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GREEN FINANCE MODEL FOR THE SUSTAINABLE DEVELOPMENT OF ZERO-WASTE CITIES

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

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ŽALIŲJŲ FINANSŲ MODELIS TVARIAI MIESTŲ BE ATLIEKŲ PLĖTRAI

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Abstract

Green finance is a way of financing climate change mitigation, adaptation and other environmental challenges. Along with the green economy concept, green finance contributes to disseminating global environmental challenges and how these challenges can be overcome. One area of environmental challenge is waste and sustainable waste management for sustainable urban development, where the green economy and green finance disciplines can have a significant positive impact.

The dissertation addresses the insufficiently effective use of the green finance model applicable to reducing municipal waste and following the "zero-waste" principles in the scientific literature and practice. It aims to develop and empirically test a green finance model that would lead to rational economic decisions for the sustainable development of zero-waste cities.

The dissertation consists of an introduction, three chapters, and general conclusions. The First Chapter aims to determine the green finance concept within related economic theories, concepts, methods, and models. It provides insights into other interrelated concepts, such as bio-economy, low-carbon finance, climate finance, and socio-environmental finance. Additionally, it provides a review of the green finance instruments. The Second Chapter investigates the role of waste management within economic theories and establishes the concept of zero-waste and inter-municipal cooperation. It also shapes the strategy for developing zero-waste cities with the active involvement of green finance mechanisms. The Second Chapter describes the methods for forming a green finance model for developing zero-waste cities. The Third Chapter provides empirical approval results of the green finance model for developing zero-waste cities on the Lithuanian regional level.

A set of general conclusions and recommendations for future research complete the dissertation. Five publications on the discussed study were published: two in the reviewed scientific journals, and three in conference proceedings.

Reziumė

Žalieji finansai – tai finansavimo būdas, kuriuo siekiama sušvelninti klimato kaitą, prisitaikyti prie jos ir spręsti kitas aplinkosaugos problemas. Kartu su žaliosios ekonomikos koncepcija, žalieji finansai prisideda prie pasaulinių aplinkosaugos iššūkių ir būdų, kaip šiuos iššūkius galima įveikti, sklaidos. Viena iš aplinkosaugos problemų sričių – atliekos ir tvarus atliekų tvarkymas siekiant tvarios miestų plėtros, kur tiek žaliosios ekonomikos, tiek žaliųjų finansų disciplinos gali turėti didelį teigiamą poveikį.

Disertacijoje nagrinėjama problema, kad mokslinėje literatūroje ir praktikoje nepakankamai efektyviai taikomas žaliųjų finansų modelis, siekiant mažinti komunalines atliekas ir laikytis nulinių atliekų principų. Disertacijos tikslas – sukurti ir empiriškai patikrinti žaliųjų finansų modelį, kurio taikymas leistų priimti racionalius ekonominius sprendimus siekiant darnios miestų be atliekų plėtros.

Disertaciją sudaro įvadas, trys skyriai, bendrosios išvados. 1 skyriuje siekiama apibrėžti žaliųjų finansų sąvoką susijusiose ekonomikos teorijose, koncepcijose, metoduose ir modeliuose, pateikti įžvalgas apie kitas tarpusavyje susijusias sąvokas, tokias kaip bioekonomika, mažo anglies dioksido kiekio technologijų finansavimas, klimato kaitos finansavimas ir socialinės aplinkosaugos finansavimas, taip pat apžvelgti žaliųjų finansų produktus. 2 skyriuje nagrinėjamas atliekų tvarkymo vaidmuo ekonominėse teorijose, nustatoma „zero-waste“ sąvoka ir savivaldybių bendradarbiavimas. Šiame skyriuje taip pat formuojama miestų, kuriuose nėra atliekų, plėtros strategija, aktyviai dalyvaujant žaliųjų finansų mechanizmams. 2 skyriuje aprašomi metodai, taikomi formuojant žaliųjų finansų modelį, skirtą miestų be atliekų plėtrai. 3 skyriuje pateikiami žaliųjų finansų modelio, skirto nulinių atliekų plėtrai, empirinio patvirtinimo Lietuvos regioniniu lygmeniu rezultatai.

Disertaciją užbaigia bendrosios išvados. Aptariamo tyrimo tema paskelbtos 5 publikacijos: 2 – recenzuojamuose mokslo žurnaluose, 3 – konferencijų medžiagoje.

Notations

Abbreviations

AHP – analytic hierarchy process (liet. *analitinės hierarchijos procesas*);
B/C ratio – benefit/cost ratio (liet. *naudos ir sąnaudų santykis*);
CBA – cost–benefit analysis (liet. *sąnaudų ir naudos analizė*);
COP – Conference of the Parties (liet. *Šalių konferencija*);
EIRR – economic internal rate of return (liet. *ekonominė vidinė grąžos norma*);
ENPV – economic net present value (liet. *ekonominė grynoji dabartinė vertė*);
EPA – Environmental Protection Agency (liet. *Aplinkos apsaugos agentūra*);
ESG – environmental, social, and governance (liet. *aplinkosaugos, socialinė ir valdymo sritis*);
EU – European Union (liet. *Europos Sąjunga*);
FIRR – financial internal rate of return (liet. *finansinė vidinė grąžos norma*);
FNPV – financial net present value (liet. *finansinė grynoji dabartinė vertė*);
GDP – gross domestic product (liet. *bendrasis vidaus produktas*);
GP – green progress (liet. *žaliasis progresas*);
IMC – inter-municipal cooperation (liet. *savivaldybių bendradarbiavimas*);
IRR – internal rate of return (liet. *vidinė grąžos norma*);
NPV – net present value (liet. *grynoji dabartinė vertė*);
RAAD – regional environmental protection department (liet. *regiono aplinkos apsaugos departamentas*);
RWMC – regional waste management centre (liet. *regioninis atliekų tvarkymo centras*);

UN – United Nations (liet. *Jungtinių tautų organizacija*);
WACC – the weighted average cost of capital (liet. *vidutinė svertinė kapitalo kaina*);
WEF – World Economic Forum (liet. *Pasaulio ekonomikos forumas*).

Definitions

Bioeconomy – a range of activities focused on using bio-substitutes for production inputs and outputs (D'Amato et al., 2017, 2019) (liet. *Bioekonomika – veikla, orientuota į biologinių pakaitalų naudojimą gamybos ištekliams ir produktams*).

Circular economy – the continuous and cyclical production process (D'Amato et al., 2017, 2019) (liet. *Žiedinė ekonomika – nenutrūkstamas ir cikliškas gamybos procesas*).

Green bond – fixed-income financial instrument utilised to generate funds for environmental preservation projects (Alsmadi et al., 2023; Cheong et al., 2020; Ehlers & Packer, 2017; Fatica et al., 2019; Gilchrist et al., 2021; Inderst et al., 2012; Löffler et al., 2021; Migliorelli & Dessertine, 2019; Sangiorgi & Schopohl, 2023; Tripathy et al., 2020; Ye & Rasoulinezhad, 2023) (liet. *Žaliosios obligacijos – fiksuotų pajamų finansinė priemonė, naudojama siekiant pritraukti lėšas aplinkosaugos projektams finansuoti*).

Green economy – a range of activities serving as a compromise to achieve sustainable development goals (Merino-Saum et al., 2018) (liet. *Žalioji ekonomika – veikla, kuri leidžianti siekti darnaus vystymosi tikslų.*).

Green finance – a range of goods, services, technologies, sectors, and stakeholders actively supporting environmental conservation, pollution reduction, and the promotion of sustainable economic growth (Sachs et al., 2019) (liet. *Žalieji finansai – įvairios prekės, paslaugos, technologijos, sektoriai ir suinteresuotosios šalys, aktyviai remiančios aplinkos išsaugojimą, taršos mažinimą ir tvaraus ekonomikos augimo skatinimą*).

Inter-municipal cooperation – a collaboration of many municipalities to enhance the effectiveness of providing public services and achieve economies of scale (Hiratsuka-Sasaki & Kojima, 2020) (liet. *Savivaldybių bendradarbiavimas – daugelio savivaldybių bendradarbiavimas siekiant padidinti viešųjų paslaugų teikimo veiksmingumą ir pasiekti masto ekonomiją*).

Sustainable development – the harmonised synthesis of sustainable economic expansion and ecological restoration (Son et al., 2023) (liet. *Tvarus vystymasis – darni tvarios ekonominės plėtros ir ekologinio atkūrimo sintezė*).

Sustainable finance – a comprehensive approach that incorporates various funding strategies to address environmental, social, and governance factors while also promoting economic value creation (Sachs et al., 2019) (liet. *Tvarūs finansai – visapusiškas požiūris, apimantis įvairias finansavimo strategijas, skirtas aplinkos, socialiniams ir valdymo veiksniams spręsti, kartu skatinant ekonominės vertės kūrimą*).

Zero-waste – the primary objective of the zero-waste concept is to address waste problems by emphasising the avoidance and prevention of waste rather than relying on waste treatment procedures problems (Zaman, 2014, 2015; Zaman & Lehmann, 2013) (liet. *Be atliekų – pagrindinis be atliekų koncepcijos tikslas – spręsti atliekų problemas, pabrėžiant atliekų vengimą ir prevenciją, užuot pasikliovus atliekų tvarkymo procedūromis*).

Zero-waste city – the adoption of sustainable development practices and lifestyles by minimising the generation of solid waste and maximising resource efficiency (Li & Li, 2024; Li et al., 2024; Qi et al., 2024) (liet. *Miestas be atliekų – tvaraus vystymosi praktikos ir gyvenimo būdo diegimas mažinant kietųjų atliekų susidarymą ir skatinant kuo efektyvesnį išteklių naudojimą*).

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Introduction

Problem Formulation

The XXI century has welcomed humanity with incredible engineering achievements, innovations, and technological advancements. Besides technological breakthroughs, another topic has to be acknowledged: the environment, which is threatened by degradation, thus distressing the human habitat.

The frequency of climate-related disasters has nearly doubled compared to the preceding two decades (United Nations Office for Disaster Risk Reduction, 2021). According to the World Economic Forum (World Economic Forum, 2021), environmental risks such as extreme weather, natural disasters, and climate failure have been among the top five risks since 2014 (World Economic Forum, 2022, 2023, 2024). The tangible effects of climate change are already apparent, as evidenced by more severe weather phenomena such as heatwaves, intense rainfall, floods, and droughts. These occurrences pose significant risks to human health, safety, welfare, livelihoods, food and water resources, infrastructure, and economic development (Steg, 2023). It can be concluded that the profound destruction and consequences resulting from catastrophic events in a shifting climate would hinder the attainment of the Sustainable Development Goals (United Nations Office for Disaster Risk Reduction, 2021; Wen et al., 2023).

Waste is one of the global environmental problems. At the country level, municipalities are usually responsible for organising sustainable and effective waste management practices. However, municipalities frequently face challenges in allocating funds for waste management projects.

Researchers (Liberati & Marinelli, 2021) identified the green finance gap, referring to the insufficient financial resources allocated to green investments, which hinders the economy's transition towards a more environmentally sustainable structure. Thus, there is a lack of evidence of cooperation between municipalities for the application of green finance instruments. The above-mentioned gaps correlate with the research problem: in scientific literature and practice, cooperating municipalities ineffectively use the green finance model to finance environmentally sustainable and green projects that reduce municipal waste and focus on "zero-waste" principles.

Relevance of the Dissertation

Many scientists predict increasing volumes of municipal waste globally (Kaza et al., 2018). Municipal waste accounts for around 10% of all waste generated in the EU (European Commission, 2023); however, it is one of the most difficult waste streams to manage due to its mixed composition, the large number of polluters of such waste type and fragmented responsibility for the management of this waste stream. Packaging waste, which has a high potential for circularity, accounts for a large proportion of municipal waste. The recently published report has shown that Lithuania is underperforming in meeting the goals of (1) recycling and preparing for reuse and (2) recycling of packaging (European Commission, 2023). These results imply that Lithuania is at risk of falling short of the 2030 target of preparing 60% of municipal waste for reuse and recycling without introducing additional measures.

Object of Research

A green finance model for financing environmentally sustainable and green projects for the sustainable development of "zero-waste" cities.

Aim of the Dissertation

The dissertation aims to develop and empirically test a green finance model that would lead to rational economic decisions for the sustainable development of waste-free cities.

Tasks of the Dissertation

To achieve the objective, the following problems had to be solved:

1. To analyse the literature on green finance concepts and municipal waste in order to explore the application of green finance in the context of municipal waste management and to define the dissertation's theoretical framework.
2. To develop and methodologically justify a green finance model allowing municipalities to exploit the green finance potential in financing green projects for the sustainable development of zero-waste cities.
3. To identify and assess the success factors, benefits and challenges of issuing green bonds.
4. To test the proposed model for assessing the possibility of municipal cooperation and develop proposals for further development of the green finance model.
5. To develop an algorithm for issuing green bonds by cooperating with municipalities to finance municipal waste reduction and/or waste control projects.

Research Methodology

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

1. Systematic and scientific literature analysis, interpretation and conceptualisation methods were used to explore the concepts of green economy and green finance.
2. The forecasting method, exponential smoothing, was used to predict waste trends within Lithuanian counties and statistically analyse the robustness of the waste trend predictions.
3. Expert interviews were chosen to collect qualitative assessments related to green bond issuance and the possibility of inter-municipal cooperation.
4. The multi-criteria decision-making method, the Analytical Hierarchy Process, was selected to analyse the expert survey.

Scientific Novelty of the Dissertation

The scientific novelty of the theoretical and empirical study of the green finance model is as follows:

1. A green finance model for the sustainable development of zero-waste cities has been developed. It includes an analysis of success factors of the

green bond issuance, a set of indicators for the assessment of the inter-municipal cooperation and the algorithm for the green bond issuance.
2. A set of success factors, benefits and challenges for issuing green bonds was developed. This allows the decision-making algorithm for green bond issuance to be tailored.
3. A set of indicators for assessing inter-municipal cooperation was developed. These indicators laid the groundwork for the Risk-Adjusted Municipal Condition Index to assess the possibility of cooperation between municipalities based on financial, solvency, social, and environmental assessment and possible risks associated with the cooperation between municipalities.

Practical Value of Research Findings

The research provides key factors of successful green bond issuance, benefits, and common challenges. The study results can benefit potential issuers, policymakers willing to promote green bonds, and educational purposes on green finance instruments and their applicability.

The proposed valuation approach for the IMC possibility serves as a valuation tool for rational decision-making for municipalities considering the possibility of joining forces in pursuit of municipal waste reduction. The proposed algorithm for issuing green bonds can serve as a clear pathway for the parties involved in the green bond issuance process.

Defended Statements

The following statements based on the results may serve as the official hypotheses to be defended:

1. Green financial instruments, such as green bonds, can be an alternative way to finance environmentally sustainable projects. Such financing often does not deliver financial or economic benefits and requires additional funds. This problem can be overcome through cooperation between municipalities.
2. Municipalities can apply a green finance model to achieve waste-free and sustainable urban development.
3. For successful cooperation between municipalities for the issue of green bonds, the possibility of cooperation needs to be assessed based on the

prospective financial, solvency, social and environmental performance of the cooperation between municipalities.

Approval of the Research Findings

The research findings of the dissertation were disseminated in five publications in reviewed scientific journals: 2 – in international peer-reviewed scientific journals included in the Scopus database (Bužinskė & Stankevičienė 2023, Bužinskė & Stankevičienė, 2023), and 3 – in proceedings of international conferences (Stankevičienė & Bužinskė, 2023; Stankevičienė & Bužinskė, 2021; Bužinskė & Stankevičienė, 2021). The author has made three presentations at three scientific conferences:

1. International scientific conference "*Contemporary issues in business, management and economics engineering* 2021", 2021, Vilnius, Lithuania.
2. International Scientific Forum *"Modern Trends in Economics, Technology and Education"*, 2021, Tbilisi, Georgia.
3. *Business transformation in uncertain global environments*: 16th annual conference of the EuroMed Academy of Business, 2023, Vilnius, Lithuania.

One scientific visit has been made during the doctoral studies:

1. Technical University Dresden, Institute of Waste Management and Circular Economy, Germany, September 2021 – May 2022.

The author also has made four presentations at doctoral seminars at Vilnius Gediminas Technical University, one presentation at the seminar of the German Federal Environmental Foundation, Germany, and two presentations at the seminars of the Technical University Dresden, Institute of Waste Management and Circular Economy, Germany.

Structure of the Dissertation

The dissertation follows a proposed structure: introduction, three chapters with corresponding conclusions, general conclusions, references, the list of the publications of the author, and a summary of the dissertation in Lithuanian. The total scope of the dissertation is 163 pages, the dissertation has 18 figures, 45 tables, 48 numbered formulas, and 278 references.

1

Theoretical Analysis of the Green Finance Concept

This Chapter aims to determine the concept of green finance within the green economy and provides insights into the other interrelated concepts, such as bio-economy, low-carbon finance, climate finance and socio-environmental finance. The environmental risks and corresponding transmission channels to the economy are analysed. The evolution of the policy decisions related to the preservation of the environment is identified and presented in chronological order. The aim of green finance in tackling environmental challenges is reviewed with the common green finance instruments and further market development implications.

The research findings on the topic of this Chapter have been published in one scientific paper (Stankevičienė & Bužinskė, 2021).

1.1. Green Finance Concept

The global population has encountered expanding environmental issues during the 20th century, leading to an increased focus on climate change by governments, policymakers, and supranational organisations (Fig. 1.1). The initial event that established the climate change discussion foundations and steps to mitigate and build resilience against it, was the UN Conference on the Human Environment in

1972 (Migliorelli & Dessertine, 2019; United Nations, 1972). The conference has produced a set of environmental management principles. The subsequent climate change event occurred two decades later. The Rio Summit in 1992, also known as the Earth Summit, resulted in the creation of Agenda 21, which advocated for advancing a sustainable economy and the implementation of strategies for environmental conservation (Migliorelli & Dessertine, 2019). The objective of reducing greenhouse gas emissions was established at the 1995 Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC). The subsequent session, COP3, occurred in 1997 in the city of Kyoto, where the establishment of the Kyoto Protocol was mandated (Migliorelli & Dessertine, 2019). The Kyoto Convention established a binding commitment to address climate change, although it was enforced only in 2005. The Millennium Summit, held in 2000, created a set of eight Millennium Development targets, one of which was to address environmental conservation. The European Climate Change Programme (ECCP) was implemented the same year, introducing regulations to reduce greenhouse gas emissions. The subsequent incident of ecological significance occurred in 2002. The Word Summit emphasised the significance of preserving the environment and presented a systematic strategy for addressing climate change, encompassing policy decisions about water, energy, health, agriculture, biological variety, and other environmental issues. During the 2012 UN Conference on Sustainable Development, the attendees reached a consensus to deliberate on Sustainable Development Goals that would possess a standardised structure, be quantifiable, and influence the present and future conditions. Participants have also concurred that the green economy may catalyse achieving Sustainable Development Goals (Acar & Yeldan, 2019; Tolliver et al., 2019). In 2014, the European Union declared its objective of reducing greenhouse gas emissions by 40% by 2030. Another significant milestone in the field of environmental conservation is the United Nations Summit on Sustainable Development held in 2015 (Tolliver et al., 2019). The Sustainable Development objectives, consisting of 17 objectives and 169 targets, have been developed. The Paris Agreement, encompassing climate change mitigation, adaptation, and financial aspects, was established in the same year (Volz, 2018). The objective of the Paris Agreement is to limit the increase in global temperature to a maximum of 1.5°C. The 2021 United Nations Climate Change Conference (COP26) was a recent event focused on addressing climate change and environmental conservation. The outcome of COP26 is the establishment of the Glasgow Climate Pact, which prioritises the mitigation of coal usage, the reduction of greenhouse gas emissions, and the advancement of climate financing for climate change adaptation. Undoubtedly, these occurrences have intensified the necessity for creating sustainable financial solutions that would cater to the demands of the evolving globe. The 28th Conference of the Parties to the UN Framework Convention on Climate Change (COP 28) occurred

in Dubai, United Arab Emirates, in 2023, with a primary emphasis on transitioning from fossil fuels to renewable energy sources.

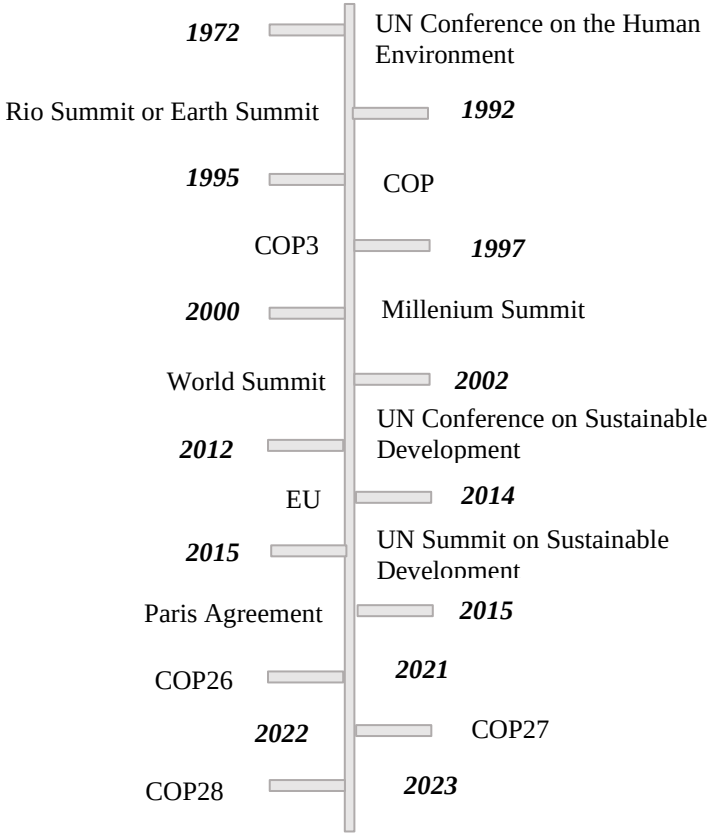

Fig. 1.1. Evolution of environmental preservation events (source: compiled by the author based on Acar & Yeldan (2019), Migliorelli & Dessertine (2019), Tolliver et al. (2019); United Nations, 1972; Volz (2018))

The issues of climate change and environmental challenges have prompted the collaboration between economic theories, policies, financing methods, and environmental evaluation and management techniques. This collaboration aims to achieve environmental, economic, and social benefits in support of the sustainability agenda (Fig. 1.2).

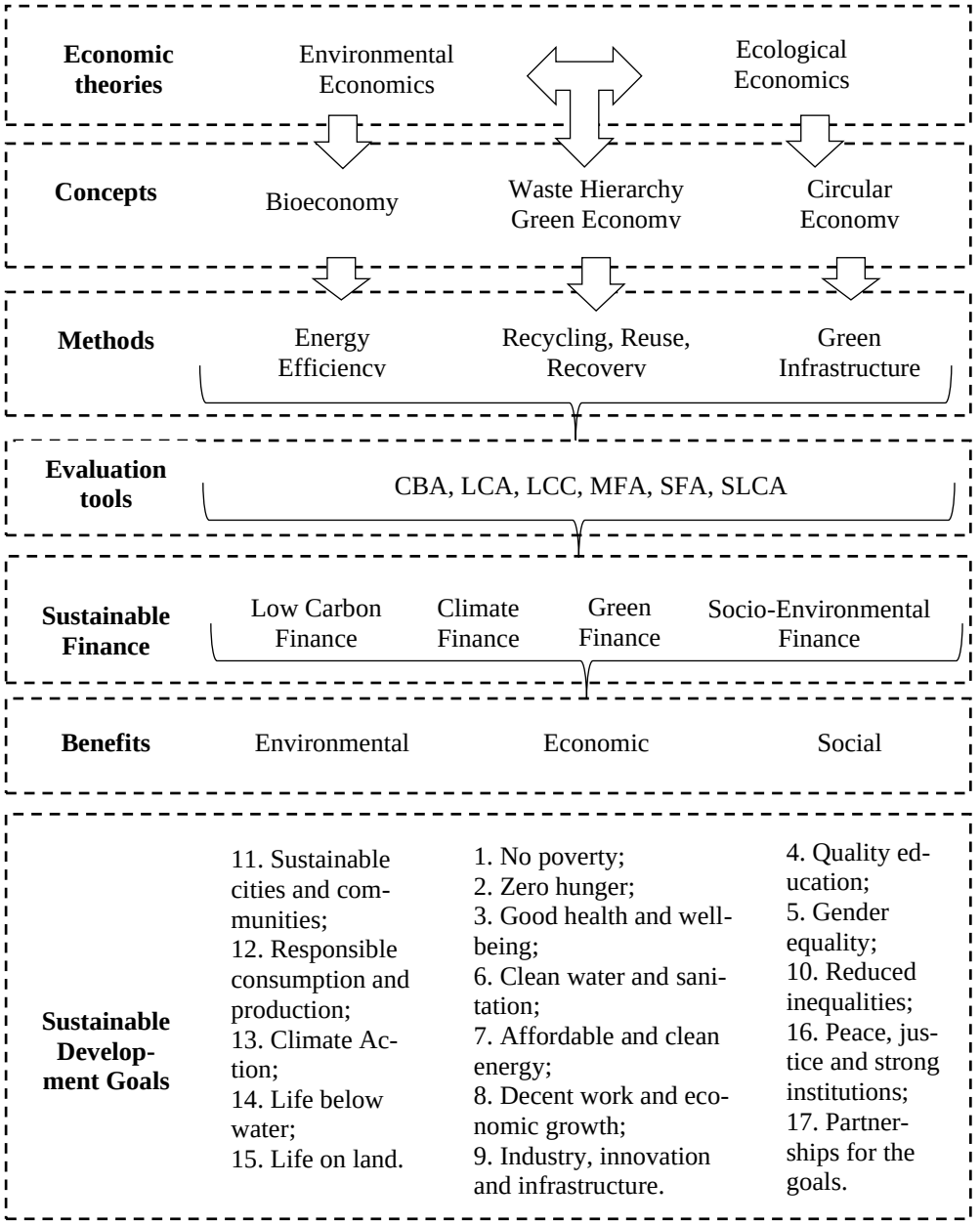

Fig. 1.2. Relationship between economic theories and concepts, policies, sustainable finance mechanisms and Sustainable Development Goals (source: compiled by the author based on Birner (2018), D'Amato et al. (2017, 2019), D'Amato & Korhonen (2021), Khoshnava et al. (2019), Loiseau et al. (2016))

The two economic theories on the climate domain are environmental and ecological economics. Environmental economics applies economic ideas to address environmental and natural resource issues, whereas ecological economics examines the interplay between economic activities and biological systems that include life (Harris & Roach, 2021).

Researchers (D'Amato et al., 2017, 2019) analysed the differences between the green economy, bioeconomy, and circular economy and established the interlinks between these fields. In this context, the circular economy concept pertains to the continuous and cyclical production process. Bioeconomy, on the other hand, emphasises the use of bio-substitutes for production inputs and outputs. Green economy also involves the implementation of nature-based solutions. Biotechnological advancements are the primary component of the bio-economy (Birner, 2018). The link between the green economy and bioeconomy resides in geographical resilience. The cohesiveness between bioeconomy and circular economy fosters industrial symbiosis. Additionally, the correlation between the green economy and the circular economy is based on resource efficiency. The notions of green economy and bio-economy encompass a wider scope than those of a circular economy (Birner, 2018). According to Shachi et al. (2021), the connection between bio-economy and circular economy is rooted in their shared objective of managing waste and encouraging the reuse of resources.

Acar and Yeldan (2019) noted that the notion of the green economy originated in 1989, but it gained significant attention only after the 2008 crisis, which prompted the exploration of alternate methods for economic growth. The green economy is regarded as a means to address sustainable development issues. It offers a range of activities as a compromise to achieve sustainable development goals (Merino-Saum et al., 2018). The relationship between the green economy and Sustainable Development Goals (SDGs) is determined by the Partnership for Action on Green Economy (PAGE). PAGE uses a set of indicators to measure the progress of the green economy, which are then linked to the corresponding SDGs (Merino-Saum et al., 2018; PAGE, 2017). The green economy facilitates change in the economy by raising awareness of environmental concerns, climate adaptability, and resilience (Cai & Guo, 2021). The green economy has a role in mitigating and controlling environmental concerns while enhancing social well-being (Acar & Yeldan, 2019). The green economy notion establishes a connection between the principles of financial inclusion and green financing. Both of these principles are believed to contribute to the development of green growth and inclusive growth. Financial inclusion facilitates the reduction of information and transaction costs disparities, hence promoting efficient allocation and utilisation of resources (Wang et al., 2022). The primary objective of the green economy is to concurrently diminish climate change and alleviate environmental hazards while enhancing societal well-being. The green economy, in conjunction with green finance,

contributes to sustainable development by solving present and future difficulties. The citation is from Yang et al. (2022).

The techniques that facilitate the application of environmental and ecological economics include resource efficiency, recycling, reuse, recovery, and the advancement of green infrastructure. The common evaluation tools applied to environmental and ecological economics are cost–benefit analysis (CBA), life-cycle assessment (LCA), life-cycle cost analysis (LCC), material flow analysis (MFA), stochastic frontier approach (SFA), and social life cycle assessment (SLCA).

Migliorelli (2021) establishes the sustainable finance framework by examining its micro, meso, and macro dimensions. At a small scale, the sustainable finance framework encompasses categorising sustainable goods and services and establishes guidelines for their operations. The labelling encompasses the environmental, social, and sustainability aspects. At the meso level, the sustainable finance framework incorporates the establishment of industry-wide standards. The prevailing norms encompass socially responsible investment (SRI), environmental, social, and governance (ESG) investing, and impact financing and investing. The macro level of the sustainable finance framework encompasses the broader development and implementation of sustainability policies. This level encompasses the integration of financial decisions with the Sustainable Development Goals (SDGs), the Paris Agreement, responsible banking, and green and climate financing. Herein, the direct links to sustainable development and climate change can be observed (Baidya & Saha, 2024). Sustainable development corresponds to the harmonised synthesis of sustainable economic expansion and ecological restoration (Son et al., 2023). Other authors (Baidya & Saha, 2024; Sahoo & Goswami, 2024) explain that sustainable development seeks to fulfil the requirements of the present day while ensuring that future generations may also fulfil their own needs without any negative impact. On the other hand, some researchers (Keith et al., 2023) argue that over time, the emphasis on cities as locations for sustainable development efforts has diminished.

