 3.22), the highest results had Sweden (rank 1), Denmark (rank 2) and Germany (rank 3). The same countries hold the leading position in the ranking since 2015 according to MULTIMOORA method. Estonia (rank 4), and Poland with Finland (rank 5) are placed in the middle of the ranking. Poland and Finland evaluated with the same score and ranked as fifths in the ranking according to MULTIMOORA method. Lithuania (rank 7) and Latvia (rank 8) take the last places in the ranking. According to TOPSIS results in 2017, the highest results had Sweden (0.933), Denmark (0.739) and Finland (0.672). The same countries hold the leading position in the ranking since 2015 according to TOPSIS method. Germany (0.607), Estonia (0.563) and Lithuania (0.469) are placed in the middle of the rating, which hold these position since 2016. Poland (0.416) is placed on the seventh position out of eight countries, while Latvia (0.250) takes the last place in the ranking. To compare to MULTIMOORA results, Sweden and Denmark ranked as countries with the best social welfare, since 2015. Both methods agree that Latvia is a country with the weakest social welfare in 2017, as well as in 2016–2014.

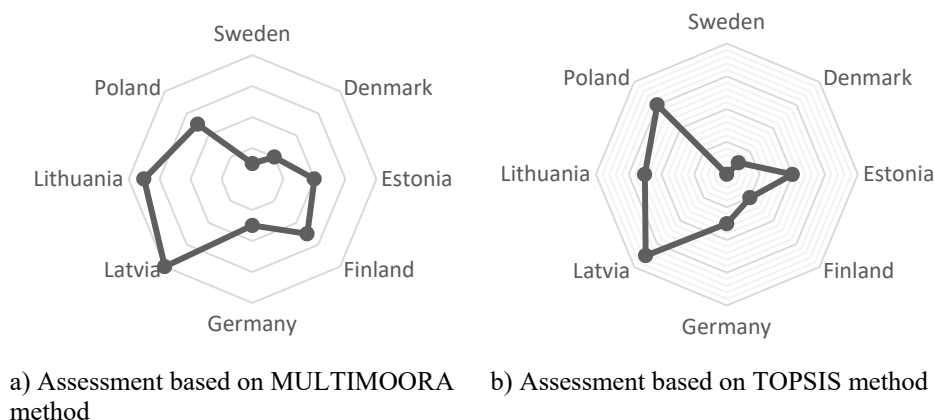


Fig. 3.22. Social pillar evaluation of Baltic Sea Region in 2017
(source: compiled by author)

According to MULTIMOORA results in 2018 (Fig. 3.23), the highest results had Sweden (rank 1), Denmark (rank 2) and Germany (rank 3). The same countries hold the leading position in the ranking since 2015 according to MULTIMOORA method. Estonia (rank 4), Finland (rank 5) and Poland (rank 6) are placed in the middle of the ranking. Lithuania (rank 7) and Latvia (rank 8) take the last places in the ranking since 2014. According to TOPSIS results in 2018, the highest results had Sweden (0.937), Denmark (0.695) and Finland (0.649). The same countries hold the leading position in the ranking since 2015 according to TOPSIS method. Germany (0.592), Estonia (0.557) and Lithuania (0.456) are placed in the middle of the rating, which hold these position since 2016. Poland (0.369) is placed on the seventh position out of eight countries, while Latvia (0.243) takes the last place in the ranking. To compare to MULTIMOORA results, Sweden and Denmark ranked as countries with the best social welfare, since 2015. Both methods agree that Latvia is a country with the weakest social welfare in 2018, as well as in 2016–2014.

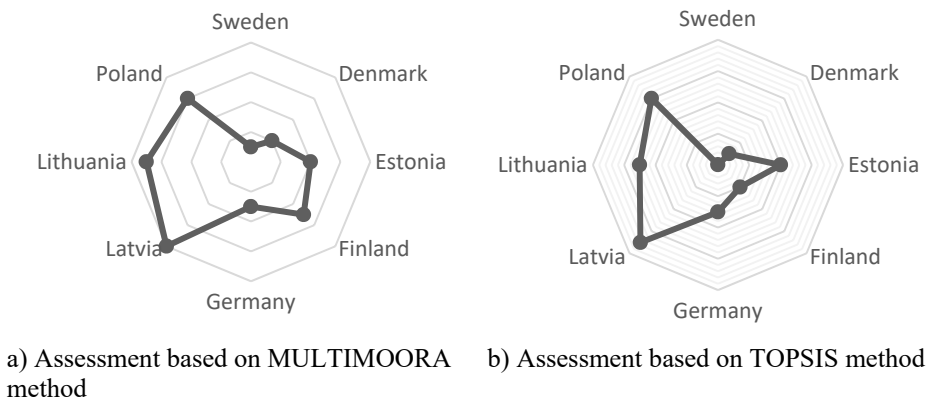


Fig. 3.23. Social pillar evaluation of Baltic Sea Region in 2018
(source: compiled by author)

According to MULTIMOORA results in 2019 (Fig. 3.24), the highest results had Sweden (rank 1), Denmark (rank 2) and Germany (rank 3). The same countries hold the leading position in the ranking since 2015 according to MULTIMOORA method. Estonia (rank 4), Finland (rank 5) and Poland (rank 6) are placed in the middle of the ranking in the same order as in 2018. Lithuania (rank 7) and Latvia (rank 8) take the last places in the ranking since 2014. According to TOPSIS results in 2019, the highest results had Sweden (0.926), Denmark (0.657) and Finland (0.629). The same countries hold the leading position in the ranking since 2015 according to TOPSIS method. Estonia (0.553), Germany (0.551) and Lithuania (0.455) are placed in the middle of the rating, which hold these position

since 2016. Poland (0.383) is placed on the seventh position out of eight countries, while Latvia (0.237) takes the last place in the ranking. To compare to MULTIMOORA results, Sweden and Denmark ranked as countries with the best social welfare, since 2015. Both methods agree that Latvia is a country with the weakest social welfare in 2019, as well as in 2014–2018.

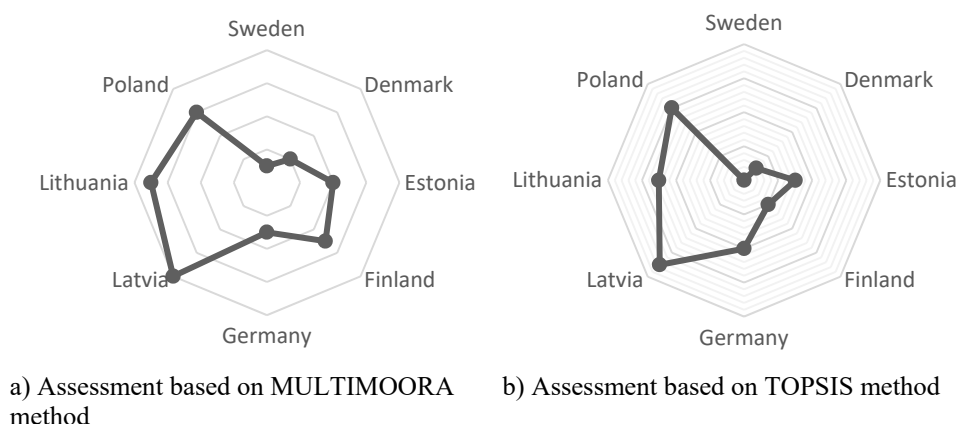


Fig. 3.24. Social pillar evaluation of Baltic Sea Region in 2019
(source: compiled by author)

The development of social pillar of circular economy in the period of 2014–2019 years according to MULTIMOORA method is represented in Figure 3.25.

Sweden results of Social welfare remained the same in the period of 2014–2019. Denmark has made a huge shift in 2015 towards the leading position in social pillar according to MULTIMOORA method. Since 2015 Denmark holds the second greatest result in Social welfare after Sweden. Estonia and Germany decreased slightly the result by insignificant shift down in social pillar. Finland and Lithuania increased the result of Social welfare in the period of 2014–2019. Latvia's and Poland's result decreased over the time much more than other countries.

The development of social pillar of circular economy in the period of 2014–2019 years according to TOPSIS method is represented in Figure 3.26. During this period of time there are no significant changes in development of Social pillar. Sweden, Estonia, Denmark and Latvia insignificantly increased the results of Social welfare from 2014 to 2019 year. Lithuania and Poland remain on the same level in this period. Finland and Germany are only two countries out of eight countries which decreased the results from 2014 to 2019 year, however the decrease in result is not significant and does not affect strongly the evaluation of social pillar.

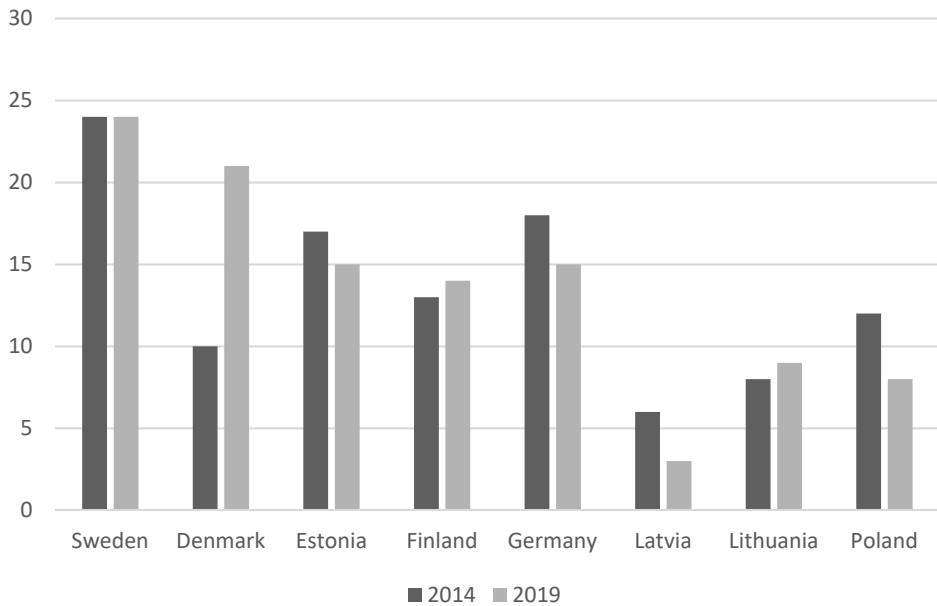


Fig. 3.25. Development of social pillar in Baltic Sea Region from 2014 to 2019 year represented by MULTIMOORA method (source: compiled by author)

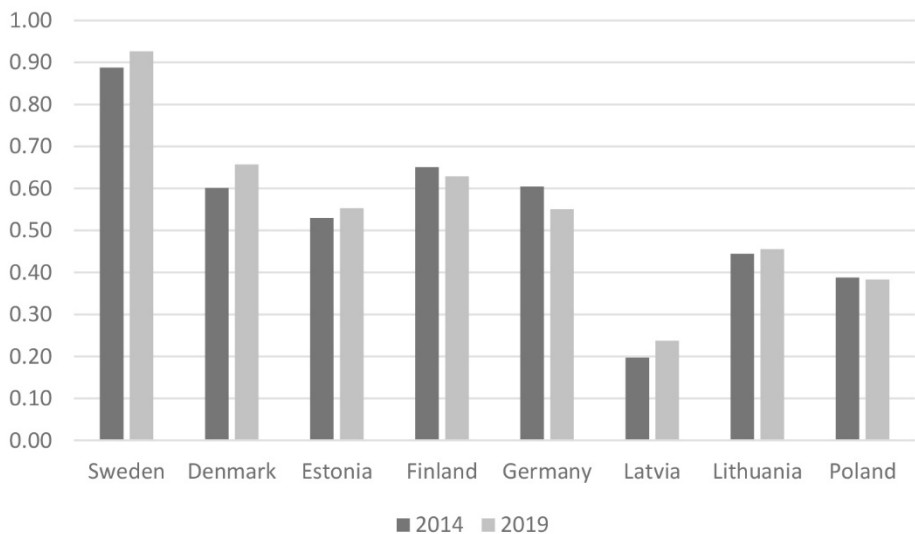


Fig. 3.26. Development of social pillar in Baltic Sea Region from 2014 to 2019 year represented by TOPSIS method (source: compiled by author)

The development over the time of social pillar of circular Economy is presented in Figure 3.27. The figure shows the decrease or increase of the results from 2014 to 2019 year by method. According to the Figure 3.27, Latvia, Lithuania and Poland did not make a significant improve according to MULTIMOORA and TOPSIS methods.

Baltic Sea Region	MULTIMOORA method		TOPSIS method	
	2014	2019	2014	2019
Sweden	 1	 1	 1	 1
Denmark	 6	 2	 4	 2
Estonia	 3	 4	 5	 4
Finland	 4	 5	 2	 3
Germany	 2	 3	 3	 5
Latvia	 8	 8	 8	 8
Lithuania	 7	 7	 6	 6
Poland	 5	 6	 7	 7

Fig. 3.27. Development of social pillar of circular economy assessed using MULTIMOORA and TOPSIS methods in Baltic Sea Region from 2014 to 2019 year (source: compiled by author)

Denmark has shifted over this period, what shows both methods: MULTIMOORA method shows the shift from sixth position to the second and TOPSIS method shows the shift from fourth place to the second. Sweden remains in the best position in the ranking by both methods. Germany decreased slightly and this decrease is shown by both methods: MULTIMOORA method from the second place to the third, and by TOPSIS method from the third position to fifth.

Overall, the results comply by both methods as represent the same tendency of social pillar assessment results.

3.5. Assessment of Circular Economy in the context of Sustainable Well-being

Environmental, social and economic dimensions interacts with each other and forms circular economy concept which can be assessed by the proposed model in Chapter 2 as a whole economy approach in Baltic Sea Region.

According to MULTIMOORA results in 2014 (Fig. 3.28), the highest results had Denmark (rank 1), Sweden (rank 2) and Finland (rank 3). Germany (rank 4),

Estonia (rank 5) and Lithuania (rank 6) take the middle position in the ranking according to MULTIMOORA method result. Latvia (rank 7) and Poland (rank 8) take the last place in the ranking. According to TOPSIS results in 2014, the highest results had Denmark (0.573), Sweden (0.527) and Finland (0.473). Germany (0.441), Poland (0.238) and Estonia (0.230) place in the middle of the rating. Lithuania (0.211) and Latvia (0.166) are placed on the seventh position out of eight countries and the last place in the ranking accordingly. However, the ranking group from 1–3 ranking places are concordant by both methods. Both methods agree that Latvia, Lithuania and Poland are countries with the weakest circular economy in 2014.

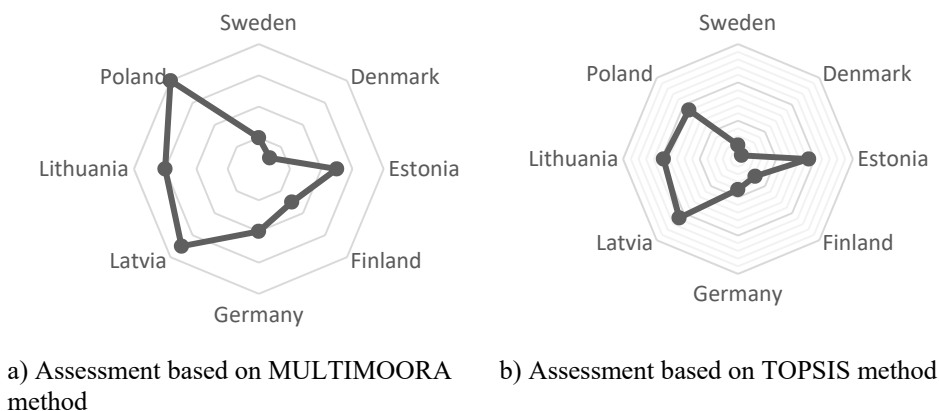


Fig. 3.28. Assessment of circular economy in Baltic Sea Region in 2014
(source: compiled by author)

According to MULTIMOORA results in 2015 (Fig. 3.29), the highest results had Denmark (rank 1), Sweden (rank 2) and Germany (rank 3). Finland (rank 4), Estonia (rank 5) and Latvia (rank 6) take the middle position in the ranking according to MULTIMOORA method result. To compare to MULTIMOORA results of 2014, Germany improved the results and shifted from the fourth rank to the third rank. Poland (rank 7) and Lithuania (rank 8) take the last place in the ranking. According to TOPSIS results in 2015, the highest results had Denmark (0.650), Sweden (0.530) and Finland (0.463). Germany (0.430), Estonia (0.283) and Lithuania (0.185) place in the middle of the rating. Latvia (0.144) and Poland (0.121) are placed on the seventh position out of eight countries and the last place in the ranking accordingly. However, the ranking group from 1–3 ranking places are concordant by both methods regarding Sweden and Denmark, but Finland was placed on the fourth rank by MULTIMOORA result. Both methods agree that Latvia, Lithuania and Poland are countries with the weakest circular economy in 2015.