Sustainable finance is a comprehensive approach incorporating various funding strategies to address environmental, social, and governance factors while promoting economic value creation (Sachs et al., 2019). Financing methods specifically designed to promote sustainable development may be classified into five distinct types (Kahlenborn et al., 2017; Migliorelli, 2021; Migliorelli & Dessertine, 2019). Traditional finance is employed to facilitate the advancement of economic growth. The other categories of finance pertain to the funding of sustainable development. Low-carbon funding aids in the reduction of climate change. Low-carbon finance is designed to fund initiatives that target the reduction of greenhouse gas (GHG) emissions (Sachs et al., 2019). Climate financing is primarily concerned with supporting efforts to adapt to climate change. Climate finance seeks to allocate financial resources to programmes that specifically address

climate change mitigation and adaptation, promoting a transition towards a decarbonised economy (Sachs et al., 2019). Environmental finance primarily centres around the conservation of the environment and ecology. It excludes projects that pose possible environmental threats from receiving any financial support. Here, the environmental concerns are perceived as a financial risk. Environmental finance places a greater emphasis on environmental conservation than green finance, which may prioritise economic growth at the expense of environmental concerns (Sachs et al., 2019). Green finance pertains to the provision of financial resources to address climate change mitigation, adaptation, and other environmental requirements. Socioenvironmental financing is a method of raising cash specifically to address environmental and social development issues.

The primary environmental advantages encompass the reduction of climate change impacts, the management of biodiversity, and the optimisation of resource use. The economic benefits encompass increased economic development and heightened innovation. Social advantages encompass a decrease in health ailments associated with unfavourable environmental circumstances, enhanced living conditions, and a rise in employment opportunities. The environmental, economic, and social advantages may be directly linked to the respective Sustainable Development Goal (SDG) categories.

Referencing (Fig. 1.2), one of the components of sustainable finance is green finance. The tools of green finance are closely linked to the financial markets, where financial markets play a crucial role in funding sustainable development goals (Siracusa, 2021). Financial markets provide sources of information for policymakers to make informed economic and governance decisions.

Financial markets facilitate the acquisition of capital for sustainable investments and the management of environmental concerns. Siracusa (2021) notes that of the 17 sustainable development goals, more than 50% of the funding for five specific goals is obtained from fixed-income markets. These goals include goal 3, which focuses on promoting good health and well-being; goal 7, which aims to provide affordable and clean energy; goal 9, which emphasises industry innovation and infrastructure; goal 11, which focuses on creating sustainable cities and communities; and goal 13, which addresses climate action. Nevertheless, scholars (Ning et al., 2023) argue that there is a requirement to enhance the integration of financial markets to support green initiatives more effectively.

Green finance, a well-recognised method for advancing sustainable development, is experiencing significant global growth and garnering increasing attention (Bai & Lin, 2024). Although the green finance industry has experienced significant expansion, it remains a relatively novel term without a universally agreed-upon definition (Lazaro et al., 2023). Although there are many terminologies and meanings, many proposed definitions of green finance describe a range of

financial instruments and programmes that aim to support sustainable development and include financial and non-financial entities (Maria et al., 2023).

Diverse definitions offered by scholars, governmental bodies, and international organisations are condensed in Table 1.1. The proposed descriptions portray green finance as a collection of strategic instruments, strategies, and procedures that operate harmoniously to save the environment and provide economic advantages.

Table 1.1. Green finance definitions (source: compiled by the author based on China Council for International Cooperation on Environment and Development Secretariat (2020), Falcone & Sica (2019); Migliorelli & Dessertine (2019); Soundarrajan & Vivek (2016); Volz (2018); K. Wang et al. (2019); X. Zhou et al. (2020))

Author	Green finance-related definitions
Organisation for Economic Cooperation and Development	Green finance seeks to promote economic growth while simultaneously reducing pollution and waste, as well as optimising the use of natural resources.
Government of Germany	Green finance is a strategic tool that facilitates the integration of the financial sector in aligning the economy with the challenges posed by climate change.
People's Bank of China	Green finance encompasses a range of policies, systems, and procedures aimed at attracting private capital investments into environmentally friendly sectors through financial services.
Soundarrajan & Vivek (2016)	Green finance refers to the integration of the financial sector in addressing climate change and transitioning towards a low-carbon and resource-efficient economy.
Falcone & Sica (2019), Volz (2018), Zhou et al. (2020)	Green finance refers to the deployment of financial resources towards investments that support the advancement of a sustainable economy and give environmental advantages.
Wang et al. (2019)	Green finance is a combination of environmental presentation with economic benefits.
China Council for International Cooperation on Environment and Development Secretariat (2020)	Green finance refers to a range of financing options that are meant for allocating funds, operating, and managing risks in environmentally friendly and sustainable projects.
Ahmed et al. (2024)	The primary goal of green finance is to attain a net carbon emission level of zero and to encourage environmentally friendly activities.

End of Table 1.1

Author	Green finance-related definitions
Li & Umair (2023)	"Green finance" refers to the integration of financial services and instruments that address many sustainability concerns, including reducing business pollution, managing the environment, enhancing sanitation, and conserving the environment.
Mohanty et al. (2023)	Green finance represents the initial coordinated endeavour by the financial sector to connect financial results with a beneficial effect on the environment.
Mohsin et al. (2023)	Financial instruments that have a beneficial effect on the environment are referred to as green finance.

The goals of green finance may be effectively described as the pursuit of environmental preservation while simultaneously fostering economic growth within the financial industry. Green finance encompasses a range of goods, services, technologies, sectors, and stakeholders that actively support environmental conservation, pollution reduction, and the promotion of sustainable economic growth (Sachs et al., 2019). Furthermore, it seeks to facilitate the attainment of targets outlined in the Sustainable Development Goals and the Paris Agreement by offering the required financial resources (Nedopil & Dordi, 2021). However, achieving the objectives of the Paris Agreement requires more cooperation from government officials and policymakers to promote green financing institutions and green bonds (Ning et al., 2023).

Green finance seeks to address the challenges posed by climate change and promote an economy that is free from carbon emissions (Cai & Guo, 2021). Green finance is regarded as an innovative method for financing sustainable economic development. An obstacle in green finance is the efficient distribution of funding to environmentally friendly initiatives undertaken by various economic actors, including commercial entities, state institutions, and other market participants (Ning et al., 2023). Researchers (Zhou & Zu, 2022) note that green finance plays a significant role in promoting the ecological progress of the economy. Researchers assert that constructing an optimum investment portfolio of green finance solutions might be an effective means of obtaining the required finances to address environmental and ecological concerns. Many green finance ideas and initiatives tend to overlook the needs of low-income and emerging economies (Arestis & Sawyer, 2022).

Green finance may be examined via the lenses of the environment, economy, and finance (Sachs et al., 2019). From an environmental perspective, green financing plays a crucial role in safeguarding the environment by fostering the growth of environmentally friendly businesses, encouraging green technologies,

and advancing the creation of legislative frameworks. Green finance promotes the growth of an environmentally sound financial market, aids in risk management, and offers financial assistance to ecologically beneficial enterprises. Green financing promotes the use of technology that drives the expansion of environmentally friendly enterprises, hence benefiting the economy.

Referencing the evolving nature of green finance, there is a gap in scientific literature towards green finance models and their applicability. Green finance is usually referred to as the set of instruments, described in Chapter 1.3. Green Finance Instruments. Therefore, the focus of this research is based on green finance instruments which can serve as a green finance model for the financing of green projects with a focus on "zero-waste".

1.2. Impact of Environmental Risks

The Network for Greening the Financial System (NGFS) conducted a study to examine the connections between environmental and climatic risks and how these risks translate into financial risks inside financial institutions (Network for Greening the Financial System, 2020b, 2020a). The authors emphasise that environmental and climatic risks can directly impact financial institutions. Also, an indirect effect occurs through their corporate and retail clients and the economic channels that transfer these risks. The environmental and climate hazards may be categorised into transition risks and physical risks, which encompass both micro and macro transmission channels.

Transition risks encompass potential shifts in legislation and regulations, technological advancements, and alterations in client demands. From the standpoint of corporations, certain rules may limit the use of ecologically harmful products, leading to increased costs for firms when incorporating such materials into their business operations, directly or indirectly. Consequently, the aforementioned organisations may see a decline in the value of their assets or an inability to fulfil their credit commitments, leading to potential financial concerns such as market and credit risks. Companies that utilise ecologically harmful materials may encounter a technical innovation that enters the market, reducing demand for their products and services. In this scenario, ecologically unsustainable enterprises may encounter similar circumstances, including market and credit hazards, necessitating the management of depreciating asset values and challenges in debt repayment. Customer choices for ecologically harmful items may be influenced by the introduction of legislation, regulations, and new taxing schemes designed to address environmental concerns. Consequently, there is a possibility of market and credit risks arising from fluctuations in the price of environmentally harmful items or if these products are included as collateral for a loan.

The physical dangers can be categorised into two subgroups: exposure to extreme weather conditions and pollution of the environment. Both of these hazards have the potential to lead to the depletion of earnings and the destruction or forfeiture of assets, both at the organisational and individual levels. Extreme weather events and environmental pollution can also lead to fluctuations in market prices, impact productivity levels, and affect the supply and demand in the labour market. Such dangers can catalyse changes in the social environment, resulting in a shift in consumer preferences, relocation to ecologically safer regions, and an increase in conflicts associated with environmental deterioration. Consequently, these risks will impact the fiscal policies and income of the countries, and the interest and currency rates. Financial hazards stem from both credit risks faced by enterprises and people, which occur due to property damage or loss, as well as market risks coming from fluctuations in asset values. Underwriting risks may also arise due to losses incurred by the insured assets. Operational risks can arise from alterations in the supply chain, hence exposing liquidity issues.

According to academics (Kedward et al., 2020), environmental hazards are often transmitted to the economy through alterations in supply and demand, as well as other systemic consequences. The fluctuations in supply impact enterprises operating in industries that rely on the health of ecosystems, such as agriculture. Climate change and its associated external factors have a detrimental effect on the supply within these sectors. Changes in demand arise in areas deemed environmentally detrimental, such as mining, where the development of laws and regulations affect the functioning of enterprises in this industry and require the support of customers. The systemic effects of climate change are seen to be inherently unpredictable yet have a significant impact on socio-economic circumstances and expenses.

A total of 13,386 natural catastrophes have been documented worldwide, resulting in an economic loss of USD 3.3 trillion (Khan et al., 2023). Natural catastrophes arise from converging dangers with economic, social, environmental, and physical vulnerabilities. Country-specific susceptibility to natural catastrophes is often determined by the degree of development and economic structure (Khan et al., 2023).

Botzen et al. (2019) and Klomp and Valckx (2014) distinguish between various categories of environmental catastrophes based on their economic impact. Climate and geological hurdles have immediate detrimental impacts on economic growth, whilst hydrometeorological catastrophes result in both short-term and long-term harmful economic consequences.

Environmental calamities immediately impact economic growth (Atsalakis et al., 2021). They exert detrimental immediate impacts on a country's macroeconomy (Sseruyange & Klomp, 2021). Environmental catastrophes harm the growth of Gross Domestic Product (GDP) (Botzen et al., 2019; Felbermayr &

Gröschl, 2014). The production interruptions caused by environmental externalities directly impact GDP growth (Panwar & Sen, 2019). Global projections indicate that the financial damages from environmental catastrophes are expected to surpass USD 300 billion annually (Natho & Thieken, 2018). Natural catastrophes have adverse consequences for financial stability and significantly influence the financial system (Chen et al., 2023). Environmental geological disasters provide a substantial peril to human existence, assets, and ecological security (Wang et al., 2023). Natural catastrophes are linked to a swift economic downturn and directly negatively affect economic growth (Khan et al., 2020).

Alternatively, as Panwar and Sen (2019) note, certain studies suggest that environmental disasters can stimulate investments in the affected area and promote technological advancements as a means of addressing the aftermath of these catastrophic events. Consequently, this can potentially contribute to positive economic growth. The study conducted in the US by Roth Tran and Wilson (2023) showed that disasters have been seen to result in a long-term increase in both total income and per capita income, namely, during eight years. The impact is primarily fuelled by an early increase in employment and, in the long term, by elevated salaries.

Researchers (Botzen et al., 2019; Klomp & Valckx, 2014; Panwar & Sen, 2019) have also noted that developing nations have greater adverse economic consequences from environmental disasters compared to developed ones. The primary cause of this difficulty is the inadequate financial and economic capacities to address the consequences of hazardous environmental occurrences. These findings are also evident in China, where the economic effects of environmental catastrophes are far more pronounced in less developed inland regions, whereas they are just half as severe in more developed coastal areas (Huang et al., 2024).

One of the subdimensions of environmental risks is municipal waste. Plastic waste is now a crucial ecological concern (Sharma et al., 2023). Authors (Sharma et al., 2023) observe that the research of the Centre for International Environmental Law (CIEL) determined that the consequences of plastic manufacture on the global climate are rather significant. For example, the presence of plastic pollution in the Mediterranean basin has been recognised as a significant risk. It is attributed to various plastic-related undertakings originating from the neighbouring nations, resulting in the Mediterranean Sea being designated as a prominent location for plastic accumulation (Sharma et al., 2023). Waste management also contributes to environmental degradation and causes environmental risks due to greenhouse gas emissions associated with the waste management processes (Erdem et al., 2023). Researchers Stankevičienė and Bužinskė (2021) observe that waste flows will be growing in the near future in Lithuania and the world; therefore, waste reduction is an important factor in the management of environmental risks.

Sachs et al. (2019) note that a mix of policies, laws, and financial measures, including the use of green bonds and securitisation, can effectively reduce hazards by mitigating financing concerns. Researchers (Kaewsaeng-on & Mehmood, 2024) analysed the relationship between environmental risk in South Asian Association for Regional Cooperation (SAARC) nations and the adoption of green finance, financial development, laws, and regulations. The study conducted in 2005–2022 revealed that green financing has a significant role in reducing environmental risks, and the implementation of effective corporate regulatory frameworks decreases environmental risks, whereas inadequate regulations raise these risks.

1.3. Green Finance Instruments

To facilitate the shift of creation, distribution, and acquisition of products and services towards environmental sustainability, green financial instruments must satisfy two essential characteristics (Vulturius et al., 2024). The instrument should prioritise economic activities aligning with the Paris Agreement's objective. Also, it has to assist borrowers in effectively managing risks associated with climate change, facilitating their transition towards zero emissions, and decreasing the financial burden for activities that align with the goals of the Paris Agreement (Vulturius et al., 2024).

Sachs et al. (2019) have identified the factors driving the development of green finance instruments (Sachs et al., 2019):

1. Enhancing public environmental understanding and education through common information channels – providing extensive knowledge on the state of the environment to enhance universal comprehension of environmental difficulties.
2. Establishing public perception – raised authorities' focus on environmental concerns.
3. Environmental protection encompasses the implementation of legislation and regulations designed to safeguard the environment. It involves the legal obligation to restrict any activities that may harm the environment.

The starting point in the evolution of green finance instruments can be attributed to the involvement of the stock exchanges. The active participation of stock exchanges plays a crucial role in promoting the growth of green finance. The Oslo Stock Exchange pioneered green finance instruments, particularly green bonds, in 2015. Over time, the quantity of exchanges has grown as more exchanges have joined the movement. Green bonds are the predominant kind of green finance instruments available for trading on stock markets.

According to Migliorelli and Dessertine (2019), the initial introduction of green bonds occurred in 2015 on the Oslo Stock Exchange. In the same year, the London Stock Market incorporated green bonds into its portfolio, while the Stockholm Stock Market produced sustainable green bonds. In 2016, Mexico and Shanghai Stock Exchanges, together with Borsa Italiana, expanded their product offerings to include green bonds. In 2017, both the Taipei and Johannesburg Stock Exchanges joined the green bond movement. Currently, green bonds have become a prevalent financial instrument available on the stock exchange.

Community-based funds are financial solutions designed to raise investments for small and medium-sized green initiatives from private persons contributing relatively small amounts of money. These funds facilitate the collaboration between individual investors and regional green projects, allowing individuals to personally invest in these specific projects. Wind power and solar power stations are frequently cited as prominent instances of environmentally friendly initiatives funded by community-based resources (Sachs et al., 2019).

Green innovations encompass the development of redesigned goods, services, processes, and business designs that actively contribute to the conservation of the environment (Calza et al., 2017). These innovations can fall into four categories: routine, disruptive, radical, and architectural. Routine innovations utilise existing business models and technologies. Disruptive innovations use existing technology but require a new business model. Radical innovations use existing business models but necessitate new technologies. Architectural innovations require both new business models and new advances in technology.

Green funds provide retail consumers the chance to invest in equity and fixed-income instruments issued by businesses that support and expand their company in an ecologically friendly manner (Migliorelli & Dessertine, 2019).

Since 2014, green indices have been more popular. These indexes primarily concentrate on fixed-income and equities financial instruments in several sectors, including renewables, water management, and solar energy (Migliorelli & Dessertine, 2019). Green indices vary in the way they choose and assign importance to the components that make up an index (Inderst et al., 2012):

1. Screening processes are employed to choose green/ESG/SRI constituents.
2. The top 20% of the best performers within a certain industry are selected.
3. Adjusting the standard index by reweighing it to account for the environmental impact.

Researchers also examine the wide variety of green finance instruments commonly offered by financial institutions (Sachs et al., 2019; Soundarrajan & Vivek, 2016). The green finance instruments may be categorised into four groups: retail green financing goods, asset management green finance instruments, corporate finance green finance instruments, and insurance green finance instruments. Retail green finance instruments encompass various offerings, such as green

mortgages, greenhouse loans, green loans for commercial buildings, green auto loans, and green credit cards. Corporate green finance instruments encompass many possibilities, such as green project financing, green securitisation, carbon finance, green indexes, and green commodities. Green asset management instruments encompass green fiscal and investment funds, as well as carbon funds. Green insurance instruments encompass both green insurance and carbon insurance. Weather derivatives are included in the distinct category of green banking instruments.

Wang and Zhi (2016) present a comprehensive analysis of green finance instruments that are more limited in availability. The details may be found in Table 1.2. Authors offer explanations of environmental and biodiversity funds, debt-for-environment swaps, forestry securitisation, weather derivatives, and nature-linked assets.

Table 1.2. Green finance instruments (source: compiled by the author based on Wang & Zhi (2016))

Green finance instruments	Description
Environmental funds and biodiversity funds	This funding provides direct financial assistance to initiatives aimed at preserving biodiversity, or indirect support to business activities focused on safeguarding areas of biodiversity. Based on the initiatives, the environmental funds and biodiversity funds support the advancement of organic farming, ecological tourism, and sustainable development in forestry and fisheries.
Debt-for-environment swaps	An agreement is reached between the creditor countries and the less developed nation, stating that the financial obligations of the less developed nation can be forgiven, provided that the less developed nation contributes resources to an environmental fund that plays a crucial role in preserving biodiversity. Currently, the United States, Sweden, and Germany are the most actively engaged countries in developing debt-for-swaps initiatives, which are helping over 30 countries.
Forestry securitisation	The forestry utilisation firms move all of their commercial earnings to an entirely separate legal entity, that subsequently raises funds from those investing by selling instruments in the capital market. These funds are then lent to the forestry exploitation enterprises.

End of Table 1.2

Green finance instruments	Description
Weather derivatives	These financial instruments are capable of mitigating the adverse financial impacts resulting from climate fluctuations. If the magnitude of climate change is above the established threshold, the company that has entered into a weather derivative contract may demand a particular proportion of reimbursement.
Nature-linked securities	These securities can shift the risk of natural disasters and climate change to investors in the global capital market. The sponsors of natural catastrophe securities often establish a special purpose vehicle (SPV) and subsequently issue fixed-income securities.

On the fixed income side, these instruments may be classified into two primary categories in relation to the project they finance within the sustainable finance concept (Fig. 1.3):

1. Use-of-proceeds bonds, the most prevalent kind of sustainable bonds, share similarities with conventional bonds but differ in that their funds are only directed towards initiatives that promote green and/or social effects. Typically, bonds that are categorised as green, social, or sustainable are referred to as use-of-proceeds bonds (Organisation for Economic Cooperation and Development, 2023; Ribeiro, 2023).
2. General purpose bonds, with sustainability-linked bonds, include financial and/or structural features that change based on the issuer's ability to meet specific predetermined sustainability and environmental, social, and governance (ESG) goals. Issuers make an unambiguous commitment to achieving better sustainability results in the future (Organisation for Economic Cooperation and Development, 2023).

According to the Climate Bonds Initiative (2024) and International Capital Market Association (2022) standard, a green use-of-proceeds bond is an unsecured fixed-income instrument that is designated for environmentally friendly initiatives. These bonds are fully aligned with the Green Bond Principles and bear the equivalent credit rating applied to the issuer's remaining fixed-income instruments. An example of such a bond is the "Climate Awareness Bond" issued by the European Investment Bank (EIB) and is supported by the EIB.

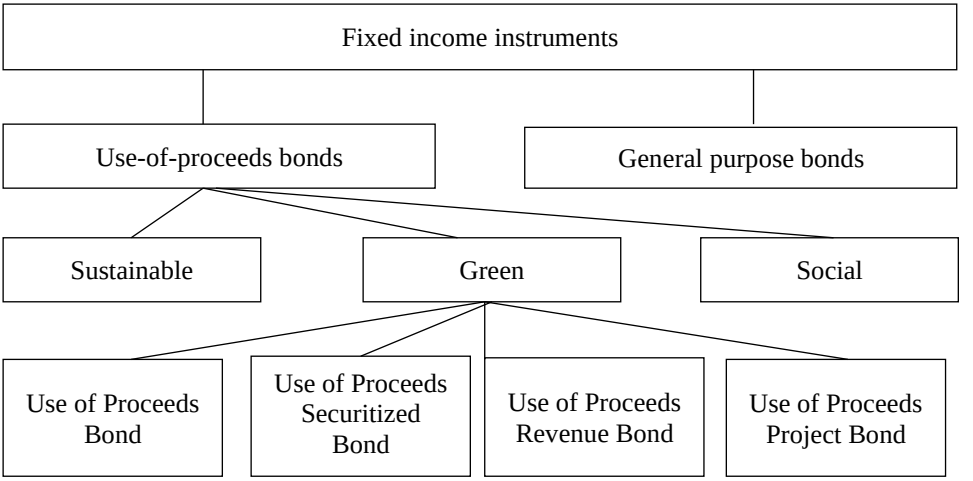

Fig. 1.3. Green bond types (compiled by the author based on Cheong et al. (2020); Inderst et al. (2012); International Capital Market Association (2022))

A secured green bond is a type of bond that is backed by collateral and is used exclusively to finance or refinance green projects. One of the examples of such a bond is "Tesla Energy", which is supported by residential solar leasing agreements. A green revenue bond is a type of fixed-income instrument that is designated for or used to refinance environmentally friendly initiatives and is aligned with the Green Bond Principles. The revenue streams of such bonds are generated by the issuers through fees, taxes, and other sources that serve as collateral for the borrowed funds. An example of such a bond is issued by the State of Hawaii, where the bond is supported by a surcharge on the power bills of state utilities.

A green project bond refers to a Green Bond Principles aligned bond that is specifically designed for financing one or more environmentally friendly projects. The only available option is to rely on the project's assets and balance sheet as a resource for debt. One of the examples of such bonds is issued by the "Invenergy Wind Farm", which is supported by the actual wind farm.

Many authors (Alsmadi et al., 2023; Cheong et al., 2020; Ehlers & Packer, 2017; Fatica et al., 2019; Gilchrist et al., 2021; Inderst et al., 2012; Löffler et al., 2021; Migliorelli & Dessertine, 2019; Sangiorgi & Schopohl, 2023; Tripathy et al., 2020; Ye & Rasoulinezhad, 2023) acknowledge that green bonds are fixed-income financial instruments utilised to generate funds for environmental preservation projects. Green bonds are utilised to finance environmentally friendly initiatives aimed at achieving the objectives of a sustainable green economy (Adekoya et al., 2021). Additionally, green bonds can function as a mechanism to achieve global decarbonisation objectives (Sinha et al., 2021). At a business level,

the issuance of corporate green bonds can serve as a clear indicator of a company's commitment to addressing environmental concerns (Flammer, 2021). Green bonds primarily finance renewable energy and green transport initiatives, making a substantial contribution to environmental conservation and pollution mitigation (Su et al., 2023). The purpose of the green bond market is to obtain funding for projects that adhere to the environmental (E), social (S), and governance (G) standards (Ribeiro, 2023). Green bonds are utilised to finance or refinance qualifying projects that are specifically designed to achieve climate mitigation and adaptation objectives, as well as other environmental aims (Organisation for Economic Cooperation and Development, 2023). Green bonds are essential instruments for funding the transition to a low-carbon economy and promoting sustainable development (Cheng et al., 2024). The green bond market has had significant growth, increasing from USD 37 billion in 2014 to reaching USD 487.1 billion in 2022, with a projected growth of USD 914.4 billion by 2030 (Cheng et al., 2024).

Otek Ntsama et al. (2021) note that several writers offer slightly varying explanations of green bonds, but all of them may be condensed into the following attributes: (1) Companies, governmental, and international institutions can issue green bonds to support sustainable economic development. (2) Green bonds are utilised to fund projects that have positive environmental impacts. (3) Green bonds encompass both the environmental objectives and financial responsibilities of the issuers.

The historical events associated with the emergence of green bonds are outlined in Figure 1.4. The European Investment Bank and International Bank for Reconstruction and Development introduced the first green bonds in 2007–2008, along with a reporting mechanism. The introduction of green bond marking occurred in 2012, with the first certified climate bond being issued by Belectric Solar. The International Capital Markets Association proposed the Green Bond Principles in 2014. Barclays and MSCI released green indices in the same year. In 2016, the government of Poland issued the first sovereign green bond. During 2017–2019, several nations and exchanges, including France, Fiji, Nigeria, Indonesia, Belgium, Lithuania, Ireland, the Netherlands, and Chile, implemented green bonds.

In 2020, the German government issued a pair of sovereign bonds consisting of regular and green bonds. The twin bonds consist of an ordinary bond and a green bond, both with identical maturity and coupon rates. However, the green bond is now trading at a yield to maturity that is 2 basis points lower. Investors demonstrate their willingness to accept reduced returns by including green bonds in their investment portfolio (Löffler et al., 2021). In 2021, the supply of green bonds reached its maximum point, totalling USD 596.30 billion, according to the Climate Bonds Initiative (2022).

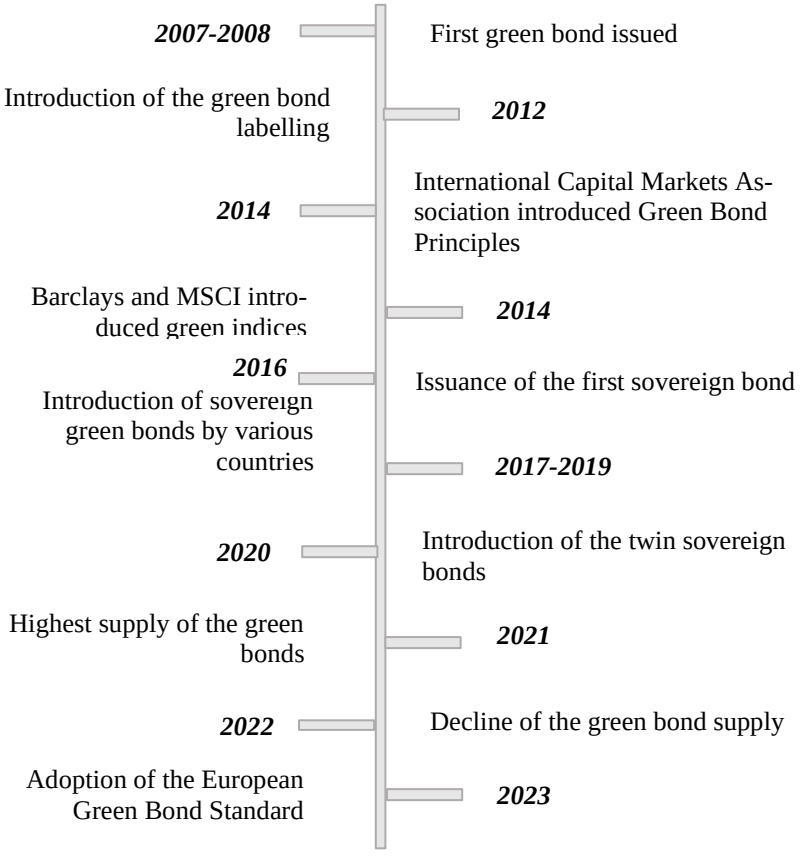

Fig. 1.4. Evolution of the green bond market (source: compiled by the author based on Cheong et al. (2020), Climate Bonds Initiative (2022), Löffler et al. (2021))

In the subsequent year, there was a noticeable worldwide decrease in the issuance of green bonds, with a reduction of around 26%. This decline may be attributed to the difficult conditions prevailing in the global capital markets (Climate Bonds Initiative, 2022). In 2023, the Council sanctioned a measure that sets a uniform framework for European green bonds. The regulation sets down standardised requirements for bond issuers who wish to designate their environmentally responsible bonds as “European green bonds” or “EuGB” (The European Parliament and the Council, 2023).

Green bonds can be linked to conventional bonds, but they differ in terms of their deal structure, reporting and auditing requirements, and the allocation of revenues (UNEP, 2019). Green bonds share similar attributes with traditional bonds,

but they incorporate pre-issue and post-issuance measures to ensure that the objectives of the issuance are successfully met (Pineiro-Chousa et al., 2021).