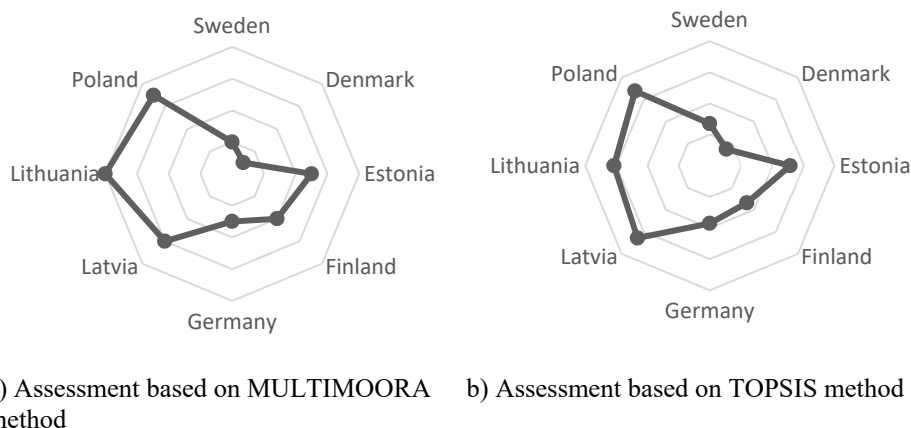


Fig. 3.29. Assessment of circular economy in Baltic Sea Region in 2015
(source: compiled by author)

According to MULTIMOORA results in 2016 (Fig. 3.30), the highest results had Sweden (rank 1), Denmark (rank 2) and Germany (rank 3). Finland (rank 4), Estonia (rank 5) and Latvia (rank 6) take the middle position in the ranking according to MULTIMOORA method result. To compare to MULTIMOORA results of 2015, Sweden improved the results and shifted from the second rank to the first position. Lithuania (rank 7) and Poland (rank 8) take the last place in the ranking.

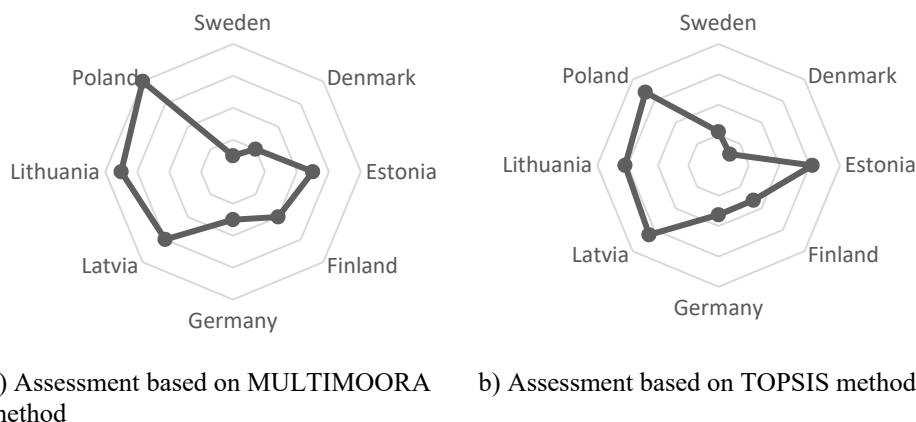


Fig. 3.30. Assessment of circular economy in Baltic Sea Region in 2016
(source: compiled by author)

According to TOPSIS results in 2016, the highest results had Denmark (0.695), Sweden (0.578) and Finland (0.475) with Germany (0.475), as evaluated by TOPSIS method by the same rank. Estonia (0.183) and Lithuania (0.179) place in the middle of the rating. Latvia (0.153) and Poland (0.118) are placed on the seventh position out of eight countries and the last place in the ranking accordingly. However, the ranking group from 1–3 ranking places are concordant by both methods. Both methods agree that Latvia, Lithuania and Poland are countries with the weakest circular economy in 2016.

According to MULTIMOORA results in 2017 (Fig. 3.31), the highest results had Sweden (rank 1), Denmark (rank 2) and Germany (rank 3) with Finland (rank 3), as Germany and Finland collected the same score by MULTIMOORA method. Estonia (rank 5) and Lithuania (rank 6) take the middle position in the ranking according to MULTIMOORA method result. Poland (rank 7) and Latvia (rank 8) take the last place in the ranking. According to MULTIMOORA results in 2016, Latvia has shifted down from sixth position to the last place in the ranking. According to TOPSIS results in 2017, the highest results had Sweden (0.598), Denmark (0.566) and Germany (0.477), Finland (0.450), Estonia (0.322) and Poland (0.249) place in the middle of the rating. Lithuania (0.211) Latvia (0.174) are placed on the seventh position out of eight countries and the last place in the ranking accordingly. However, the ranking group from 1–3 ranking places are concordant by both methods. Both methods agree that Latvia, Lithuania and Poland are countries with the weakest circular economy in 2017.

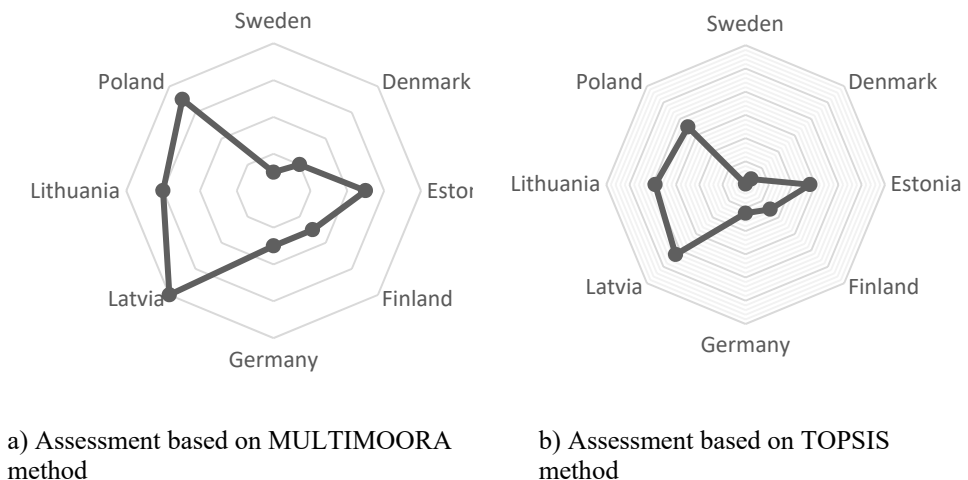


Fig. 3.31. Assessment of circular economy in Baltic Sea Region in 2017
(source: compiled by author)

According to MULTIMOORA results in 2018 (Fig. 3.32), the highest results had Sweden (rank 1), Denmark (rank 2) and Germany (rank 3). Estonia (rank 4), Finland (rank 5) and Lithuania (rank 6) take the middle position in the ranking according to MULTIMOORA method result. Latvia (rank 7) and Poland (rank 8) and take the last place in the ranking. According to TOPSIS results in 2018, the highest results had Sweden (0.631), Denmark (0.614) and Germany (0.497). Finland (0.471), Estonia (0.309) and Lithuania (0.230) place in the middle of the rating. Latvia (0.159) and Poland (0.118) are placed on the seventh position out of eight countries and the last place in the ranking accordingly. However, the ranking group from 1–3 ranking places are concordant by both methods. Both methods agree that Latvia and Poland are countries with the weakest circular economy in 2018.

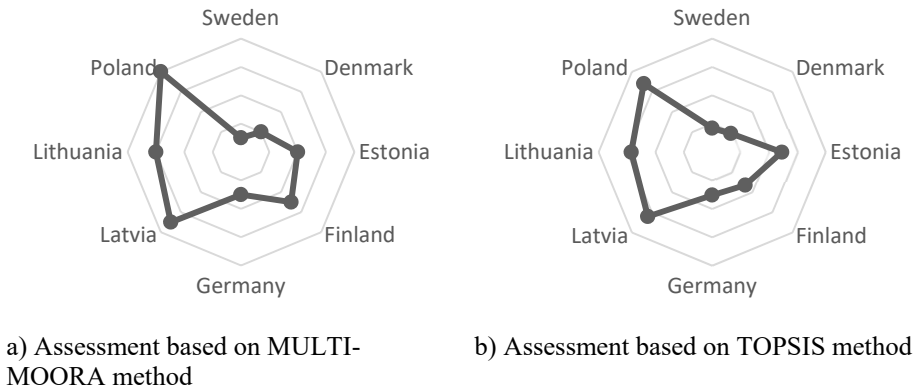


Fig. 3.32. Assessment of circular economy in Baltic Sea Region in 2018
(source: compiled by author)

According to MULTIMOORA results in 2019 (Fig. 3.33), the highest results had Sweden (rank 1), Denmark (rank 2) and Germany (rank 3). Estonia (rank 4), Finland (rank 5) and Lithuania (rank 6) take the middle position in the ranking according to MULTIMOORA method result. Also, the same results have been received using MULTIMOORA method in 2018. Poland (rank 7) and Latvia (rank 8) and take the last place in the ranking. According to TOPSIS results in 2019, the highest results had Denmark (0.688), Sweden (0.643) and Germany (0.493). Finland (0.486), Estonia (0.196) and Lithuania (0.187) place in the middle of the rating. Latvia (0.154) and Poland (0.115) are placed on the seventh position out of eight countries and the last place in the ranking accordingly. However, the ranking group from 1–3 ranking places are concordant by both methods. Both methods agree that Latvia and Poland are countries with the weakest circular economy in 2019.

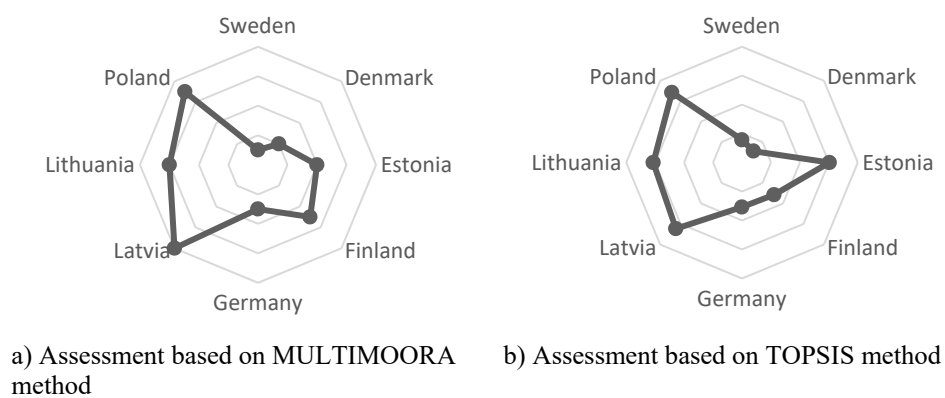


Fig. 3.33. Assessment of Circular Economy in Baltic Sea Region in 2019
(source: compiled by author)

The development of circular economy in Baltic Sea Region from 2014 to 2019 year according to MULLTIMOORA method is represented in Figure 3.34.

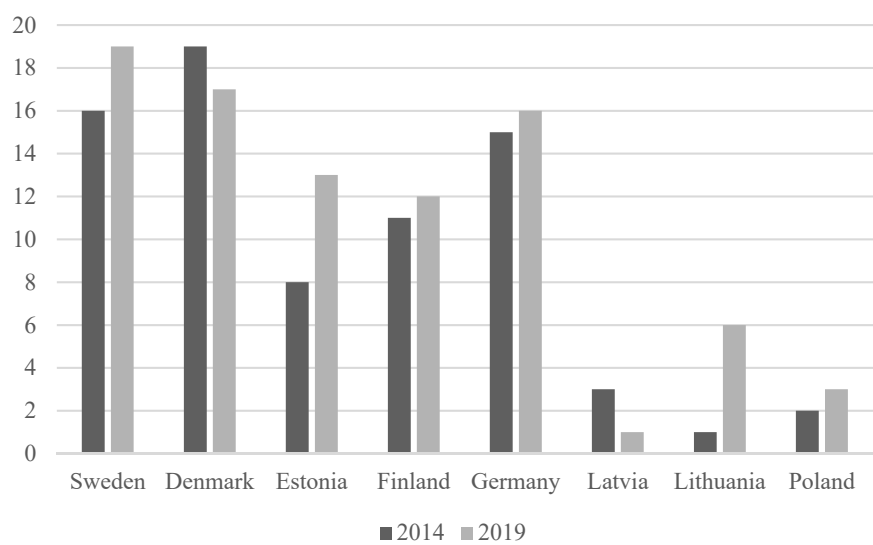


Fig. 3.34. Development of circular economy in Baltic Sea Region from 2014 to 2019 year represented by MULTIMOORA method (source: compiled by author)

Sweden results of Circular Economy have decreased from 2014 to 2019 year, however Denmark shifted down by 2019. Lithuania has made the biggest shift up with the improvement of Circular Economy by 2019. Estonia has a significant improvement as well in the result of Circular Economy assessment. Germany, Finland and Poland made some slight improvements in their results of circular economy from 2014 to 2019 year according to MULTIMOORA method. Latvia's result decreased over the time and Latvia represents the weakest circular economy among Baltic Sea Region by 2019 according to MULTIMOORA method.

The development of circular economy in Baltic Sea Region from 2014 to 2019 year according to TOPSIS method is represented in Figure 3.35. Sweden and Denmark have improved their results of Circular Economy from 2014 to 2019 year. Finland and Latvia did not make a significant change in the results from 2014 to 2019 year and their Circular Economy remain the same by 2019. Estonia and Lithuania slightly decreased the results of circular economy. Poland shifted down by 2019 and this shift is the biggest of all the Baltic Sea Region countries according to TOPSIS method results.

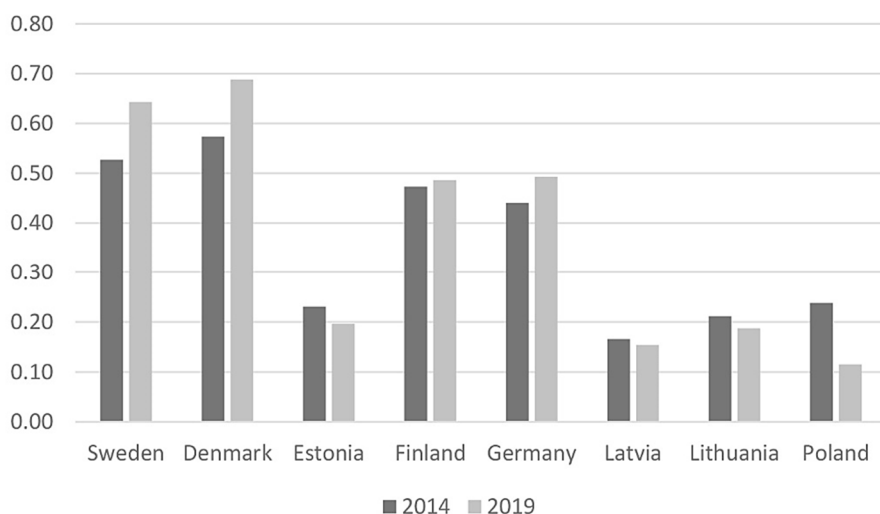


Fig. 3.35. Development of circular economy in Baltic Sea Region from 2014 to 2019 year represented by TOPSIS method (source: compiled by author)

The development over the time of Circular Economy is presented in Figure 3.36. The figure shows the decrease or increase of the from 2014 to 2019 year by method.

Baltic Sea Region	MULTIMOORA method		TOPSIS method	
	2014	2019	2014	2019
Sweden	 2	 1	 2	 2
Denmark	 1	 2	 1	 1
Estonia	 5	 4	 6	 5
Finland	 3	 5	 3	 4
Germany	 4	 3	 4	 3
Latvia	 7	 8	 8	 7
Lithuania	 6	 6	 7	 6
Poland	 8	 7	 5	 8

Fig. 3.36. Development of circular economy assessed using MULTIMOORA and TOPSIS methods in Baltic Sea Region from 2014 to 2019 year
(source: compiled by author)

According to the Figure 3.36, Sweden, Denmark, Finland and Germany are the members of Baltic Sea Region with the most developed circular economy to compare to other members of Baltic Sea Region. Estonia holds the middle position in ranking, while Lithuania, Latvia and Poland show the weakest assessment of Circular Economy in the concordance by TOPSIS and MULTIMOORA methods

3.6. Overview of the results and discussion

Circular economy is quite a new economic approach which aims to eliminate the waste until zero from every production or consumption step, promotes recycling and secondary usage of the materials in the same way maintain economic development. Circular economy includes environmental, economic and social pillars aligned with the sustainability approach, which leads to sustainable well-being.

Circular economy approach has many requirements to be implemented to perform the transition from linear economy to circular. There are many barriers in environmental, economic and social components of circular economy, which are preventing the transision. That is why it is important to monitor the development of circular economy and each component of it.

Each country has different economy, targets, goals and strategies to achieve the aim. Circular economy assessment model allows identifying the weakest point for future improvement. According to the result of circular economy assessment model application to Baltic Sea Region in the period of 2014–2019, it could be determined that Sweden and Denmark has the most developed circular economy in Baltic Sea Region. Sweden has more developed social pillar than Denmark,

however Denmark environmental pillar shows better results than environmental pillar of Sweden. For example, Denmark deals better with production-based CO₂ emissions, recycling of biowaste and generates more renewable electricity than Sweden. However, Sweden has larger environmentally related expenditures and trade in recyclable raw materials. Germany according to result of assessment of circular economy ranked as third or fourth among eight countries. Germany's social pillar would need to be improved in the areas of health, as some indicators such as "healthy life years and expectancy at birth" and "people having a long-standing illness or health problems" are lower than Denmark's and Sweden's. government effectiveness of Germany and participation rate in education and training by older population is less than in Sweden and Denmark. Also, financial and environmental wealth of social pillar of Germany should be improved to improve the evaluation of circular economy.