The green bond issuance procedure is governed by four fundamental principles: the distribution of proceeds, the assessment and choice of projects, the administration of money, and reporting (Tona et al., 2023). Even though the principal characteristic of green bonds is use-of-proceeds, issuers typically construct them in a way that achieves compliance with other well-acknowledged frameworks for sustainable development (Organisation for Economic Cooperation and Development, 2023). A significant number of green bonds are issued in accordance with the Green Bonds Standards established by the International Capital Markets Association (UNEP, 2019) or are in line with the Green Bond Principles (Pineiro-Chousa et al., 2021). Sachs et al. (2019) note that the issuance of green bonds in accordance with the Green Bond Principles requires the certification of these bonds and subsequent reporting. Green bond issuing entails ensuring that green bonds adhere to defined environmentally beneficial objectives. Green labelling refers to the certification provided by a third party to ensure that the funds raised from bonds are utilised specifically for projects that have positive environmental impacts. On the other hand, unlabelled bonds are not certified by a third party but are nevertheless associated with initiatives that provide environmental benefits.

The proceeds generated from the issue of the green bonds are allocated towards sustainable energy and transport, waste management projects, and other efforts aimed at mitigating climate change. The citation is from Ning et al. (2023). Green bonds possess identical attributes to conventional bonds; however, the funds generated from the issuing of green bonds can exclusively be allocated to environmentally sustainable initiatives (Naeem et al., 2022). The funds earned via the sale of green bonds are allocated to various initiatives that yield economic advantages.

The primary attributes of green bonds, as identified by Wang and Zhi (2016), are as follows:

- Minimal investment risks;
- Ability to generate substantial investment funds required for financing environmentally sustainable initiatives.
- Bonds provide greater flexibility and liquidity due to the adaptable market regulations and methods of altering investment portfolios.
- Bonds adhere to rigorous transparency standards.

Additional attributes of green bonds pertain to the premium, yield, and spread of these bonds. Academics (Bachelet et al., 2019; Migliorelli & Dessertine, 2019) have observed that green bonds issued by national governments, municipalities, or major financial institutions have a negative premium, but green bonds issued

by individual enterprises have a positive premium. Furthermore, researchers (Baker et al., 2018) have noted that municipal green bonds are issued with reduced interest rates but at a higher price on the US market. Therefore, Baker et al. (2018) and Löffler et al. (2021) have also noted that investors are willing to sacrifice a small portion of their investment returns to include green bonds in their investment portfolio. The green spread refers to the disparity in yield between a green bond and a comparable regular/reference bond (Bongaerts & Schoenmaker, 2019). There is a debate over the disparity in yields between green and conventional bonds. According to Sun et al. (2022), the yields of green bonds issued by non-financial and multinational corporations are lower compared to those issued by financial institutions. However, there is no difference in yields for bonds issued by financial organisations.

1.4. Implications for the Future Development of Green Finance

The green bond market has grown substantially over the years, while it remains a niche sector (Migliorelli & Dessertine, 2019). Three considerations support the growth of the green bond market (Banga, 2019). Initially, policymakers, governments, investors, and other stakeholders have now acknowledged the impacts of environmental concerns on the economy, financial sector, and private firms. The awareness of climate conservation concerns has necessitated the implementation of legal and preventative actions to establish an economy that is resilient to climate change. Investors include environmental, social, and governance elements in their decision-making process in response to environmental concerns. Furthermore, the expansion of the green bond market may be attributed to the adoption of the Paris Agreement and the following governmental actions aimed at encouraging global investments in green bonds. Furthermore, the use of green bonds was a component of the progressive economic strategy that emerged following the 2008 financial crisis. Following the crisis, institutional investors transitioned towards sustainable financial market solutions that aim to maintain the value of assets while also ensuring consistent revenue and minimising risks.

The emergence of the green bond market offers investors a chance to participate in environmentally-friendly initiatives. Green financing is expected to prevent global CO_2 emissions equivalent to the combined CO_2 emissions of the European Union and Japan (Alonso-Conde & Rojo-Suárez, 2020; Glomsrød & Wei, 2018). The authors (Makpotche et al., 2024) provide evidence that corporate green bond issuers achieve long-term reductions in their CO_2 emissions and enhance their resource utilisation efficiency and environmental performance. The researchers (Kung et al., 2022) established a favourable correlation between green

bonds and green development. Green bonds provide several benefits for bond issuers, including enhanced liquidity, heightened corporate value, and integration of low-carbon technology. The research conducted by academics (Bakry et al., 2023) shows that green finance and renewable energy have been identified as having substantial and restraining impacts on CO2 emissions, underscoring the imperative to further the promotion of green financing and renewable energy.

The researchers (Alharbi et al., 2023) have surveyed 44 countries worldwide and demonstrated that the implementation of green finance, namely through the issuance of green bonds, has a substantial positive impact on the promotion and development of renewable energy generation. The study conducted by Cheng et al. (2024) investigates the impact of green bonds on resource efficiency in Asian economies from 2015 to 2022. The findings demonstrate a favourable correlation between the issuance of green bonds and resource efficiency. Specifically, a 1% increase in green bonds is associated with substantial short-term (0.33%) and long-term (0.43%) enhancements in resource efficiency.

Many authors observe the benefits of green finance. First, green finance positively impacts the preservation of the environment. However, the impact of green finance on the environment depends on the development and spread of green finance (Zhou et al., 2020). Also, green finance helps to control economic development by varying its size, rapidness and infrastructure (Wang & Zhi, 2016). Green finance contributes to developing clean energy (Sachs et al., 2019). The development of green finance can be advantageous from several perspectives (Sachs et al., 2019). Green finance addresses environmental concerns by providing funding for climate change responses. Green finance may support green growth by providing capital that combines economic growth with environmental sustainability. Green financing also facilitates the expansion of green industries, the transition of enterprises towards sustainable practices, and adherence to global rules designed to address environmental issues.

Academics (Soundarrajan & Vivek, 2016) observe the following benefits of green finance:

- Green financing facilitates the promotion of investments in environmentally sustainable technology and infrastructure, leading to enhanced long-term resource management and, thus, a heightened competitive advantage for the country.
- Green finance aids in addressing environmental concerns, enhances compliance with environmental regulations and facilitates the transition to more stringent standards.
- Green finance enhances the value and credibility of enterprises that adhere to its guidelines.

- Green finance enhances the economic state of countries by prompting governments to promote the transition to local markets and technology in response to the scarcity of global resources.

Another important benefit corresponding to the green bonds is the green growth stimulation (Ning et al., 2023). It has also been proven that carbon emissions decrease following the initial issue of a green bond (ElBannan & Löffler, 2024). Green finance also leads to enhanced environmental, social, and governance (ESG) performance among highly polluting companies (Qian & Yu, 2024). It substantially increases green production (Jiakui et al., 2023).

Relatively, the notion of green finance is still emerging, and, as anticipated, inherent challenges impede its progression. Academics recognise that the effective growth of green finance relies on the essential cooperation of the financial industry, regulators, policymakers, and enterprises (Falcone & Sica, 2019). Researchers (Soundarrajan & Vivek, 2016) identify the subsequent challenges associated with green finance: governments need to work on improving the attractiveness of green investments to attract international investors:

- It is important to accurately assess and assign appropriate costs to risks associated with new technologies, processes, or infrastructures.
- The availability of green financing instruments and the marketplaces in which they are traded are currently restricted.
- Policymakers, public capital providers, and private investors have competing objectives towards green finance.
- Accessibility of green finance is scarce to investors with low financial resources and cash.

Nevertheless, the growth of the green bond market is accompanied by several challenges. According to Bongaerts and Schoenmaker (2019), academics contend that the green bond market may overstate its role in environmental conservation. Furthermore, scholars note that green bonds offer modest financial and economic advantages for investors prepared to participate in initiatives that promote environmental sustainability. The issuance of green bonds incurs supplementary expenses, and green bonds encounter liquidity concerns. Greenwashing is present in the green bonds market, indicating the necessity to regulate the requirements of green projects. Cheong et al. (2020) note that the primary obstacles facing the green bond market are the lack of universally accepted market rules, the practice of greenwashing, and the rising expenses associated with issuing such bonds.

Researchers (Liu et al., 2022) observed the development of the green bond market in China and concluded that the growth of the green bond market is primarily influenced by the local economy and environmental governance, with institution-specific factors playing a secondary role. On the contrary, the authors state that the effects of policy support for green finance were minimal. Academics

(Yamahaki et al., 2022) investigated the barriers to the green bond market development in Brazil and concluded that the unpredictable macroeconomic climate, insufficient legislative safeguards for investors and the underperformance of low-carbon investments in terms of risk-adjusted returns hinder the growth of the green bond market. Researchers (Jiakui et al., 2023) observe that in China, the implementation of green finance laws may effectively expedite the expansion of green finance. Researchers (Lee et al., 2023) observe that a robust economy and strong political backing are crucial criteria for exercising the green finance benefits.

As noted by Liberati and Marinelli (2021) the existence of the green finance gap is present, implying the scarcity of diverse methods, concepts and models. However, the overcoming of the aforementioned challenges and barriers related to the green bond and green finance market would correspond to closing the gap in scientific literature and practice.

1.5. Conclusion of the First Chapter and Formulation of the Dissertation Tasks

The following conclusions have been drawn after the literature analysis:

1. Natural disasters occur when hazards intersect with economic, social, environmental, and physical hazards. Environmental dangers may impact the national economy by affecting supply and demand and causing other systemic effects. The susceptibility of countries to natural catastrophes is often determined by their degree of development and economic structure.
2. The green economy is integral to addressing sustainability concerns and improving social welfare. The concept of the green economy links the financial inclusion ideals with green finance. These ideas are thought to support the advancement of sustainable growth and equitable growth.
3. Green finance, a widely acknowledged approach to promoting sustainable development, is expanding worldwide and gaining more attention. Despite the recent market growth, a broadly accepted definition of green finance is lacking. Most of the definitions provided by scientists and organisations can be summarised as follows: green finance encompasses a variety of financial tools and activities designed to promote sustainable development, including both financial and non-financial enterprises.
4. Green finance includes a broad spectrum of financial instruments and services, which can be categorised into investment, banking, and insurance offerings. Debt and equity are the primary financial vehicles used in green financing. In response to the increasing need, more financial tools, such as green bonds and carbon market instruments, have been created,

together with new financial establishments, such as green banks and green funds.

5. There is a lack of academic research on green finance models and their practicality in light of the changing landscape of green finance. The existence of the gap is evidenced by academics Liberati and Marinelli (2021). To address the gap, this research focuses on the formulation of the green finance model for the sustainable development of "zero-waste" cities and its empirical approbation.

2

Methodology for Formulation of Green Finance Model for the Sustainable Development of Zero-Waste Cities

This Chapter investigates the role of waste management within economic theories and establishes the zero-waste concept, overviewing the inter-municipal cooperation approach. Also, it shapes the strategy for the development of zero-waste cities with the active involvement of green finance mechanisms. The Chapter describes the methods used to form a green finance model for the development of zero-waste cities.

The findings of the Second Chapter have been published in two scientific papers (Bužinskė & Stankevičienė, 2021; Bužinskė & Stankevičienė, 2023a).

2.1. Establishment of Green Finance Model for the Development of Zero-Waste Cities

Chapter 2.1 summarises the results of establishing the green finance model for the development of the zero-waste cities. It is structured in the following way: Section 2.1.1 covers the context of the waste management within green finance and green

economy and Section 2.1.2 covers the concept of zero-waste and presents the formulation of the green finance model for the development of zero-waste cities.

2.1.1. Context of Waste Management within Green Finance and Green Economy

The escalating quantity of waste is a consequence of the rising population, economic and demographic expansion, and inhabitants' consumption patterns and lifestyles (Ríos & Picazo-Tadeo, 2021). The municipal waste concept can differ among nations, with some countries solely defining the waste generated by households, while others additionally include workplace waste (Malek et al., 2023).

The waste management system is a complex framework of environmental, financial, economic, social, and regulatory determinations. In their study, Singh and Basak (2018) argue that a comprehensive evaluation of the waste management system should incorporate a meticulous assessment of both environmental and economic factors to address the variability in waste management strategies. Hence, the waste management system is influenced by both internal and external forces. Internal elements often pertain to the financial aspect of the system, whereas external factors are associated with the social and environmental aspects. Researchers (Medina-Mijangos & Seguí-Amórtegui, 2020) emphasise the significance of evaluating these external elements, as they might significantly influence the economic viability of such a system. When developing effective solutions for municipal waste management, it is important to simultaneously consider the economic and environmental aspects, as recommended by circular economy principles (Fan et al., 2020; Singh & Basak, 2018). Therefore, a suitable waste management system should be founded on its environmental advantages and financial and economic effectiveness.

Integrating environmental, financial, and economic considerations into the waste management system establishes the foundation for sustainability in municipal waste management. An effective and enduring municipal waste management system comprises economic, environmental, and social aspects and the government's adoption of sustainable development strategies (Cucchella et al., 2014). Efficient municipal waste management should be customised to align with environmental and social requirements while being fiscally and economically viable. Various elements influence this waste management system (Malinauskaite et al., 2017). Researchers suggest that political considerations are crucial in the effective management of waste. Given the order from the European Union, political leaders and policymakers must assume responsibility for implementing the required adjustments at the national and local levels. Government rules, tax systems, subsidies, and other support mechanisms are crucial for advancing waste management.

Furthermore, technology and innovations play a significant role in waste management and act as change catalysts.

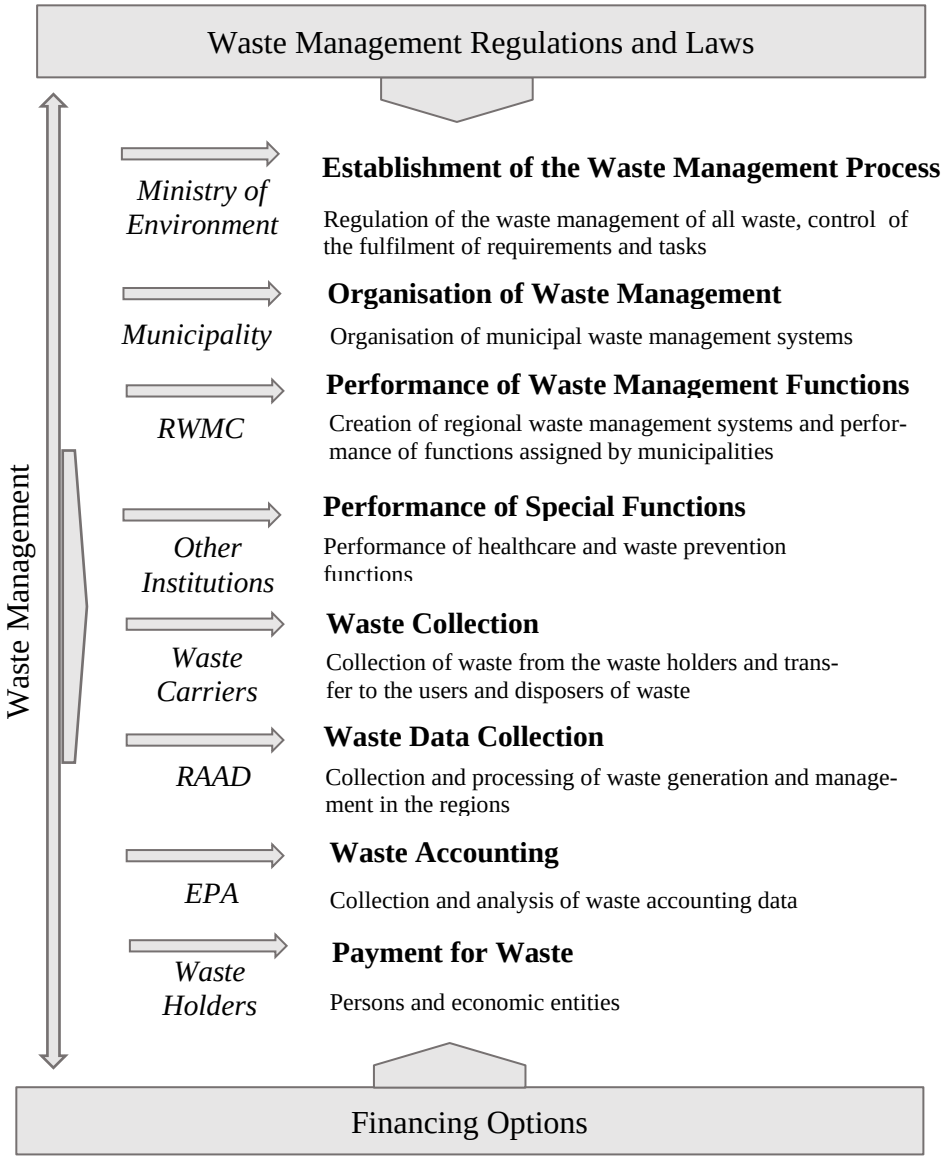

Fig. 2.1. Waste management process (source: compiled by the author based on Lietuvos Respublikos valstybės kontrolė (National Audit Office of Lithuania), 2013)

Furthermore, technology and innovations play a significant role in waste management and act as catalysts for change. Technology is accompanied by economic variables like business models, finance, cost valuation, and benefits. These economic components must be synchronised to address the difficulties posed by emerging technology and breakthroughs. Hence, the authors emphasise the significance of educational elements, highlighting the crucial role played by the level of collaboration between government agencies and research centres in the effective establishment of municipal waste management systems. Finally, it is important to consistently enhance social elements, such as the community's perception and understanding of waste management.

Sustainable municipal waste management has economic, social, and environmental advantages (Pin et al., 2018). First, it pertains to the process of making the economy more environmentally friendly and achieving the objectives of a circular economy. Therefore, municipal waste management leads to establishing employment opportunities in the environmentally friendly sector, thereby leading to enhanced social welfare. It is crucial to note that sustainable municipal waste management also encompasses enhancing societal health and boosting safety. Furthermore, sustainable municipal waste management facilitates waste avoidance, aids in the reduction of greenhouse gas emissions, and fosters responsible conduct among community members by promoting the recycling and reuse of waste.

Researchers (Pin et al., 2018) analyse the possible obstacles to the progress of sustainable municipal waste management. The authors highlight the exorbitant expenses associated with waste disposal and collection, the lack of a well-established market for products derived from waste, the scarcity of political determination, the absence of suitable regulations and strategies, the inadequate state of municipal waste management infrastructure and limited technical expertise, the insufficient recognition of challenges in municipal waste management, and the inappropriate collaboration between the public and private sectors.

2.1.2. Zero-Waste Concept and Formulation of the Green Finance Model for the Development of Zero-Waste Cities

The primary objective of the zero-waste concept is to address waste problems (Zaman, 2014, 2015; Zaman & Lehmann, 2013) by emphasising the avoidance and prevention of waste rather than relying on waste treatment procedures. Zero-waste initiatives yield financial, economic, social, and environmental advantages (Pietzsch et al., 2017; Roetman & Daniels, 2011). Zero-waste projects at the social level effectively mitigate health hazards and positively influence society's lifestyles. The environment can be improved by reducing waste flows and

implementing stricter environmental control measures. Zero-waste initiatives contribute to a symbiotic relationship between cost reduction and increased profitability, facilitated by improved productivity, superior product or service design, and heightened competitiveness at financial and economic levels.

Nevertheless, the effective implementation of zero-waste programs may encounter execution difficulties stemming from both the micro and macro environment (Pietzsch et al., 2017). Common microenvironmental difficulties encompass the heightened demand for political backing in waste management laws, the necessity for societal behavioural change and educational prerequisites, the desire for tax reforms, and the need for higher research and development resources to advance waste management systems. Microenvironmental challenges are typically issues that arise at the organisational level, where businesses encounter uncertainties in comprehending the technical strategies for achieving zero-waste objectives at a reasonable expense. These challenges also involve the practical implementation of waste management solutions and the enhancement of products or services.

Scientists, policymakers, and governments emphasise the need to educate individuals about zero-waste practices. Increasing knowledge in this area will have a beneficial impact on waste generation patterns. Zero-waste models encompass educating society about waste management issues and methods of engaging in waste reduction as a crucial component of effective municipal waste reduction.

Minelgaitė and Liobikienė (2019) examined the disparity between the intentions of European Union citizens to reuse, recycle, and recover waste and their actual behaviour. They based their analysis on the Eurobarometer survey "Attitudes of Europeans towards waste management and resource efficiency". The researchers concluded that countries aiming to reduce waste generation should prioritise the promotion of sustainable consumption and production practices. Moreover, the researchers discovered that promoting awareness of global waste issues and empowering individuals to act might effectively encourage waste-reducing behaviour. The study proposes that waste-reusing behaviour can be encouraged by efforts to enhance the quality and durability of products. Similarly, to promote recycling behaviour, it is recommended that recycling facilities be improved, focusing on ensuring that the waste from these facilities is effectively recycled.

The growing volume of waste on a worldwide scale and the comparatively low rates of recycling and composting are attracting more attention from policymakers throughout the world. The Waste Framework Directive 2008/98/EC, a law enacted by the European Union in 2008, establishes fundamental principles for waste management. These principles include practices that prevent harm to the environment and human health and the "polluter pays" and "increased producer responsibility" concepts. The Directive also presents a standardised waste

management hierarchy. However, researchers (Chen et al., 2020) assessed the movement patterns of global waste from municipalities and proposed that achieving the European Commission's circular economy goals by 2030 may require additional targeted regulations.

Figure 2.2 presents a comparison between the zero-waste and waste management hierarchy concepts. The core tenets of the zero-waste movement are initially minimising waste generation and subsequently repurposing waste materials to minimise overall waste quantities. Therefore, it is necessary to implement a system for the proper segregation and collection of waste to promote its reuse. Lastly, to achieve zero-waste, production methods should contain a design that is customised to the circular use of resources. Thus, the closed cycle of resources is preserved.

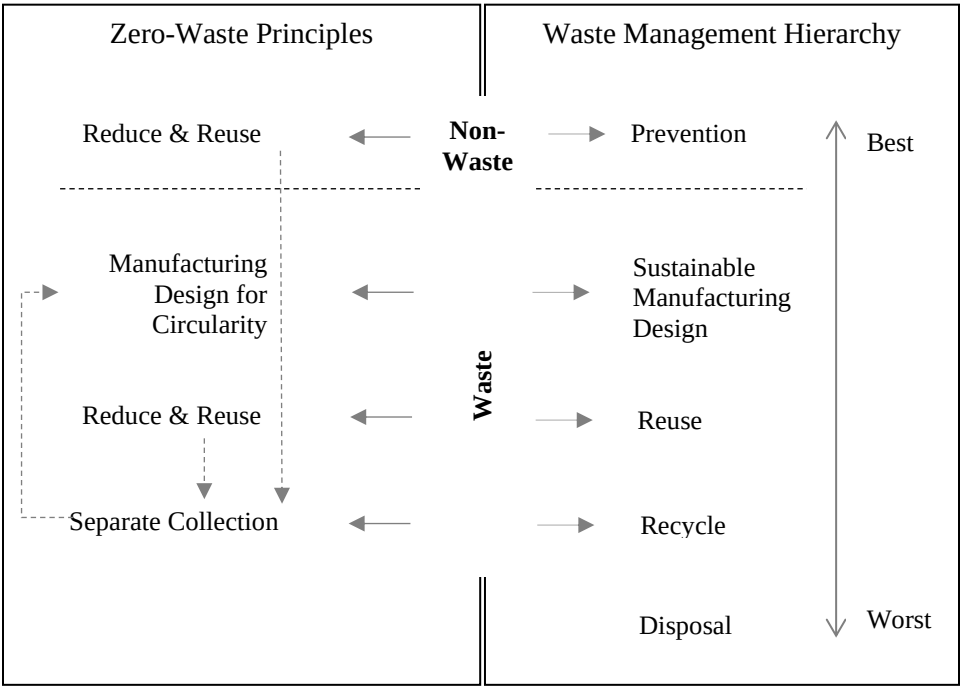

Fig. 2.2. Interrelation between zero-waste and waste management hierarchy (source: compiled by the author based on Vilella (2018); European Union Law (2008); Zero Waste Europe (2020))

According to the waste management hierarchy, waste avoidance is the most preferable waste management option, followed by sustainable production design, waste recycling, and reuse. The key characteristic of these techniques lies in the

fact that zero-waste eliminates waste disposal from the waste management cycle, as this practice is detrimental to the environment and does not align with the fundamental zero-waste concept. Similarly, the zero-waste approach does not endorse the use of thermal treatment or waste-to-energy technologies, as these procedures may result in the release of residual components into the atmosphere.

The concept of the "zero-waste" city aims to encourage the adoption of sustainable development practices and lifestyles by minimising the generation of solid waste and maximising resource efficiency (Li & Li, 2024; Qi et al., 2024). Thus, the aim of the "zero-waste" city concept is focused on the effective resolution of environmental problems related to solid waste at the city level (Li et al., 2024).

The green finance model for the development of zero-waste cities is based on the four-stage process depicted in Figure 2.3. The first stage of the green finance model for the development of zero-waste cities is based on the modelling of the financing options for green projects. This step aims to analyse the possible alternative ways for financing green projects with a focus on "zero-waste". The methods applied for the analysis are net present value, internal rate of return, benefit–cost ratio analysis and green weighted average cost of capital along with computation of the green progress. A detailed explanation of this research stage is summarised in Chapter 2.4.

The second stage of the research is dedicated to the analysis of the success factors, benefits and challenges of issuing green bonds in Lithuania. The analysis of this stage is based on the expert interview with subsequent analysis of the obtained answers via the Analytical Hierarchy Process. A detailed overview of the research methodology of the second stage is depicted in Chapter 2.5.

The third stage of the green finance model for the development of the "zero-waste" cities is dedicated to the assessment of the inter-municipal cooperation possibility for the issuance of green bonds dedicated to the financing of green projects with a focus on "zero-waste". Herein, the new valuation approach for the assessment of the possibility of inter-municipal cooperation is proposed for effective cooperation between smaller issuers, such as smaller municipalities of Lithuania. The proposed valuation approach is based on the assessment of financial, solvency, social and environmental conditions of cooperating municipalities along with an assessment of the Financial Condition Index and Risk-Adjusted Municipal Condition index. The detailed explanation of this research stage is summarised in Chapter 2.6.

The last stage of the research is dedicated to the modelling of the green bond issuance algorithm for municipalities. This research stage concludes the previous research results obtained from Stages 1, 2, and 3 of the research methodology and proposes the twelve-step process for green bond issuance by cooperating

municipalities. A detailed overview of the research methodology of the second stage is depicted in Chapter 2.7.

STAGE	STAGE I	STAGE II	STAGE III	STAGE IV
	Modelling of Financing Options for Green Projects	**Analysis of the success factors, benefits and challenges of issuing green bonds**	**Assessment of inter-municipal cooperation possibility**	**Modelling algorithm for the green bond issuance by municipalities**
GOAL	Demonstrate alternatives for financing green projects focused on zero-waste for municipalities	Distinguish success factors, benefits, and challenges associated with the current green bond issuances	Formulate a four-dimensional method for evaluation of the municipality's performance	Define the green bond issuance process based on the results obtained from the previous research stages
METHODS	Green Progress; Green WACC; Cost–Benefit Analysis; Scenario analysis	Expert Interview; Analytical Hierarchy Process	Expert Interview; Financial, solvency, waste, social indicators; Risk-Adjusted Municipal Condition Index	Synergy of the results obtained from Stage 2 and Stage 3 for issuance algorithm; Best market practice for roles and responsibilities
OUTCOME	Green bonds are recognised as a potential financing method for green projects focused on zero-waste	Criteria for successful green bond issuance are determined	Financial, solvency, social and environmental conditions of cooperating municipalities are assessed	The green bond issuance process for municipalities in inter-municipal cooperation with roles and responsibilities is formulated
IMPACT	Scenario analysis for different funding ways for financing green projects is proposed	A set of success factors, benefits and challenges related to the green bond issuance is developed	A set of indicators for the assessment of inter-municipal cooperation possibility is established	Proposed process for issuing green bonds for municipalities in inter-municipal cooperation for the sustainable development of the "zero-waste" cities

Fig. 2.3. Green finance model for the development of zero-waste cities (source: developed by the author)

The detailed overview of the methods and related processes of each research stage is summarised in Table 2.1. The below table provides a high-level overview of the methods depicted in Figure 2.3. A detailed explanation of the formulas can be found in subsequent sections of the Second Chapter.

Table 2.1. Development of stages of a green finance model for the sustainable development of zero-waste cities (source: summarised by the author)

Stage	Process	Applied assessment method
Stage I	Data collection	Collection of information on waste management projects in the financial statements of waste management centres
	Development of research assumptions and scenarios	Developing five financing scenarios and formulating research assumptions
	Net present value (NPV)	$NPV = CF_0 + \sum_{t=1}^{n} \frac{CF_n}{(1+r)^n}$
	Internal rate of return (IRR)	$0 = NPV = CF_0 + \sum_{t=1}^{n} \frac{CF_n}{(1+IRR)^n}$
	Economic Net Present Value (ENPV)	$ENVP{=}PV(B){-}PV(C)$
	Economic Internal rate of return (EIRR)	$B_0 - C_0 + \frac{B_1 - C_1}{(1+ERR)} + \frac{B_2 - C_2}{(1+ERR)^2} + \cdots + \frac{B_T - C_T}{(1+ERR)^T} = 0$
	Cost/benefit ratio	$B/C = \frac{PV(B)}{PV(C)}$
	Green Progress	$Green\ Progress = \frac{WCEE_t - WCEE_{t-1}}{WCEE_{t-1}}$
	Green Weighted Average Cost of Capital (Green WACC)	$\left[\frac{E}{E+D}\right] K_e + \left[\frac{D}{E+D}\right] k_d(1-t_c)(1+GP) = WACC$
Stage II	Expert interview	Formulating the survey questions and collecting the results of the expert evaluation
	Application of Analytical Hierarchy Process	Pairwise comparison matrix $C = [C_{ij}]_{nxn} \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix}$

End of Table 2.1

Stage	Process	Applied assessment method
Stage II	Application of Analytical Hierarchy Process	The reciprocal values $R = \left[\frac{1}{C_{ij}}\right]_{nxn} \begin{bmatrix} \frac{1}{C_{11}} & \frac{1}{C_{12}} & \frac{1}{C_{13}} \\ \frac{1}{C_{21}} & \frac{1}{C_{22}} & \frac{1}{C_{23}} \\ \frac{1}{C_{31}} & \frac{1}{C_{32}} & \frac{1}{C_{33}} \end{bmatrix}$
		Normalisation $X_{ij} = \frac{C_{ij}}{\sum_{i=1}^{n} C_{ij}} \begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix}$
		The determination of the weights of the criteria $W_{ij} = \frac{\sum_{j=1}^{n} X_{ij}}{n} \begin{bmatrix} W_{11} \\ W_{12} \\ W_{13} \end{bmatrix}$
		The consistency index $CR = \frac{CI}{RI}$
Stage III	Data collection	Collection of financial, environmental and social data from selected municipalities
	Expert interview	Formulating survey questions and systemising the results of the expert evaluation
	Assessment of financial, solvency, social and environmental conditions	Assessment of financial, solvency, social and environmental state
	Financial Condition Index	Calculation of the Financial Condition Index for selected municipalities Financial Condition Index = $w_1*DI_1+w_2*DI_2+\cdots+w_n*DI_n$
	Risk-Adjusted Financial Condition Index	Calculation of the Risk-Adjusted Municipal Condition Index for selected municipalities Risk-Adjusted Financial Condition Index = $w_1*DI_1*R_1+w_2*DI_2*R_2+\cdots+w_n*DI_n*R_n$
Stage IV	Formulation of the green bond issuance algorithm	Formulating an algorithm for municipal green bond issuance in cooperation between municipalities based on the results of the previous research phases

The comprehensive explanation of the applied methods is depicted in the subsequent sections of the Second Chapter. Each section provides a detailed research methodology, and the corresponding computation sequence of each method applied.

2.2. Modelling of the Financing Options for Green Projects

The first stage of the research is dedicated to modelling the financing options for green projects. The research methodology of "Stage 1" is summarised in Figure 2.4.

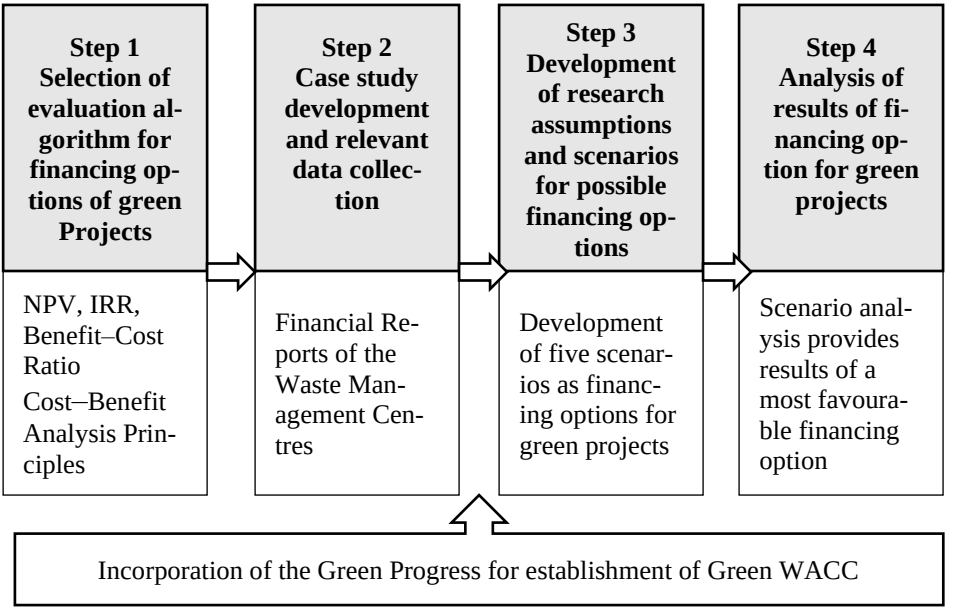

Fig. 2.4. Research methodology for the first stage of the green finance model for the development of the zero-waste cities "Modelling of Financing Options for Green Projects" (source: developed by the author)

The research methodology for the first stage of the green finance model for the development of the zero-waste cities "Modelling of Financing Options for Green Projects" is divided into four steps. The first step is dedicated to the selection of evaluation tools of possible financing alternatives for green projects

focused on "zero-waste". The following evaluation tools are selected: net present value, internal rate of return, and benefit–cost ratio analysis.

The second stage of the research is dedicated to the development of relevant case studies and data collection. Based on the financial reports of the Waste Management Centres, the most common financing methods for green projects are identified. The third step of the research is focused on the development of research assumptions and proposes five scenarios with diverse financing options for green projects with a focus on "zero-waste". The last step of the research is dedicated to the analysis of obtained results from the scenario analysis. The research methodology for the first stage of the green finance model for the development of the zero-waste cities, "Modelling of Financing Options for Green Projects", also incorporates the Green Progress measure and Green Weighted Average Cost of Capital in the scenario analysis.

2.2.1. Financial Ratios for the Modelling of Financing Options for Green Projects

The study modelling financing options for green projects starts with selecting the evaluation method for financing green projects. Based on the scientific literature analysis, the computation of the Net Present Value (NPV), Internal Rate of Return (IRR), and cost-benefit ratio (B/C ratio), along with the cost–benefit analysis principles, are selected for the study. Data gathering is the second stage of the research process. This study chose its research objective and firms for analysis and gathered the pertinent data. Investment analysis is the third phase in the research process. The study of investments is conducted according to the principles of the cost–benefit study, as proposed by the European Commission (European Commission, 2014). The third step includes the development of relevant research assumptions and scenarios for possible financing options. The final step of research is the formulation of conclusions based on the results from the scenario analysis.

Cost–benefit analysis (CBA) enables the evaluation of the societal welfare implications arising from the expected benefits and expenses associated with a certain project (Gigli et al., 2019; Nik Ab Rahim et al., 2021). One of the advantages of cost–benefit analysis, as advocated by the European Commission and the Organisation for Economic Cooperation and Development (OECD), is its capacity to assess the environmental consequences of a project and integrate these impacts into economic policy (O'Mahony, 2021). Implementing the cost–benefit analysis (CBA) approach for project valuation is a topic that has been examined by scholars (Beria et al., 2012). These academics have analysed the advantages and disadvantages associated with the use of CBA in this context. The primary benefits of utilising the cost–benefit analysis approach are its notable precision and the transparency of the derived outputs. These findings may be readily

examined and evaluated by analysts, investors, and politicians on a worldwide scale. However, the CBA technique presents certain implementation issues due to its reliance on a substantial quantity of data for accurate computations. Acquiring such data can be a labour-intensive process. Quantifying the economic gains in cost–benefit analysis can frequently challenge the intangible nature of these benefits. The underlying justification for the cost–benefit analysis may be succinctly outlined through three fundamental characteristics, as identified by Gigli et al. (2019). (1) It is necessary to assess the costs and benefits of a project in monetary terms to enhance comparability among variables. (2) The utilisation of scenario analysis is recommended, wherein potential project scenarios are compared to the existing business-as-usual scenario. (3) It is imperative that the present value of benefits exceeds the present value of costs. The European Commission defines cost–benefit analysis as part of a comprehensive seven-stage process (European Commission, 2014; Gigli et al., 2019). The CBA must incorporate the contextual factors of the project, including established project objectives, physical components, and activities that contribute to the achievement of project objectives. Technical viability, environmental sustainability, financial and economic analysis, and risk assessment are all included in CBA.

Based on the guidelines provided by the European Commission (2014), it is recommended that the study of waste management initiatives adhere to a time range of 30 years. Hence, the prediction of the financial data gathered has been implemented to fulfil the time-related specifications.

Fiscal adjustments have been implemented to incorporate fiscal considerations, such as inflation and value-added tax, into the financial costs of the company's financial figures. The European Commission's advice has been followed in adjusting the initial investment, replacement costs, residual value, and operational expenses.

In a recent study, Stankevičienė and Bužinskė (2021) noted that exponential smoothing is a suitable technique for waste forecasting. The researchers found that this method was efficient in accurately predicting future outcomes. Hence, exponential smoothing was selected as a forecasting approach for the 30-year financial projections of the Vilnius County Waste Management Centre. Exponential smoothing was calculated by using the MS Office Excel Forecast Sheet functionality.

NPV may be computed by employing the below formula (Dobrowolski & Drozdowski, 2022; Wang, 2021):

$$NPV = CF_0 + \sum_{t=1}^{n} \frac{CF_n}{(1+r)^n}, \tag{2.1}$$

where r – discount rate, n – project lifetime, CF – cash flow, CF_0 – initial investment.

NPV has been extensively discussed in the literature (Bora, 2015; Mackevičius & Tomaševič, 2010; Wang, 2021). One notable advantage is its widespread use on a global scale, which suggests that the computational process and interpretation of findings may be readily implemented. NPV metric is utilised to assess the cash flows associated with various stages of a project over a set timescale. NPV is a valuable tool in the evaluation of project portfolios since it provides an unbiased appraisal of the projects. One of the drawbacks associated with the NPV technique is its failure to adequately reflect the financial robustness of a given project. NPV approach is influenced by the discount rate chosen for a particular project. Typically, the discount rate remains constant throughout the project's duration, regardless of fluctuations in market circumstances. The interpretation of NPV technique findings may lead to misinterpretation in projects of varying sizes, as it suggests that larger projects provide higher NPV. This, in turn, poses challenges in making project-related decisions. The NPV technique encompasses the incorporation of financial forecasts that pertain to the expected project timeline, hence necessitating the utilisation of a resilient forecasting methodology.

IRR is a metric that quantifies the expected return on investment throughout the duration of a project. Typically, projects that possess an IRR beyond the required level of return are considered to be acceptable, whereas initiatives exhibiting an IRR below the required rate of return are not deemed justifiable for implementation (Militaru, 2020; Wang, 2021). The internal rate of return (IRR) may be computed by employing the below mathematical expression (Wang, 2021):

$$0 = NPV = CF_0 + \sum_{t=1}^{n} \frac{CF_n}{(1+IRR)^n}, \tag{2.2}$$

where *IRR* – the internal rate of return, *n* – project lifetime, *CF* – cash flow, CF_0 – initial investment.

The advantages of using the IRR approach are mostly attributed to its straightforward use. IRR allows for a simple comparison between the calculated rate and the needed rate of return, so offering a logical basis for making investment decisions. The disadvantages associated with the IRR technique are aligned with the cash flows generated by the project. According to Wang (2021), in cases when project cash flows exhibit fluctuations between positive and negative values during the duration of the project, multiple IRR can arise.

The advantages of IRR have been discussed by Bora (2015) and Mackevičius & Tomaševič (2010). They argue that the findings obtained from IRR calculations are informative and offer a reliable measure of the project's profitability and economic efficiency. The IRR is also associated with project risk since it indicates that projects with greater IRR values are often riskier. The limitations of the IRR technique are associated with its complexity and sensitivity to future cash flows of the project. Certain components of the projects that have the potential for

successful execution may face rejection if the investors' required rate of return surpasses the IRR.

The Economic Net Present Value (ENPV) assesses the prospective societal and environmental advantages of a project in relation to its associated expenses. In general, projects with a positive ENPV should be deemed acceptable. The calculation of the ENPV involves determining a difference between the present value of economic benefits and the present value of economic costs. The calculation of the ENPV may be determined by utilising the formula proposed by Gigli et al. (2019):

$$ENVP = PV(B) - PV(C), \tag{2.3}$$

where $PV(B)$ − the present value of economic benefits; $PV(C)$ – the present value of economic costs.

The formula for the calculation of the ERR is the following (Gigli et al., 2019):

$$B_0 - C_0 + \frac{B_1 - C_1}{(1+ERR)} + \frac{B_2 - C_2}{(1+ERR)^2} + \cdots + \frac{B_T - C_T}{(1+ERR)^T} = 0. \tag{2.4}$$

The Benefit-Cost (B/C) ratio serves as a metric for evaluating the relative advantages of a project by comparing its possible benefits to its associated expenses (Ihuah, 2014). The acceptance of the project is conditional upon the B/C ratio surpassing a threshold of 1, but the project has to be declined if the ratio falls below 1. The B/C ratio may be computed using the formula provided by Gigli et al. (2019):

$$B/C = \frac{PV(B)}{PV(C)}, \tag{2.5}$$

where $PV(B)$ − the present value of economic benefits; $PV(C)$ − the present value of economic costs.

2.2.2. Green Progress

The conceptual framework for computing Green Progress (GP) consists of two distinct steps, as illustrated in Figure 2.5. Initially, statistical data on the quantities of waste created in the ten counties of Lithuania is gathered, including the population size and registered commercial units within these areas. The data presented in this study was obtained from the Environmental Protection Agency of the Republic of Lithuania. Consequently, data analysis is conducted, followed by the computation of GP.

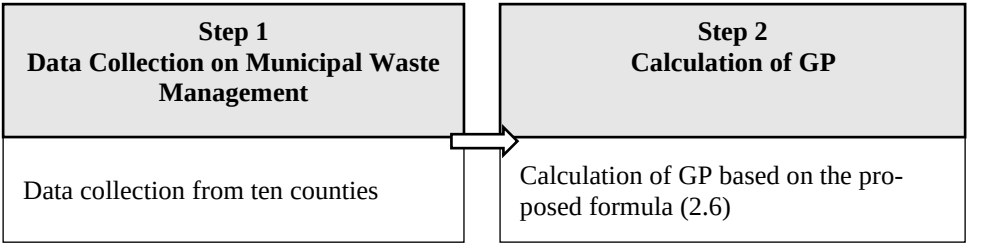

Fig. 2.5. Research methodology for Green Progress (source: developed by the author)

The Green Progress concept encompasses the assessment of the municipal waste management system, specifically focusing on the quantity of municipal waste created within the designated region of study and during a set timeframe. The Green Progress assessment evaluates the impact of waste management initiatives on a municipal level, indicating the overall effectiveness of the waste management system. Therefore, the outcomes derived from the computation of the GP suggest the need to reassess the waste management plan. This reassessment should involve a more comprehensive study using methodologies such as life cycle assessment, multi-objective methods, or indicators.

$$Green\ Progress = \frac{WCEE_t - WCEE_{t-1}}{WCEE_{t-1}}, \tag{2.6}$$

where *WCEE* represents the amount of waste created per capita and the number of registered economic organisations, and the variable "t" denotes the specific year in which the observation was made.

The results can potentially encompass a range of negative, positive, and neutral values. The presence of negative values in the data indicates a good trend in the functioning of the municipal waste management system. Specifically, it suggests a decrease in waste amounts relative to the number of residents and registered business organisations. On the other hand, positive numbers imply a rise in the quantities of waste, whereas zero values signify no change between the variables.

2.2.3. Green Weighted Average Cost of Capital

Various methodologies are available for assessing the economic, financial, and environmental aspects of waste management systems. The environmental effectiveness of the waste management system may be evaluated by employing cost–benefit analysis, life cycle assessment, and multi-objective techniques (Fan et al., 2020) or by utilising indicators (Rogge & De Jaeger, 2012). Diverse stakeholders

with a specific interest in a firm are concerned with its financial performance and the assessment of its value. A widely used income-based valuation technique is linked to the idea of capital cost or WACC (Adamczyk & Zbroszczyk, 2017).

WACC is a well-recognised and reliable technique used to assess the value of a company or the viability of a project. The calculation of WACC includes the assessment of all forms of capital, such as long-term debts, issued shares, bonds, and other financial instruments (Ameli et al., 2021; Indrawan et al., 2020). WACC is a measure that represents a company's sources of funding, which can be in the form of stock or debt (European Commission, 2019; Lilford et al., 2018; Ross et al., 2007). The calculation of WACC involves the estimation of equity and debt funding and the determination of interest rates for both financing forms and the corporation tax rate. The WACC is subject to fluctuations based on country-specific factors and the market sector of the analysed firm. Additionally, the WACC is influenced by the kind of investor and their willingness to risk (Vartiainen et al., 2019). Researchers (Suto & Takehara, 2017) noted that most companies obtain funding for their business requirements by using debt and equity financing methods. They also consider the advantages and disadvantages that arise from factors such as the macroeconomic environment, market structure, and taxation. Previous studies (Sharfman & Fernando, 2008; Suto & Takehara, 2017) have investigated environmental risks and factors affecting WACC. These studies have found that environmental risk management is positively associated with the debt cost and negatively associated with the equity cost and the overall WACC. Previous research conducted by Atan et al. (2018) and Mohamad (2020) demonstrated a strong and positive correlation between the assessment of Environmental, Social, and Governance (ESG) factors and the WACC. Researchers (Park & Noh, 2018) have noted that enterprises with greater greenhouse gas emissions (GHG) and energy consumption relative to their revenues tend to have higher capital costs. Academics also acknowledge the limitations of the WACC computation. The WACC calculation may not fully capture all the risks involved with business operations or a project (Lilford et al., 2018). WACC employs a uniform calculation method that disregards variations in industry sectors, the incorporation of technology in business operations, and the specific area in which a firm operates (Bachner et al., 2019).

Although the WACC technique has its drawbacks, as noted before, it is nevertheless utilised in research as a valuation tool. An indicator is used to assess the environmental performance of the waste management system.

The conceptual model for calculating WACC consists of three steps (Fig. 2.6). The model starts by determining the values of the constituents of the cost of debt. The calculations involve assessing beta, the risk-free rate, and the rate of return on the stock market.

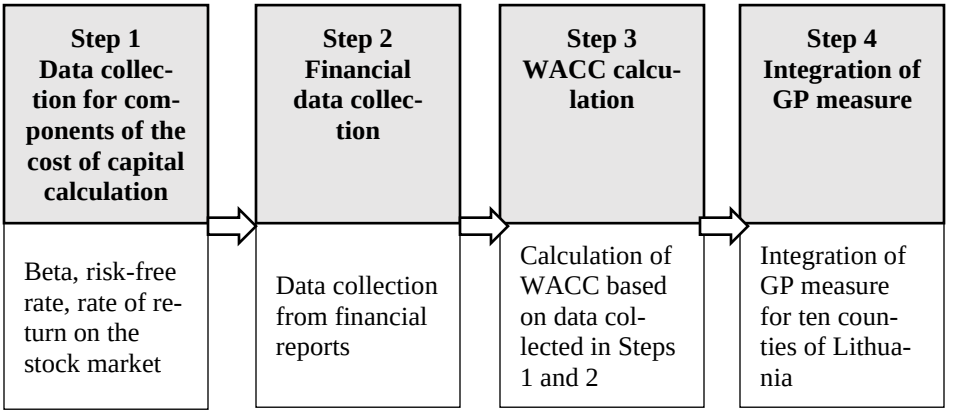

Fig. 2.6. Research methodology for Green WACC (source: developed by the author)

The initial step in formulating the conceptual model for computing WACC involves determining the values of the various constituents that form the cost of debt. The calculations encompass the assessment of beta, the risk-free rate, and the rate of return on the stock market.

Given that municipalities are not publicly traded, the determination of debt costs implies the exploration of alternate methodologies for assessing beta, risk-free rate, and stock market return. The determination of the risk-free rate in Lithuania is based on the "BEREC Report on WACC parameter calculations according to the WACC Notice of the European Commission of 7 November 2019" (Body of European Regulators for Electronic Communications, 2020). Meanwhile, the representation of the return rate on the stock market is derived from the average annual return of Lithuanian companies' stocks during the period of 2011–2020 (INVL Asset Management, 2021).

The scientific literature extensively discusses many methods for determining beta, including market, bottom-up, and accounting betas (Damodaran, 2006, 2012). Furthermore, Indrawan et al. (2020) suggest that the estimation of beta can be facilitated by considering the computation of beta for firms operating within the same sector, as it can serve as a suitable substitute for determining the beta of a specific company within that sector. However, given the complex nature of the municipality's scope of activities and the diverse range of services offered, the aforementioned approaches would not be the most suitable.

According to Rutkowska-Ziarko (2018), Rutkowska-Ziarko and Markowski (2020), and Rutkowska-Ziarko and Pyke (2017, 2018), the calculation of beta may be accomplished by utilising the accounting beta valuation approach. In this approach, the correlation between the profitability of the market portfolio and the firm being analysed is determined, as well as the variability of the profitability

ratios of the market. The profitability ratio chosen for the computations is Return on Equity (ROE). According to Xu et al. (2021), the concept of Return on Equity (ROE) is used to evaluate a company's ability to effectively utilise both internally generated and externally raised money for investment purposes, as well as to generate economic growth through the deployment of these assets. The market portfolio is comprised of Lithuanian firms listed on the Baltic Main List and Baltic Secondary List of the NASDAQ OMX trading list. The financial information required to compute the accounting beta using the Return on Equity (ROE) is obtained from the financial reports of municipalities and companies listed on the Baltic Main List and Baltic Secondary List of the NASDAQ OMX. The data covers the period from 2011 to 2020.

The calculation method for determining the accounting beta coefficient of the return on equity, denoted as β_i (ROE), is as follows (Rutkowska-Ziarko, 2018; Rutkowska-Ziarko & Markowski, 2020; Rutkowska-Ziarko & Pyke, 2017, 2018):

$$\beta_i(ROE) = \frac{COV_{iM}(ROE)}{S_M^2(ROE)}, \tag{2.7}$$

where $COV_{iM}(ROE)$ is a covariance between the return on equity of a company and market portfolio, $S_M^2(ROE)$ is a variance of return on equity of a market portfolio.

During the second step, the collection of financial data is undertaken to calculate the WACC. Lithuania comprises a total of ten counties, each of which is associated with a single largest municipality. To calculate WACC, such municipalities have been chosen from each county.

During the third step of the analysis, the WACC is computed, followed by its adjustment using the GP measure. Ruiz et al. (2016) presented the notion of including environmental performance measurements in WACC. Scholars have noted that investment projects that have significant environmental or social benefits may lead to a reduction in the interest rate. This might be an indication that funding investment initiatives is becoming less expensive. This study applies the valuation method introduced by Ruiz et al. (2016) to assess the environmental performance of municipalities based on their waste management efforts. The formula for integrating environmental performance measures, denoted as GB (Ruiz et al., 2016), can be expressed as follows:

$$\left[\frac{E}{E+D}\right] K_e + \left[\frac{D}{E+D}\right] k_d(1 - t_c)(1 - GB) = WACC, \tag{2.8}$$

where *E* – equity financing, *D* – debt financing, *Ke* – cost of equity, *Kd* – cost of debt, *tc* – tax rate, *GB* – green benefit.

Bužinskė and Stankevičienė (2021) conducted a study that demonstrates the inverse relationship between municipal waste management and its positive impact. To incorporate the GP measure into the WACC calculation method, as suggested by Ruiz et al. (2016), it is necessary to modify the WACC formula to account for the inclusion of GP. In this manner, integrity is maintained between the formula and the underlying notion.

$$\left[\frac{E}{E+D}\right] K_e + \left[\frac{D}{E+D}\right] k_d(1 - t_c)(1 + GP) = WACC. \quad (2.9)$$

An important factor to consider is that the GP measure is computed at a county level, and WACC is produced based on the financial performance of the municipality within each respective area. The justification for this difference derives from the municipality's involvement in the waste management system. In Lithuania, the responsibility for organising the waste management system lies with the municipalities. As a consequence, the outcomes of these initiatives occur at a regional level through the GP calculation.

2.3. Research Methodology for the Analysis of Success Factors of Issuing Green Bonds

This Section presents a technique for determining the characteristics contributing to the success of issuing green bonds and identifying the possible advantages and difficulties associated with the issue. The approach follows a four-step procedure illustrated in Figure 2.7. The initial research stage involves examining the scientific literature on the issuing procedure of green bonds and their possible obstacles and advantages.

This work places considerable importance on identifying the research criteria and clearly outlining the scope of the investigation. This research is divided into two parts: (1) investigating the criteria categorised as pairwise comparison matrices and (2) examining the criteria included in the open questions section. The subsequent phase of the study entails identifying individuals with substantial experience in the specific area of research and organising the research scope into a pairwise comparison matrix. The fourth study stage involves utilising the analytical hierarchy process (AHP) approach to determine the research variables that hold substantial significance, as assessed by specialists. The last research stage involves analysing the responses given by experts to the open-ended questions.

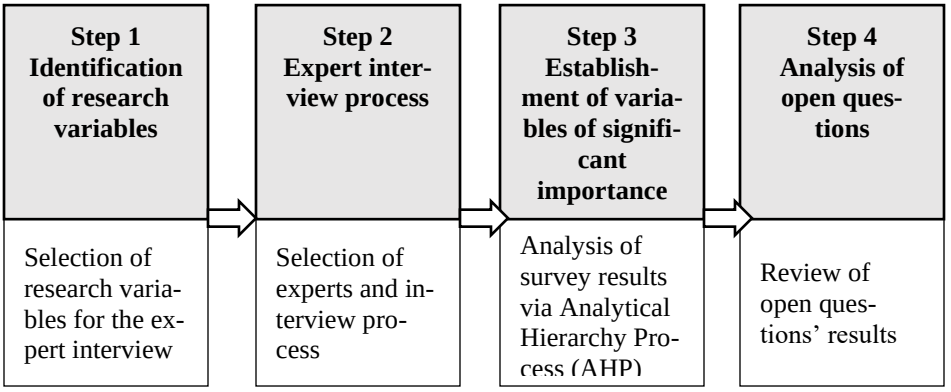

Fig. 2.7. Research methodology for analysis of success factors of issuing green bonds in Lithuania (source: developed by the author)

AHP is a widely applied technique for multi-criteria decision-making. It facilitates determining criterion weights and prioritising options through pairwise comparisons of the chosen criteria (Alrawad et al., 2023; Yan Liu et al., 2020). AHP was first introduced in 1972 by Saaty. The approach described in the literature is extensively utilised in several fields, such as environmental research, management studies, manufacturing, engineering processes, and energy efficiency calculations (Yu et al., 2021). One advantage of AHP is its suitability for examining qualitative and quantitative research inquiries. Therefore, this multi-criterion decision-making procedure is employed within this study due to the qualitative character of the research variables. Although the approach has broad application, it is important to acknowledge its possible drawbacks. One such drawback is the requirement to formulate a substantial number of comparisons to arrive at a choice (Leal, 2020).

As per the method established by Saaty and Özdemir (2015), the experts participating in the interview possess the following attributes: substantial experience in the specific domain relevant to their judgment; demonstrate consistency in their perspectives about the study subject they are tasked with evaluating; a comprehensive breadth of knowledge in their field of expertise. The quantity of specialists necessary for the assessment of criteria exhibits variability across various research. According to Brunelli (2015), the opinion of a solitary expert is sufficient to provide a judgment. Conversely, the study conducted by Wang et al. (2018) suggests that the input of ten experts is required for a comprehensive evaluation. Similarly, according to Yap et al. (2017), four experts are necessary for a well-informed decision. In contrast, Sevinç et al. (2018) contend that the collective expertise of fifteen individuals is essential for an accurate assessment. Lastly,

Petroutsatou and Ladopoulos (2022) argue that the input of thirteen experts is crucial in making an informed judgment.

AHP may be divided into five primary stages, as outlined by Elshafei et al. (2022), Sevinç et al. (2018), Vafaei et al. (2016), Vojtek and Vojteková (2019), and Wang et al. (2018). However, the objective of this study is to comprehend the importance of the chosen research variables. Consequently, the last stage of AHP utilised in this study pertains to establishing the weights of the selected criteria, as no additional alternatives are examined.

1. The problem is restructured into a hierarchical framework. The process encompasses establishing the problem's objective and identifying potential criteria and sub-criteria associated with the problem.

2. The construction of the pairwise comparison matrix involves comparing specified criteria using a rating scale. The representation of numerous square matrices may be shown as follows (Yap et al., 2017):

$$C = \left[C_{ij}\right]_{nxn} \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix}. \tag{2.10}$$

The reciprocal values can be depicted in the subsequent manner (Yap et al., 2017):

$$R = \left[\frac{1}{C_{ij}}\right]_{nxn} \begin{bmatrix} \frac{1}{C_{11}} & \frac{1}{C_{12}} & \frac{1}{C_{13}} \\ \frac{1}{C_{21}} & \frac{1}{C_{22}} & \frac{1}{C_{23}} \\ \frac{1}{C_{31}} & \frac{1}{C_{32}} & \frac{1}{C_{33}} \end{bmatrix}. \tag{2.11}$$

The representation of the normalisation process for the pairwise comparison matrix may be expressed as follows (Yap et al., 2017):

$$X_{ij} = \frac{C_{ij}}{\sum_{i=1}^{n} C_{ij}} \begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix}. \tag{2.12}$$

3. The determination of the criteria weights may be expressed as follows (Yap et al., 2017):

$$W_{ij} = \frac{\sum_{j=1}^{n} X_{ij}}{n} \begin{bmatrix} W_{11} \\ W_{12} \\ W_{13} \end{bmatrix}. \tag{2.13}$$

4. The assessment of the consistency of the results. The consistency index must be less than 10%. The consistency ratio is calculated using the following formula:

$$CR = \frac{CI}{RI}, \tag{2.14}$$

where CR – consistency ratio, CI – consistency index, RI – random index. The random index value depends on the value of n, that is, the size of the pairwise comparison matrix. The Random index values are summarised in Table 2.

Table 2.2. Randomised index values (source: compiled by the author based on Sevinç et al. (2018), Wang et al. (2018), Yap et al. (2017)).

R	1	2	3	4	5	6	7	8	9	10
N	0	0	0.52	0.9	1.12	1.24	1.32	1.41	1.45	1.49

The consistency index is determined by employing the accompanying formula:

$$CR = \frac{\lambda - n}{n-1}, \tag{2.15}$$

where n – number of criteria, λ – average value of the consistency vector.

The evaluation of responses given by the experts to the open-ended questions relies on a qualitative study of the answers.

2.4. Modelling the Valuation Approach of the Inter-Municipal Cooperation Possibility

The concept of inter-municipal cooperation (IMC) has been widely recognised and practised in several countries since the 1960s, as documented by Bučaitė-Vilkė and Lazauskienė in 2019. IMC refers to the collaboration of many municipalities to enhance the effectiveness of providing public services and achieve economies of scale (Hiratsuka-Sasaki and Kojima 2020).