Estonia and Finland are countries, which evaluation of circular economy stays in the middle of ranking. Estonia has weaker social and environmental pillars than Finland. Waste management and energy sectors of environmental pillar need to be improved in order Estonia could shift up in the ranking among Baltic Sea Region members. On the other hand, Finland's environmental pillar faces issues in material management, especially with circular material use rate. The economic pillar of Finland has an issue in the promotion of green investment and green fiscal policies to compare to Sweden and Denmark.

Circular economy of Latvia, Lithuania and Poland have been ranked as the weakest evaluation among Baltic Sea Region. Social sector of these countries requires much more attention to be shifted towards Sweden and Denmark results. Also, as economic pillar shows, these countries need to strengthen the economy to be able to participate in the support of circular economy much actively, as economic pillar relates to social and environmental pillars. Lithuania, Latvia and Poland do not spend much expenditures on environmentally-friendly activities as other members of Baltic Sea Region do.

The proposed model of circular economy assessment could help the government to develop the strategy for circular economy implementation, based on each country's indicator system. Systemized and grouped indicators representing each component of circular economy gives a benefit of strategic decision making applied to the policies where the corrections are needed to be done.

To sum up, the circular economy assessment model can evaluate the circular economy, rank the countries of selected region and compare the development of circular economy between them. What is the most important, that this model can identify issues within the circular economy pillars, which can be identified and this information could provide the reason why the circular economy has been ranked in the way the result show and what government/stakeholders could do to impact the improvements towards the implementation of circular economy.

Some research limitations occur due to data availability for specific pillars of Circular Economy, which is the reflexion of the lack of circular economy conceptualisation. Some data on economic and social pillars of circular economy are not available as there are a lack of studies conceptualising circular economy as three-pillar based concept which could be assessed on practise. Also, the research has some limitation in MCDM methods TOPSIS and MULTIMOORA. Both methods need weight system and consistency of judgement, however, more research are needed to establish the level of importance of indicators within each component of circular economy. In addition to this, statistical databases did not provide all the necessary data for 2020 and 2021 years to be included into the assessment of circular economy that is why the range of circular economy assessment represented in the thesis finishes by 2019 year.

For future research would be beneficial to specify and provide empirical insights of social and economic components of circular economy. It would be interesting to observe circular economy development in the context of sustainable well-being on –micro and –meso levels to be able to evaluate the development and spread of circular economy of entities. The universal approach of circular economy valuation on –micro and –meso levels would determine the barriers of circular economy development, technological spread and would allow to monitor the sustainable development of economic pillar. Also, it would be beneficial to analyse economic benefits and the possible practical ways circular economy would help to reach and maintain sustainable development of countries economies. As circular economy requires economic support and investments to be implemented – the ability of countries economy to implement circular economy concept should be analysed from theoretical and practical point of view. It would be beneficial to discuss the distribution of costs, investments and implementation of various economic strategies suitable for the particular region to support transition towards circular economy.

3.7. Conclusions of the Chapter 3

1. The research finding provide an original tool, which allows to assess circular economy and its components. The model is based on MULTIMOORA and TOPSIS methods and the concordance of the results shows the reliability of the model. MULTIMOORA and TOPSIS methods let to use indicators with different units of measurement, what gives a possibility to compose a data based on circular economy pillars. TOPSIS method ranks the indicators by the greatest impact, while MULTIMOORA ranks showing the best evaluated results.

2. Baltic Sea Region has been selected for circular economy assessment as the first macro-regional strategy in Europe has been established for the countries with geographical location around Baltic Sea. Baltic Sea Region countries have been evaluated within environmental, social and economic dimensions of circular economy.
3. The assessment results of environmental pillar of circular economy in Baltic Sea Region in the period of 2014–2019 show that the highest rank got Sweden, Denmark and Germany by MULTIMOORA and TOPSIS methods. The weakest evaluation got Estonia and Poland.
4. The assessment results of economic pillar of circular economy in Baltic Sea Region in the period of 2014–2019 show that the highest rank got Sweden, while Denmark and Germany got the second and third position in the ranking by MULTIMOORA and TOPSIS methods. The weakest evaluation got Estonia and Poland.
5. The assessment results of social pillar of circular economy in Baltic Sea Region in the period of 2014–2019 show that the highest rank got Sweden, by MULTIMOORA and TOPSIS methods. The weakest evaluation got Latvia.
6. The assessment results of circular economy in Baltic Sea Region in the period of 2014–2019 show that the highest rank got Sweden and Denmark by MULTIMOORA and TOPSIS methods. The weakest evaluation got Latvia.

General Conclusions

1. The conducted theoretical analysis of Circular Economy, based on literature review, has shown that, circular economy consists of three pillars: environmental, economic and social and does not operate without any of the pillars. Economic dimension supports both environmental and social dimensions, giving the values for social capital and protection for natural capital. However, social dimension is not such active circular economy component as environmental or economic dimensions, but not less important, as it composes the conceptualized world view of stakeholders. Moreover, as literature analysis shows, circular economy is a tool for sustainable development, which leads to sustainable well-being. The proposed definition of circular economy describes it as an economic system based on business models, which are replacing “take-make-waste” concept by “take-make-reuse-dispose” concept implemented on micro-, meso- and macro- levels based on environmental, economic and social dimensions with the aim to accomplish sustainable development leading to sustainable well-being for current and future generations.
2. The literature analysis helped to determine circular economy indicators and formulate the strategy of their selection. The strategy of indicators

selection based on the components of circular economy, which are divided into the areas of targets. Indicators have been selected by the environmental, social and economic dimensions, which will correspond to the aim of circular economy. Environmental dimension includes waste management, air pollution and CO₂ emissions, energy and material management group of indicators. Economic dimension includes macroeconomic indicators, industrial indicators, green investment, green fiscal policy and technological development. Social dimension includes indicators of health, social justice, well-being and healthy ageing, education, science and technology, financial and environmental wealth.

3. Circular economy indicators selection strategies have been proposed based on the literature analysis and European Union regulations. The indicators selection strategy is based on the target areas of circular economy, which are aligned with sustainable well-being. 10R strategy used for indicators selection of environmental pillar. 6E strategy has been proposed to select indicators of economic pillar, while 6S strategy has been proposed for social pillar indicators selection. Strategy 6E defines the economic aspects of the circular economy and describes the contribution of the circular economy to the country's economic prosperity. The 6S strategy defines the social aspects of the circular economy, which are an integral part of a country's economic prosperity. Strategies 6E and 6S fulfill the research gaps on the topic of the circular economy by providing an advanced tool for analyzing the circular economy from an economic and social perspective.
4. Circular economy assessment model has been developed based on circular economy components. The model includes indicators selection strategies and formation of a decision-making matrix. MCDM methods MULTIMOORA and TOPSIS have been applied to assess circular economy. MCDM methods TOPSIS and MULTIMOORA are described as applicable for assessing circular economy and used to evaluate a complex criterion by giving a possibility to systemize, analyze and group indicators with different units of measurement, that have maximizing or minimizing values. The concordant results by two methods show the reliable assessment of circular economy expressed as ranking from the highest score to the lowest score.
5. The model has been empirically tested on Baltic Sea Region in the period of 2014–2019. Circular economy and its components: environmental, economic and social pillars have been assessed in Baltic Sea Region. The results of circular economy assessment identify the most developed circular economy among the member of Baltic Sea Region as well as the issues countries are facing in implementation of circular economy. In

2019 the most developed circular economy among the member of Baltic Sea Region had Sweden (1), Denmark (2) and Germany (3) according to MULTIMOORA method. Estonia (4) and Finland (5) are in the middle of rating, while Lithuania (6), Poland (7) and Latvia (8) rated as countries with the weakest circular economy among Baltic Sea Region according to MULTIMOORA method. In 2019, according to TOPSIS method, the most developed circular economy among the member of Baltic Sea Region had Denmark (0.69), Sweden (0.64) and Germany (0.49). Finland (0.48) and Estonia (0.2) are in the middle of rating, while Lithuania (0.19), Latvia (0.15) and Poland (0.12) rated as countries with the weakest circular economy among Baltic Sea Region according to TOPSIS method. The circular economy assessment model could be used in the analysis of circular economy development over the time and determination of the areas need to be improved in the future in order to implement circular economy approach. The proposed model of circular economy assessment could help the government to develop the strategy for circular economy implementation, based on each country's indicator system and determine the process of strategical decision making applied to the policies where the corrections are needed to be done.

References

- Alaerts, L.; Van Acker, K.; Rousseau, S.; De Jaeger, S.; Moraga, G.; Dewulf, J.; De Meester, S.; Van Passel, S.; Compernelle, T.; Bachus, K.; Vrancken, K.; Eyckmans, J. 2019. Towards a more direct policy feedback in circular economy monitoring via a societal needs perspective, *Resources, Conservation and Recycling*, 149, 363–370.
- Andrews-Speed, P. 2013. Chapter 18 – Reform Postponed: The Evolution of China’s Electricity Markets, *Evolution of Global Electricity Markets*, 531–567.
- Avdiushchenko, A.; Zajac, P. 2019. Circular Economy Indicators as a Supporting Tool for European Regional Development Policies, *Sustainability*, 11(11).
- Baležentis, A.; Baležentis, T. 2011. Assessing the efficiency of Lithuanian transport sector by applying the methods of multimoora and data envelopment analysis, *Transport*, 26 (3).
- Baležentis, A.; Baležentis, T. 2011. Framework of Strategic Management Model for Strategy Europe 2020: Diachronic Analysis and Proposed Guidelines, *Engineering Economics*, 22 (3), 271–282.
- Baležentis, A.; Baležentis, T.; Valkauskas, R. 2011. Evaluating situation of Lithuania in the European Union: Structural indicators and MULTIMOORA method, *Ukio technologinis ir Ekonominis Vystymasis*, 16 (4).
- Baležentis, A.; Baležentis, T.; Brauers W. K. M. 2012. Personnel selection based on computing with words and fuzzy MULTIMOORA, *Expert Systems with Applications*, 39 (9), 7961–7967.

- Bilal, M.; Khan, K. I. A.; Thaheem, M. J.; Nasir, A. R. 2020. Current state and barriers to the circular economy in the building sector: Towards a mitigation framework, *Journal of Cleaner Production*, 276–123250.
- Bilbao-Terol, A.; Arenas-Parra, M.; Canal-Fernandez, V.; Antomil-Ibias, J. 2014. Using TOPSIS for assessing the sustainability of government bond funds, *Omega*, 49, 1–17.
- Bjørn, A.; Bey, N.; Georg, S.; Röpke, I.; Hauschild, M. Z. 2017. Is Earth recognized as a finite system in corporate responsibility reporting? *Journal of Clean Production*, 163 (2017), 106–117.
- Blomsma, F.; Brennan, G. 2017. The emergence of circular economy: a new framing around prolonging resource productivity. *Journal of Industrial Ecology*, 21 (3), 603–614.
- Bocken, N. M. P.; Short, S. W. 2016. Towards a sufficiency-driven business model: Experiences and opportunities, *Environmental Innovation and Societal Transitions*, 18, 41–61.
- Borrello, M.; Caracciolo, F.; Lombardi, A.; Pascucci, S.; Cembalo, L. 2017. Consumers' perspective on circular economy strategy for reducing food waste. *Sustainability*, 9 (1), 141.
- Boulding, K. E. 1966. The Economics of Knowledge and the Knowledge of Economics, *The American Economic Review*, 56 (1/2), 1–13.
- Brauers, W. K. M.; Zavadskas E. K. 2012. Robustness of MULTIMOORA: A method for multi-Objective Optimization, *Informatica*, 23, 1–25.
- Brauers, W. K. M.; Baležentis, A.; Baležentis, T. 2012. Economic ranking of the European Union countries by multimooora optimization, *7th International Conference "Business and Management 2012"*, May, 2012.
- Brauers, W. K. M.; Ginevičius, R.; Podvieszko, A. 2012. Evaluation of performance of Lithuanian commercial banks by multi-objective optimization, *7th International Scientific Conference Business and Management*, May, 2012.
- Brauers, W. K. M.; Kildienė, S. Zavadskas, E. K. 2013. The construction sector in twenty European countries during the recession 2008–2009 – country ranking by MULTIMOORA, *International Journal of Strategic Property Management*, 17(1).
- Brauers, W. K. M.; Zavadskas, E. K. (2010). Multi-Objective Decision Making with a Large Number of Objectives. An Application for Europe 2020, *International Journal of Operations Research*, 10(2), 67–79.
- Brauers, W. K. M.; Zavadskas, E. K. 2010. Robustness in the MULTIMOORA model: the example of Tanzania. *Transformations in Business and Economics*, 9(3), 67–83.
- Brauers, W. K. M. 2004. Optimization methods for a stakeholder society. A revolution in economic thinking by multiobjective optimization: Nonconvex Optimization and its Applications, *Kluwer Academic Publishers, Boston, U.S.A.*
- Busu, C.; Busu, M. 2018. Modelling the Circular Economy Processes at the EU Level Using an Evaluation Algorithm Based on Shannon Entropy. *Processes* 6(11), 225.

- Byun, H. S.; Lee, K. H. 2005 A Decision Support System for the Selection of a Rapid Prototyping Process Using the Modified TOPSIS Method, *International Journal of Advanced Manufacturing Technology*, 26(11–12), 1338–47.
- Chen, S. M.; Yang, M. W.; Lee, L. W.; Yang, S. W. 2012. Fuzzy multiple attributes group decision making based on ranking interval type-2 fuzzy sets, *Expert Systems with Applications*, 39(5): 5295–5308.
- Chen, Z. P.; Yang, W. 2011. An MAGDM based on constrained FAHP and FTOPSIS and its application to supplier selection, *Mathematical and Computer Modelling*, 54(11–12), 2802–2815.
- Cheng, T. C.; Zhao, M. Y., Chau, K. W., Wu, X. Y. 2006. Using genetic algorithm and TOPSIS for Xinanjiang model calibration with a single procedure, *Journal of Hydrology*, 316 (1–4), 129–140.
- Chinis, A.; Vaidya O. S. 2016. Efficiency ranking method using DEA and TOPSIS (ERM-DT): case of an Indian bank, *Benchmarking: An International Journal*, 23 (1).
- Chizaryfard, A.; Trucco, P.; Nuur, C. 2021. The transformation to a circular economy: framing an evolutionary view, *Journal of Evolutionary Economics*, 31, 475–504.
- Clube, R. K. M.; Tennant, M. 2020. The Circular Economy and human needs satisfaction: Promising the radical, delivering the familiar, *Ecological Economics*, 177, 106772.
- Constanza, R.; Caniglia, B.; Fioramonti, L.; Kubiszewski, I.; Lewis, H.; Lovins, L.H.; McGlade, J.; Mortensen, L. F.; Philipsen, D.; Pickett, K. E.; Ragnarsdóttir, K. V.; Roberts, D.; Sutton, P.; Trebeck, K.; Wallis, S.; Ward, J.; Weatherhead, M.; Wilkinson, R. 2018. Toward a Sustainable Wellbeing Economy, *Solutions*, 9 (2).
- Costanza, R.; Daly, L.; Fioramonti, L.; Giovannini, E.; Kubiszewski I.; Mortensen, L. F.; Pickett, K. E.; Ragnarsdóttir, K. V.; De Vogli, R.; Wilkinson, R. 2016. Modelling and measuring sustainable wellbeing in connection with the UN Sustainable Development Goals. *Ecological Economics*, 130, 350–355.
- D'Adamo, I.; Falcone, P.M.; Imbert, E; Morone, P. 2020. A Socio-economic Indicator for EoL Strategies for Bio-based Products, *Ecological Economics*, 178.
- D'Amato, D; Veijonaho, S; Toppinen, A. 2020. Towards sustainability? Forest-based circular bioeconomy business models in Finnish SMEs, *Forest Policy and Economics*, 110, 101848.
- De Almeida, S.T.; Borsato, M. 2019. Assessing the efficiency of End of Life technology in waste treatment –A bibliometric literature review, *Resources Conservation and Recycling*, 140, 189–208.
- DeBoer, J; Panwar, R; Kozak, R; Cashore, B. 2020. Squaring the circle: Refining the competitiveness logic for the circular bioeconomy, *Forest Policy and Economics*, 110, 101858.
- Dolinsky, M.; Maier, S. 2015. Market-based approach in shift from linear economy towards circular economy supported by game theory analysis, *Creative and knowledge Society*, 5, 1–10.