Municipalities can independently deal with public issues, including the preferences of residents (Miceikienė et al., 2021; Trinajstic et al., 2022). Municipalities engage in IMC to fulfil their responsibilities. For instance, researchers (Wolfschütz & Bischoff, 2021) examined the municipalities in West Germany and discovered that communities experiencing a population decline are more likely to participate in IMC. Additionally, governmental subsidies have a positive impact on the development of IMC. According to a study in Poland, smaller towns are more inclined to initiate IMC due to issues related to economies of scale

(Chodakowska, 2021). Research done in the Czech Republic found that smaller municipalities are more likely to join IMC, whereas larger municipalities have fewer advantages from joining IMC (Struk & Bakoš 2021). With the rising expectations of citizens for high-quality public services, municipalities are collaborating to improve services like transportation, healthcare, and waste management. This collaboration also allows them to access financing opportunities that would not be available to individual municipalities (Bintara et al., 2023; Olzhebayeva et al., 2023; Su et al., 2023; Romero-Subia et al., 2022; Mao et al., 2021; Glyptis et al., 2020).

The impacts of IMC are extensively examined in scholarly literature. In their study, Banaszewska et al. (2022) examined Polish towns to assess their progress in enhancing business development opportunities and economic growth. Researchers discovered that the use of IMC leads to a decrease in local unemployment rates by 0.4%. The observed outcomes can be attributed to the enhancement in the synchronisation of local government strategies. In a study by Zafra-Gómez et al. (2020), Spanish small municipalities were examined to assess the efficiency of providing drinking water services through direct public provision and IMC. The study found that direct public provision is associated with cost efficiency, whereas IMC is associated with the optimal utilisation of installed capacity. In a study by Ferraresi et al. (2018), Italian towns were examined to determine the impact IMC involvement has on effectiveness. The researchers discovered that being involved in IMC resulted in a 5% decrease in per capita costs. Furthermore, this effect continued to rise for up to six years after joining IMC. IMC facilitates the achievement of economies of scale, as evidenced by studies conducted by Allers and de Greef (2018), Bel and Sebő (2021), and Gendźwiłł et al. (2019). In a study by Sarra et al. (2020), the researchers examined the use of IMC in Italian towns. They discovered that the most effective population size for implementing IMC is 55,000 persons. As the population increases above this threshold, the effectiveness of IMC decreases. Economic incentives foster collaboration among local governments (Kovacs, 2019).

A study on Japanese municipalities found that IMC has a significant role in enhancing the efficiency of public service delivery (Baba & Asami, 2019). Researchers (Casula, 2020) provide an outline of how IMC may efficiently cut transaction costs and manage risks in municipalities that are involved in IMC. IMC enables the utilisation of economies of scale, leading to various advantages (Jacobsen & Kiland, 2017). The researchers (Silva et al., 2018) note that the motivation to join the IMC is driven by factors such as cost reduction, the ability to achieve economies of scale, incentives from local government and EU funds, and the opportunity to share similar aims and solutions.

The research conducted by Giacomini et al. (2018) examined a small Italian IMC and its impact on enhancing the efficiency and effectiveness of public

services. The study found that the success of an IMC is heavily influenced by the specific type of IMC chosen and the promotion of the service delivery organisation model. The chosen form of IMC also presents difficulties, such as those encountered with local government organisations (Bel et al., 2022). The research of the IMC in the provision of fire services demonstrated that the selection of the organisational form for the IMC could influence citizen satisfaction (Holum & Jakobsen, 2016). A study in the Czech Republic has found that public officials with extensive experience in the public sector offer diminished support for IMC (Bakoš et al., 2021).

Lithuania has 60 municipalities, which may be regarded as relatively substantial with respect to population compared to other European countries. According to Bučaitė-Vilkė et al. (2018), 7% of urban municipalities have a population above 280,000 residents, while 75% of municipalities have a population below 29,000. The smallest municipality has a population of about 3,500.

The Law on the Local Self-Government of the Republic of Lithuania outlines the IMC concept. According to this law, municipalities in Lithuania have the authority to engage in collaborative activities or agreements with other municipalities. They also can outsource the responsibility of providing certain services to another municipality (Mikalauskas, 2019). In Lithuania, the IMC operate voluntarily, meaning that there is no official registry that collects data on the type of cooperation, duration, participants, and other relevant information on IMCs (Mikalauskas, 2019). Typically, cooperation occurs through project activities focused on tourism, environmental protection, social services, and education. However, a joint company is established rarely, e.g., in the waste management sector, specifically for the creation of ten regional waste management centres (Mikalauskas, 2019).

Researchers (Bučaitė-Vilkė et al., 2018) have noted that Lithuania may be described as a country with a limited IMC implementation. The obstacles hindering the development of the IMC in Lithuania include inadequate financial autonomy and restricted authority to provide services without limitations. There is a noticeable absence of the required circumstances and environment for the growth of IMC. However, it is anticipated that this situation will improve with the implementation of the new Regional Strategy for the years 2017–2030 (Mikalauskas, 2019). There is a lack of scientific information about the analysis of the maturity of IMC, the management style, and the division of responsibility and expenses or profits.

According to Golinska-Dawson et al. (2020), literature and research on waste management in the IMC are scarce. IMC offers several key advantages for waste management, including streamlined access to EU subsidies, decreased waste management expenses, and reduced infrastructure maintenance costs (Golinska-Dawson et al., 2020).

Researchers (Hiratsuka-Sasaki & Kojima, 2020) have formulated a thorough analysis of the IMC for solid waste management. Initially, IMCs might be formed with adjacent municipalities to facilitate collaboration for managing waste. Therefore, many municipalities might distribute the responsibilities of municipal waste treatment among IMC members. Furthermore, larger towns can receive waste from smaller municipalities for treatment. Municipalities may collaborate when a waste treatment facility is temporarily non-operational. In addition, the establishment of municipal waste plants with improved infrastructure, such as sewage treatment facilities, also fosters collaboration among towns. Finally, municipalities have the option to collaborate with private sector organisations to enhance their municipal waste management or explore the possibility of outsourcing.

The decision-making algorithm that determines how municipalities should issue green bonds in IMC for the development of zero-waste cities is based on a three-step procedure, as shown in Figure 2.8. The initial research stage involves analysing scientific literature on the IMC method and examining the factors that influence its implementation, such as triggers, drivers, and barriers. The initial phase of the research involves developing a valuation methodology to assess the potential for inter-municipal collaboration. In this context, the metrics for evaluating financial, environmental, and social performance are carefully chosen, and subsequently, the corresponding data is gathered from the appropriate sources. The second phase of the research is the process of choosing certain towns to be included in the study. This includes conducting interviews and collecting data from the interviewees, focusing specifically on zero-waste programs within the specified scope. In the third phase, the valuation technique is applied to assess the potential for inter-municipal cooperation among the selected municipalities identified in the second step. The last phase of the study involves creating a green bond issuing structure specifically tailored for municipalities aiming to establish a zero-waste city.

The assessment of the IMC possibilities is determined by evaluating the four categories of municipal performance that influence the choice to engage in IMC (Fig. 2.9). The financial performance area encompasses the municipality's fiscal standing and its capacity to bear additional expenses. The solvency domain offers valuable information about a municipality's capacity to repay its obligations. The social condition of the municipality offers valuable information on the possible difficulties encountered by the municipality, such as the number of residents requiring waste management services or the income of residents, which affects their capacity to afford the service. The environmental performance domain pertains to the waste management strategies used within the municipality.

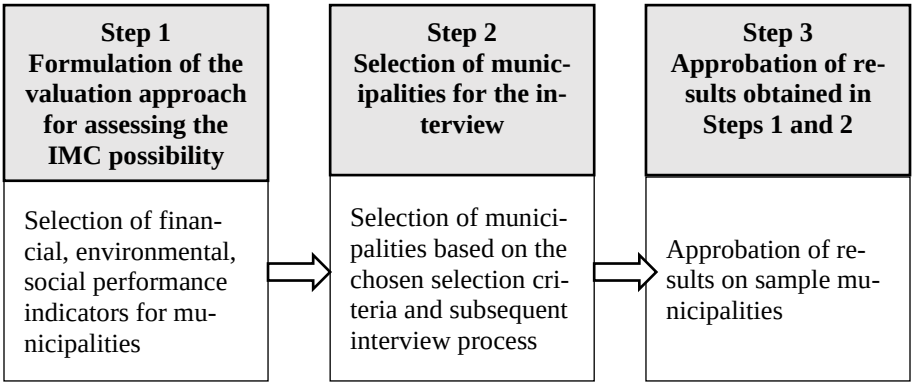

Fig. 2.8. Proposed research methodology for the modelling of the valuation approach of the inter-municipal cooperation possibility (compiled by the author)

The assessment of the IMC prospect is based on four dimensions of the valuation technique, which are derived from relevant literature and data sources. Evaluation of financial performance using Brown's 10-Point Test (Brown, 1993), Wang, Dennis, and Tu's Solvency Test (2007) for the measurement of solvency, Smiciklas et al. (2017) for the methodology of Key Performance Indicators for Smart Sustainable Cities, and the official statistics of Lithuania provided by the State Data Agency (2023) for social state information.

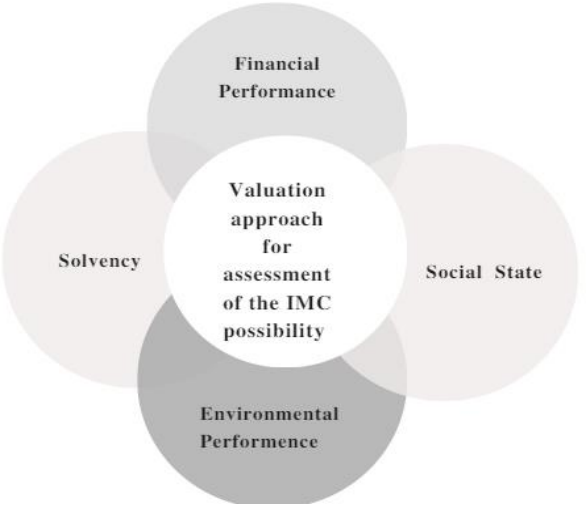

Fig. 2.9. Valuation approach for the assessment of the IMC possibility (compiled by the author)

The specific indications corresponding to each domain are reported in Table 2.1. Wang, Dennis, and Tu's Solvency Test excluded the Operating Ratio, Long-Term Liability per Capita, and Revenue per Capita ratios as they align with Brown's 10-Point Test. The Tax per Capita ratio was excluded from the Solvency Test group of Wang, Dennis, and Tu because municipalities are not liable to pay taxes.

The valuation approach for assessing the IMC possibility is based on the creation of the index for the evaluation of the risk-adjusted financial condition of municipalities willing to enter into the IMC. The Financial Condition Index for municipalities is proposed by Ritonga (2015):

$$\boldsymbol{Financial\ Condition\ Index} = \boldsymbol{w_1} * \boldsymbol{DI_1} + \boldsymbol{w_2} * \boldsymbol{DI_2} + \cdots + \boldsymbol{w_n} * \boldsymbol{DI_n}, \tag{2.16}$$

where *w* – weight of dimension index, *DI* – dimension index. According to the author, the indicator's values range from 0 to 1, with 1 representing the highest financial condition.

Ritonga (2015) states that the Financial Condition Index is determined by calculating the Indicator Index, which follows the Min-Max approach for normalisation as described by OECD (2008):

$$\boldsymbol{I_{qc}^t} = \frac{\boldsymbol{x_{qc}^t} - \boldsymbol{min_c}(\boldsymbol{x_q^t})}{\boldsymbol{max_c}(\boldsymbol{x_q^t}) - \boldsymbol{min_c}(\boldsymbol{x_q^t})}, \tag{2.17}$$

where x_{qc}^t – individual indicator, $min_c\left(x_q^t\right)$ – the minimum value of an indicator, $max_c\left(x_q^t\right)$ – the maximum value of an indicator, where the values of the I_{qc}^t vary from 0 to 1.

The chosen approach for determining the weights for the Financial Condition Index is the Equal Weighting Technique, as described by Ezell et al. (2021). The technique was chosen based on the responses provided by municipal responders. The Equal Weighting Technique may be succinctly expressed by the following formula:

$$\boldsymbol{w_i} = \frac{\boldsymbol{1}}{\boldsymbol{N}}, \tag{2.18}$$

where *N* – is a set of all attributes.

The Financial Condition Index includes the calculation of the Dimension Index, as described by Ritonga (2015):

$$\boldsymbol{Dimension\ Index} = \frac{\boldsymbol{I_{indicator-1}} + \boldsymbol{I_{indicator-2}} + \cdots + \boldsymbol{I_{indicator-n}}}{\boldsymbol{n}}. \tag{2.19}$$

N represents the total count of indicators that make up the Dimension Index. The Dimension Index is computed for each of the four categories of municipal performance in this study.

Table 2.1. Indicators of the valuation approach for the assessment of the IMC possibility (compiled by the author based on Brown (1993), Wang et al. (2007), Smiciklas et al. (2017), State Data Agency (2023))

Dimension	Indicator	Meaning
Financial position	$\frac{\text{Total revenues}}{\text{Population}}$ (2.20)	A low ratio signifies a greater ability to earn more revenue.
Financial position	$\frac{\text{Total general fund revenues from own resources}}{\text{total general fund revenues}}$ (2.21)	A high percentage signifies that the city operates autonomously from governmental agencies.
Financial position	$\frac{\text{General fund sources from other funds}}{\text{Total general fund sources}}$ (2.22)	A low ratio indicates that the city's administration may be funded without the need for operational adjustments.
Financial position	$\frac{\text{Operating expenditures}}{\text{Total expenditures}}$ (2.23)	A low ratio signifies effective infrastructure maintenance.
Financial position	$\frac{\text{Total revenue}}{\text{Total expenditures}}$ (2.24)	A high ratio signifies that the city produced a sufficient quantity of revenue to offset the costs related to the services delivered in that specific year.
Financial position	$\frac{\text{Unreserved general fund balance}}{\text{Total general fund revenues}}$ (2.25)	A high ratio signifies the presence of funds that may be employed to resolve a temporary shortfall in revenue.
Financial position	$\frac{\text{Total general fund cash and investments}}{\text{Total general fund liabilities}}$ (2.26)	A high ratio signifies the presence of funds that might be used to ease a temporary shortage in revenue.
Financial position	$\frac{\text{Total general fund liabilities}}{\text{Total general fund revenues}}$ (2.27)	A low ratio suggests that the short-term obligations may be easily fulfilled by the consistent stream of profits.

Continued Table 2.1

Dimension	Indicator	Meaning
Financial position	$\frac{\text{Direct long} - \text{term debt}}{\text{Population}}$ (2.28)	A low ratio signifies that the municipality possesses the capability to meet its responsibilities in repaying its total long-term debt.
Financial position	$\frac{\text{Debt service}}{\text{Total revenues}}$ (2.29)	A low ratio signifies that the municipality has sufficient financial resources to fulfil its responsibilities regarding the repayment of interest and principal for loans or other debts within the designated timeframe.
Solvency	$\frac{\text{Cash + Cash Equivalents + Investments}}{\text{Current Liabilities}}$ (2.30)	A higher number in these ratios indicates a larger amount of designated assets that may be used to meet immediate commitments, hence demonstrating fiscal health in terms of solvency.
Solvency	$\frac{\text{Cash + Cash Equivalents + Investments + Receivables)}}{\text{Current Liabilities}}$ (2.31)	
Solvency	$\frac{\text{Current Assets}}{\text{Current Liabilities}}$ (2.32)	
Solvency	$\frac{\text{Total Revenues}}{\text{Total Expenses}}$ (2.33)	A higher number for these ratios indicates an improved degree of financial stability.
Solvency	$\frac{\text{Total Surplus (Deficit)}}{\text{Population}}$ (2.34)	
Solvency	$\frac{\text{Restricted and Unrestricted Net Assets}}{\text{Total Assets}}$ (2.35)	A higher ratio indicates a more favourable position for fulfilling long-term financial obligations.
Solvency	$\frac{\text{Long} - \text{Term Liabilities}}{\text{Total Assets}}$ (2.36)	A higher numerical value indicates a higher level of long-term financial stability.
Solvency	$\frac{\text{Long} - \text{Term Liabilities}}{\text{Population}}$ (2.37)	
Solvency	$\frac{\text{Total Taxes}}{\text{Population}}$ (2.38)	An elevated tax burden per person indicates a heightened financial responsibility for inhabitants and a diminished level of financial stability with regard to the delivery of services.

End of Table 2.1

Dimension	Indicator	Meaning
Solvency	$\frac{\text{Total Revenue}}{\text{Population}}$ (2.39)	A higher per capita income indicates a larger financial responsibility for each individual, leading to less ability to provide services.
Solvency	$\frac{\text{Total Expenses}}{\text{Population}}$ (2.40)	A higher per capita spending indicates a government that spends more, leading to reduced solvency for the provision of services to support such expenditure levels.
Waste management	Municipal solid waste collected amount per capita (2.41)	Annual per capita collection of municipal solid waste
Waste management	Landfilled solid waste amount (2.42)	Annual per capita landfilling rate of municipal solid waste
Waste management	Burned waste amount (2.43)	Per capita annual incineration rate of municipal solid waste
Waste management	Recycled waste amount (2.44)	Annual per capita municipal solid waste recycling rate
Social state	Number of permanent residents (2.45)	Population count at the start of the year
Dimension	Indicator	Meaning
Social state	Demographic old-age dependency ratio (2.46)	The old-age dependency ratio is calculated as the ratio of the population aged 65 and over to the population under 15 per 100 individuals.
Social state	Monthly salary (2.47)	Average monthly salary

The proposed modification to Ritonga's (2015) technique entails incorporating the risk element associated with participating in IMC, as well as considering other dimensions of municipal performance, such as municipal and social aspects. The following formula is suggested for the computation of the Risk-Adjusted Municipal Condition Index (source: compiled by the author):

$$\boldsymbol{Risk - Adjusted\ Municipal\ Condition\ Index} = \boldsymbol{w_1 * DI_1 * R_1 + w_2 * DI_2 * R_2 + \cdots + w_n * DI_n . * R_n} \quad (2.48)$$

R represents the level of risk associated with an individual indication. The individual indicator risk is determined by a survey conducted among towns. The Risk-Adjusted Municipal Condition Index scores range from 0 to 1, with 1 being the highest level of success in assessing IMC.

2.5. Modelling the Strategic Decision-Making Algorithm for Inter-Municipal Cooperation for the Green Bond Issuance

The modelling of the strategic decision-making algorithm for IMC for the green bond issuance is depicted in Figure 2.10. The research methodology for the decision-making algorithm for IMC on green bond issuance is based on the four-step process. The model of the algorithm integrates the results obtained from the previous research stages and provides a unified result in the form of a strategic decision-making algorithm for municipalities willing to cooperate to issue green bonds.

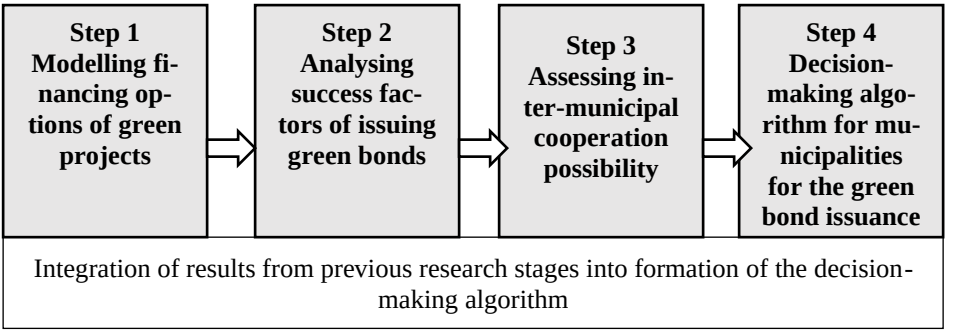

Fig. 2.10. Decision-making algorithm for IMC for the green bond issuance (compiled by the author)

The results of this last research stage are best presented visually, using a process flow with the subsequent explanation of each process step. The representation by the process flow is also supported by the summarised roles and responsibilities overview for a better explanation of the proposed solution.

2.6. Conclusions of the Second Chapter

The following conclusions have been made after the formulation of the Green Finance Model for the Development of Zero-Waste Cities:

1. The assessment framework of the green finance model for the development of zero-waste cities is based on the four-stage evaluation process. The first stage covers the assessment of alternatives for municipalities to finance green projects focussing on zero-waste. The next stage involves the analysis of success factors, benefits and challenges of issuing green bonds in Lithuania. The third stage focuses on the assessment of the possibility of inter-municipal cooperation. The last stage involves modelling the decision-making algorithm for municipalities for green bond issuance.
2. The first stage of the research covering the assessment of alternatives for municipalities of the financing of green projects with a focus on zero-waste includes modelling five possible financing scenarios for municipalities. The valuation approach considers the Green Progress measure of municipal performance attributable to waste management along with the incorporation of the Green WACC, which is also tailored to be a measure for environmentally sustainable projects.
3. The second stage of the research involves the analysis of success factors, benefits and challenges of issuing green bonds in Lithuania. Herein, the analysis is based on the opinion of experts working in the field of sustainability in relation to the possible advantages, key determinants of the successful issuance of green bonds and current impediments to issuing green bonds. The answers of the experts are analysed via the AHP method to distinguish the key results.
4. The third stage of the research corresponds to the modelling of the valuation approach of the inter-municipal cooperation possibility. The valuation approach is based on the four pillars of municipal performance: financial and solvency state, social conditions, and environmental performance. Experts from selected municipalities provide their feedback on the above-mentioned four pillars of municipal performance, which, in turn, serves as input for the validation of the valuation approach of the inter-municipal cooperation possibility.
5. The fourth stage of the research contributes to the modelling strategic decision-making algorithm for inter-municipal cooperation for green bond issuance. This stage incorporates the findings from previous stages of the research to formulate the decision steps for municipalities in the green bond issuance process.

3

Empirical Approbation of the Formulation of the Green Finance Model for the Sustainable Development of Zero-Waste Cities

This Chapter presents the approbation of the green finance model for the development of zero-waste cities using the case of Lithuania. The overview of the model is presented according to the conceptual model and its stages depicted in the Second Chapter. The model is applied to the case of Lithuania and its municipalities; however, it can be applied to any other country, county, or municipality.

The findings of the Third Chapter have been published in two scientific papers (Bužinskė & Stankevičienė, 2023b; Stankevičienė & Bužinskė, 2023).

3.1. Modelling Results of the Financing Options for Green Projects

Chapter 3.1 summarises the modelling results of the financing options for green projects. It is structured as follows: Section 3.1.1. presents the results of the Green Progress measure, Section 3.1.2. covers the Green Weighted Cost of Capital, Section 3.1.3. depicts the data collection process for the cost–benefit analysis,

Section 3.1.4. covers scenario analysis development, and Section 3.1.5. depicts scenario analysis results.

3.1.1. Results of the Green Progress Measure

Table 3.1 displays the GP measure values for ten Lithuanian counties throughout the 2017–2020 timeframe. The values are computed by utilising the formula presented in Chapter 2.

Table 3.1. Green Progress measure for ten counties of Lithuania, years 2017–2020 (source: compiled by the author)

County	GP, 2017	GP, 2018	GP, 2019	GP, 2020
Alytus	9%	8%	0%	5%
Kaunas	6%	7%	–5%	23%
Klaipėda	2%	–5%	–5%	3%
Marijampolė	–9%	88%	0%	3%
Panevėžys	3%	13%	–10%	9%
Šiauliai	8%	–11%	11%	8%
Tauragė	–20%	8%	9%	9%
Telšiai	17%	1%	–25%	23%
Utena	–6%	–41%	0%	–42%
Vilnius	3%	–18%	0%	11%

The negative value of the GP measure signifies enhanced waste management in the county, whilst the positive value shows compromised waste management performance. A 0 value suggests no improvement in the waste management initiatives of the municipality. The GP calculation results show that Utena County has developed the strongest efforts towards waste reduction.

3.1.2. Results of the Green Weighted Average Cost of Capital

The financial data required to calculate the Green WACC was obtained from the financial statements of all ten counties in Lithuania. Data on the assets (Table 3.2), debts (Table 3.3), and net income (Table 3.4) was gathered for the period spanning from 2017 to 2020.

The assets of municipalities (Table 3.2) have been consistently growing during the years of observation, except for Alytus and Utena municipalities, where they were declining. Utena municipality did not disclose information on its assets for 2019; consequently, the data for 2018 was used instead. The data was used to compute the valuation of municipalities' assets and liabilities.

Table 3.2. Assets (EUR) of ten counties for 2017–2020 (source: compiled by the author based on the financial reports)

Municipality/Year	2017	2018	2019	2020
Alytus	155,167,187	157,523,652	158,680,698	9,150,985
Kaunas	733,706,700	754,420,450	843,612,120	945,338,060
Klaipėda	515,129,380	543,687,960	47,1891,745	656,007,510
Marijampolė	192,643,900	195,591,030	200,317,640	211,922,930
Panevėžys	217,208,290	231,699,980	259,528,680	266,133,841
Šiauliai	283,841,600	311,160,700	363,633,680	413,591,220
Tauragė	120,876,240	131,567,460	149,796,600	169,409,840
Telšiai	128,486,930	135,631,660	143,433,100	160,135,900
Utena	79,507,301	80,547,551	80,547,551	80,083,299
Vilnius	1,567,374,540	1,631,273,920	1,727,009,200	1,892,821,670

Debts of the municipalities (Table 3.3) have been consistently growing during the years of monitoring, except for Klaipėda municipality, which had a decrease in 2020. Utena municipality did not disclose information on its indebtedness for 2019; consequently, the data from 2018 was used instead. The data was used to compute the valuation of municipalities' assets and liabilities.

Table 3.3. Debts (EUR) of the ten counties for 2017–2020 (source: compiled by the the author based on the financial reports)

Municipality/Year	2017	2018	2019	2020
Alytus	3531387	3397639	3870288	17770442
Kaunas	88522010	94746530	106145050	127225020
Klaipėda	20762290	22452250	25827160	3403002
Marijampolė	16374710	15508600	14177630	15800400
Panevėžys	13598850	11548310	13425890	12831899
Šiauliai	17447200	19156350	25362090	37875980
Tauragė	9171100	9070300	10760630	14624410
Telšiai	15232150	15532270	15102680	16571920
Utena	1193116	1832159	1832159	217641
Vilnius	309914280	275501970	285505910	338362710

The data on net revenue of all ten counties was gathered to determine the accounting beta coefficient. However, the calculations showed that only the

accounting beta coefficient of Vilnius municipality is significant and can be used in the computations. Hence, the net income of Vilnius municipality is presented in Table 3.3 for the period spanning from 2017 to 2020.

Table 3.4. Net income (EUR) of Vilnius municipality (source: compiled by the author based on financial report)

Municipality	2017	2018	2019	2020
Vilnius	122501200	76262580	75599360	21106940

The calculation of the accounting beta includes information on the market portfolio's return on equity. The market portfolio in this study consists of Lithuanian firms that are listed on the Baltic Main List of the Nasdaq Baltic Regulated Market. The firms' return on equity is reported by Nasdaq in the fact sheet (Table 3.5).

Table 3.5. ROE (%) of the market portfolio companies for 2017–2020 (source: compiled by the author based on Nasdaq Baltic Main List (Nasdaq OMX Group, 2022))

Company name	2017	2018	2019	2020
Apranga	24.74	13.12	16.03	8.09
AUGA group	6.54	–7.01	–3.57	1.95
Grigeo	17.35	23.01	18.96	16.09
Ignitis Grupė	7.2	–1.8	4.44	10.81
Invalda INVL	19.38	0.53	27.35	6.27
INVL Baltic Farmland	7.58	9.04	8.71	6.52
INVL Baltic Real Estate	11.02	9.16	26.27	14.86
INVL Technology	18.76	16.25	3.27	15.21
Klaipėdos Nafta	8.66	5.85	3.92	16.69
Linas	5.14	6.35	1.31	6.04
Linas Agro Group	5.29	–2.89	5.03	7.59
Novaturas	53.45	37.3	24.41	–33.91
Panevėžio statybos trestas	3.01	–10.19	1.17	–31.34
Pieno žvaigzdės	–6.22	8.78	14.94	24.75
Rokiškio sūris	6.37	1.45	3.14	2.94
Šiaulių bankas	16.5	21.72	17.6	12.93
Telia Lietuva	18.02	17.52	16.89	16.94

End of Table 3.5

Company name	2017, %	2018, %	2019, %	2020, %
Utenos trikotažas	3.92	12.29	6.8	–4.33
Vilkyskiu pieninė	21.17	–3.61	–1.43	11.73
Vilniaus baldai	34.35	14.84	22.9	0.69
Žemaitijos pienas	7.29	13.69	13.15	10.9

The risk-free rate of Lithuania is derived from the "BEREC Report on WACC parameter calculations pursuant to the WACC Notice of the European Commission of 7 November 2019" (Body of European Regulators for Electronic Communications, 2020) and is precisely 0.59%. The rate of return on the stock market is determined by calculating the average annual return of Lithuanian firms' stocks from 2011 to 2020, as reported by INVL Asset Management in 2021, is 7.1%. The tax rate utilised in the analysis is 0%.

Tables 3.6–3.8 display the computed values for beta, risk-free rate, and rate of return on the stock market. The Vilnius municipality's return on equity calculation findings are shown in Table 3.6. During the observed period, the return on equity of the municipality is declining, suggesting a decrease in its ability to create income from the available equity.

Table 3.6. ROE of the Vilnius municipality (source: compiled by the author)

Municipality	ROE (%), 2017	ROE (%), 2018	ROE (%), 2019	ROE (%), 2020
Vilnius	9.74	5.63	5.24	1.36

The market portfolio's return on equity (Table 3.7) is derived from the return on equity of the Lithuanian businesses listed on the Nasdaq Baltic Main List. Here, the mean value of the equity return is computed for the observed year. The results indicate that the return on equity of the market portfolio varies during the years of observation, suggesting that the firms in the portfolio encounter difficulties in generating revenue from equity.