- Dong, L.; Gu, X.; Wu, X. 2019. An improved MULTIMOORA method with combined weights and its application in assessing the innovative ability of universities, *Expert systems*, 36(2).
- Dorfeshan, Y.; Mousavi, M.; Mohagheghi, V.; Vhdani, B. 2018. Selecting project-critical path by a new interval type-2 fuzzy decision methodology based on MULTIMOORA, MOOSRA and TPOP methods, *Computers & Industrial Engineering*, 120, 160–178.
- Eghabali-Zarch, M.; Tavakkoli-Moghaddam, R.; Esfahanian, E.; Sepehri, M. M.; Azaron, A. 2018. Pharmacological therapy selection of type 2 diabetes based on the SWARA and modified MULTIMOORA methods under a fuzzy environment, *Artificial Intelligence in Medicine*, 87, 20–33.
- Ellen MacArthur Foundation (EMF). 2013. Towards the circular economy. *Journal of Industrial Ecology*, 1 (1), 4–8.
- Ergüden, E.; Çatlioğlu, E. 2016. Sustainability Reporting Practices In Energy Companies with Topsis Method, *Muhasebe ve Finansman Dergisi*, 201–221.
- European Commission (EC) 2009. European Union Strategy for the Baltic Sea Region.
- European Commission (EC) 2014. Towards a circular economy: A zero waste programme for Europe, Communication from the commission to the European Parliament, the Council, The European Economic and Social Committee and the Committee of the Regions, Brussels, Document COM 398:5.
- European Commission (EC). 2010. Strategy “Europe 2020”, Brussels.
- European Commission (EC). 2011. Roadmap to a Resource Efficient Europe – COM (2011) 571 Final, European Commission, Brussels.
- European Commission (EC). 2013. Environment Action Programme.
- European Commission (EC). 2014. “Horizon 2020”, Brussels.
- European Commission (EC). 2015. Closing the Loop – an EU Action Plan for the Circular Economy – COM (2015) 614 Final. Brussels.
- European Commission (EC). 2017. Framework for Sustainable production and consumption.
- European Commission (EC). 2018. Measuring Progress towards Circular Economy in the European Union – Key Indicators for a Monitoring Framework – SWD (2018) 17 Final. European Commission, Strasbourg.
- European Commission (EC). 2018. Programme “Innovation Union”.
- European Commission (EC). 2019. A long-term strategy for a European Circular Economy – setting the course for success.
- European Commission (EC). 2020. Circular Economy Indicators.
- European Commission, (EC). 2019a. Report on the Implementation of the Circular Economy Action Plan (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions).

- European Commission. 2012. European Resource Efficiency Platform (EREP). Brussels, 16 p.
- European Environment Agency (EEA). 2016. Circular Economy in Europe – Developing the Knowledge Base. EEA Report No 2/2016. Copenhagen: European Environment Agency.
- European Environment Agency (EEA). 2018. Programme “Innovation Union”, Brussels
- Eurostat database. 2019. Sustainable development Indicators.
- Fan, Y.; Fang, C. 2020. Circular economy development in China-current situation, evaluation and policy implications, *Environmental Impact Assessment Review*, 84, 106441.
- Fattahi, R.; Khalilzadeh, M. 2018. Risk evaluation using a novel hybrid method based on FMEA, extended MULTIMOORA, and AHP methods under fuzzy environment, *Safety science*, 102, 290–300.
- Fedajev, A.; Stanujkic, D.; Karabasevic, D.; Brauers, W. K. M.; Zavadskas, E. K. 2020. Assessment of progress towards “Europe 2020” strategy targets by using the MULTIMOORA method and the Shannon Entropy Index. *Journal of Cleaner Production*, 244.
- Ferrante, L.; Germani, A. 2020. Does Circular Economy Play a Key Role in Economic Growth?, *Economics Bulletin*, 4(3).
- Fonseca, L. M.; Domingues, J. P.; Pereira, T. M.; Martins, F. F.; Zimon, D. 2018. Assessment of Circular Economy within Portuguese Organizations, *Sustainability*, 10, 2521.
- Garcia-Barragan, J. F.; Eyckmans, J.; Rousseau, S. 2019. Defining and Measuring the Circular Economy: A Mathematical Approach, *Ecological Economics*, 157, 369–372.
- Geissdoerfer, M.; Savaget, P.; Bocken, N. M. P; Hultink, E. J. 2017. The Circular Economy – A new sustainability paradigm?, *Journal of Cleaner Production*, 143, 757–768.
- Geng, Y.; Doberstein, B. 2008. Developing circular economy in China: challenges and opportunities for achieving “leapfrog development”, *International Journal of Sustainable Development and World Ecology* 15(3): 231-239.
- Geng, Y.; Fu, J.; Sarkis, J.; Xue, B. 2012. Towards a national circular economy indicator system in China: an evaluation and critical analysis. *Journal of Cleaner Production*, 23, 216–224.
- Ghisellini, P.; Cialani, C.; Ulgiati, S. 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems, *Journal of Cleaner Production*, 114, 11–32.
- Giampietro, M. 2019. On the Circular Bioeconomy and Decoupling: Implications for Sustainable Growth, *Ecological Economics*, 162, 143–156.
- Girard, L.F. 2020. The circular economy in transforming a died heritage site into a living ecosystem, to be managed as a complex adaptive organism, *Aestimum*, 77, 145–180.
- Gower, R.; Schroeder, P. 2016. Virtuous circle: How the circular economy can save lives and create jobs in low and middle income countries. London, UK: *Tearfund and Institute of Development Studies*.
- Grigoryan, A. A.; Borodavkina, N.Y. 2017. The Baltics on their way to a Circular Economy. *Baltic Region*, 9 (3), 4–14.

- Guo-gang, J. 2011. Empirical Analysis of Regional Circular Economy Development--Study Based on Jiangsu, Heilongjiang, Qinghai Province. *Energy Procedia*, 5, 125–129.
- Haynes, K., Murray, A. 2015. Sustainability as a lens to explore gender equality: A missed opportunity for responsible management. In Flynn, P.; Haynes, K; Kilgour, M. Integrating gender equality into management education. Greenleaf: Sheffield.
- Heck, P. 2006. Circular Economy Related International Practices and Policy Trends: Current Situation and Practices on Sustainable Production and Consumption and International Circular Economy Development Policy Summary and Analysis, *Institute for Applied Material Flow Management (IfaS), Environmental Campus Birkenfeld*.
- Helne, T.; Hirvilammi, T. 2015. Wellbeing and Sustainability: A Relational Approach, *Sustainable Development* 23, 167–175.
- Heshmati, A. 2015. A review of Circular Economy and its Implementation. *Sogang University and IZA discussion Paper*, 9611.
- Homrich, A.S.; Galvão, G.; Abadia, L.G.; Carvalho, M.M. 2018. The circular economy umbrella: trends and gaps on integrating pathways, *Journal of Clean Production*, 175 (2018), 525–543.
- Hwang, C.L; Yoon, K. 1981. Multiple Attributes Decision Making Methods and Applications, *Springer, Berlin*.
- Ionascu, I; Ionascu, M. 2018. Business models for circular economy and sustainable development: the case of lease transactions, *Amfiteatru Economic* 20(48), 356–372.
- Kalmykova, Y.; Rosado, L.; Patricio, J. 2016. Resource consumption drivers and pathways to reduction: economy, policy and lifestyle impact on material flows at the national and urban scale. *Journal of Clean Production*, 132, 70–80.
- Kirchherr, J.; Reike, D.; Hekkert, M. 2017. Conceptualizing the circular economy: an analysis of 114 definitions, *Resources, Conservation and Recycling*, 127, 221–232.
- Kiselev, A.V.; Magaril, E.R.; Rada, E.C. 2019. Energy and Sustainability Assessment of Municipal Wastewater Treatment under Circular Economy Paradigm, *Transactions on Ecology and the Environment*, 237.
- Kjell, O. 2011. Sustainable Well-Being: A Potential Synergy between Sustainability and Well-Being, *Research. Review of General Psychology*, 15(3), 255–266.
- Kottner, A.; Štofová, L.; Szaryszová, P.; Lešková, E. 2016. Indicators of green public procurement for sustainable production Production Management and Engineering Sciences – *Scientific Publication of the International Conference on Engineering Science and Production Management*, ESPM 2015, Routledge in Association with GSE Research 2016, 435–442.
- Koulinas, G. K.; Demesouka, O. E.; Marhavidas, P., K.; Vavatsikos A. P.; Koulouriotis, D. E. 2019. Risk Assessment Using Fuzzy TOPSIS and PRAT for Sustainable Engineering Projects. *Sustainability*, 11(3), 615.
- Krysovaty, A; Zvarych, R; Zvarych, I; Krysovaty, T; Krysovata, K. 2020. Methodological architectonics of inclusive circular economy for eco-security of society under pandemic, *Economic Annals-XXI*, 184 (7–8).

- Ladu, L.; Imbert, E.; Quitzow, R.; Morone, P. 2020. The role of the policy mix in the transition toward a circular forest bioeconomy, *Forest Policy and Economics*, 110, 101937.
- Lahti, T.; Wincent, J.; Parida, V. 2018. A Definition and Theoretical Review of the Circular Economy, Value Creation, and Sustainable Business Models: Where Are We Now and Where Should Research Move in the Future? *Sustainability*, 10 (8), 2799.
- Leontief, W. 1991. The economy as a circular flow, *Structural Change and Economic Dynamics*, 2 (1), 181–212.
- Leviston, Z.; Walker, I.; Green, M.; Price, J. 2018. Linkages between ecosystem services and human wellbeing: A Nexus Webs approach. *Ecological Indicators*, 93, 658–668.
- Lewandowski, M. 2016. Designing the business models for circular economy – Towards the conceptual framework. *Sustainability*, 8(1): 43.
- Li, H.; Bao, W.; Xiu, C.; Zhang, Y.; Xu, H. 2010. Energy conservation and circular economy in China's process industries. *Energy*, 35, 4273–4281.
- Li, J.; Lu, H.; Guo, J.; Xu, Z.; Zhou, Y. 2007. Recycle technology for recovering resources and products from waste printed circuit boards. *Environmental Science & Technology*, 41(6): 1995–2000.
- Li, X.; Deng, B.; Ye, H. 2011. The research based on the 3-R Principle of Agro-circular Economy Model-The Erhai Lake Basin as an Example, *Energy Procedia*, 5, 1399–1404.
- Li, X.; Xiao, R. 2017. Analyzing network topological characteristics of eco-industrial parks from the perspective of resilience: A case study. *Ecological Indicators*, 74, 403–413.
- Liang, W.; Zhao, G.; Hong, C. 2019. Selecting the optimal mining method with extended multi-objective optimization by ratio analysis plus the full multiplicative form (MULTIMOORA) approach, *Neural Computing and Applications*, 1–16.
- Lieder, M.; Rashid, A. 2016. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. *Journal of Clean Production*, 115, 36–51.
- Lin, B.C.A. 2020. Sustainable Growth: A Circular Economy Perspective, *Journal of Economic Issues*, 54 (2), 465–471.
- Lin, Y. H.; Lee, P. C.; Chang, T. P.; Ting, H. I. 2008. Multi-attribute group decision making model under the condition of uncertain information, *Automation in Construction* 17(6): 792–797.
- Liu, H.; Zhao, H.; You, X.; Zhou, W. 2019. Robot evaluation and selection using the Hesitant Fuzzy Linguistic MULTIMOORA method. *Journal of Testing and Evaluation*, 47(2), 1405–1426.
- Liu, H.C.; Ren, M.L.; Wu, J.; Lin, Q.L. 2014. An interval 2-tuple linguistic MCDM method for robot evaluation and selection, *International Journal of Production Research*, 52 (10), 2867–2880.
- Liu, Q.; Li, H.; Zuo, H.; Zhang, F.; Wang, L. 2009. A survey and analysis on public awareness and performance for promoting circular economy in China: A case study from Tianjin, *Journal of Clean Production*, 17 (2), 265–270.

- Liu, X.; Zhou, X.; Zhu, B.; He, K.; Wang, P. 2019a. Measuring the maturity of carbon market in China: an entropy-based TOPSIS approach. *Journal of Cleaner Production*, 229, 94–103.
- Lyubomirsky, S.; Sheldon, K.; Schkade, D. 2005. Pursuing happiness: The architecture of sustainable change. *Review of General Psychology*, 9, 111–131.
- Ma, N.; Houser, J.B. 2014. Recycling of steelmaking slag fines by weak magnetic separation coupled with selective particle size screening, *Journal of Clean Production*, 82, 221–231.
- Maghsoodi, A. I.; Abouhamheh, G.; Khalilzadeh, M.; Zavadskas E. K. 2018. Ranking and selecting the best performance appraisal method using the MULTIMOORA approach integrated Shannon's entropy. *Frontiers of Business Research in China*, 12(2), 1–20.
- Martin, M.; Røyne, F.; Ekvall, T.; Moberg, Å. 2018. Life cycle sustainability evaluations of bio-based value chains: reviewing the indicators from a Swedish perspective, *Sustainability*, 10 (2018), 547.
- Measuring (2018). Measuring progress towards circular economy in the European Union – Key indicators for a monitoring framework.
- Mehralian, G.; Nazari, A.J.; Zarei, L.; Rasekh, H.R. 2016. The effects of corporate social responsibility on organizational performance in the Iranian pharmaceutical industry: The mediating role of TQM, *Journal of Cleaner Production*, 135, 689–698.
- Milios, L. 2021. Towards a Circular Economy Taxation Framework: Expectations and Challenges of Implementation, *Circular Economy and Sustainability*, 2021.
- Millar, N.; McLaughlin, E.; Börger T. 2019. The circular economy: swings and roundabouts? *Ecological Economy*, 158, 11–19.
- Montis, A.; Toro, P.; Droste-Franke, B.; Omann, I.; Stagl, S. 2000. Criteria for quality assessment of MCDA methods, *3rd Biennial Conference of the European Society for Ecological Economics*, Vienna.
- Moraga, G.; Huysveld, S.; Mathieux, F.; Blengini, G.A.; Alaerts, L.; Van Acker, K.; De Meester, S.; Dewulf, J. 2019. Circular economy indicators: what do they measure? *Resource, Conservation, Recycling*, 146 (2019), 452–461.
- Moreau, V.; Sahakian, M.; Griethuysn, P.; Vuille, F. 2017. Coming full circle: why social and institutional dimensions matter for the circular economy. *Journal of Industrial Ecology*, 21 (3), 497–506.
- Morseletto, P. 2020. Targets for Circular Economy, *Resources, Conservation and Recycling*, Vol 153, 104553.
- Murray, A.; Skene, K.; Haynes, K. 2017. The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*, 140 (3), 369–380.
- Nordenstam, L.; Bennstam, M.; Ödlund, L. Considering investment resources when assessing potential CO₂ reductions of CHP – a case study, *Energy Procedia*, 116, 273–284.
- Oakley, K.; Wand, J. 2018. The art of the good life: culture and sustainable prosperity, *Cultural Trends*, 27 (1), 4–17.

Omrani, H.; Alizadeh, A.; Amini M. 2020. A new approach based on BWM and MULTI-MOORA methods for calculating semi-human development index: An application for provinces of Iran, *Socio-Economic Planning Sciences*, 70.

Organization for Economic Co-Operation and development (OECD). 2020. Green Growth Indicators.

Palacios, L. D. T; Rodriguez, J.; Martinez, P. R. 2021. Economic, technological and sustainability-based qualifications with reference to Europe: Iberia's new metal mining projects, *Mineral Economics*, 34–2.

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

Pavić, Z.; Novoselac, V. 2013. Notes on TOPSIS Method, *International Journal of Research in Engineering and Science (IJRES)*, 1(2): 5–12.

Pietro-Sandoval, V.; Jaca, C.; Ormazabal, M. 2018. Towards a consensus on the circular economy. *Journal of Cleaner Production*, 179, 605–615.

Piowar, A. 2020. Challenges associated with environmental protection in rural areas of Poland: empirical studies' results, *Economics & Sociology*, 13 (1), 217–229.

Pla-Julian, I.; Guevara, S. 2019. Is circular economy the key to transitioning towards sustainable development? Challenges from the perspective of care ethics, *Futures*, 105, 67–77.

Podvieszko, A. 2011. Augmenting Multi-criteria Decision Aid Methods by Graphical and Analytical Reporting Tools, Springer. 236–251.

Potting, J.; Hekkert, M.; Worrell, E.; Hanemaaijer, A. 2017. Circular Economy: Measuring Innovation in the Product Chain, *PBL – Netherlands Environmental Assessment Agency*, 2544.

Qing, Y.; Qiongqiong, G.; Mingyue, C. 2011. Study and Integrative Evaluation on the development of Circular Economy of Shaanxi Province. *Energy Procedia* 5, 1568–157.

Raftowicz-Filipkiewicz, M. 2016. From sustainable development to circular economy, *Economic and Environmental Studies (E&ES)*, 16 (1), 103–113.

Raworth, K. 2017. A Doughnut for the Anthropocene: humanity's compass in the 21st century, *Comment*, 1 (2).

Reike, D.; Vermeulen, W. J. V.; Witjes, S. 2018. The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource, Value Retention Options. *Resources, Conservation and Recycling*, 135, 246–264.

Repo, P.; Anttonen, M.; Mykkanen, J.; Lammi, M. 2018. Lack of congruence between European citizen perspectives and policies on circular economy, *European Journal of Sustainable Development*, 7 (1), 249–264.

Ritzén, S.; Sandström, G. Ö. 2017. Barriers to the Circular Economy – Integration of Perspectives and Domains, *Procedia CIRP*, 64, 7–12.