Table 3.7. ROE of the market (source: compiled by the author)

Market portfolio	ROE (%), 2017	ROE (%), 2018	ROE (%), 2019	ROE (%), 2020
	13.79	8.83	11.01	5.78

Table 3.8 shows the results of the beta calculation for Vilnius municipality. In 2017, the beta reached 0.98, which is nearly precisely the same as the market's volatility. During 2018 and 2020, the beta coefficient exhibited lower volatility

compared to the market. The beta coefficient of Vilnius municipality is used as a proxy for the betas of other municipalities in the research due to the accessibility of financial data.

Table 3.8. Results of the beta calculation of Vilnius municipality (source: compiled by the author)

Municipality	β (ROE), 2017	β (ROE), 2018	β (ROE), 2019	β (ROE), 2020
Vilnius	0.98	0.42	0.33	0.53

The results of the WACC calculation of ten counties of Lithuania for 2017–2019 are shown in Table 3.9. The results imply that in 2017, fund lenders required a return exceeding 6%. In 2018, the rate of return decreased by half, and in 2019, the rate decreased by almost 1%. The results imply that raising funds for municipalities becomes more affordable. The results of WACC increased in 2020, and subsequently, so did the results of Green WACC. One of the reasons might be the global pandemic situation, which also affected the municipalities. On an individual municipality level, the highest WACC can be observed in Utena municipality, which means that this municipality experiences the highest return expected by lenders. On the other hand, the lowest return lenders expected to receive for providing funds is in Vilnius municipality.

Table 3.9. WACC and the Green WACC for 2017–2020 (source: compiled by the author)

Municipality	WACC. 2017	Green WACC. 2017	WACC. 2018	Green WACC. 2018	WACC. 2019	Green WACC. 2019	WACC. 2020	Green WACC. 2020
Alytus	6.89%	6.90%	3.88%	3.88%	2.72%	2.72%	3.84%	3.85%
Kaunas	6.56%	6.58%	3.79%	3.82%	2.50%	2.50%	3.73%	3.78%
Klaipėda	6.77%	6.77%	3.86%	3.85%	2.69%	2.69%	4.03%	4.03%
Marijampolė	6.53%	6.52%	3.74%	3.86%	2.69%	2.69%	3.89%	3.89%
Panevėžys	6.66%	6.66%	3.81%	3.82%	2.68%	2.68%	3.92%	3.93%
Šiauliai	6.62%	6.63%	3.73%	3.73%	2.72%	2.72%	3.90%	3.92%
Tauragė	6.57%	6.55%	3.75%	3.76%	2.66%	2.66%	3.85%	3.98%
Telšiai	6.82%	6.83%	3.85%	3.86%	2.68%	2.68%	3.85%	3.90%
Utena	6.92%	6.92%	3.89%	3.86%	2.74%	2.74%	4.04%	4.04%
Vilnius	6.49%	6.51%	3.77%	3.68%	2.63%	2.63%	3.84%	3.90%

The Green WACC results demonstrate the impact of waste management initiatives implemented by municipalities on their financial performance. The findings suggest that towns with enhanced waste management policies might take advantage of the reduced interest rate. In contrast, towns that fail to enhance their waste management effectiveness are associated with a higher rate of return demanded by lenders. The findings suggest that the environmentally beneficial performance of a municipality leads to increased affordability in lending capabilities.

It is important to acknowledge that in certain instances, the GP impact on WACC is either inconsequential or has no bearing on the Green WACC. In 2018, Alytus municipality's WACC was 3.88%, while the GP was 8%. Based on this, the Green WACC is expected to drop. However, the use of Formula 4 in the WACC calculation results in an unchanged WACC value. Utena municipality demonstrated a significant improvement in waste management practices in 2017, as evidenced by a negative 6% GP rate. Nevertheless, the Green WACC was unaffected by this number and stayed constant at 6.92%.

The results of the computation of the Green WACC are applied in the subsequent cost–benefit analysis process.

3.1.3. Data Collection for Cost–Benefit Analysis

Waste Management Centres are the subject of the study. These organisations are responsible for waste management in the ten counties of Lithuania. The study employs data from the financial statements of all these waste management enterprises for 2016–2020. The figures refer to the original capital, continuing expenditures, replacement expenses, residual value, and revenues necessary for funding waste management activities. Also, supplementary costs, such as loan repayment and taxes, were incorporated.

Table 3.10. The residual value of equipment and machinery of the ten waste management centres (source: compiled by the author based on the financial reports of companies)

Vilnius	Kaunas	Klaipėda	Šiauliai	Panevėžys	Marijampolė	Alytus	Telšiai	Utena	Tauragė
1594695	575984	330305	380767	211134	65802	450351	199375	275427	125158

The financial outcomes of the waste management facilities presented in Tables 3.10 and 3.11 were forecasted for 30 years. The operational expenses, revenues, loan repayment, and taxes were anticipated utilising the exponential smoothing approach, which has yielded statistically significant results in forecasting. The financial and social discount rates are two key concepts in the field of economics.

Financial data have been adjusted through fiscal adjustments in response to market developments. The shadow wage was utilised in the calculation of the initial investment, employing a conversion factor of 0.8. This conversion factor aligns with the European Commission's urban labour dualism cluster of the regional labour market, as stated in their report from 2014.

Table 3.11. Financial results of the ten waste management centres (source: compiled by the author based on the financial reports of companies)

County	Expenditure type, €	2016	2017	2018	2019	2020
Vilnius	Initial investment	627567	215800	2296450	4642043	4322935
	Replacement costs	793313	17016035	14317657	18776451	19865363
	Operating costs	9005059	13387308	12487080	13024187	12838571
	Revenues	11845908	18022297	15994855	16552765	15783794
	Loan repayment	295550	171338	156062	88285	80181
	Taxes	238404	596432	650486	675513	525142
Kaunas	Initial investment	7505426	583756	583756	513470	513470
	Replacement costs	0	0	0	2269039	2640185
	Operating costs	12255862	12712557	14065071	14087146	17025142
	Revenues	6333834	6888454	9281856	9247286	10226825
	Loan repayment	0	0	0	0	0
	Taxes	0	0	0	0	0
Klaipėda	Initial investment	5190735	766598	217088	217088	506708
	Replacement costs	3779342	3756222	3286646	3105106	2884031
	Operating costs	8935454	9197916	8334415	8539668	8753549
	Revenues	8911916	9484364	8585422	8826993	9055678
	Loan repayment	55263	44913	43412	47918	68362
	Taxes	8523	137171	147605	151071	135633

Continued Table 3.11

County	Expenditure type, €	2016	2017	2018	2019	2020
Šiauliai	Initial investment	3600197	525596	719396	3476	3476
	Replacement costs	0	0	742366	213183	190171
	Operating costs	6837466	7733175	7649775	8373008	10936747
	Revenues	4695235	6024165	6408344	6742405	8888043
	Loan repayment	0	0	0	0	0
	Taxes	0	0	0	0	0
Panevėžys	Initial investment	402186	194530	49720	49720	8208
	Replacement costs	1400346	1565208	1984661	2512163	2776210
	Operating costs	2075298	2753400	4069335	4549225	5140040
	Revenues	1619194	3235938	470447	5741105	5607923
	Loan repayment	15280	13350	19456	32225	27904
	Taxes	70084	73595	94303	27448	64059
Marijampolė	Initial investment	2470639	87548	87548	87548	87548
	Replacement costs	0	0	0	995000	1195000
	Operating costs	3714902	4926326	4679634	4801024	5021219
	Revenues	4264527	6488027	5758148	4901935	5074088
	Loan repayment	209841	121650	110804	66538	54063
	Taxes	3576	8946	9757	6449	11976
Alytus	Initial investment	7789527	2234484	2240276	2240276	2240276
	Replacement costs	1538943	1646566	2187635	2252354	2543983
	Operating costs	4056087	4170793	4960288	5074228	5856314
	Revenues	4247569	4305515	5114301	5229069	6034498
	Loan repayment	126123	118359	158469	90225	91738
	Taxes	33920	13185	0	0	0
Telšiai	Initial investment	1960686	8110	8110	6176	6176
	Replacement costs	150586	345941	484700	908441	1052651
	Operating costs	3140111	3010181	2663247	3240964	3041692
	Revenues	2832609	3204212	2871819	2980833	3055228
	Loan repayment	20795	10677	2388	1416	0
	Taxes	4610	45970	5215	52407	48621
Utena	Initial investment	2914156	434175	243015	243015	109739
	Replacement costs	870632	1036178	1127689	1258742	1325805
	Operating costs	1344626	1630351	1633193	1827594	2127214

End of Table 3.11

County	Expenditure type, €	2016	2017	2018	2019	2020
	Revenues	1132600	1723561	1906704	2011129	2021184
	Loan repayment	108031	93562	76233	59790	54862
	Taxes	0	0	0	0	0
Tauragė	Initial investment	1432432	443993	443993	333078	43444
	Replacement costs	1191640	1203437	1135081	407256	498104
	Operating costs	1941714	2134521	2020497	2086277	2273155
	Revenues	2003726	2346207	2219223	2133828	2567296
	Loan repayment	12205	29864	17442	11496	6824
	Taxes	45776	21722	14728	12465	18438

The assumptions used in the study were formulated to predict the future condition of the firm, fill in any information gaps, or offer indicative sources of information that were utilised to create the financing scenarios. The following assumptions were made for additional financial projections:

1. From 2016 to 2020, waste management centres implemented three significant waste management initiatives: promoting waste prevention, increasing the separate collection, recycling, and recovery of municipal waste to encourage efficient use of natural and other resources, and managing municipal waste in a manner that is environmentally sustainable and compliant with public health standards. The initiatives facilitated the establishment of essential systems, procedures, and infrastructure for the effective management of municipal waste. The financial data of these projects is utilised as input for the first investment forecasts in this study. The exponential smoothing method has not yielded reliable results. As a result, the following assumptions were made: future projections of the initial investment will be based on 20% of the average value of established waste management projects. It is also assumed that every ten years, the forecasted initial investment will decrease by 5%. This assumption is based on the waste management initiatives that were implemented between 2016 and 2020, which established a solid foundation for the waste management systems.
2. The increasing amount of waste in Lithuania, as documented by Stankevičienė and Bužinskė (2021), together with the growing population, rising costs for products and services, and the deterioration of machinery, may impact future investment requirements. It is assumed that

an additional 30% of the initial investment amount every year will be required for replacement expenditures, as the exponential smoothing method has not yielded reliable results.

3. Operating expenses and revenues are projected using exponential smoothing, a method known for its solid results.

The analysis encompasses three categories of economic benefits: (1) saved expenses on raw materials such as glass, plastics, paper, and paperboard; (2) generated money from the increasing number of residents utilising waste management services; and (3) prevented expenditures associated with unemployment by employing more individuals in waste management centres. The glass, plastics, and paper and paperboard goods recycled from the bulky waste collection locations yield significant economic advantages. Approximately half of the glass and plastics and around 70% of the paper and paper products collected at the bulky waste collection site are deemed suitable for use in the manufacturing process. Eurostat (Eurostat, 2021) measures the average price indicators per tonne of secondary market materials. The obtained data is depicted in Tables 3.12 and 3.13.

Table 3.12. Selected secondary material amounts and corresponding prices (source: compiled by the author based on Eurostat (2021))

Material	% of waste type collected at the bulky waste site that can be used as a secondary material	Price (€/tonne, years 2012–2020, EU27)
Glass	50%	55.1
Plastics	50%	244.7
Paper and paperboard	70%	104.4

Table 3.13. Collected glass, plastics and paperboard in a bulky waste collection cited by the waste management centres operating in the ten counties of Lithuania (source: compiled by the author)

County	Material, tonnes	2016	2017	2018	2019	2020
Vilnius	Glass	150767	223531	195174	302431	410139
	Plastics	51220	33857	21349	93417	158451
	Paper and paperboard	47392	66516	67357	115150	167253
Kaunas	Glass	9117	10453	10805	9481	7064
	Plastics	37772	46871	35245	47943	53784
	Paper and paperboard	18424	17265	21096	20916	14605

End of Table 3.13

County	Material, tonnes	2016	2017	2018	2019	2020
Klaipėda	Glass	7939	9503	9051	8867	9449
	Plastics	18491	31656	27168	24159	23861
	Paper and paperboard	13532	20050	16501	16401	16007
Šiauliai	Glass	4662	6085	3837	4247	4555
	Plastics	24558	32223	24418	25111	22990
	Paper and paperboard	10255	9828	8104	9207	10591
Panevėžys	Glass	5077	8754	4909	4205	3271
	Plastics	5906	5855	5593	4556	4918
	Paper and paperboard	5077	8754	4909	4205	3271
Marijampolė	Glass	838	113	309	2306	366
	Plastics	5244	4969	5411	3172	5510
	Paper and paperboard	4050	2464	2657	2928	2034
Alytus	Glass	2802	3146	3239	2988	2079
	Plastics	5921	4587	3579	5210	6664
	Paper and paperboard	4756	4027	3991	5446	5387
Telšiai	Glass	2171	2841	1012	585	786
	Plastics	9540	3921	4315	3825	4262
	Paper and paperboard	5920	5443	10170	10624	5871
Utena	Glass	2885	2667	2331	2329	2656
	Plastics	6908	4420	4582	7358	5073
	Paper and paperboard	4070	3313	3114	2793	3464
Tauragė	Glass	3329	3367	3603	3452	2914
	Plastics	4126	3828	4071	3753	2793
	Paper and paperboard	2093	1361	1512	1995	1321

The research incorporates the economic impact of including service availability for residents of the counties (Table 3.14). The data about the utilisation of waste management services by residents in each county is obtained from the Environmental Protection Agency (Environmental Protection Agency of the Republic of Lithuania, 2020). The findings are presented in Table 4. The obtained data has been projected over 30 years using exponential smoothing. The number of new residents using the service is determined by comparing the number of residents accessing the service in year t with the number in year t-1. If the prediction indicates a reduction in the number of residents utilising the waste management service, the service availability is not considered for that county due to the absence of economic advantages. The counties where this economic advantage is not

calculated based on the number of residents getting the service would decline include Klaipėda, Šiauliai, Marijampolė, Alytus, Telšiai, Utena, and Tauragė.

Table 3.14. Service availability (source: compiled by the author based on the Environmental Protection Agency of the Republic of Lithuania, 2020)

County	2016	2017	2018	2019	2020
Vilnius	796090	785961	974700	821199	865975
Kaunas	559946	560143	561309	564503	568608
Klaipėda	350222	351823	353133	346801	349607
Šiauliai	295440	293509	286781	289030	289306
Panevėžys	219905	224929	190013	215284	212158
Marijampolė	166093	162528	145876	141581	141354
Alytus	189392	187550	180400	178239	179053
Telšiai	147507	143885	142431	140352	132343
Utena	145557	141634	235631	231207	119145
Tauragė	110732	108113	106184	104501	102493

The research incorporates the economic advantage of avoiding unemployment expenses in each of the counties. The data on employee groupings, including administration, qualified workers, unqualified workers, etc., was gathered from the financial records and other documents of the waste management centres. The data on salaries was collected for the respective employee groupings. Exponential smoothing was utilised to forecast the number of workers in each employee category over a 30-year timeframe. When the projection indicates a decline in the number of employees, the saved unemployment costs are not calculated for that county, as there are no economic gains. The prediction enables the estimation of the number of new employees to be employed by the organisation, suggesting that the firm will provide salaries that are comparable to the average salaries for 2016–2020. The average salary is utilised to determine the unemployment benefits that the state will provide to those who are jobless and have an income that aligns with this average. Next, the estimated number of new workers is multiplied by the average unemployment benefits, representing the expenses that would be saved by avoiding unemployment. This assumes that the predicted additional employees will be employed in the waste management centres. The accompanying initiatives and presumptions were established for the ten counties of Lithuania:

1. Vilnius county: the prognosis indicated that an annual increase of 1–2 competent workers is expected, whereas the projection suggests the addition of two new workers from this category per year. The average pay of a skilled worker is EUR 794, whereas that of an unskilled worker is

EUR 614. The average unemployment compensation for an eligible employee is EUR 395.77, whereas for a worker, it is EUR 339.91.

2. Kaunas county: the prediction for the number of skilled workers indicated a need to hire one additional qualified worker per year. Similarly, the prognosis for unskilled workers indicated a need to hire seven new workers from this category annually. The average income of a skilled worker is EUR 1048.64, while that of an unskilled worker is EUR 856.63. The average unemployment compensation for a skilled worker is EUR 495.26, whereas for an unskilled worker, it is EUR 435.68.
3. Klaipėda county: according to the specialist projection, it is expected that 1–2 new specialists would need to be hired each year. The average remuneration of a specialist amounts to EUR 1723.74. The average unemployment benefit for a specialist is EUR 702.41.
4. County of Šiauliai: the waste management centre provides little data on the number of employees and their wages; hence, the economic benefit cannot be assessed.
5. Panevėžys county: the waste management centre provides little data on the number of employees and their wages; hence, the economic benefit cannot be assessed.
6. The county of Marijampolė: the projection of the workforce indicated that an additional worker should be hired annually. The average wage of an employee is EUR 1041. The average unemployment compensation received by an individual worker amounts to EUR 492.89.
7. Alytus county: the expert workforce estimate indicates a need to hire three new qualified workers per year. Additionally, the projection for qualified workers suggests the requirement to engage one new worker from this category each year. The average pay of a specialist is EUR 1474.54, while that of a competent worker is EUR 1163. The average unemployment benefit for a specialist is EUR 627.41, whereas for a trained worker, it is EUR 530.75.
8. Telšiai county: the waste management centre provides finite statistics on the number of employees and their salaries; therefore, the economic benefit is not calculated.
9. Utena county: according to the prediction, it is recommended to hire 1–2 more skilled staff per year. The average wage of a skilled workforce is EUR 807. The average unemployment payment for eligible employees amounts to EUR 420.28.
10. Tauragė county: the waste management facility provides little data on personnel count and compensation; thus, the economic benefit cannot be assessed.

3.1.4. Scenarios development

A set of five scenarios was established to determine the most advantageous funding strategy for projects that promote environmental sustainability.

1. Scenario 1 depicts the company's provision of finance for large-scale projects. This scenario illustrates the typical situation that occurs when no financial assistance is given to the advancement of environmentally friendly projects.
2. Scenario 2 involves the provision of project funding through loans. It is presumed that 10% of the original investment is funded by a loan. This scenario facilitates the assessment of the feasibility of green financing.
3. Scenario 3 depicts the circumstance when the project's funding is obtained from EU grants or via subsidies from municipalities. This scenario exemplifies the typical method of financing green initiatives when more funding is required for project development. In this particular situation, it was presumed that the magnitude of EU funding was 70%.
4. Scenario 4 depicts a scenario where the necessary finances for project development are acquired by issuing green bonds. In this situation, the local government releases a green bond with predetermined attributes. After a number of years, the municipality conducts a tap issue, which involves issuing a new bond with identical features. Over 30 years, the municipality has conducted a total of three fresh issuances and three tap issuances.
5. Scenario 5 illustrates a mixed financing strategy in which 40% of the required investment is funded by the enterprise, 20% is funded by the municipality, and 40% is funded through the issuing of green bonds. This scenario depicts a circumstance where the corporation has limited external options for project funding and must develop a finance mix for future projects.

As a funding alternative, it is expected that the municipality would issue green bonds. In theory, the municipality should bear the costs of issuing, obtaining a second opinion, and repaying the face value. Nevertheless, to determine the most appropriate financing strategy, these expenses were also incorporated into the research. The expenses associated with issuing and obtaining a second opinion for the green bonds are factored into the scenario analysis, which considers the use of green bonds as a means of financing. The research assumes that the municipality will issue green bonds. As a result, the expenses associated with issuing municipal bonds and the estimated costs of obtaining a second opinion are considered in view of the availability of information. The costs associated with issuing municipal bonds are subject to variation owing to many circumstances. As a result, an estimate of the likely issuance costs is determined based on the study completed by Joffe (2015). According to Joffe (2015), municipal bonds issued in amounts over USD 10 million typically represent an average of 1.23% of their face value.

The analysis regards the face value as EUR 1000. External reviewers may assess green bonds differently for many reasons. However, the authors (Kaminker et al., 2018) suggest a range of USD 10,000–100,000 for the evaluation. With an initial sum of USD 10,000 and an exchange rate of EUR 1, the equivalent value is USD 1,1052 (European Central Bank, 2022).

Table 3.15. Assumptions on the green bonds (source: compiled by the author)

County	Population %	1st issue, € million	1st tap issue, € million	2nd issue, € million	2nd tap issue, € million	3rd issue, € million	3rd tap issue, € million
Vilnius	100	20	20	20	20	40	40
Kaunas	69	13.8	13.8	13.8	13.8	27.6	27.6
Klaipėda	39	7.8	7.8	7.8	7.8	15.6	15.6
Šiauliai	32	6.4	6.4	6.4	6.4	12.8	12.8
Panevėžys	26	5.2	5.2	5.2	5.2	10.4	10.4
Marijampolė	17	3.4	3.4	3.4	3.4	6.8	6.8
Alytus	16	3.2	3.2	3.2	3.2	6.4	6.4
Telšiai	16	3.2	3.2	3.2	3.2	6.4	6.4
Utena	15	3.0	3.0	3.0	3.0	6.0	6.0
Tauragė	11	2.2	2.2	2.2	2.2	4.4	4.4

The research assumes that the green bonds will be issued through both new offerings and tap issues. As part of the research, three new offerings of green bonds and three tap issues are examined for each county, as shown in Table 3.15. The magnitude of the new and tap issues is contingent upon the county's population. Vilnius County is the biggest in Lithuania and has the highest number of green bond issues. The magnitude of green bond issuances in other counties fluctuates in proportion to their population size relative to Vilnius County.

3.1.5. Scenario Analysis Results

The outcomes of the scenario analysis for the Waste Management Centre operating in the ten counties of Lithuania are displayed in Tables 3.16 to 3.25. The summarised findings present a comparison of financing choices and recommend the most advantageous solution for funding green initiatives.

Table 3.16. Summary of scenario analysis results for the Vilnius County Waste Management Centre (source: compiled by the author)

County	Financing scenarios	FNPV, (€)	FIRR (%)	ENPV, (€)	EIRR (%)	B/C ratio
Vilnius	S1. Company's funds	–273 149 980	27.90	376 219 522	15.36	1.46
	S2. Loan	–208 879 439	21.91	410 909 568	16.48	1.52
	S3. EU funds	–62 810 031	10.11	583 834 002	22.74	1.95
	S4. Green bonds	–100 607 689	7.31	547 967 493	–	1.84
	S5. Mixed financing	–103 746 092	13.48	543 851 697	21.15	1.83

The financial net present value (FNPV) analysis of all financing alternatives for Vilnius County Waste Management Centre (Table 3.16) indicates that all of them require extra funding. The most favourable outcome is noticed in the EU funds financing option, where 70% of investment requirements are obtained without any obligation to repay the funds. The utilisation of green bonds as a financing option has demonstrated the next possible alternative after EU funds, even though this kind of financing incurs supplementary expenses, such as issuance, second opinion, and repayment of the principal amount at maturity. The economic net present value (ENPV) computations are positive for all scenarios of Vilnius county (Table 3.16), suggesting that significant economic gains are assessed in monetary terms and projects can be approved. Therefore, all projects may be approved. The scenario using EU funds exhibits the greatest EIRR, indicating that this financing option is the most favourable in terms of EIRR, along with the green bonds option. The B/C ratio guideline stipulates that an investment choice is deemed lucrative when the ratio exceeds 1. In all cases, the B/C ratio is greater than 1, suggesting that all proposals may be accepted. The greatest B/C ratio can be observed in EU funds and green bond options, with EUR 1 of expenses corresponding to EUR 1.84–1.95 of benefits.

The FNPV analysis of all financing alternatives for the Kaunas County Waste Management Centre (Table 3.17) indicates that additional finance is required for all of them. The financing option of EU funds has the least negative consequence while financing using green bonds also demonstrates favourable outcomes. ENPV computations provide negative results across all scenarios, suggesting that the projects' costs outweigh the economic benefits. However, the green bonds option has the least negative impact, indicating a favourable outcome for this option. The B/C ratio for the green bonds, EU funds, and mixed financing options suggests that for every EUR 1 in expenses, there are EUR 0.26–0.28 in benefits. FIRR and

EIRR cannot be computed due to the presence of negative cash flows in the anticipated years, except for FIRR in the green bonds scenario, where it reaches 25.66.

Table 3.17. Summary of scenario analysis results for the Kaunas County Waste Management Centre (source: compiled by the author)

County	Financing scenarios	FNPV, (€)	FIRR (%)	ENPV, (€)	EIRR (%)	B/C ratio
Kaunas	S1. Company's funds	–638 299 587	–	–807 186 945	–	0.22
	S2. Loan	–614 432 623	–	–783 529 118	–	0.23
	S3. EU funds	–8 960 526	–	–641 582 152	–	0.26
	S4. Green bonds	–419 712 042	26.00	–589 636 712	–	0.28
	S5. Mixed financing	–471 267 903	–	–647 140 610	–	0.26

Table 3.18. Summary of scenario analysis results for the Klaipėda County Waste Management Centre (source: compiled by the author)

County	Financing scenarios	FNPV, (€)	FIRR (%)	ENPV, (€)	EIRR (%)	B/C ratio
Klaipėda	S1. Company's funds	–358 400 604	–	–380 643 024	–	0.16
	S2. Loan	–342 296 036	–	–364 538 455	–	0.17
	S3. EU funds	–243 697 095	–	–265 939 513	–	0.22
	S4. Green bonds	–81 854 843	0.08	–378 704 174	–	0.16
	S5. Mixed financing	–243 732 983	–	–265 975 403	–	0.22

The FNPV analysis of all financing alternatives for the Klaipėda County Waste Management Centre (Table 3.18) indicates that each of them needs more funding. The option of green bond financing yields the least negative result. The ENPV estimate provides negative results across all scenarios, suggesting that the projects do not generate sufficient economic benefits to offset their expenditures. Nevertheless, the alternative, including EU funds, has the least adverse impact, followed by mixed financing. The options of EU funds and mixed financing have the greatest B/C ratio, which suggests that for every EUR 1 of expenses, there are EUR 0.22 of corresponding benefits. FIRR and EIRR cannot be computed due to

the presence of negative cash flows in the anticipated years, except for FIRR in the green bonds scenario, where it reaches 0.08%.

Table 3.19. Summary of scenario analysis results for the Šiauliai County Waste Management Centre (source: compiled by the author)

County	Financing scenarios	FNPV, (€)	FIRR (%)	ENPV, (€)	EIRR (%)	B/C ratio
Šiauliai	S1. Company's funds	–359 728 373	–	–633 852 192	–	0.04
	S2. Loan	–348 140 610	–	–622 304 897	–	0.04
	S3. EU funds	–278 614 024	–	–576 115 720	–	0.05
	S4. Green bonds	–34 841 607	0.06	–531 100 689	–	0.05
	S5. Mixed financing	–278 650 415	–	–576 152 033	–	0.05

The FNPV analysis of all financing alternatives for the Šiauliai County Waste Management Centre (Table 3.19) indicates that all choices require extra funding. The option of green bond financing provides the least negative outcome. The ENPV computations provide negative results across all scenarios, demonstrating insufficient economic benefits to offset the project expenditures. However, the alternative with green bonds is the least detrimental, indicating the favourable outcome of this choice. The B/C ratio reaches 0.05 for mixed financing, green bonds, and EU funds scenarios, suggesting that for every EUR 1 of expenses, there are EUR 0.05 of corresponding benefits. The absence of FIRR and EIRR calculations is due to the negative cash flows expected in the upcoming years, except for FIRR in the green bonds scenario, where it reaches 0.06.

The FNPV analysis of all financing alternatives for the Panevėžys County Waste Management Centre (Table 3.20) indicates that none of them require further funding since the company's income surpasses its expenses. The green bonds financing option has the most favourable result, followed by EU funds and mixed financing alternatives. The ENPV computations provide negative results across all scenarios, showing that the projects do not generate sufficient economic benefits to offset their expenditures. However, the alternative with green bonds has the least negative impact, indicating a favourable outcome for this option. EU funds, green bonds, and company funds alternatives have a B/C ratio of 0.03, meaning that for every EUR 1 of expenses, there are EUR 0.03 in benefits. FIRR and EIRR cannot be computed due to the presence of negative cash flows in the anticipated years.

Table 3.20. Summary of scenario analysis results for the Panevėžys County Waste Management Centre (source: compiled by the author)

County	Financing scenarios	FNPV, (€)	FIRR (%)	ENPV, (€)	EIRR (%)	B/C ratio
Panevėžys	S1. Company's funds	90 550 841	–	–313 299 252	–	0.03
	S2. Loan	92 227 115	–	–311 625 905	–	0.02
	S3. EU funds	102 284 767	–	–301 585 821	–	0.03
	S4. Green bonds	508 281 478	–	–299 945 509	–	0.03
	S5. Mixed financing	102 248 455	–	–586 249 871	–	0.01

Table 3.21. Summary of scenario analysis results for the Marijampolė County Waste Management Centre (source: compiled by the author)

County	Financing scenarios	FNPV, (€)	FIRR (%)	ENPV, (€)	EIRR (%)	B/C ratio
Marijampolė	S1. Company's funds	–220 809 168	–	–286 939 496	–	0.02
	S2. Loan	–214 060 723	–	–280 191 054	–	0.02
	S3. EU funds	–173 570 070	–	–239 716 852	–	0.03
	S4. Green bonds	150 547 547	–	–233 001 586	–	0.03
	S5. Mixed financing	–173 606 501	–	–244 981 714	–	0.01

The FNPV analysis of all financing alternatives for the Marijampolė County Waste Management Centre (Table 3.21) indicates that scenarios, except for green bonds, require more funding. The green bond option has the most favourable result. The ENPV computations provide negative results across all scenarios, demonstrating insufficient economic benefits to offset the project expenditures. However, the alternative with green bonds has the least negative impact, indicating a favourable outcome for this option. The B/C ratio varies from 0.1 to 0.03, indicating that for every EUR 1 of expenses, there are EUR 0.01–0.03 in benefits. FIRR and EIRR cannot be computed due to the presence of negative cash flows in the anticipated years.

The FNPV analysis of all financing alternatives for the Alytus County Waste Management Centre (Table 3.22) indicates that further finance is required for all of them. The option of EU funds provides the least negative outcome. The ENPV

computations provide negative results across all scenarios, demonstrating insufficient economic benefits to offset the project expenditures. However, options using EU funds and mixed financing have the least negative impact, indicating a favourable outcome for these options. The B/C ratio varies from 0.03 to 0.05, indicating that for every EUR 1 of expenses, there are EUR 0.03–0.05 in benefits. FIRR and EIRR cannot be computed due to the presence of negative cash flows in the anticipated years.

Table 3.22. Summary of scenario analysis results for the Alytus County Waste Management Centre (source: compiled by the author)

County	Financing scenarios	FNPV, (€)	FIRR (%)	ENPV, (€)	EIRR (%)	B/C ratio
Alytus	S1. Company's funds	–925 329 438	–	–1 028 188 562	–	0.03
	S2. Loan	–884 917 202	–	–987 847 143	–	0.04
	S3. EU funds	–642 443 795	–	–745 798 635	–	0.05
	S4. Green bonds	–870 191 891	–	–1 032 261 605	–	0.03
	S5. Mixed financing	–642 480 422	–	–745 835 222	–	0.05

Table 3.23. Summary of scenario analysis results for the Telšiai County Waste Management Centre (source: compiled by the author)

County	Financing scenarios	FNPV, (€)	FIRR (%)	ENPV, (€)	EIRR (%)	B/C ratio
Telšiai	S1. Company's funds	–130 372 921	–	–152 766 115	–	0.09
	S2. Loan	–125 580 427	–	–148 015 416	–	0.09
	S3. EU funds	–96 825 459	–	–119 511 207	–	0.11
	S4. Green bonds	219 198 282	–	–114 793 647	–	0.12
	S5. Mixed financing	–96 862 047	–	–119 547 597	–	0.11

The FNPV analysis of all financing alternatives for the Telšiai County waste management facility (Table 3.23) indicates that scenarios, except for green bonds, require more funding. The most favourable outcome may be obtained when utilising green bonds. The ENPV computations provide negative results across all scenarios, demonstrating insufficient economic benefits to offset the project

expenditures. However, the alternative with EU funds and the company's funds has the least negative impact, indicating a favourable outcome for this option. The B/C ratio varies from 0.09 to 0.12, indicating that for every EUR 1 of expenses, there are EUR 0.09–0.12 in benefits. FIRR and EIRR cannot be computed due to the presence of negative cash flows in the anticipated years.

The FNPV analysis of all financing alternatives for the Utena County Waste Management Centre (Table 3.24) indicates that scenarios, except for green bonds, require more funding. The choice of green bonds has a favourable result. The ENPV calculations provide negative results across all scenarios, suggesting that the projects do not generate sufficient economic benefits to offset their expenditures. However, the alternative with green bonds is the least detrimental, indicating the favourable outcome of this choice. The B/C ratio varies from 0.07 to 0.12, indicating that for every EUR 1 of expenses, there are EUR 0.07–0.12 in benefits. FIRR and EIRR cannot be computed due to the presence of negative cash flows in the anticipated years.

Table 3.24. Summary of scenario analysis results for the Utena County Waste Management Centre (source: compiled by the author)

County	Financing scenarios	FNPV, (€)	FIRR (%)	ENPV, (€)	EIRR (%)	B/C ratio
Utena	S1. Company's funds	–262 864 038	–	–298 358 488	–	0.1
	S2. Loan	–253 672 158	–	–410 693 371	–	0.07
	S3. EU funds	–198 520 882	–	–234 015 331	–	0.12
	S4. Green bonds	76 748 172	–	–224 856 103	–	0.12
	S5. Mixed financing	–198 556 733	–	–234 051 180	–	0.12

Table 3.25. Summary of scenario analysis results for the Tauragė County Waste Management Centre (source: compiled by the author)

County	Financing scenarios	FNPV, (€)	FIRR (%)	ENPV, (€)	EIRR (%)	B/C ratio
Tauragė	S1. Company's funds	–158 925 712	–	–185 434 543	–	0.03
	S2. Loan	–152 428 279	–	–179 083 173	–	0.03
	S3. EU funds	–113 443 687	–	–140 974 937	–	0.04

End of Table 3.25

County	Financing scenarios	FNPV, (€)	FIRR (%)	ENPV, (€)	EIRR (%)	B/C ratio
	S4. Green bonds	242 449 678	–	–134 656 428	–	0.04
	S5. Mixed financing	–165 535 724	–	–141 011 019	–	0.04

The FNPV analysis of all financing alternatives for the Tauragė County Waste Management Centre (Table 3.25) indicates that scenarios, except for green bonds, require more funding. The green bond financing option has the least negative result. The ENPV computations provide negative results across all scenarios, signifying an insufficiency of economic benefits to offset the project expenses. However, the green bond financing option and the EU funds are the least detrimental, indicating the favourable outcome of both choices. The B/C ratio varies from 0.03 to 0.04, indicating that for every EUR 1 of expenses, there are EUR 0.03–0.04 in benefits. FIRR and EIRR cannot be computed due to the presence of negative cash flows in the anticipated years.

3.2. Results of the of the Success Factor Analysis of Issuing Green Bonds

The findings section offers a comprehensive overview of the data collection procedure and the results obtained through the application of the AHP. It also summarises the responses to the open-ended questions.

The data-gathering procedure started by identifying the experts who participated in the survey. Nine experts, each with a minimum of five years of experience in their respective fields of expertise, were chosen to take part in the survey (Table 3.26). The specialists possess expertise in three overarching domains: financial markets, sustainable finance, and ESG. Three experts represented the academic field, four experts came from the banking sector, and two experts were from the corporate sector.

Table 3.26. Fields of expertise of respondents (source: compiled by the author)

Number of Experts	Area of Expertise
3	Financial markets
4	Sustainable finance
2	ESG

The research scope is determined by analysing the literature on success-dependent criteria for issuing green bonds and the associated advantages and obstacles of their issuance. The literature identifies the following study requirements for constructing a pairwise comparison matrix of success-dependent elements for issuing green bonds:

1. Excellent credit score (Mankata et al., 2022);
2. Providing clear and specific instructions at the country level regarding the procedure for issuance (Mankata et al., 2022);
3. Appropriate criteria for determining the eligibility of a green project (Mankata et al., 2022);
4. Priority is assigned to financially stable initiatives (Mankata et al., 2022);
5. The administration of funds clearly and transparently (Fatica & Panzica, 2021);
6. Procedure for assessing and opting for projects (Fatica & Panzica, 2021);
7. Reporting and external review (Fatica & Panzica, 2021);
8. Issuer's reputation (Bhutta et al., 2022; Cheng et al., 2022);
9. ESG score (Cheng et al., 2022);
10. The size of the issue of green bonds (Bhutta et al., 2022).

The literature has contributed to the identification of the following study criteria for constructing a pairwise comparison matrix evaluating the advantages of issuing green bonds:

1. Currency risk management tool (Mankata et al., 2022);
2. Spike investor enthusiasm for environmental finance (Mankata et al., 2022);
3. Enhancing the competence of institutional investors (Mankata et al., 2022);
4. Provision of tangible and quantitative advantages (Mankata et al., 2022);
5. Supporting government policies (Mankata et al., 2022);
6. Encouragement of participation of society (Mankata et al., 2022);
7. Establishing and maintaining an effective bond market (Mankata et al., 2022);
8. Minimal exposure to investment risks (Wang, 2021);
9. Capacity to get substantial funding required for financing environmentally sustainable projects (Wang, 2021);
10. Bonds offer greater flexibility and liquidity (Wang, 2021).

The scientific literature has provided the following study criteria for constructing the pairwise comparison matrix of the challenges associated with issuing green bonds:

1. Greenwashing (Cheng et al., 2022);

2. The green bond market may overstate its significance concerning environmental preservation (Bongaerts & Schoenmaker, 2019);
3. Green bonds provide limited financial and economic advantages to investors who are ready to participate in initiatives that promote environmental sustainability (Bongaerts & Schoenmaker, 2019);
4. Issuance costs (Bongaerts & Schoenmaker, 2019; Cheng et al., 2022)
5. Lack of universally accepted market standards (Bongaerts & Schoenmaker, 2019).

The survey participants, who were experts in the field, were requested to complete three pairwise comparison matrices to identify the success factors, advantages, and challenges associated with issuing green bonds based on the criteria described earlier. The experts were requested to assess the importance of these qualities to Lithuania, utilising the Saaty rating scale (Table 3.27).

Table 3.27. Saaty rating scale (source: compiled by the author based on Alrawad et al. (2023); Leal (2020); Sevinç et al. (2018); Yap et al. (2017))

Intensity of Importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

The experts were also requested to provide their perspectives on other outstanding questions:

1. What criteria, in your perspective, contribute to the credibility of a green bond?
2. What are the primary success requirements for issuing green bonds in Lithuania?
3. What are the additional advantages of issuing green bonds in Lithuania?
4. What are additional obstacles that may arise while issuing green bonds in Lithuania?
5. Would recognising the environmental benefits provided by the issuance of green bonds aid in enhancing its effectiveness?
6. How may the effectiveness or success of the green bond be augmented?

The findings of the survey on the identification of success criteria in the issue of green bonds, as well as the possible advantages and difficulties associated with the issuance based on the suggested conceptual model, are condensed in Tables 3.28–3.30. The experts provided a detailed summary of the outcomes,

including the weights assigned to each component. The final weights are expressed as percentages. The consistency ratios associated with the responses of individual experts meet the criterion of being below 10% (Yap et al., 2017).

Experts examined the following criteria to analyse the elements contributing to the success of issuing green bonds in Lithuania (Table 3.28): (1) a favourable credit score of the issuer, (2) providing clear and specific instructions at the country level regarding the procedure for issuance, (3) appropriate criteria for determining which projects are eligible for green financing, (4) priority given to financially stable projects, (5) the administration of funds clearly and transparently, (6) procedure for assessing and opting for projects, (7) reporting and external review process, (8) the issuer's reputation, (9) the ESG score of the issuer, (10) the size of the issue of green bonds. The acronyms "Ex.1–Ex.9" represent the expert, whereas "FW" denotes the final weight in percentage of the criterion. The final weight is calculated as the average of all respondent's answers to the specific question.

Experts assert that the most crucial factors for the successful issuance of a green bond are:

1. Issuer's reputation (final weight 17%);
2. Excellent credit score (final weight 15%);
3. ESG score (final weight 12%);
4. Appropriate criteria for determining the eligibility of a green project (final weight 11%);
5. Priority is assigned to financially stable initiatives (final weight 11%);
6. Procedure for assessing and opting for projects (final weight 10%).

Table 3.28. Results of the pairwise comparison matrix for success factors of issuing green bonds (source: compiled by the author)

Criteria	Ex. 1, %	Ex. 2, %	Ex. 3, %	Ex. 4, %	Ex. 5, %	Ex. 6, %	Ex. 7, %	Ex. 8, %	Ex. 9, %	FW
Excellent credit score	21.4	15.3	17.8	19.8	20.0	19.8	7.0	5.8	6.8	15
Providing clear and specific instructions at the country level regarding the procedure for issuance	2.7	2.8	2.2	2.5	2.7	2.3	11.1	9.6	6.5	5
Appropriate criteria for determining the eligibility of a green project	10.1	10.7	8.2	11.8	9.7	8.9	12.0	16.0	15.4	11
Priority is assigned to financially stable initiatives	11.4	10.6	11.1	13.7	10.7	12.4	11.4	9.0	8.9	11

End of Table 3.28

Criteria	Ex. 1, %	Ex. 2, %	Ex. 3, %	Ex. 4, %	Ex. 5, %	Ex. 6, %	Ex. 7, %	Ex. 8, %	Ex. 9, %	FW
The administration of funds in a clear and transparent manner	4.6	5.4	4.7	4.0	4.7	4.6	14.9	13.1	12.6	8
Procedure for assessing and opting for projects	5.3	6.8	5.1	4.4	6.4	5.4	17.5	18.6	17.2	10
Reporting and external review	6.2	6.5	6.8	6.4	7.5	5.6	7.5	5.0	5.8	6
Issuer's reputation	17.5	19.2	22.4	18.9	19.4	22.2	7.5	11.3	16.6	17
ESG score	13.8	14.8	15.2	11.9	12.4	11.67	7.9	8.9	8.1	12
The size of the issue of green bonds	7.0	8.0	6.4	6.8	6.5	7.2	3.2	2.7	2.0	6
Consistency	0.7	0.1	5.5	1.00	4.4	4.7	9.5	9.5	8.4	

Experts analysed the following factors to clarify the advantages of issuing green bonds in Lithuania (Table 3.29): (1) currency risk management tool, (2) spike investor enthusiasm for environmental finance, (3) enhancing the competence of institutional investors, (4) provision of tangible and quantitative advantages, (5) supporting government policies, (6) encouragement of participation of society, (7) establishing and maintaining an effective bond market, (8) minimal exposure to investment risks, (9) capacity to get substantial funding required for financing environmentally sustainable projects, and (10) bonds offer greater flexibility and liquidity. Experts assert that the primary advantages of the green bond issue are:

1. Currency risk management tool (final weight 16%);
2. Capacity to get substantial funding required for financing environmentally sustainable projects (final weight 14%);
3. Provision of tangible and quantitative advantages (final weight 13%);
4. Establishing and maintaining an effective bond market (final weight 12%);
5. Encouraging society to participate (final weight 10%).

Table 3.29. Results of the pairwise comparison matrix for success factors of issuing green bonds (source: compiled by the author)

Criteria	Ex. 1, %	Ex. 2, %	Ex. 3, %	Ex. 4, %	Ex. 5, %	Ex. 6, %	Ex. 7, %	Ex. 8, %	Ex. 9, %	FW
Currency risk management tool	6.6	6.62	6.7	8.8	8.3	7.5	7.9	3.0	1.6	6

End of Table 3.29

Criteria	Ex. 1, %	Ex. 2, %	Ex. 3, %	Ex. 4, %	Ex. 5, %	Ex. 6, %	Ex. 7, %	Ex. 8, %	Ex. 9, %	FW
Spike investor enthusiasm for environmental finance	4.6	4.57	3.9	4.2	4.5	4.2	4.3	17.9	5.2	6
Enhancing the competence of institutional investors	3.9	3.87	3.1	3.1	3.2	3.4	3.4	19.7	6.0	6
Provision of tangible and quantitative advantages	13.9	13.91	10.8	14.8	13.5	14.7	14.8	2.7	17.8	13
Supporting government policies	9.99	9.99	11.1	9.99	9.8	10.1	10.8	7.9	4.8	9
Encouraging society to participate	11.6	11.63	7.8	7.2	7.9	8.4	8.7	18.2	6.7	10
Establishing and maintaining an effective bond market	13.7	13.66	13.0	11.6	12.5	13.0	11.9	4.1	14.1	12
Minimal exposure to investment risks	16.2	16.18	14.8	18.4	20.0	17.7	14.8	3.2	19.1	16
Capacity to get substantial funding required for financing environmentally sustainable projects	9.9	9.93	15.8	11.2	10.6	11.3	13.4	18.3	21.4	14
Bonds offer greater flexibility and liquidity	9.6	9.64	13.5	10.6	9.7	9.7	10.0	4.9	3.4	9
Consistency	0.8	0.8	9.9	9.0	9.5	8.0	8.5	8.1	6.4	

Experts analysed the following factors for understanding the difficulties of issuing green bonds in Lithuania (Table 3.30): (1) greenwashing, (2) the green bond market may overstate its significance concerning environmental preservation, (3) green bonds provide limited financial and economic advantages to investors who are ready to participate in initiatives that promote environmental sustainability, (4) issuance costs, and (5) the lack of universally accepted market standards. The primary obstacles linked to the issuance of green bonds, as stated by experts, are:

1. Greenwashing (final weight 39%);

2. The green bond market may overstate its significance in relation to environmental preservation (final weight 23%);

3. Green bonds provide limited financial and economic advantages to investors who are ready to participate in initiatives that promote environmental sustainability (final weight 15%);

4. The lack of universally accepted market standards (final weight 12%).

Table 3.30. Results of the pairwise comparison matrix for benefits of issuing green bonds (source: compiled by the author)

Criteria	Ex. 1, %	Ex. 2, %	Ex. 3, %	Ex. 4, %	Ex. 5, %	Ex. 6, %	Ex. 7, %	Ex. 8, %	Ex. 9, %	FW
Greenwashing	53.1	51.2	45.8	45.6	44.1	35.2	10.2	29.0	32.6	39
The green bond market may overstate its significance in relation to environmental preservation	25.8	23.3	28.8	20.1	22.6	20.7	6.5	28.4	32.6	23
Green bonds provide limited financial and economic advantages to investors who are ready to participate in initiatives that promote environmental sustainability	6.0	10.5	11.3	16.5	16.3	23.4	7.6	29.0	18.0	15
Issuance costs	10.60	9.9	8.01	11.6	11.4	13.8	7.6	8.5	12.3	10
The lack of universally accepted market standards	4.6	5.2	6.1	6.1	5.7	6.9	68.1	5.1	4.7	12
Consistency	7.2	7.1	4.7	6.6	8.2	8.2	3.5	0.6	8.1	

The initial open question focused on the expert opinions about the reliability of green bonds. Reputation, ESG score, and credit rating are considered essential factors in determining the dependability of green bonds, according to experts. Significant emphasis is put on the overarching objective of the project that will be funded by the green bond, as well as the transparency of the project management strategy and the allocation of funds. It is noteworthy that experts have recognised the significance of a green bond's dependence on internationally recognised certification standards, such as ICMA or the EU taxonomy regulation (Regulation 2020/852 of the European Parliament and of the Council of 18 June 2020), along with the associated EU Green Bond Standard (EUGBS). Furthermore, it is crucial to clearly articulate the advantages of green bond issuance, with a specific emphasis on promoting sustainability and safeguarding the environment.

The second question addressed the expert opinion on the additional success criteria for green bond issuance in Lithuania. Experts have recommended the

significance of effectively communicating many aspects related to the issuance of green bonds, such as the objective, project outcomes, and their contribution to sustainability or environmental preservation, to both investors and the general public. A broader breadth of communication might be organised through a promotional campaign. Furthermore, experts noted that the level of governmental assistance should align with the level of success in issuing green bonds. Specialists concur that it is necessary to promote green finance, green bonds as a means of financing, and green investment at the national level. They argue that such governmental initiatives would align with the achievement of successful green bond issuance. Furthermore, experts recommended that market participants interested in the issuance of green bonds should employ established and effective strategies to enhance the likelihood of their success.

The third question addressed the expert views about the additional advantages of green bond issuing in Lithuania. Experts concurred that the issuance of green bonds in Lithuania led to heightened financial market activity, resulting in a wider range of financial instruments for investors. Issuing green bonds would also contribute to the diversification of investors' portfolios. Green bond issuing facilitates the acquisition of financing for a range of initiatives, including those centred on sustainability and environmental conservation, projects that have difficulties in securing funding, and those funded through loans. Moreover, the issue of green bonds serves to enhance public understanding of environmental concerns and educate the general population on the subject of green financing.

The fourth open question addressed the expert opinions on additional problems associated with the issue of green bonds in Lithuania. The appeal of the green bond offered might be affected by the tiny domestic market and limited local financial capacity, while the prospects of attracting overseas investors may be inadequate. From the perspective of investors, the experts expressed worries about the trustworthiness of project transparency, the transparent utilisation of funds, and the advantages derived from the initiatives. Experts have identified many hurdles on the issuer's side, including difficulties in achieving the certification standards for green bonds, limited availability of data, and a lack of confidence from potential investors. Additionally, investors in green finance often have insufficient knowledge and expertise in this area. Additionally, the experts highlighted the lack of the public's trust in green bonds, maybe stemming from a dearth of accessible information for a broader demographic.

The fifth open question pertains to the view of specialists in comprehending the environmental value offered by green bonds and its impact on the success of their issuance. The consensus among experts affirms that the issuance of green bonds will undeniably contribute to enhancing comprehension of green bonds, hence yielding valuable benefits. This outcome suggests that other assessment criteria might be considered for future progress.

The sixth open question refers to the expert views on the enhancement of the effect or success of the green bond issue in Lithuania. Experts suggested that for green bond issuance in Lithuania to be effective, it is vital to have government backing and to promote green finance and green bonds on a larger scale. The importance of informative and educational efforts was acknowledged. Experts have also recommended that effective communication of various aspects related to the issuance of green bonds (such as the purpose, project outcomes, contribution to sustainability or environmental protection, impact assessment, and benefits tracking) by trustworthy stakeholders in the process should enhance the likelihood of its success.

3.3. Modelling Results of the Valuation Approach of the Inter-Municipal Cooperation Possibility

Out of the 60 municipalities in Lithuania, the survey and approval of findings will only involve two specific municipalities: Vilnius municipality, which surrounds the capital city of Vilnius, and Tauragė. Both municipalities are included in the EU project "EU Missions 100 climate-neutral and smart cities by 2030", which includes capital cities and smaller to medium-sized towns from each EU member state (European Commission, 2023). The objective of this initiative is to encourage the adjustment to climate change, the restoration of water and oceans, the cultivation of healthy soils, and the management of illnesses such as cancer. Town participation in this project demonstrates their dedication to environmental sustainability.

The following questions have been posed to the municipalities:

1. What are the typical sources of funding for sustainable projects?
2. Have you contemplated issuing debt securities, such as green bonds, sustainable bonds, or sustainability-linked bonds, to finance waste management initiatives independently?
3. Have you thought about joining the IMC to collectively issue debt securities for waste management projects?
4. Assess the significance of the indicators in each category (financial state, solvency, environmental, and social).
5. Assess the possible risks associated with engaging in IMC, including factors such as financial stability, solvency, and the impact on the environment and society.

Participants were instructed to rank domains on a scale of 1 to 10, with 1 being the least dangerous and 10 representing the riskiest element when making decisions on IMC cooperation for zero-waste initiatives.

The interview with representatives of the chosen municipalities was conducted in February 2023. To ensure respondent confidentiality, survey data are provided as responses from Municipalities 1 and 2.

The study findings are consolidated in Tables 3.31 and 3.32. Typically, municipalities finance their initiatives by using EU funding, private investors, public-private partnerships, or soft loans. None of the municipalities have contemplated issuing green bonds to finance their ongoing green projects. Both municipalities were uncertain about the broad acceptability of green funding methods according to the Law on Local Self-Government of the Republic of Lithuania or the strategic plans they are required to adhere to. Municipalities have not yet explored the option of participating in ICM to issue green debt instruments for funding green projects. However, one idea is that it may be more feasible to pursue this method through the Local Government Funding Agency.

Table 3.31. Summary of results of the survey (source: compiled by the author)

#	Question	Municipality 1	Municipality 2
1	What are the potential sources of funding for the project? What are the methods to provide financial support?	Financing via EU funds, private investors, and public-private partnerships	Soft loan, EU funds
2	Have you contemplated the possibility of independently issuing debt securities, such as green bonds, sustainable bonds, or sustainability-linked bonds, to finance your waste management projects?	Unclear whether it is permissible under the Law on Local Self-Government of the Republic of Lithuania.	No. It is uncertain if such action would be included in the strategic strategy.
3	Have you considered participating in the IMC to collectively issue debt securities for waste management projects?	No	No. However, the most optimal method for issuing green bonds would be via utilising the Local Government Funding Agency strategy.

Municipalities have assessed the significance of the indicators within each of the four domains. Respondents discovered that every indication holds equal significance within its respective category. Consequently, the same weights are used in future calculations for indicators of each of the four value domains.

The risk assessments of the indicators by municipalities are consolidated in Table 3.32. The final risk rating is determined by calculating the geometric average to acquire the final risk score for each indication or collection of indicators. The risk rating has been utilised as a percentage in future computations.

Table 3.32. Summary of evaluation of indicators by municipalities (source: compiled by the author)

Risk Rating Mun. 1	Risk Rating Mun. 2	Indicator
8	9	Financial position
6	9	Solvency
8	5	Municipal solid waste collection per capita
9	8	Waste treatment ways per capita (landfill, recycling, and incineration)
9	5	Number of permanent residents
8	5	Demographic old-age dependency ratio
5	5	Monthly salary

The appraisal methodology of the IMC possibility starts with an examination of Brown's 10-Point Test (Brown, 1993). Since Brown's 10-Point Test is appropriate for the structure of balance sheets and income statements of US municipalities, it is necessary to map additional formulae to the Lithuanian balance sheet and income statement of municipalities. The formulae suggested by Brown have been examined by researchers (Natrini & Ritonga, 2017), which facilitated the creation of the required mapping for Lithuanian municipalities. The results of the mapping exercise are presented in Table 3.33, where three ratios are represented as "Not identified".

The subsequent step in the valuation process of the IMC possibility is data collection. The investigation has found the following data sources: (1) the financial status and solvency of chosen municipalities may be assessed through their financial reports; (2) the environmental domain can be evaluated using Waste Accounting data from The Environmental Protection Agency (2023); while (3) the social domain can be analysed using data from the Official Statistics Portal of the State Data Agency (2023). The data was collected for 2019–2021, as waste accounting data for 2022 was not available during the study's development.

Table 3.33. Brown's 10-Point Test mapping to the format of local municipal balance sheet and income statement (source: compiled by the author)

Ratio	Modified equation for Lithuania
$\frac{Total\ revenues}{Population}$ (1)	$\frac{Total\ revenues}{Population}$
$\frac{Total\ general\ fund\ revenues\ from\ own\ resources}{total\ general\ fund\ revenues}$ (2)	Not identified
$\frac{General\ fund\ sources\ from\ other\ funds}{Total\ general\ fund\ sources}$ (3)	Not identified
$\frac{Operating\ expenditures}{Total\ expenditures}$ (4)	$\frac{Total\ public\ service\ expenditure}{Total\ expenditures}$
$\frac{Total\ revenue}{Total\ expenditures}$ (5)	$\frac{Operating\ income}{Total\ expenditures}$
$\frac{Unreserved\ general\ fund\ balance}{Total\ general\ fund\ revenues}$ (6)	Not identified
$\frac{Total\ general\ fund\ cash\ and\ investments}{Total\ general\ fund\ liabilities}$ (7)	$\frac{Cash + Cash\ Equivalents\ + Short - Term\ investments}{Total\ Liabilities}$
$\frac{Total\ general\ fund\ liabilities}{Total\ general\ fund\ revenues}$ (8)	$\frac{Total\ Liabilities}{Operating\ income}$
$\frac{Direct\ long-term\ debt}{Population}$ (9)	$\frac{Long-term\ liabilities}{Population}$
$\frac{Debt\ service}{Total\ revenues}$ (10)	$\frac{Long-term\ liabilities}{Operating\ income}$

The next step in the IMC valuation process involves calculating specific indicators for the financial and solvency aspects and analysing the data acquired for the environmental and social aspects. The outcomes of the IMC feasibility

assessment for Vilnius municipality, including the evaluation of each specific indicator, are consolidated in Table 3.34.

Table 3.34. Application of valuation approach of the IMC possibility on Vilnius municipality (source: compiled by the author)

Ratio group	Ratio Nr.	2019	2020	2021	Evaluation
Fin. position	(1)	1088.78	1238.79	1480.56	The capacity to generate supplementary income is declining.
Fin. position	(4)	0.04	0.04	0.04	Effective management of infrastructure. Risk is reduced by maintaining a constant ratio value.
Fin. position	(5)	1.01	0.99	1.05	The municipality achieved a favourable level of fairness between different periods while also reducing risk through an improved ratio value.
Fin. position	(7)	0.25	0.55	0.73	The municipality's capacity to meet short-term obligations has been strengthening, hence minimising risk.
Fin. position	(8)	0.51	0.28	0.26	The municipality's capacity to meet short-term financial commitments is enhanced by the regular inflow of yearly income, hence minimising risk.
Fin. position	(9)	191.11	200.56	225.27	The municipality is seeing challenges in meeting its long-term financial responsibilities.
Fin. position	(10)	0.28	0.28	0.26	The risk is minimised due to the consistent ratio value. The municipality can fulfil its debts on time.
Solvency	(11)	3.73	3.00	4.65	The ability to meet existing obligations with assets is improving. The level of risk is reduced to a minimum.
Solvency	(12)	4.13	3.35	5.04	The ability to meet existing obligations with assets is improving. The level of risk is reduced to a minimum.

End of Table 3.34

Ratio group	Ratio Nr.	2019	2020	2021	Evaluation
Solvency	(13)	1.08	1.01	1.41	The capacity to meet existing obligations with assets is growing. Risk is mitigated.
Solvency	(14)	93.27	25.72	80.80	There is a noticeable leaning towards improvement.
Solvency	(15)	0.00	0.00	0.00	Challenges associated with the repayment of long-term financial commitments.
Solvency	(17)	0.09	0.09	0.08	The long-term financial solvency is declining
Solvency	(21)	1077.40	1247.45	1411.84	Increased government expenditure and reduced service-level solvency to maintain the higher spending.
Waste management	(22)	0.44	0.32	0.35	The waste collection is diminishing.
Waste management	(23)	0.06	0.07	0.06	The amount of waste that has been disposed of in landfills remains relatively constant.
Waste management	(24)	0.01	0.02	0.15	There is a growing number of burning waste, which poses a high risk.
Waste management	(25)	0.22	0.09	0.12	There has been a decline in the quantity of recycled waste, which is a cause for concern.
Social	(26)	810538	820511	810797	The risk is minimal, and there are no substantial fluctuations.
Social	(27)	103	103	105	Risk is minimal, and the variations are not substantial.
Social	(28)	1650	2290	2535	Low-risk, salary increases

The findings of the IMC possibility assessment for Tauragė municipality, including the appraisal of each specific indicator, are shown in Table 3.35.