- Rodriguez-Anton, J. M. 2020. Relationship between tourism competitiveness and sustainable development goals in Africa, *Estudios De Economia Aplicada*, 38, 2.
- Sachs, J. 2016. Happiness and sustainable development: concepts and evidence. Chapter 4, in the World Happiness Report 2016 Update, in Helliwell, J.; Layard, R.; Sachs, J. (Eds.), New York, NY: UN Sustainable Development Solutions Network.
- Saraiva, A. B.; Souza, R. G.; Mahler, C. F.; Valle, R. A. B. 2018. Consequential lifecycle modelling of solid waste management systems – Reviewing choices and exploring their consequences. *Journal of Clean Production*, 202, 488–496.
- Sarkar, A. 2013. A TOPSIS method to evaluate the technologies, *International Journal of Quality and Reliability Management*, 31(1).
- Sassanelli, C.; Rosa, R.; Rocca, R.; Terzi, S. 2019. Circular economy performance assessment methods: A systematic literature review, *Journal of Cleaner Production*, 229, 440–453.
- Sauvé, S.; Bernard, S.; Sloan, P. 2016. Environmental sciences: sustainable development and circular economy: alternative concepts for trans-disciplinary research. *Environmental Development*, 17, 48–56.
- Scheel, C. 2016. Beyond sustainability. Transforming industrial zero-valued residues into increasing economic returns. *Journal of Clean Production*, 131, 376–386.
- Schroeder, P.; Anggraeni, K.; Weber, U. 2018. The Relevance of Circular Economy Practices to the Sustainable Development Goals, *Research and Analysis*, 23.
- Sebestova, J; Sroka, W. 2020. Sustainable Development Goals and SME Decisions: The Czech Republic vs. Poland, *Journal of Eastern European and Central Asian Research*, 7 (1).
- Shen, L.; Olfat, L.; Govindan, K.; Khodaverdi, R; Diabar, A. 2013. A fuzzy multi criteria approach for evaluating green supplier 's performance in green supply chain with linguistic preferences, *Resources, Conservation and Recycling*, 74 ,170–179.
- Shen, X.; Qi, C. 2012. Countermeasures towards Circular Economy Development in West Regions; *Energy Procedia*, 16 (2012), 927–932.
- Siksnyte, I.; Zavadskas, E. K.; Bausys, R.; Streimikiene, D. 2019. Implementation of EU energy policy priorities in the Baltic Sea Region countries: Sustainability assessment based on neutrosophic MULTIMOORA method, *Energy Policy*, 125, 90–102.
- Skvarciany, V.; Lapinskaite, I.; Volskyte, G. 2021. Circular economy as assistance for sustainable development in OECD countries, *Oeconomia Copernicana*, 12 (1).
- Smol, M.; Kulczycka, J.; Avdiushchenko, A. 2017. Circular economy indicators in relation to eco-innovation in European regions, *Clean Technical Environment Policy*, 19, 669–678.
- Solangi, Y. A.; Tan, Q.; Mirjat, N. H.; Ali, S. 2019. Evaluating the strategies for sustainable energy planning in Pakistan: An integrated SWOT-AHP and Fuzzy-TOPSIS approach. *Journal of Cleaner Production*, 236.
- Stahel, W. R. 2016. Circular economy, *Nature*, 531,435–438.

- Stankevičienė, J.; Nikanorova, M. 2019. Financial System Sustainability Assessment Model Creation, *Trends Economics and Management*, 33(1), 87–98.
- Stiglitz, J.E.; Sen, A.; Fitoussi, J.P. 2009. Report by the Commission on the Measurement of Economic Performance and Social Progress. *Paris: Commission on the Measurement of Economic Performance and Social Progress*.
- Su, B.; Heshmati, A.; Geng Y.; Yu, X. 2013. A review of the circular economy in China: moving from rhetoric to implementation. *Journal of Cleaner Production*, 42, 215–227.
- Su, W. H.; Zeng, S. Z.; Ye, X. J. 2013. Uncertain group decision-making with induced aggregation operators and Euclidean distance, *Technological and Economic Development of Economy* 19(3): 431–447.
- Sun, L.; Miao, C.; Yang, L. 2018. Ecological-economic efficiency evaluation of green technology innovation in strategic emerging industries based on entropy weighted TOPSIS method. *Ecological Indicators*, 73, 554–558.
- Teodor, C; Trica, C.L.; Ignat, R.; Dracea, R.M. 2020. Good practices of efficient packaging waste management, *Amfiteatru Economic* 55, 937–953.
- Tiwari, V.; Jain, P. K.; Tandon, P. 2019. An integrated Shannon entropy and TOPSIS for product design concept evaluation based on bijective soft set. *Journal of Intelligent Manufacturing*, 30, 1645–1658.
- Tseng, M. L.; Tan, R. R.; Chiu, A. S. F; Chien, C. F.; Tsai, C. K. 2018. Circular economy meets industry 4.0: Can big data drive industrial symbiosis? *Resources, Conservation and Recycling*, 131, 146–147.
- Ture, H.; Dogan, S.; Kocak, D. 2019 Assessing EURO 2020 Strategy Using Multicriteria Decision Making Methods: VIKOR and TOPSIS. *Social Indicators research*, 142: 645–665.
- Turner, R.K.; Pearce, D.W. 1990. The ethical foundations of sustainable economic development, *International Institute for Environment and Development*, 90–101.
- United Nations (UN). 2020. Sustainable Development indicators
- United Nations. 2015. 2030 Agenda for Sustainable Development, *UN Sustainable Development Summit, General Assambley*, New York.
- United Nations. 2019. Net official development assistance given or received as a percentage of gross national income.
- Ūsas, J.; Balezentis, T.; Streimikiene, D. 2021. Development and integrated assessment of the circular economy in the European Union: the outranking approach, *Journal of Enterprise Information Management*, 1741–0398.
- Uvarova, I.; Atstaja, D.; Korpa, V. 2020. Challenges of the Introduction of Circular Business Models within Rural SMEs of EU, *International Journal of Economic Sciences*, 9 (2).
- Van Schoubroeck, M.; Van Dael, S.; Van Passel, R.; Malina A. 2018. Preview of sustainability indicators for biobased chemicals, *Renewable and Sustainable Energy Reviews*, 94 (2018), pp. 115–126.

- Vence, X.; López Pérez, S.D.J. 2021. Taxation for a Circular Economy: New Instruments, Reforms, and Architectural Changes in the Fiscal System. *Sustainability*, 13, 4581.
- Vermander, B. 2008. China's Environmental Challenge and Its Implications for International Policies on Global Warming, *The 25th Taiwan-European Conference December 2-3, 2008*, Institute of international Relations at National Chengchi University.
- Vuta, M; Cioaca, S.I.; Vuta, M.; Enciu, A. 2019. An empirical analysis of corporate social responsibility effects on financial performance for Romanian listed companies, *Amfiteatru Economic*, 21–52.
- Wang, M.; Zhao, X.; Gong, Q.; Ji, Z. 2019. Measurement of Regional Green Economy Sustainable Development Ability Based on Entropy Weight-Topsis-Coupling Coordination Degree – A case study in Shandong Province, China. *Sustainability*, 11(1), 280.
- Webster, K. 2015. The Circular Economy: a Wealth of Flows, *Ellen MacArthur Foundation, Isle of Wight*.
- Wen, Z.; Meng, X. 2015. Quantitative assessment of industrial symbiosis for the promotion of circular economy: a case study of the printed circuit boards industry in China's Suzhou New District, *Journal of Clean Production*, 90, 211–219.
- Whiting, K.; Konstantakos, L.; Carrasco, A.; Carmona, L.G. 2018. Sustainable Development, Wellbeing and Material Consumption: A Stoic Perspective, *Sustainability*, 10, 474.
- World Commission on Environment and Development (WCED). 1987. Report of the World Commission on Environment and Development: Our Common Future. *Oxford University Press*, 43.
- Wu H.; Shi Y.; Xia Q.; Zhu W. 2014. Effectiveness of the policy of circular economy in China: A DEA-based analysis for the period of 11th five-year-plan. *Resources, Conservation and Recycling* 83, 163–175.
- Xing, J.; Vilas-Boas, J.; Almeida, I. 2017. A New Conceptual Perspective on Circular Economy: preliminarily confirmation of the 7R Principle by a descriptive Case Study in Eastern China. In *Proceedings of 23rd Annual International Sustainable Development Research Society (ISDRS) Conference*, Universidad de los Andes School of Management, Bogotá, Colombia, 14th–16th June.
- Zaidi, S.A.H.; Mirza, F.M.; Hou, F.J.; Ashraf, R.U. 2019. Addressing the sustainable development through sustainable procurement: What factors resist the implementation of sustainable procurement in Pakistan?, *Socio-Economic Planning Sciences*, 68, 100671.
- Zavadskas, E. K.; Mardani, A.; Turskis, Z.; Jusoh, A.; Nor, K. 2016. Development of TOPSIS Method to Solve Complicated Decision-Making Problems: An Overview on Developments from 2000 to 2015. *International Journal of Information Technology & Decision Making*, 15, 1–37.
- Zavadskas, E. K.; Bausys, R.; Juodagalviene, B; Garnyte-Sapranaviciene, I. 2017. Model for residential house element and material selection by neutrosophic MULTIMOORA method, *Engineering Applications of Artificial Intelligence*, 64 (1), 315–324.
- Zhu, D.J. 2005. Circular Economy: new economy for 21 century, *Empirical Reference*, 8(2005), 28–30.

- Zhu, D.J.; Qiu, S.F. 2007. Analytical tool for urban circular economy planning and its preliminary application: a case of Shanghai, *Urban Ecological Planning*, 31 (3), 64–70.
- Zotti, J.; Bigano, A. 2019. Write circular economy, read economy's circularity. How to avoid going in circles, *Economia Politica* 36, 629–652.

List of Scientific Publications by the Author on the Topic of the Dissertation

Papers in the Reviewed Scientific Journals

- Stankevičienė, J.; Nikanorova, M. 2020. Eco-innovation as a pillar for Sustainable Development of Circular Economy. *Business: Theory and Practice*, 21(2), 531–544, eISSN 1822-4202.
- Stankevičienė, J.; Nikanorova, M.; Gentjan, Ç. 2020. Analysis of Green Economy dimension in the context of Circular Economy: The case of Baltic Sea Region. *E&M Economics and Management*, 23, 1, ISSN 1212-3609.
- Nikanorova, M.; Imoniana, J. O.; Stankevičienė, J. 2020. Analysis of Social Dimension and Well-being in the context of Circular Economy. *International journal of global warming*. Geneva: Inderscience Enterprises Ltd., Vol. 18, No. 3, ISSN 1758-2083.
- Nikanorova, M.; Stankevičienė, J. 2020. Development of environmental pillar in the context of circular economy assessment: Baltic Sea Region case. *Entrepreneurship and Sustainability Issues*, 8, 1, ISSN 2345-0282.

Papers in Other Editions

- Stankevičienė, J.; Nikanorova M. 2017. Analysis of economic and environmental welfare in the context of circular economy. *Contemporary issues in business, management and education'2017: 5th international scientific conference*, 11–12 May 2017, Vilnius Gediminas Technical University: conference proceedings, eISSN 2029-7963.

Summary in Lithuanian

Įvadas

Problemos formulavimas

Šiandien pasaulis susiduria su neefektyviu išteklių ir energijos naudojimu, neefektyviu atliekų tvarkymu bei su sunkumais mažinant taršą ir palaikant „žalią“ aplinką. Žiedinės ekonomikos modelis, apimantis tvarumo principus, leidžia pridėtinės vertės ekonominius aspektus paversti pagrindiniais aspektais. Taikant žiedinės ekonomikos modelį, verslas visame pasaulyje turi atitikti aplinkosaugos ir tvarumo principus, užtikrinančius ekonomikos sąsajas su aplinkos ir socialiniais aspektais. Gerovė tvarumo srityje yra nepakankamai apibrėžta sąvoka, kadangi siekiant ją aptarti išsamiau dažniausiai vartojama ir daugiausiai dėmesio skiriama „poreikių“ sąvokai. Dauguma tyrimų pabrėžia, kad gerovės samprata yra pagrįsta įvairiais aspektais, veikiančiais žmonių gyvenimą, pavyzdžiui, tokiais kaip socialinė, ekonominė ir ekologinė gerovė.

Žiedinės ekonomikos principų integravimas yra būtinas siekiant paskirstyti išteklius ir sumažinti vartojimo ir gamybos daromą neigiamą poveikį aplinkai. Tačiau aiškaus Žiedinės ekonomikos vertinimo įrankio trūkmas, kuris nustatytų jos principus, pritaikytus konkrečiam regionui, neleidžia nustatyti žiedinės ekonomikos raidos ir jos komponentų. Sukurtas jos vertinimo įrankis turėtų reikšmingą poveikį Žiedinės ekonomikos plėtrai, padedant nustatyti tobulėjimo spragas. Be to, kritinė literatūros analizė parodė šias ekonomines ir mokslinių tyrimų problemas:

1. Žiedinės ekonomikos apibrėžimais nėra pakankamai išplėtotas, kad būtų sukurta standartinė koncepcija, apibūdinanti žiedinę ekonomiką kaip tvarios plėtros priemonę, kuri būtų siekiama tvarios gerovės.

2. Žiedinės ekonomikos vertinimo priemonių ir rodiklių trūkumas neleidžia suformuoti ir išanalizuoti žiedinės ekonomikos ir jos komponentų.

3. Esami žiedinės ekonomikos vertinimo metodai neleidžia įvertinti jos raidos konkrečios šalies ar regiono gerovės kontekste. Esamos apytikrės ekonomikos matavimo priemonės yra pritaikytos konkrečiam regionui, įvertinant tik konkretų aplinkos aspektą, ir negali būti naudojamos be pakeitimų kitai šaliai ar regionui.

Darbo aktualumas

Žiedinės ekonomikos samprata yra viena iš naujausių ekonominių modelių, kurios tikslas – užtikrinti tvarią šalies ar regiono plėtrą ir išspręsti bendras aplinkosaugos problemas, turinčias neigiamą poveikį ekonomikai ir visuomenei. Žiedinės ekonomikos metodas apima daug neišspręstų mokslinių klausimų: žiedinės ekonomikos komponentus, ekonominius, aplinkosaugos, socialinius rodiklius ir kitus, susijusius su jos vertinimu Europos Sąjungoje. Be to, mokslininkai diskutuoja apie universalius trimačius žiedinės ekonomikos vertinimo modelius, kurie atitiktų tvarios plėtros principus.

Žiedinė ekonomika padidins ES išteklių efektyvumą iki 3 % per metus, o tai atitinka 0,6 trln. eurų per metus iki 2030 m. Tikėtina, kad BVP per metus augs maždaug 7 %, o tai turės teigiamą poveikį užimtumui (Europos Komisija, 2016). Be to, 2013 m. Europos Komisija paskelbė aplinkosaugos veiksmų programą (EAP, 2013), kurioje išdėstyti žiedinės ekonomikos principai, siekiant skatinti aplinką tausojančią veiklą ir kontroliuojant esamą neigiamą žmogaus veiklos poveikį aplinkai. Po dvejų metų Europos Sąjunga pateikė žiedinės ekonomikos įgyvendinimo veiksmų planą (EC, 2015). 2018 m. Europos Sąjunga paskelbė žiedinės ekonomikos įgyvendinimo rezultatus ir pažangą, kuri rodo nuolatinį Europos Sąjungos susidomėjimą žiedinės ekonomikos įgyvendinimu. Siekiant sumažinti neigiamą poveikį aplinkai, buvo pradėta daugybė kitų programų, tokių kaip „Horizontas 2020“, „Horizontas 2030“ ir ilgalaikė 2050 m. vizija, vadinama „Ilgalaikė klestinčios, modernios, konkurencingos ir neutralios klimato atžvilgiu ekonomikos vizija iki 2050 m. – Švari planeta visiems“ (EC, 2018).

Atsižvelgiant į Europos Sąjungos interesą implementuoti žiedinę ekonomiką ir skatinti Europos Sąjungos šalis integruoti žiedinės ekonomikos principus į savo ekonomiką, rodo universalus įrankio poreikį, kuriuo pagalba galima įvertinti žiedinę ekonomiką visame Europos Sąjungos regione, bei analizuoti jos sudedamąsias dalis ir palyginti tarp Europos Sąjungos narių.

Tyrimo objektas

Šalies žiedinė ekonomika tvarios gerovės kontekste.

Darbo tikslas

Nustačius žiedinės ekonomikos rodiklius, parengti šalies žiedinės ekonomikos tvarios gerovės kontekste išsivystymo lygio vertinimo modelį.

Darbo uždaviniai

1. Teoriškai pagrįsti ekonomikos, aplinkosaugos bei socialinės dimensijų sąsajas žiedinėje ekonomikoje tvarios gerovės kontekste.
2. Pasiūlyti žiedinės ekonomikos rodiklių pasirinkimo gaires, kurios bus naudojamos vertinant šalies žiedinės ekonomikos išsivystymo lygį, atsižvelgiant į tvarios gerovės komponentus.
3. Parinkti žiedinės ekonomikos rodiklius, atitinkančius siūlomas žiedinės ekonomikos vertinimo rodiklių pasirinkimo gaires ir tvarią gerovę.
4. Suformuoti žiedinės ekonomikos išsivystymo lygį vertinimo modelį tvarios gerovės kontekste.
5. Remiantis suformuotu modeliu, įvertinti pasirinktų šalių žiedinės ekonomikos išsivystymo lygį tvarios gerovės kontekste.

Tyrimų metodika

1. Pirminių ir antrinių šaltinių rinkimo, grupavimo ir sisteminimo, apibendrinimo ir lyginamosios, loginės ir literatūros analizės metodai.
2. Parinkus kriterijus ir alternatyvas buvo nustatyta grupės sprendimų matricą, naudojant rodiklių sistemą.
3. Kriterijai ir alternatyvos buvo optimizuojamos pagal maksimizacijos ir minimizacijos poreikį, reikšmės buvo normalizuojamos naudojant rodiklių sistemą ir paruoštos daugiakriterinių analizės metodų panaudojimui.
4. Daugikriteriniai sprendimų priėmimo metodai MULTIMOORA ir TOPSIS buvo taikomi vertinant šalies žiedinės ekonomikos išsivystymo lygį: maksimalaus tikslinio ataskaitos taško nustatymas naudojant MULTIMOORA metodą bei Euklido atstumo nustatymas iki geriausio hipotetinio sprendimo naudojant TOPSIS metodą.
5. Pritaikius pilnąją sandaugos formą pagal MULTIMOORA metodą bei santykinį artumo koeficientą pagal TOPSIS metodą atliktas reitingavimas pagal žiedinės ekonomikos išsivystimą tvarios gerovės kontekste. Taikant metodų papildomumo (trianguliacijos) principą buvo patikrintas išvadų patikimumas ir palyginti gauti rezultatai.
6. Rezultatų aprobavimas taikant šalies atvejo analizės metodą.

Darbo mokslinis naujumas

1. Žiedinės ekonomikos samprata apibrėžta remiantis aplinkos, ekonomikos ir socialiniais aspektais, kurie atitinka tvarios gerovės sampratą.
2. Europos Sąjungos, Reike ir kiti, (2018) ir Potting ir kiti, (2017) pristatytos 10R žiedinės ekonomikos strategijos buvo papildytos siūlomais ekonominiais aspektais (6E) ir socialiniais aspektais (6S), atsižvelgiant į žiedinės ekonomikos sąsajas su tvaria gerove. 6E strategijoje apibrėžiami žiedinės ekonomikos ekonominiai aspektai ir aprašomas žiedinės ekonomikos indėlis į šalies ekonominę gerovę. 6S strategija apibrėžia žiedinės ekonomikos socialinius aspektus, kurie

yra neatsiejama šalies ekonominės gerovės dalis. 6E ir 6S strategijos užpildo žiedinės ekonomikos mokslinių tyrimų spragas, pateikdamos pažangią priemonę analizuojant žiedinę ekonomiką ekonominiu ir socialiniu požiūriu.

3. Pasiūlyta rodiklių sistema, reikalinga siekiant įvertinti šalies žiedinės ekonomikos išsivystymo lygį. Rodikliai parenkami atsižvelgiant į žiedinės ekonomikos aplinkos, ekonominius ir socialinius aspektus ir grupuojami pagal tikslinę sritį.
4. Disertacijoje siūlomos rodiklių parinkimo gairės apima ekonomikos bei socialinius žiedinės ekonomikos aspektus, kurie leidžia ją vertinti pagal aplinkos, ekonomikos ir socialinę dimensijas, įvertinti kiekvieną žiedinės ekonomikos komponentą bei nustatyti jos raidos problemas kiekvienoje srityje ir tai lemia sklandžią žiedinės ekonomikos plėtrą.

Darbo rezultatų praktinė reikšmė

1. Apibrėžta žiedinės ekonomikos sistema suteikia galimybę praktikams, politikos formuotojams, institucijoms, vyriausybei, verslui geriau suprasti žiedinės ekonomikos komponentus ir tikslus, skatinančius tolimesnį jos įgyvendinimą ir plėtrą.
2. Pasiūlytos žiedinės ekonomikos rodiklių atrankos gairės apibrėžia tikslines sritis, padedančias nustatyti tvarios žiedinės ekonomikos plėtros problemas ir leidžiančias vyriausybei priimti efektyvius politinius sprendimus, skatinančius žiedinės ekonomikos plėtrą.
3. Žiedinės ekonomikos vertinimo modelis padėtų plėtoti jos vertinimą nustatytu laikotarpiu arba įgyvendinant Vyriausybės išleistus naujus žiedinės ekonomikos plėtros politikos nuostatus. Tai pat, pasiūlytas žiedinės ekonomikos modelis atskleistų ekonominę naudą taikant žiedinės ekonomikos principus.
4. Žiedinės ekonomikos vertinimo modelis galėtų pateikti gaires formuojant žiedinės ekonomikos plėtros politikos nuostatus ir padėtų vyriausybei priimančią strateginius sprendimus, susijusius su žiedinės ekonomikos įgyvendinimo politika.

Ginamieji teiginiai

1. Išplėtus žiedinės ekonomikos modelį trimis aspektais: ekonominiu, aplinkos ir socialiniu – užtikrinama žiedinės ekonomikos modelio atitiktis tvariai gerovei.
2. Šalies žiedinės ekonomikos išsivystymo lygio vertinimo problemą galima išspręsti taikant sukurtą vertinimo modelį, kuris integruoja žiedinės ekonomikos rodiklius, sugrupuotus pagal aplinkos, ekonomines ir socialines sritis.
3. Pasiūlytų įrankių (MULTIMOORA ir TOPSIS) sąranga integruota į žiedinės ekonomikos vystymosi vertinimo modelį leidžia įvertinti šalies žiedinės ekonomikos išsivystymo lygį tvarios gerovės kontekste pagal atskirus jos aspektus ir detalizuoti remiantis atskirais rodikliais.
4. Siūlomas šalies žiedinės ekonomikos išsivystymo lygio vertinimo modelis leidžia integruoti žiedinę ekonomiką į šalies ekonominį modelį ir skatina žiedinės

ekonomikos plėtrą, o tai leidžia pagerinti šalies arba regiono išteklių efektyvesnį paskirsymą bei užtikrinti ekonominę naudą.

1. Žiedinės ekonomikos koncepcijos teorinė analizė

Žiedinės ekonomikos modelis, priešingai nei linijinės ekonomikos modelis, apima atliekų perdirbimą, pakartotinio medžiagų panaudojimo procesus ir efektyvų išteklių naudojimą, kurie lemia ekologinių inovacijų ir technologijų plėtrą, darbo vietų kūrimą, ekologiškų investicijų padidėjimą, socialinių įpročių pokyčius ir skatina tvarų ekonomikos augimą (Lahti ir kiti, 2018). Kitaip tariant, žiedinė ekonomika veikia kaip natūrali ekosistema - jei yra natūralių atliekų - jas galima grąžinti į aplinką, tačiau visos medžiagos, kurias galima perdirbti ir išmesti, turi būti perdirbtos ir pašalintos, kad būtų pasiektas „nulis“. Toks atliekų perdirbimo principas – vienas iš pagrindinių žiedinės ekonomikos principų. Žiedinės ekonomikos koncepcija siūlo naudoti išteklius tol, kol įmanoma, iš jų išgauti maksimalią vertę, o pasibaigus produktų galiojimo ir medžiagų tarnavimo laikui, juos atnaujinti (Stahel 2012).

Žiedinės ekonomikos samprata kyla iš ekologinės pramonės plėtros (EID) teorijos ir idėjos, kad tvari ekonomika ir aplinkosauga gali koegzistuoti (Geng ir Doberstein, 2008). Zhu ir Qiu (2007) pasiūlė 3R žiedinės ekonomikos principus: sumažintą medžiagų naudojimą, pakartotinį jų naudojimą ir perdirbimą. Pasak Zhu ir Qiu (2007), žiedinė ekonomika yra tvaraus ekonomikos augimo modelis, kuriuo siekiama sumažinti išlaidas ir atliekas, pagerinti gamybos efektyvumą ir pagerinti produktų naudojimą. Pasak Kirchherr ir kiti, (2017), žiedinė ekonomika apibūdina ekonominę sistemą, pagrįstą 4R principais: išteklių naudojimo mažinimu, išteklių pakartotiniu naudojimu, perdirbimu ir išteklių atstatymu, kurie pakeistų produkto gyvavimo ciklą gamybos / paskirstymo ir vartojimo procesuose, mikro- lygiu (produktai, įmonės, vartotojai), mezo- lygmeniu (ekopramoniniai parkai) ir makro- lygiu (miestas, regionas, šalis). Tačiau, Shen ir Qi (2012) pristato 5R žiedinės ekonomikos principus, pridedant „permaštyti“ ir „perkurti“ principus, o tai reiškia permaštytą siekiant išsaugoti aplinką ir atkurti jau pažeistą ekosistemą. Lee ir kiti, (2015) 5R žiedinės ekonomikos principų idėją palaiko „permaštymo“ principu, kuris atnaujina 4R principą.

Xing ir kiti, (2017) siūlo 7R principą, papildant jį „atsparumu“ ir „reguliavimu“. „Reguliavimas“ palaiko žiedinės ekonomikos socialinį aspektą, kuris reiškia vyriausybės kontrolę, valdymą ir žiedinės ekonomikos reguliavimą. Vyriausybė, laikydamasi žiedinės ekonomikos įstatymų ir kitų teisės aktų, formuoja teigiamą verslo, gamintojų ir vartotojų požiūrį į žiedinę ekonomiką. „7R“ principai apima visas žiedinės ekonomikos suinteresuotąsias šalis: vyriausybę, tiekėjus, ne pelno organizacijas, gamintojus ir vartotojus. „7R“ praktika paskatina ekonomikos augimą gerindama gamybos efektyvumą, socialinę pažangą ir aplinkosaugą, taip pat mažindama išlaidas ir aplinkos taršą.

Reike ir kiti, (2018) ir Potting ir kiti, (2017) „7R“ žiedinės ekonomikos principus papildo 10R principais kurie skirstomi į trumpiausią ciklą (L1) – „Atsisakymas“, „Pakartotinis naudojimas“, „Remontas“ ir „Sumažinimas“, vidutinio ilgio ciklą (L2) sudaro – „Atnaujinti“, „Atkurti“ ir „Pakartotinai naudoti“ ir ilgą ciklą (L3) apima – „Permaštyti“, „Susigrąžinti“, „Perdirbti“.

Mokslininkai siūlo skirtingus žiedinės ekonomikos apibrėžimus. Pasak Kirchherr ir kiti, (2017), žiedinė ekonomika apibūdinama kaip ekonominė sistema, paremta verslo modeliais, kurie produkto „gyvavimo ciklo“ sąvoką pakeičia medžiagų mažinimu, alternatyviu pakartotiniu jų naudojimu, perdirbimu ir atnaujinimu gamybos / paskirstymo ir vartojimo procesuose, mikro-, mezo- ir makro- lygiu, siekiant tvarios plėtros, o tai reiškia aplinkosaugos ir ekonominės gerovės, socialinio teisingumo dabartinių ir ateities kartų labui.

Be to, Stahel (2016) pasiūlė sampratą, kuomet, žiedinė ekonomika paverčia savo gyvavimo ciklą turinčias prekes kitais ištekliais, uždarančiais kilpas pramonės ekosistemose neturinčių atliekų. Toks požiūris pakeistų ekonominę logiką, nes siūlomi kitokie gamybos principai: pakartotinai panaudojama tai, ką šiuo metu galima pakartotinai panaudoti arba perdirbti, ko negalima pakartotinai naudoti, o taip pat suremontuoti tai, kas sugedo, bei atstatyti tai, ko negalima taisyti.

Pagrindiniai žiedinės ekonomikos diegimą ir plėtrą skatinantys aspektai (Heshmati, 2015):

- Žemės degradacija;
- Miškų kirtimas;
- Vandens išsekimas;
- Oro tarša;
- Biologinės įvairovės praradimas;
- Atliekų susidarymas;
- Išteklių ir energijos trūkumas augančiai paklausai patenkinti.

Pietro-Sandoval ir kiti, (2018) nustatė keturis svarbius komponentus, reikalingus žiedinės ekonomikos koncepcijai sukurti:

1. Išteklių ir energijos perdirbimas, išteklių poreikių sumažinimas ir atliekų vertės atkūrimas;
2. Daugiapakopis požiūris;
3. Tvarios plėtros pasiekimas;
4. Glaudus ryšys su visuomenės inovacijų metodais.

Žiedinės ekonomikos modelis, kuriuo siekiama išsaugoti planetą, ilgainiui visuomenei ir verslui suteikia esminį konkurencinį pranašumą. Kadangi žiedinė ekonomika sukuria daugiau išteklių vertės, padeda įmonėms patenkinti besikeičiančius rinkos reikalavimus, mažinti aplinkosaugos sąnaudas, didinti vartotojų pasitenkinimą ir užtikrinti nenutrūkstamą išteklių tiekimą (Preston 2012). Nepaisant to, įmonėms, taikančioms žiedinės ekonomikos principus, taip pat gali būti naudinga sutaupyti medžiagų ir energijos sąnaudų, sumažinti priklausomybę nuo išteklių (pvz., pakartotinai naudojant ir perparduodant prekes), pagerinti klientų sąveiką ir sumažinti garantijos naudojimą pereinant prie ilgesnio laikotarpio panaudojimo produktų.

Pastarųjų dešimtmečių tvarios plėtros idėja yra populiari ne tik tarp tyrinėtojų, bet ir tarp pramonės, verslo, politikos atstovų. Tvari plėtra skatinama naudojant tris aspektus – ekonominį, socialinį ir aplinkos, kurių principas yra patenkinti dabarties poreikius ir užtikrinti galimybę ateities kartoms patenkinti savo poreikius taupant aplinką ir išteklius (WCED 1987). Dėl gyventojų skaičiaus augimo, itin padidėjusios gamybos ir vartojimo,

nekontroliuojamų atliekų, ekonomikos augimo, išteklių stygiaus, klimato kaitos ir daugelio kitų priežasčių – būtina imtis veiksmų siekiant išlaikyti ekonomikos augimą ir tuo pačiu metu saugoti aplinką, mažinti kenksmingas atliekas ir saugius išteklius.

Žiedinė ekonomika veikia kaip priemonė, kuria galima užtikrinti tvarią plėtrą. Žiedinė ekonomika gali būti apibūdinama kaip tarpdisciplininis modelis, apimantis aplinkos, inžinerijos, socialinius ir ekonominius mokslus įtraukiant socialinius mokslus, etikos, teisingumo, bendrų aplinkai nekenksmingų normų, vertybių ir mąstysenos aspektus. Žiedinės ekonomikos apibrėžimas, kurį pateikė Kirchherr ir kiti (2017) nurodo tvarios plėtros principus, tokius kaip – aplinkos, ekonominės ir socialinės gerovės užtikrinimas dabartinių ir ateities kartų labui. Žiedinė ekonomika yra susijusi su tvaria plėtra, įskaitant visus tvarumo tikslus – socialinius, ekonominius ir aplinkosaugos. Rodriguez-Antonas (2020) žiedinę ekonomiką apibrėžia kaip pagrindinę tvarios plėtros pasiekimo priemonę, kadangi ji susijusi su sveikata, švietimu, skurdo panaikinimu, nelygybės mažinimu, ekonomikos augimu ir gamtos išteklių paskirstymu. 2013 m. Europos Komisija išleido Aplinkos veiksmų programą (EAP, 2013), kurioje pateikiami žiedinės ekonomikos principai:

1. Ekologinės naujovės yra klestėjimo ir sveikos aplinkos raktas.
2. Susidariusios atliekos yra lygios „nuliui“ arba gali būti pakartotinai naudojamos, perdirbamos arba daro minimalų poveikį, kurio negalima pašalinti fiziniams dėsniams.
3. Gamtos ištekliai naudojami efektyviai, biologinė įvairovė yra saugoma, atkuriamą ir vertinama.
4. Tarša ir anglies dioksido augimas yra tvariai valdomi.

Pagrindinis tvarumo tikslas yra patenkinti poreikius (WCED, 1987), kuris pasiekiamas taikant ekonominį modelį, besiremiantį tvarumo koncepcija. Tačiau tiksliai nustatyti, kokie yra šie poreikiai, neįmanoma (Kjell, 2011). Taigi žmogaus gerovė yra pagrindinis tvarumo klausimas, pripažįstant, kad žmonės yra susiję ir priklausomi nuo gamtos, gaudami specifinę ir kiekybiškai vertingą naudą iš tinkamo šių sistemų veikimo (Whiting ir kiti, 2018).

Tvarios plėtros tikslai visame pasaulyje veikia tvarios gerovės link, skiriant dėmesio aplinkos, socialiniams ir ekonominiams tvarumo aspektams (Costanza ir kiti, 2016). Teisingumas ir žmogaus gerovė arba „galutiniai tikslai“ pateikiami kaip tvarios plėtros tikslas, kuris apibūdinamas kaip tvarus, teisingas, klestintis, aukštos kokybės gyvenimas. Šis tikslas įgyvendinamas taikant tvarumo metodą, kuris padeda išlaikyti sveikesnę planetos aplinką, kurti sveiką ekonomiką ir apsaugoti gerovės galimybes.

Šiuo metu žiedinė ekonomika daugiausia susijusi su ekologine ir pramonine ekonomika, o socialinis aspektas tebėra jos diskusijų objektas. Pagal Geissdoerfer ir kiti, (2017) socialiniai aspektai, kaip žiedinės ekonomikos komponentas, turi siaurą autorių aprėptį. Paprastai darbo vietų kūrimo ir nedarbo veiksniai priskiriami žiedinės ekonomikos socialinės sričiai. Tačiau gyvenimo būdo ir vartotojų elgsenos pokyčiai, taip pat efektyvi mokesčių sistema yra įtraukiami į socialinę dimensiją (Webster 2015). Vis dėlto socialiniai veiksniai taip pat integruojami į žiedinės ekonomikos vertinimo metodą. Pasak Giselinį ir kiti, (2016), socialinių veiksnių sėkmė žiedinės ekonomikos sampratoje sukuria kliūtį jos plėtrai ir integracijai. Moreau ir kiti (2017) teigia, kad žiedinė ekonomika gali ignoruoti socialinį teisingumą, tačiau tiesioginis jos socialinis poveikis vis dar nežinomas. Socialiniai aspektai turi atitikti aplinkos ir ekonomikos

principus. Žiedinė ekonomika negali pradėti vystytis, jei ji neatitinka paklausos. Padi-dėjus jos paklausai, įtraukiant ir skatinant verslo ir vartotojų vyriausybės, ji gali vys-tytis. Pasak Leader ir Rashid (2016), žiedinė ekonomika gali sutelkti dėmesį ne tik į gamybos etapą, bet ir tuo pačiu atsižvelgti į atsakingą vartojimą. Tai galima suderinti su kiekvienu produkto kūrimo etapu. Štai kodėl siekiant skatinti žiedinę ekonomiką būtina skatinti atsakingą vartojimą, kadangi vartotojas tampa pagrindiniu žiedinio verslo modelių varikliu. Taigi socialinis komponentas tampa lemiamas keičiant varto-tojų elgseną ir įpročius atsakingo vartojimo link. Borello (2017) teigia, kad dar nėra tyrimų apie vartotojų norą dalyvauti žiedinėje ekonomikoje.

Žiedinę ekonomiką galima apibūdinti kaip tarpdisciplininį modelį, apimančią aplin-kos, inžinerijos, ekonominis mokslus įtraukiant etikos, teisingumo, bendrųjų aplinkos normų, vertybių ir pasaulėžiūros aspektus.

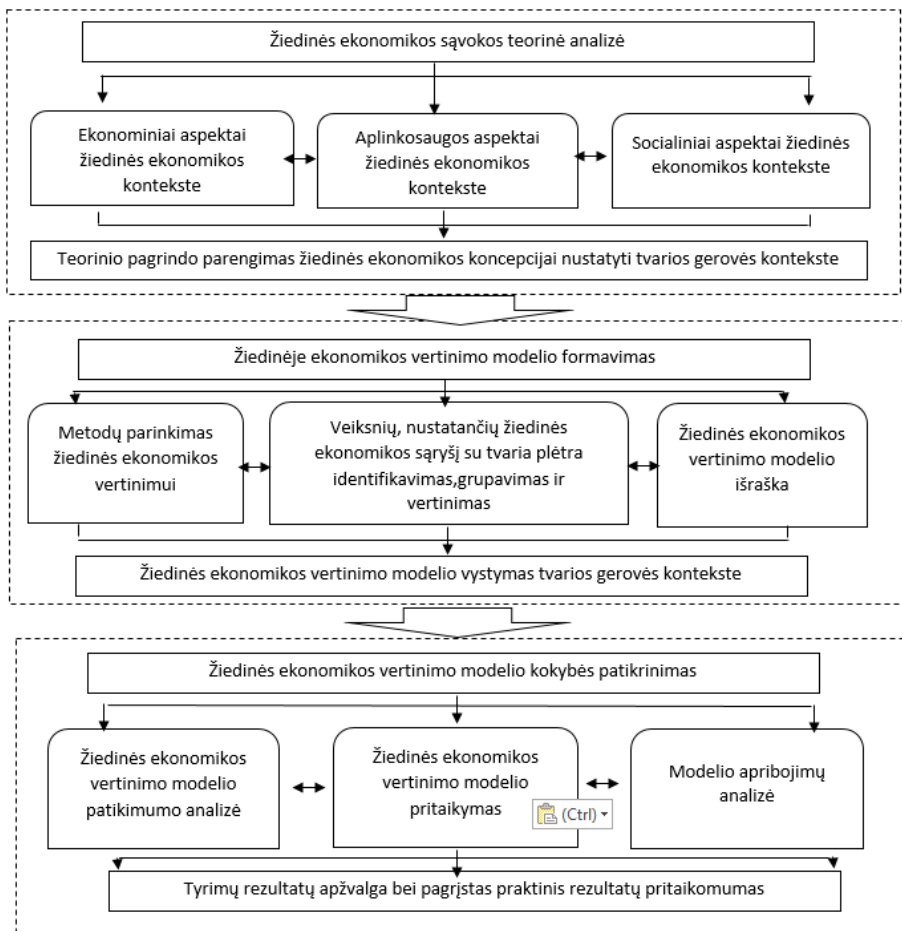
2. Žiedinės ekonomikos vertinimo modelio formulavimo metodologija tvarios gerovės kontekste

Žiedinės ekonomikos vertinimo modelis apima rodiklių rinkinį, suskirstytą į atskiras sričių grupes. Kadangi trijų dimensijų matavimui surinkti rodikliai turi skirtingus matavimo vie-netus, reikėtų atitinkamai rinktis vertinimo metodus. Kelių kriterijų sprendimų priėmimo metodai (MCDM) gali būti naudojami vertinant kriterijų rinkinį su skirtingais matavimo vienetais, taip būtų galima įvertinti ir suskirstyti kriterijus. Daugikriteriniai sprendimų pri-ėmimo metodai kiekybiškai įvertina bet kokią sudėtingą objektą, aprašytą pagal kriterijų rinkinį. Taikant daugikriterinius sprendimo priėmimo metodus, galima atlikti kelių alter-natyvių objektų vertinimą, juos palyginti bei išanalizuoti priežastis, dėl kurių vienos al-ternatyvos veikia geriau nei kitos. Žiedinės ekonomikos vertinimo modeliui sukurti buvo pasirinkti MULTIMOORA ir TOPSIS metodai.

MULTIMOORA metodą pristatė Brauers ir Zavadskas (2010), kurie atnaujino MCDM metodą MOORA pridėdami daugelio objektų optimizavimą. MULTIMOORA metodą naudojo įvairių sričių mokslininkai: Hafezalkotob ir kiti (2019) MULTIMOORA metodą pritaikė inžinerijos srityje, siūlydami jį naudoti hibridinių transporto priemonių varikliuose. Kokybiškų funkcijų diegimo analizėje Wu ir kiti (2020) tai pat naudojo MUL-TIMOORA metodą. Vertindami ES energetikos politikos prioritetų įgyvendinimą Baltijos jūros regione, MULTIMOORA metodą naudojo Siksnelytė ir kiti (2019). Li ir kiti (2019), naudodamas MULTIMOORA metodą, įvertino keleivių pasitenkinimą viešuoju trans-portu. Geetha ir kiti (2019) šį metodą naudojo sveikatos priežiūros atliekų šalinimo meto-dams įvertinti.

TOPSIS metodas, pagrįstas geometrinių atstumų nustatymu nuo geriausių ir blogiausių sprendimų: trumpiausiu geometriniu atstumu nuo geriausio sprendimo ir ilgiausiu geo-metriniu atstumu nuo blogiausio sprendimo (Zavadskas ir kiti, 2016). TOPSIS metodas buvo naudojamas Memari ir kiti (2019) pasirinkus tvarų tiekėją. Kuriant elektrines trans-porto priemones, tvarumo modelių palyginimas pateiktas naudojant TOPSIS metodą Sa-maie ir kiti (2020). Gorgij ir kiti (2019), vertindami požeminio vandens kokybę, naudojo TOPSIS metodą. ES šalių ekonominis ir aplinkosauginis efektyvumas TOPSIS metodu buvo įvertintas Vavreko ir Chovancovos (2019). Kredito kortelių platformas TOPSIS me-todu įvertino Yildirim (2019).

Žiedinės ekonomikos vertinimo modelio formulavimas pavaizduotas S2.1 paveiksle. Atlikus literatūros analizę ir pateikus žiedinės ekonomikos apibrėžimą bei sąsajas su tvaria plėtra ir tvaria gerove, parengiamas teorinis pagrindas žiedinės ekonomikos sampratai nustatyti tvarios gerovės kontekste. Parinkus metodus, tinkančius įvertinti žiedinę ekonomiką ir pritaikius jos vertinimo indikatorių strategiją, suformuojamas modelis, vertinantis šalies žiedinę ekonomiką arba jos pažangą per nustatytą laikotarpį. Gauti rezultatai pateiktų šalies žiedinės ekonomikos išsivystymo lygio vertinimus bei leistų išanalizuoti tam tikro įvertinimo priežastis.

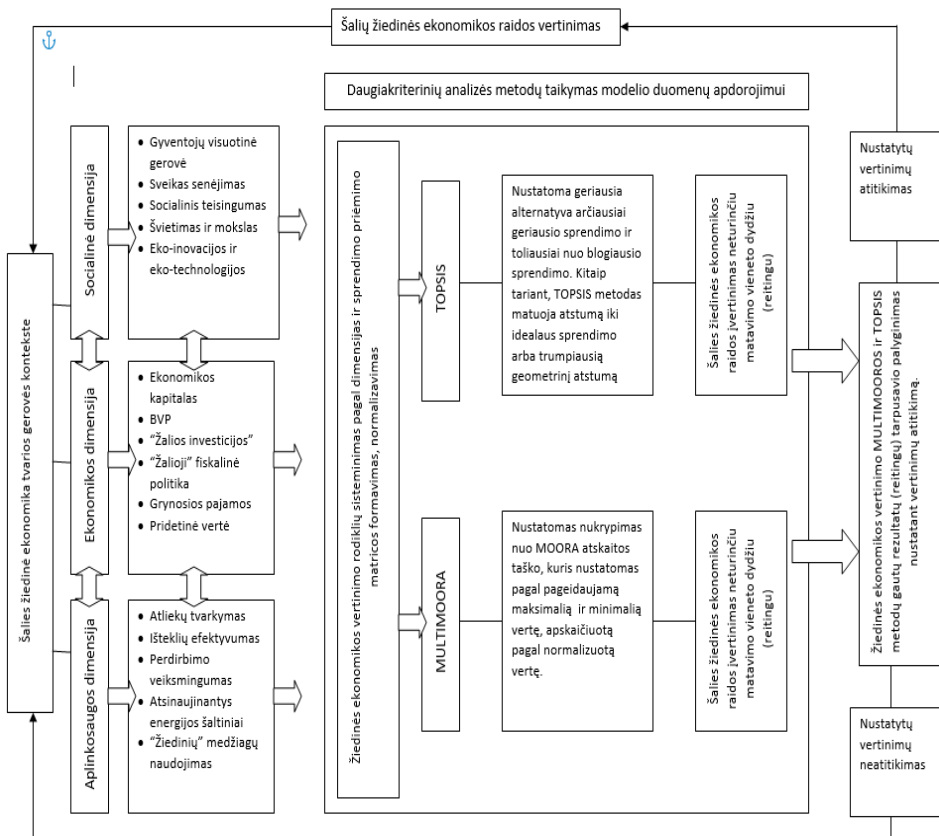


S2.1 pav. Žiedinės ekonomikos vertinimo modelio formavimo teorija (sudaryta autorės)

Žiedinės ekonomikos vertinimo modelį galima suskirstyti į kelis etapus, kaip parodyta S2.2 paveiksle. Žiedinės ekonomikos vertinimo modelio kūrimas prasideda renkant

duomenis, atitinkančių apibrėžtas tikslų ir strategijų sritis pasirinktoje geografinėje vietoje ir laikotarpyje.

Surinkti duomenys yra grupuojami pagal žiedinės ekonomikos komponentų grupes: aplinkos, ekonomikos ir socialinius aspektus sudarant sprendimo priėmimo matricą, paruoštą daugikriteriniams sprendimų priėmimo metodams MULTIMOORA ir TOPSIS taikymui. Daugikriteriniai sprendimų priėmimo metodai MULTIMOORA ir TOPSIS leidžia įvertinti pasirinktų šalių žiedinės ekonomikos išsivystymo lygį, bei palyginti pasirinktų šalių žiedinės ekonomikos išsivystymo lygį tarpusavyje naudojant reitingavimo sistemą.



S2.2 pav. Žiedinės Ekonomikos vertinimo modelio formavimas
(sudaryta autorės)

Žiedinės ekonomikos vertinimo modelis yra pagrįstas šešiais pagrindiniais etapais, kaip parodyta S2.1 lentelėje. Aplinkos, socialinių ir ekonominių aspektų vertinimo rodikliai žiedinės ekonomikos kontekste yra renkami ir grupuojami, sisteminami sprendimų

matricioje, kaip parodyta pirmame etape. Kadangi visi rodikliai turi įvairius matavimo vienetus, vertės yra normalizuojamos, kaip parodyta antrame etape. Trečiame etape vertės yra maksimaliai padidintos arba sumažintos pagal MULTIMOORA ir TOPSIS metodų taisykles. Maksimaliai padidinus arba sumažinus vertes, galima sužinoti atskaitos tašką, kaip parodyta ketvirtame etape. Penktame etape gaunama MULTIMOORA pilno dauginimo forma, o santykinį geriausio ir blogiausio sprendimo artumo koeficientą galima gauti taikant TOPSIS metodą. Paskutiniame etape reikšmių rangą galima gauti atsižvelgiant į TOPSIS ir MULTIMOORA metodų rezultatą.

S2.1 lentelė. Žiedinės ekonomikos vertinimo modelio formavimo etapai (sudaryta autorės)

Etapai	Proceso seka	
Duomenų rinkimas	Duomenys buvo renkami naudojant šias duomenų bazines: – Europos statistikos duomenų bazė - Eurostatas (2020 m.), – Ekonominio bendradarbiavimo ir plėtros organizacija (2020 m.), – Europos Komisija (2020 m.), – Jungtinių tautų duomenų bazė (2020 m.).	
Tyrimo apimtis	Šalių žiedinės ekonomikos vertinimas remiantis ekonomine, aplinkos ir socialine sritimis bei žiedinės ekonomikos vystymosi palyginimas 2014-2019 m. laikotarpyje.	
I etapas – rodiklių parinkimas bei sisteminimas	Žiedinės ekonomikos vertinimo rodikliai yra klasifikuojami į grupes pagal atskiras sritis ir apibendrinti sprendimų priėmimo matricioje.	
II etapas – sprendimų priėmimo matricos normalizavimas	Normalizuojama sprendimų priėmimo matrica.	Taikoma formulė: $x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{j=1}^m x_{ij}^2}}$
III etapas – nustatomos idealiai geriausios ir idealiai blogiausios alternatyvos	Surandamos maksimalios ir minimalios reikšmės naudojant TOPSIS metodą.	Taikomos formulės: $V^* = \{V_1^*, V_2^*, \dots, V_m^*\} = \left\{ \left(\max_j \omega_j r_{ij} / i \in I_1 \right), \left(\min_j \omega_j r_{ij} / i \in I_2 \right) \right\}$ $V^- = \{V_1^-, V_2^-, \dots, V_m^-\} = \left\{ \left(\min_j \omega_j r_{ij} / i \in I_1 \right), \left(\max_j \omega_j r_{ij} / i \in I_2 \right) \right\}$
	Surandamos maksimalios ir minimalios reikšmės naudojant MULTIMOORA metodą.	Taikoma formulė: $y_j^i = \sum_{i=1}^{i=g} x_{ij}^* - \sum_{i=g+1}^{i=n} x_{ij}^*$

S2.1 lentelės pabaiga

Etapai	Proceso seka	
IV etapas – idealiai geriausios alternatyvos nustatymas	Ieškomas kiekvienos alternatyvos atstumas nuo idealiai geriausios alternatyvos, naudojamas atstumo skaičiavimas Euklidinėje erdvėje pagal TOPSIS metodą.	Taikoma formulė: $D_j^* = \sqrt{\sum_{i=1}^m \left(\omega_i r_{ij}^{\sim} - V_i^* \right)^2}$
	Pagal normalizuotų rodiklių reikšmes randamas maksimalus tikslinis ataskaitos taškas naudojant MULTIMOORA metodą.	Taikoma formulė: $\min_j \left\{ \max_i \left r_i - x_{ij}^* \right \right\}$
V etapas – idealiai blogiausios alternatyvos nustatymas	Ieškomas kiekvienos alternatyvos atstumas nuo idealiai blogiausios alternatyvos, naudojamas atstumo skaičiavimas Euklidinėje erdvėje pagal TOPSIS metodą.	Taikomos formulės: $D_j^- = \sqrt{\sum_{i=1}^m \left(\omega_i r_{ij}^{\sim} - V_i^- \right)^2}$
	Tikslinio ataskaitos taško nustatymas naudojant MULTIMOORA metodą.	Taikoma formulė: $\left s_i r_i - s_i x_{ij}^* \right $
VI etapas – alternatyvų santykinis atstumas	Skaičiuojamas kiekvienos alternatyvos santykinis atstumas nuo idealiai blogiausios alternatyvos pagal TOPSIS metodą.	Taikoma formulė: $C_j^i = \frac{D_j^-}{D_j^* + D_j^-}$
	Bendrasis alternatyvos naudingumas išreiškiamas neturinčiu matavimo vieneto dydžiu pagal MULTIMOORA metodą.	Taikoma formulė: $U_j = \prod_{i=1}^n x_{ij}$
V etapas – galutinis alternatyvų rangavimas	Alternatyvos yra sureitinguojamos naudojant TOPSIS ir MULTIMOORA metodus nuo geriausiai besivystančios šalies žiedinės ekonomikos kontekste iki blogiausios besivystančios šalies žiedinės ekonomikos kontekste.	
VIII etapas – gautų rezultatų palyginimas	Nustatyti šalių žiedinės ekonomikos vystymosi reitingų rezultatai palyginami remiantis TOPSIS ir MULTIMOORA gautais rezultatais. Nežymiai besiskiriantys rezultatai parodo modelio patikimumą.	

Žiedinės ekonomikos vertinimo modelio I etape renkami aplinkos, socialinių ir ekonominių komponentų rodikliai, grupuojami pagal tikslines sritis ir susisteminami į sprendimų priėmimo matricą, kuri bus normalizuota, kaip parodyta II etape pagal TOPSIS ir MULTIMOORA metodus. Sisteminti rodikliai turi vienodą svorį (Chen ir kiti, 2012; Chen ir Yang 2011; Lin ir kiti, 2008; Su ir kiti, 2013), kai kuriuose MCDM tyrimuose siūloma, kad visi rodikliai būtų lygiaverčiai, tuomet pats algoritmas nustato santykinį atstumą nuo idealios alternatyvos. Tačiau ekspertų nuomonių vertinimas gali būti netikslus, nes turi būti tiriamos ekspertų ypatybės, o tai gali lemti mažą tyrimo tikslumą, ypač tais atvejais,

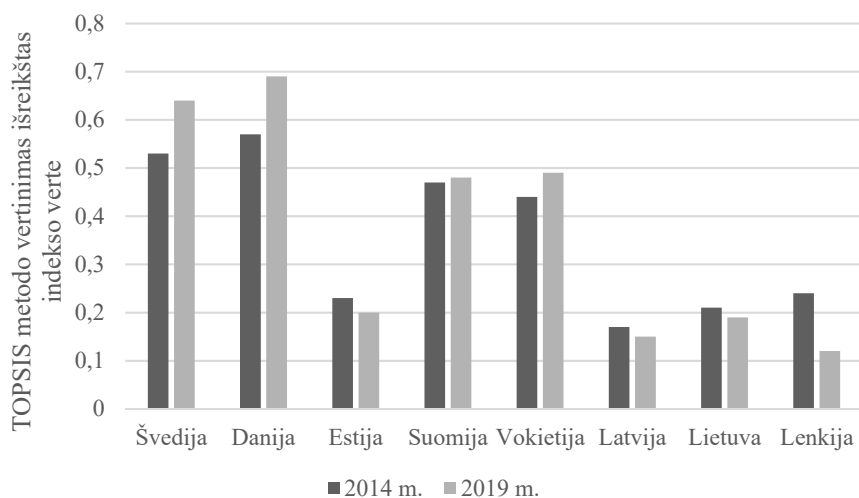
kai alternatyvų ir rodiklių skaičius yra labai didelis. Taip pat ekspertų nuomonių vertinimas gali būti netikslus dėl ekspertų subjektyvaus vertinimo, nepaisant užduodamo konteksto. III etape idealiai geriausios ir idealiai blogiausios alternatyvos nustatomos naudojant TOPSIS ir MULTIMOORA metodus, o geriausia – IV etape. V etapas apskaičiuoja idealiausią blogiausio atvejo alternatyvą, kuri naudojama TOPSIS ir MULTIMOORA metoduose, siekiant užpildyti alternatyvų reitingą. Žingsnyje apskaičiuojamas kiekvienos alternatyvos santykinis atstumas nuo idealiausio blogiausio atvejo alternatyvos remiantis TOPSIS metodu, o bendras alternatyvos naudingumas išreiškiamas MULTIMOORA metodu, neturiniu vieneto, todėl yra išreiškiamas pažymiu ar rangu. Galutinis alternatyvų reitingas pateikiamas VII etape, naudojant TOPSIS ir MULTIMOORA metodus, nuo geriausiai besivystančios šalies žiedinės ekonomikos iki blogiausiai besivystančios šalies žiedinės ekonomikos. VIII etape pateikto modelio tvirtumas patikrinamas lyginant TOPSIS ir MULTIMOORA metodų rezultatus. Esant dideliems neatitikimams, reikia grįžti prie I etapo ir patikrinti rodiklių parinkimo tikslumą.

3. Baltijos jūros regiono šalių žiedinės ekonomikos vertinimas tvarios gerovės kontekste

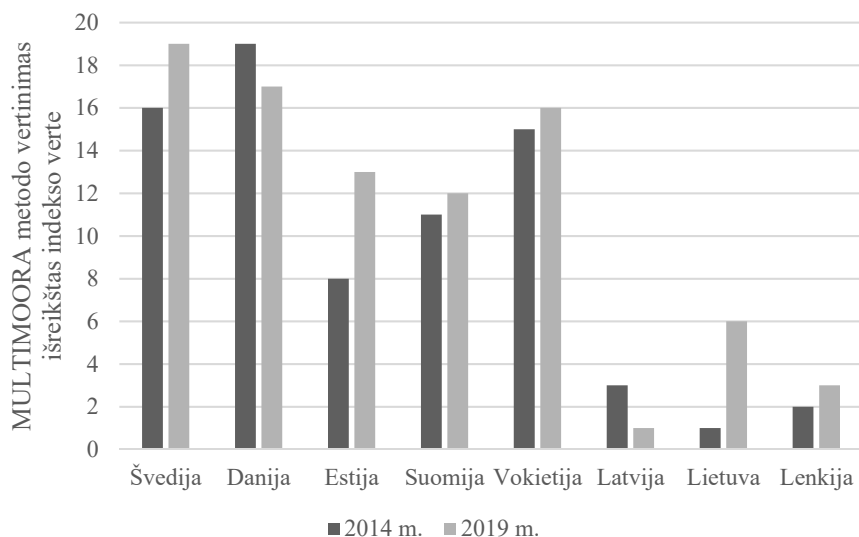
Pirmoji makroregioninė strategija Europoje buvo sukurta šalims, kurios geografiškai išsidėsčiusios aplink Baltijos jūrą ir pavadintoms Baltijos jūros regionu. Šios strategijos veiksmų planą pristatė Europos Komisija (2009 m.). Strategija grindžiama pagrindiniais iššūkiais, susijusiais su jūros išsaugojimu, regiono sujungimu ir gerovės didinimu. Strategija turi keletą tikslų, susijusių su skirtingomis sritimis ir politika, pavyzdžiui: švarus jūros vanduo su sveika gyvūnija, saugi laivyba ir patikimos energijos rinkos, siekiant sukurti bendrą energijos rinką, prisitaikymas prie klimato kaitos kartu su rizikos valdymu ir kiti. Tai indėlis į „Europa 2020“ (Europos Komisija, 2010 m.) strategiją. Baltijos jūros regionui priklauso Švedija, Danija, Estija, Suomija, Vokietija, Latvija, Lietuva ir Lenkija.

Žiedinės ekonomikos duomenys 2014–2019 m. buvo renkami naudojant šias duomenų bazes: Europos statistikos duomenų bazė – Eurostatas (2020 m.), Ekonominio bendradarbiavimo ir plėtros organizacija (2020 m.), Europos Komisija (2020 m.).

Žiedinės ekonomikos plėtra Baltijos jūros regione 2014 m. ir 2019 m. laikotarpiu, pasak TOPSIS, pavaizduota S3.1 pav. Nuo 2014 m. iki 2019 m. Švedija ir Danija pagerino savo Žiedinės ekonomikos plėtros rezultatus ir yra įvertintos stipriausią žiedinę ekonomiką turinčios šalys Baltijos jūros regione. Vokietija įvertinta trečia vieta pagal žiedinės ekonomikos raidą Baltijos jūros regione ir uždaro pirmąjį trejetą šalių su geriausia žiedine ekonomika Baltijos jūros regione. Suomija įvertinta ketvirta vieta ir jos rezultatai yra labai artimi Vokietijai, tačiau per 2014–2019 metus Suomija neturėjo reikšmingų rezultatų pokyčių. Estija įvertinta penkta vieta iš aštuonių Baltijos jūros šalių atsižvelgiant į žiedinės ekonomikos pažangą, atsidurdama rangavimo viduryje. Lietuva, Latvija ir Lenkija yra blogiausiai įvertintos šalys pagal žiedinės ekonomikos pažangą Baltijos jūros regione, be to, Lenkijos žiedinės ekonomikos pažanga nuo 2014 m. tik prastėjo, kaip rodo TOPSIS metodo rezultatai.



S3.1 pav. Žiedinės ekonomikos vertinimas Baltijos jūros regione 2014 ir 2019 m. naudojant TOPSIS metodą (sudaryta autorės)



S3.2 pav. Žiedinės ekonomikos vertinimas Baltijos jūros regione 2014 ir 2019 m. naudojant MULTIMOORA metodą (sudaryta autorės)

2014 m. ir 2019 m. žiedinės ekonomikos plėtra Baltijos jūros regione taikant MULTIMOORA metodą parodyta S3.2 paveiksle. Švedija, Danija ir Vokietija įvertintos kaip geriausia žiedinę ekonomiką turinčios šalys Baltijos jūros regione, kas atitinka TOPSIS metodo rezultatus. Suomija ir Estija pagal MULTIMOORA ir TOPSIS metodus lieka reitingo viduryje. Remiantis MULTIMOORA ir TOPSIS metodais, Lietuva, Latvija ir Lenkija buvo įvertintos kaip prasčiausia žiedinę ekonomiką turinčios šalys Baltijos jūros regione.

Išvados

1. Atlikus žiedinės ekonomikos mokslinės literatūros analizę, buvo išgryninta žiedinės ekonomikos koncepcija, kuri remiasi tvarios gerovės principais ir apima aplinkos, ekonominę bei socialinę sritis. Ekonominės, aplinkos ir socialinės sričių išgryninimas leidžia kompleksiskai vertinti šalies žiedinės ekonomikos išsivystymo lygį, taip užtikrinant žiedinės ekonomikos įgyvendinimą ir plėtrą. Ekonominė sritis palaiko aplinkosaugos ir socialinius aspektus, bei užtikrina žiedinės ekonomikos įgyvendinimą ir plėtrą. Stipri ekonominė dimensija užtikrina strateginių išteklių bei finansavimo paskirstymą, kas leidžia integruoti žiedinės ekonomikos aspektus į tvarią šalies plėtrą. Vis dėlto, socialinė sritis nėra toks aktyvus žiedinės ekonomikos elementas kaip aplinkos ar ekonominė sritys, bet ne mažiau svarbi, nes socialinė sritis sudaro konceptualų suinteresuotųjų šalių požiūrį į žiedinę ekonomiką bei formuoja ilgalaikius įpročius. Siūlomas žiedinės ekonomikos apibrėžimas apibūdina ją kaip ekonominę sistemą, pagrįstą verslo modeliais, kurie pakeičia „imk-gamink-išmesk“ koncepciją „imk-daryk-vėl naudok- perdirbk“ koncepcija, įgyvendinama mikro-, mezo- ir makrolymenimis ir pagrįsta aplinkos, ekonominiais ir socialiniais aspektais, siekiant tvarios plėtros, kuri užtikrintų tvarią dabartinių ir ateities kartų gerovę.
2. Mokslinių šaltinių analizė padėjo parinkti šalies žiedinės ekonomikos išsivystymo lygio vertinio rodiklius ir suformuluoti jų pasirinkimo gaires. Rodiklių parinkimo gairės, pagrįstos žiedinės ekonomikos elementais, suskirstytos į tikslines sritis. Rodikliai buvo atrinkti remiantis aplinkos, socialiniais ir ekonominiais aspektais, kurie atitinka žiedinės ekonomikos sampratą. Aplinkos aspektą apima atliekų tvarkymas, oro tarša ir CO₂ emisija, energijos ir medžiagų valdymo rodiklių grupė. Ekonominė sritis apima makroekonominius ir pramonės rodiklius, žalias investicijas, žalią fiskalinę politiką ir technologinę plėtrą. Socialinė sritis apima sveikatos, socialinio teisingumo, gerovės ir sveiko senėjimo, švietimo, mokslo ir technologijų, finansinės ir aplinkos gerovės rodiklius.
3. Žiedinės ekonomikos rodiklių atrankos gairės buvo pasiūlytos remiantis mokslinės literatūros analize ir Europos Sąjungos reglamentais. Pasiūlyta Reike *et al.* (2018) ir Europos Sąjungos palaikyta 10R strategija buvo naudojama aplinkos srities rodikliams parinkti. Be to, Europos Sąjungos pasiūlyta 10R strategija buvo papildyta 6E strategija, skirta ekonominės srities rodiklių atrankai, o 6S strategija – socialinės srities rodiklių parinkimui. 6E strategija apibrėžia žiedinės ekonomikos ekonominius aspektus ir apibūdina žiedinės ekonomikos indėlį į

- šalies ekonominę gerovę. 6S strategija apibrėžia žiedinės ekonomikos socialinius aspektus, kurie yra neatsiejama šalies ekonominės gerovės dalis. 6E ir 6S strategijos užpildo žiedinės ekonomikos tyrimų spragas, pateikdamos pažangią žiedinės ekonomikos analizės priemonę ekonominiu ir socialiniu požiūriu.
4. Šalies žiedinės ekonomikos išsivystymo lygio vertinimo modelis sukurtas remiantis tvaros plėtros komponentais atitinkančiais tvarią gerovę. Modelis apima rodiklių pasirinkimo strategijas ir sprendimų priėmimo matricos formavimą. Kelių kriterijų sprendimų priėmimo metodai MULTIMOORA ir TOPSIS buvo pritaikyti žiedinės ekonomikos vertinimui, kurie yra apibūdinami kaip tinkantys žiedinės ekonomikos išsivystymo lygio įvertinimui, nes yra naudojami vertinant sudėtingus kriterijus, suteikiant galimybę sisteminti, analizuoti ir grupuoti rodiklius su skirtingais matavimo vienetais, kurių vertės yra maksimalios arba minimalios. Atlikto tyrimo rezultatai pagal abu pritaikytus metodus parodė adekvачius rezultatus ir patvirtino pasiūlytos šalies žiedinės ekonomikos išsivystymo lygio vertinimo modelio naudojimo patikimumą.
 5. Modelis buvo empiriškai išbandytas Baltijos jūros regione 2014–2019 m. Šalies žiedinės ekonomikos išsivystymo lygio ir jos atskirų sričių vertinimas Baltijos jūros regione buvo atliktas remiantis aplinkos, ekonominiais ir socialiniais aspektais. Tyrimo rezultatai rodo labiausiai išsivysčiusią žiedinę ekonomiką tarp Baltijos jūros regiono narių, taip pat problemas, su kuriomis šalys susiduria ją įgyvendindamos. 2019 m. labiausiai išsivysčiusią žiedinę ekonomiką tarp Baltijos jūros regiono narių turėjo Švedija (1), Danija (2) ir Vokietija (3) pagal MULTIMOORA metodą. Estija (4) ir Suomija (5) įvertintos vidutiniškai, o Lietuva (6), Lenkija (7) ir Latvija (8) įvertintos prasčiausiai pagal MULTIMOORA metodą. Pagal TOPSIS metodą labiausiai išsivysčiusią žiedinę ekonomiką tarp Baltijos jūros regiono narių turėjo Danija (0,69), Švedija (0,64) ir Vokietija (0,49). Suomija (0,48) ir Estija (0,2) įvertintos vidutiniškai, o Lietuva (0,19), Latvija (0,15) ir Lenkija (0,12) įvertintos prasčiausiai pagal TOPSIS metodą. Šalies žiedinės ekonomikos išsivystymo lygio vertinimas leidžia efektyviau paskirstyti ribotus išteklius, kas prisideda prie šalies arba regiono ekonominės naudos augimo. Tvarios plėtros principai įtraukiami į šalies žiedinės ekonomikos išsivystymo lygio vertinimą ir prisideda prie šalies tvarios gerovės tikslų pasiekimo. Šalies žiedinės ekonomikos išsivystymo lygio vertinimo modelis galėtų būti naudojamas analizuojant šalies žiedinės ekonomikos raidą tam tikru metu, taip pat nustato silpniausias jos sritis, kurias ateityje reikėtų tobulinti, kas leistų žiedinės ekonomikos įgyvendinimą. Siūlomas šalies žiedinės ekonomikos išsivystymo lygio vertinimo modelis galėtų padėti vyriausybei parengti šalies žiedinės ekonomikos įgyvendinimo strategiją, pagrįstą šalies rodiklių sistema, ir nustatyti strateginių sprendimų priėmimo procesą, taikomą sritims, indikatoriai kurių rodo silpniausią pažangą žiedinės ekonomikos įgyvendinimo link.

Annexes¹

- Annex A.** Representation of Circular Economy concept in the context of Sustainable Well-being
- Annex B.** Declaration of Academic Integrity
- Annex C.** The Coauthors Agreements to Present Publications for the Dissertation Defence
- Annex D.** Copies of scientific publications by the autor on the topic of the dissertation

¹The annexes are supplied in the enclosed compact disc.

Marta NIKANOROVA

THE ASSESSMENT OF CIRCULAR ECONOMY
IN THE CONTEXT OF SUSTAINABLE WELL-BEING

Doctoral Dissertation

Social Sciences,
Economics (S 004)

ŽIEDINĖS EKONOMIKOS VERTINIMAS
TVARIO GEROVĖS KONTEKSTE

Daktaro disertacija

Socialiniai mokslai,
ekonomika (S 004)

2021 07 16. 14,0 sp. l. Tiražas 20 egz.
Leidinio el. versija <https://doi.org/10.20334/2021-039-M>
Vilniaus Gedimino technikos universitetas
Saulėtekio al. 11, 10223 Vilnius
Spausdino BĮ UAB „Baltijos kopija“,
Kareivių g. 13B, 09109 Vilnius