Table 3.35. Application of valuation approach of the IMC possibility on Tauragė municipality (source: compiled by the author)

Ratio group	Ratio Nr.	2019	2020	2021	Evaluation
Financial position	(1)	250.19	259.65	313.76	The capacity to generate supplementary income is declining.
Financial position	(4)	0.97	0.98	1.04	The municipality achieved a favourable level of fairness between different periods while also reducing risk through an improved ratio value.
Financial position	(5)	0.24	0.37	0.55	The municipality's capacity to meet short-term financial obligations has been improving, hence reducing the risk.
Financial position	(7)	4.27	6.09	4.97	The municipality's capacity to meet short-term financial commitments through its yearly revenue stream varies, indicating a moderate level of risk.
Financial position	(8)	34.33	42.98	47.40	The municipality is seeing challenges in meeting its long-term financial responsibilities.
Financial position	(9)	2.20	2.57	2.57	The municipality can repay its obligations in a timely manner.
Financial position	(10)	250.19	259.65	313.76	The capacity to generate more income is declining.
Solvency	(11)	0.52	0.65	1.14	The ability to meet current liabilities with assets is improving. The level of risk is reduced to a minimum.
Solvency	(12)	1.31	1.23	1.68	The ability to meet existing obligations with available assets is growing. Risk is mitigated.

End of Table 3.35

Ratio group	Ratio Nr.	2019	2020	2021	Evaluation
Solvency	(13)	1.29	1.22	1.68	The ability to meet current liabilities with assets is improving. The level of risk is minimised.
Solvency	(14)	–7.37	–4.84	13.37	A tendency towards progress is evident.
Solvency	(15)	0.00	0.00	0.00	Challenges associated with fulfilling long–term financial commitments.
Solvency	(17)	0.81	0.60	0.64	The long–term financial solvency is declining.
Solvency	(21)	0.52	0.65	1.14	The liquidity of the company is improving, as it is becoming more capable of meeting its short–term obligations with its current assets. The level of risk is reduced to a minimum.
Waste management	(22)	0.43	0.35	0.33	The waste collection is experiencing a decline, indicating a moderate level of risk.
Waste management	(23)	0.25	0.14	0.12	The amount of waste being disposed of in landfills is decreasing, indicating a reduced risk.
Waste management	(24)	0.00	0.02	0.04	There is a growing number of burning waste, which poses a high risk.
Waste management	(25)	0.18	0.18	0.18	Stability and low-risk
Social	(26)	93659	91822	92667	Risk is minimal, and the variations are not substantial.
Social	(27)	142	145	153	Moderate risk with a propensity for growth
Social	(28)	1092	1498	1649	Low-risk, salary increases

To conduct a more rigorous empirical examination of the IMC possibility, the same set of indicators from four domains was computed for an additional eight

municipalities, namely Kaunas, Klaipėda, Panevėžys, Šiauliai, Alytus, Marijampolė, Utena, and Telšiai. This step is necessary to calculate the Financial Condition Index and Risk-Adjusted Municipal Condition Index.

Table 3.36 provides a summary of the estimated components of the Risk-Adjusted Municipal Condition Index for Vilnius municipality. The dimension indexes are computed for four dimensions, while the weights and risk ratings are derived from the survey of municipalities. The results indicate that the financial situation and solvency of Vilnius municipality have remained consistent during the years of monitoring. However, there has been an improvement in the performance of waste management and social dimensions.

Table 3.36. Components of the Risk-Adjusted Municipal Condition Index of Vilnius municipality (source: compiled by the author)

Dimension Index	Value	Weight	Value
Financial Position Dimension Index FY 2019	0.34	Financial Position Weight FY 2019	0.17
Financial Position Dimension Index FY 2020	0.39	Financial Position Weight FY 2020	0.17
Financial Position Dimension Index FY 2021	0.35	Financial Position Weight FY 2021	0.17
Financial position risk score			0.9
Solvency Dimension Index FY 2019	0.41	Solvency Weight FY 2019	0.17
Solvency Dimension Index FY 2020	0.34	Solvency Weight FY 2020	0.17
Solvency Dimension Index FY 2021	0.34	Solvency Weight FY 2021	0.17
Solvency risk score			0.8
Waste Management Dimension Index FY 2019	0.29	Waste Management Weight FY 2019	0.25
Waste Management Dimension Index FY 2020	0.13	Waste Management Weight FY 2020	0.25
Waste Management Dimension Index FY 2021	0.46	Waste Management Weight FY 2021	0.25
Waste management risk score			0.86
Social Dimension Index FY 2019	0.67	Social Weight FY 2019	0.33
Social Dimension Index FY 2020	0.67	Social Weight FY 2020	0.33
Social Dimension Index FY 2021	0.74	Social Weight FY 2021	0.33
Social risk score			0.63

The findings of the calculation of the Risk-Adjusted Municipal Condition Index for Vilnius municipality are presented in Table 3.37. Here, the statistics suggest that the overall state of the municipality is improving following a little decline in 2020, which may be attributable to the worldwide pandemic. Nevertheless, the results do not attain a value of 1, indicating that there is still potential for improvement in all four areas when it comes to enrolling into ICM.

Table 3.37. Risk-Adjusted Municipal Condition Index of Vilnius municipality (source: compiled by the author)

Indicator	Value
Risk-Adjusted Municipal Condition Indicator FY 2019	0.31
Risk-Adjusted Municipal Condition Indicator FY 2020	0.27
Risk-Adjusted Municipal Condition Indicator FY 2021	0.35

The findings of the assessment of the Risk-Adjusted Municipal Condition Index components for Tauragė municipality are presented in Table 3.38. The results suggest that the financial status and solvency of Tauragė municipality remained consistently steady during the years of monitoring, save for a decrease in solvency in 2020, which may be attributed to the pandemic scenario. There has been little improvement in the waste management sector, whereas a tiny decline may be noted in the social sector.

Table 3.38. Components of the Risk-Adjusted Municipal Condition Index of Tauragė municipality (source: compiled by the author)

Dimension Index	Value	Weight	Value
Financial Position Dimension Index FY 2019	0.21	Financial Position weight FY 2019	0.17
Financial Position Dimension Index FY 2020	0.29	Financial Position weight FY 2020	0.17
Financial Position Dimension Index FY 2021	0.26	Financial Position weight FY 2021	0.17
Financial position risk score			0.9
Solvency Dimension Index FY 2019	0.28	Solvency Average FY 2019	0.17
Solvency Dimension Index FY 2020	0.09	Solvency Average FY 2020	0.17
Solvency Dimension Index FY 2021	0.28	Solvency Average FY 2021	0.17

End of Table 3.38

Dimension Index	Value	Weight	Value
Solvency risk score			0.8
Waste Management Dimension Index FY 2019	0.45	Waste Management Weight FY 2019	0.25
Waste Management Dimension Index FY 2020	0.40	Waste Management Weight FY 2020	0.25
Waste Management Dimension Index FY 2021	0.52	Waste Management Weight FY 2021	0.25
Waste management risk score			0.86
Social Dimension Index FY 2019	0.24	Social Weight FY 2019	0.33
Social Dimension Index FY 2020	0.23	Social Weight FY 2020	0.33
Social Dimension Index FY 2021	0.23	Social Weight FY 2021	0.33
Social risk score			0.63

The findings of the assessment of the Risk-Adjusted Municipal Condition Index for Tauragė municipality are presented in Table 3.39. The findings indicate that the municipal circumstances exhibit a similar pattern to those in Vilnius municipality, namely, a period of progress after a modest decline in 2020, which can likely be attributed to the worldwide pandemic.

Table 3.39. Risk-Adjusted Municipal Condition Index of Tauragė municipality (source: compiled by the author)

Indicator	Value
Risk-Adjusted Municipal Condition Indicator FY 2019	0.13
Risk-Adjusted Municipal Condition Indicator FY 2020	0.06
Risk-Adjusted Municipal Condition Indicator FY 2021	0.17

Nevertheless, once again the results of Tauragė municipality are not approaching 1, but rather are closer to 0, indicating that it would be more difficult for this municipality to engage in IMC. Similar results can be observed in Vilnius municipality.

3.4. Modelling Algorithm Results for the Green Bond Issuance for Municipalities in Inter-Municipal Cooperation

The final phase of the proposed study involves formulating a strategic algorithm for green bond issuance for municipalities in inter-municipal cooperation in the case of Lithuania. Before analysing the algorithm, the theoretical overview of the potential green bond can be summarised. Green bonds have similar characteristics as conventional bonds (Ferrer et al., 2021; UNEP, 2019), and investors willing to invest in green bonds expect financial returns to be equivalent to those of traditional bonds with similar size and terms (The World Bank, 2013). Therefore, the return can be set around 5%–10%, depending on the creditworthiness of the issuer, with a term of 5–30 years. Depending on the economic situation, an inflation risk may arise and affect the success of the green bond issue. Therefore, potential issuers of green bonds should keep in mind the possible need to account for inflation when planning to issue a bond with a fixed or floating interest rate. The redemption conditions would be dependent on the type of green bond to be issued.

The algorithm's visual depiction is presented in Figure 3.1, along with the appropriate sequential instructions.

The issue of green bonds follows an algorithm that relies on a 12-step procedure. The comprehensive explanation of each stage, including pivotal moments of choice:

1. Municipalities must consider the legal requirements and local restrictions when planning to issue green bonds. Key factors to examine include the legal requirement for towns to issue bonds as stipulated by legislation, or, alternatively, the procedure for negotiating the issuance with the relevant government entities.
2. The subsequent actions involve assessing performance and considering the option of engaging in IMC with another municipality. This may be accomplished by utilising the valuation technique suggested in this work to evaluate the feasibility of IMC.
3. Once the evaluation provides positive results and towns choose to engage in IMC, it becomes imperative to establish a mutual agreement regarding the roles and obligations of each municipality. Another aspect to contemplate is the consensus over the methodology for monitoring green bonds. The next aspect to address is to get a consensus on the individuals who will be held accountable within the IMC for approving the green bond prospectus.
4. The identification of green assets or zero-waste projects, which will be funded through the revenues generated from the issue of green bonds, is

necessary. It is crucial to note that assessing the environmental sustainability of the municipality is not an appropriate metric at this stage.

5. It is necessary to appoint external stakeholders, including the issuing bank, external auditor, second opinion provider, and rating agency.
6. The requisite documents on the green bond issue must be prepared. The materials available here consist of a green bond prospectus, due diligence report, audited financial statements along with their publication, capacity opinion letter, and transaction documentation. It is crucial to note that the green bond prospectus must have the relevant approvals from the Lithuanian Financial Supervisory Authority (FSA) and the municipalities themselves.

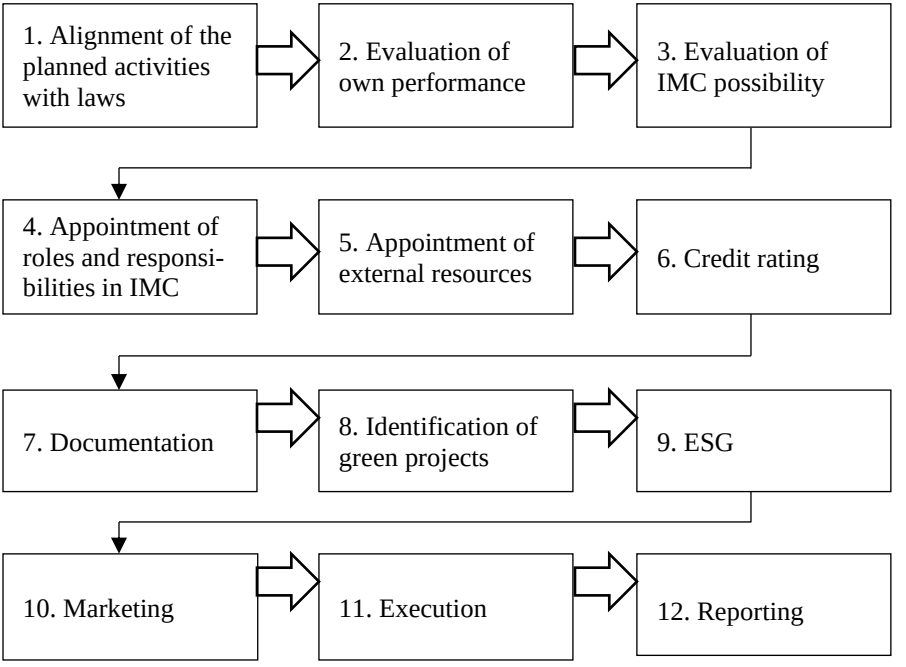

Fig. 3.1. Algorithm for the issuance of green bonds by municipalities in inter-municipal cooperation (compiled by the author)

7. Obtaining a credit rating is a crucial stage in the process of issuing green bonds. Initially, the municipality must choose a credit rating agency and furnish the required information for the evaluation of the ultimate credit rating.
8. The ESG component involves creating the green bond framework and obtaining a second opinion from a chosen supplier.

9. The marketing aspect is a crucial milestone in the successful issuance of green bonds. Initially, it is necessary to conduct a private placement exclusively for chosen investors to obtain their input regarding the issuing of green bonds. Consequently, the investor presentations are meticulously crafted and subsequently conducted with investors.
10. The execution phase includes activities such as book building, pricing, and the drafting of final terms for the issue of green bonds. This phase also involves determining the timetable for allocating bond proceeds and applying for listing.
11. Reporting is the final stage of the green bond issuing procedure. Procedures must be devised to track and report on the use of funds.

A detailed overview of the roles and responsibilities of the stakeholders involved in the green bond issuance process is summarised in Table 3.40. Based on the provided information, the municipalities should be able to assign the roles and responsibilities of all stakeholders involved in the process. The following is the split of responsibilities: (1) Muni – tasks should be performed by the municipalities, (2) IB – tasks should be executed by the issuer bank of the green bonds, (3) LC – activity should be accomplished by the legal counsel, (4) A – task should be executed by the auditors, (5) RA – responsibility for the completion of the activity has been taken by the rating agency, (6) SOP – responsibility for the deliverable has to be placed on the second opinion provider.

Table 3.40. Roles and responsibilities split of stakeholders involved in green bond issuance process (source: compiled by the author)

#	Steps and sub-steps	Muni	IB	LC	A	RA	SOP
1	Alignment of the planned activities with laws	x					
2	Evaluation of own performance	x					
3	Evaluation of IMC possibility	x					
4	Appointment of roles and responsibilities in IMC						
	Appointment of the roles of internal resources	x					
	Green bond proceeds tracking approach	x					
	Responsibility for approval of Green Bond Prospectus	x					
5	Appointment of external resources						
	Issuer bank	x					
	Auditors	x					
	Second Opinion Provider	x	x				

End of Table 3.40

#	Steps and sub-steps	Muni	IB	LC	A	RA	SOP
6	Credit rating						
	Selection of the Rating Agency	x	x				
	Preparation of answers to the Rating Agency's assessment questionnaire	x	x				
	The final announcement of the credit rating					x	
7	Documentation						
	Bond prospectus	x	x	x			
	Due diligence	x	x	x			
	Draft prospectus for approval by FSA	x		x			
	Approval of the Prospectus	x					
	Publication of audited financial statements for the financial year	x					
	Auditor's letter				x		
	Capacity opinion letter			x			
	Transaction documentation	x	x				
8	Identification of green projects	x					
9	ESG						
	Preparation of the Green Bond Framework	x					
	Issuance of the Second Party Opinion						x
10	Marketing						
	Private placement for selected investors	x	x				
	Meetings with investors	x	x				
11	Execution						
	Price setting	x	x				
	Approval of final terms of the issue	x		x			
	Application for listing on the stock exchange	x		x			
12	Reporting on the use of proceeds and projects being financed	x					

As portrayed in Table 3.40, the initial responsibility for the kick-off of the green bond issuance process is on the shoulders of municipalities. Herein, the municipalities are expected to align their actions with laws, as the activities of municipalities are regulated. Thus, municipalities should assess their performance and capabilities and evaluate the possibility of joining with another municipality

for the green bond issuance. After the decision is taken in favour of IMC, municipalities are expected to review current resource capacities and appoint roles and responsibilities for the green bond issuance process. Municipalities can share resources such as treasury, sustainability, IT, reporting, investor relations, and legal services and optimise their expenses of the green bond issuance process. Then, municipalities should agree on ways to track the use of funds raised from the green bond issue and agree on the process of the approval of the Green Bond Prospectus.

Another important step for municipalities in the green bond issuance process is the appointment of external resources. Municipalities should decide on the bank they select for the green bond issuance and appoint auditors for the auditing of financial statements. After onboarding the issuer bank, municipalities, along with the issuer bank, will agree on the Second Opinion Provider for the green bond issue and the Rating Agency. The latter will provide the necessary documentation, which will be filled out by the issuer bank and municipality, and, in turn, will announce a credit rating after the examination of the documentation.

The next step for municipalities in the green bond issuance process is the preparation of documentation. Herein, municipalities, issuer banks, and legal counsel will join forces to formulate the bond prospectus and prepare the necessary due diligence. Then, municipalities and legal counsel will provide a draft prospectus for approval by the Financial Services Authority (FSA). Thus, municipalities are expected to approve the prospectus and publish the audited financial statements. In turn, auditors will prepare an auditors letter, and legal counsel will take responsibility for the preparation of the capacity opinion letter, which would show the evaluation of a municipality's legal capability to fulfil its responsibilities. As a final sub-step in the documentation step, municipalities, together with the issuer bank, would prepare the necessary transaction documentation.

The ESG part is one of the key steps in the green bond issuance process. Municipalities would be responsible for the preparation of the Green Bond Framework, which, in turn, would be reviewed by the Second Party Opinion Provider. The latter will issue the second opinion report based on the findings from the Green Bond Framework.

The subsequent step in the green bond issuance process is marketing, which will be led by municipalities and the issuer bank. After favourable feedback from potential investors, municipalities and the issuer bank will switch to the execution with the definition of the price for the planned green bond issue. After that, municipalities and legal counsel will define the final terms of the issue and apply for the listing on the stock exchange. As a result, after the successful issuance of the green bonds, municipalities will be responsible for the regular reporting of the use of proceeds of the issued green bonds.

3.5. Discussion and Research Limitations

The subsequent results of the modelling of the financing options for green projects might be emphasised:

1. The study shows that issuing green bonds can be an alternative financing of environmentally sustainable projects. For six out of ten municipalities surveyed, financing with green bonds would be a favourable solution. However, the results indicate that this type of financing often does not provide financial and/or economic benefits and requires additional financing.
2. To overcome the need for additional funding when issuing green bonds and extra costs associated with the issue, a new strategic solution for municipalities is necessary. One of the solutions here might be inter-municipal cooperation of municipalities for the green bond issuance.
3. The study demonstrates that economic benefits are straightforward and can be easily reproduced. The significance of offering these economic advantages is demonstrated by researchers (De Feo et al., 2019) about the development of readily duplicable instruments. Nevertheless, the study encounters challenges in comprehending and measuring the economic advantages for each county, mostly owing to data limitations. Typically, there is a lack of publicly accessible data to do estimates about the general economic advantages of waste management programs. Consequently, the research chose to incorporate three factors: (1) the saved expenses of producing paper and paperboard, glass, and plastics; (2) the saved costs of unemployment; and (3) the extra income generated from the expansion of service availability. Projections indicated a decrease in some economic advantages, or possibly a cluster of them, in smaller counties, suggesting that the economic costs outweigh the available economic benefits.
4. The economic benefits chosen for the research may be computed and predicted for the future without any additional difficulties for Vilnius municipality, primarily because of the population expansion in this county.
5. Based on the financial reports of waste management facilities, a number of them are now experiencing losses. This business condition impacts the outcomes of the research. For instance, the Kaunas Waste Management Centre is now experiencing financial losses, as indicated by the modelling findings, which demonstrate significant deficits from a financial and economic standpoint. It is important to acknowledge that the economic advantages and financing possibilities provided by EU funds or green bonds do not significantly enhance the situation.
6. Furthermore, the research suggests examining the possibility of municipalities to participate in a cluster to reap the advantages of inter-municipal

collaboration. In a study conducted by Struk and Bakoš (2021), researchers examined the lasting financial effects of inter-municipal cooperation in the Czech Republic on the management of municipal solid waste. The study revealed an annual cost reduction of 13.5% in the supply of municipal solid waste management. Therefore, inter-municipal cooperation can be utilised to collectively raise funds in financial markets.

7. There is a demand for a new assessment instrument for zero-waste initiatives to validate their implementation. Research has shown that using conventional evaluation methods, zero-waste initiatives may be perceived as providing minimal financial or economic advantages. This may deter potential investors. Implementing zero-waste initiatives is more advantageous for society and the environment, especially in small counties, rather than delaying them. Future research should concentrate on developing a new instrument for evaluating zero-waste initiatives. Researchers (Stankevičienė & Bužinskė, 2023) have proposed the new assessment method "Green EVA" for the determination of the Green Economic Value Added to environmentally sustainable projects. Therefore, future research can be associated with the application of the Green EVA for the evaluation of green projects with a focus on zero-waste for the ten counties in Lithuania.

Data availability significantly influences the results of the modelling of the financing options for green projects:

1. Financial reports of waste management centres differ in their structure, which means that the availability of information also varies. For example, the information about the number of employees is limited and often cannot be used in research.
2. The reliability of forecasting using exponential smoothing varies, indicating that assumption-based predictions should be used instead of relying solely on this forecasting method.
3. In some cases, the economic benefits used in the study were insufficient to justify the economic costs. This outcome was influenced by missing data and general demographic conditions, such as a shrinking population.

Analysis of success factors of issuing green bonds, its benefits and challenges in Lithuania revealed that the issuer's decision to issue a green bond in Lithuania is influenced by factors such as the appropriateness of criteria for green project qualification and the procedures for project assessment and selection. This study emphasises the need to prioritise financially viable initiatives above ecologically good ones, as the latter typically do not yield significant financial gains. Moreover, green bond issuance should adhere to certification standards such as ICMA and EU Green Bond Standard (EUGBS) and follow best practices established by experienced and credible market players. These certification requirements should

serve as a benchmark for achieving successful green bond issuance. From the issuer's viewpoint, the government's promotion of green finance and green bonds is a crucial component in the decision to issue a green bond, as it helps attract local and overseas investors. Key considerations for investors deciding to invest in a green bond in Lithuania mostly revolve around the issuer's reputation, credit rating, and ESG score. Investors like transparent information regarding many aspects of the green bond issue, such as its aim, project outcomes, prospective advantages, use of profits, certification, and impact on sustainability or environmental protection.

The advantages of issuing green bonds in Lithuania for the issuers lie in the potential financing of projects related to sustainability and environmental preservation, projects facing funding difficulties, or projects funded through loans. Another advantage for the issuer of green bonds is the capacity to get substantial investment funds required for funding eco-friendly initiatives. Researchers (Hussain et al., 2022; Teti et al., 2022) indicate that green bonds can lower loan costs, which is advantageous for funding majors. Investing in bonds in Lithuania offers benefits such as enhanced bond market efficiency, a wider range of fixed-income instruments, higher portfolio diversification, and minimal investment risks from an investor's viewpoint. Researchers (Chopra & Mehta, 2023; Elsayed et al., 2022; Maino, 2022; Naeem et al., 2022, 2023; Tiwari et al., 2023) have recognised the advantages of diversification. Research on portfolios containing green and conventional bonds in the USA and Europe demonstrated that green bonds enhance returns and decrease volatility (Baranowski & Kopnina, 2022; Han & Li, 2022). Researchers (Boutabba & Rannou, 2022) suggest that retaining green bonds until they mature might be a helpful approach for investors to address liquidity issues.

The challenges of green bond issuance in Lithuania for the issuer are linked to the ability of the green bond issuance to achieve expected outcomes. The primary constraints in the industry today revolve around market-specific aspects, including size, financial potential, and restricted chances for international investment. Challenges in recruiting foreign investors have been noted in the Czech Republic, Hungary, Poland, and Slovakia (Hadas-Dyduch et al., 2022). Another problem for potential investors is the lack of standardised market certification criteria, making it challenging to fulfil certification prerequisites. Similar issues with the absence of international certification have been noted in Europe (Nikolaj et al., 2022) and Asian nations (Jain et al., 2022). Issuers are greatly concerned about the availability and consistency of data connected to environmental factors. Similar data problems are also present in research on Northern Europe (Tona et al., 2023). Potential investor attitude, particularly a lack of confidence in green bonds, is a difficulty for issuers. Enhancing the knowledge and competence of potential investors in the green bond market might help address this issue.

Challenges for investors in Lithuania regarding green bond issuance include concerns about greenwashing and assessing the actual impact of the green bond market on environmental conservation. Greenwashing poses a danger to the advancement of the green bond market (Lin & Hong, 2022; Maino, 2022). Potential investors may have a deeper understanding of the financial and economic advantages of initiatives that promote environmental sustainability; they may choose to participate in these projects by investing in green bonds.

Studying the accessibility and clarity of green bond issuance documents positively impacts the liquidity of green bonds (Lebelle et al., 2022). The lack of universal market norms may lead to doubts about the trustworthiness of project transparency, the transparent allocation of funds from eco-friendly initiatives, and their advantages for potential investors. The absence of universal or regional norms has been identified as a difficulty in the Czech Republic, Hungary, Poland, Slovakia (Hadas-Dyduch et al., 2022), Asia (Jain et al., 2022), and India (Kumar, 2022a).

The survey participants stressed the significance of communication and information accessibility for investors and the public in the success of a green bond offering. The importance of having access to information and understanding the advantages of green bonds was evident in the Czech Republic, Hungary, Poland, Slovakia, and other countries. Issuers of green bonds in Lithuania should consider the purpose of the issuance and its potential environmental benefits, the outcomes of the project being financed, the use of proceeds, certification, contribution to sustainability or environmental protection, and the environmental challenges faced by the issuer when establishing communication about green bonds.

The government of Lithuania can promote green finance and green bonds by focusing on (1) providing information to different audiences, (2) increasing awareness of environmental challenges, (3) highlighting the significance of green finance in environmental protection, (4) explaining green finance mechanisms, (5) outlining the benefits of green bond issuance, and (6) educating on how to recognise greenwashing.

The analysis of success factors, benefits and challenges of issuing green bonds in Lithuania provides ideas and practical applications for potential issuers, investors, and governments interested in advancing sustainable and green financing. Issuers should prioritise their reputation, credit rating, and environmental, social, and governance scores to enhance the chances of a successful green bond offering. Issuers must refrain from greenwashing by offering open and precise details on the environmental effects of their initiatives. Researchers (Torvanger et al., 2021) suggest that the green bond market's success and growth rely on cooperation between green bond issuers and prospective investors, clear communication, and public disclosure of green finance operations. Investors should thoroughly assess green bond issuers to verify their dedication to sustainable and ecologically responsible activities. Policymakers should promote the growth of

green bond markets through regulatory assistance and financial incentives. Mr. Mark Carney, Governor of the Bank of England and Chairman of the Financial Stability Board, emphasised in his lecture at Lloyd's of London that governments should take the lead in transitioning to a low-carbon economy (Carney, 2015).

The constraints of the analysis of success factors, benefits, and challenges of issuing green bonds in Lithuania mostly relate to the extent of the success factors, as well as the advantages and difficulties associated with the issuance of green bonds. With the publication of more studies by researchers, there is a possibility of discovering new study variables that may be valuable to investigate in terms of their applicability to Lithuania. Consequently, a potential area for future study may be assessing the novel factors that contribute to success, advantages, and obstacles associated with the issuance of green bonds in Lithuania, drawing upon the discoveries made by other academics.

A potential constraint of the analysis of success factors, benefits, and challenges of issuing green bonds in Lithuania might be the limited number of experts who took part in the poll. Although the chosen approach for analysing expert opinion does not necessitate a huge number of participants, this study utilised the input of nine experts. Given the nascent nature of green bond issuance in Lithuania, the chosen number of respondents appears to be adequate, considering the small number of experts involved in this domain. However, as the concept of green bonds develops in the country and more professionals become involved in issuing them, it would be beneficial to conduct further research involving a wider range of experts. This research could focus on the factors that contribute to the success of green bond issuance, as well as the benefits and challenges associated with it.

It is crucial to acknowledge an applicable variable as a constraint in the analysis of success factors, benefits, and challenges of issuing green bonds in Lithuania. Given the present state of the green bond market in Lithuania, which remains relatively small, the proposed survey is pertinent and offers benefits to issuers, investors, and policymakers. However, as the green bond market matures, the previously stated characteristics of success for issuing green bonds, as well as their advantages and obstacles, may become irrelevant or change. Hence, it is plausible to do such research in the future, given better-developed circumstances in the green bond market. Furthermore, an additional constraint might be attributed to the relevance of the research for a certain nation. According to the study's discussion points, there are commonalities across nations that have comparable attributes such as population, GDP, and growth of the green bond market. However, it is important to verify the validity of these generalisations. One potential area for future research may be to compare the conditions within the region. This entails a comparable study in Latvia and Estonia to see if specified research factors yield equivalent outcomes in the region.

The research on the results modelling of the valuation approach of the IMC possibility offers insights into the appraisal method of the IMC potential and decision-making algorithm for the issuing of green bonds by municipalities in Lithuania. Mikalauskas (2019) studied IMC and its benefits for municipalities in Lithuania, which found that IMC offers benefits such as acquiring new skills, learning from peers, resolving complex situations efficiently, improving service delivery, introducing new services, accessing various financing methods, enhancing visibility for municipalities involved in IMC, and saving costs through economies of scale. Municipalities in IMC can get the same benefits through the issuing of green bonds. Municipalities may enhance their skill set through the issuing process, successfully tackle waste management difficulties, tap into previously untapped money, enhance dependability and confidence as a governing entity, and use resources more efficiently.

The choice to implement IMC is usually impacted by many aspects that correspond with IMC's advantages. The scientific literature lacks appropriate guidance on the valuation methodologies for deciding whether to engage in IMC. The suggested valuation method for evaluating the IMC potential fills a gap in the existing scientific literature.

The research on the modelling results of the valuation approach of the IMC possibility has several limitations. First, the proposed valuation technique for assessing the IMC possibility is limited by the availability of data. Insufficient data on waste management hinders the evaluation of the environmental domain. Furthermore, the available data about the social condition of municipalities is limited and mostly focused on statistical figures, without enough information regarding the welfare of the residents inside the municipality. Therefore, the assessment of the viability of IMC is conducted using a valuation technique that involves empirically testing four aspects of ten municipalities selected from a total of sixty. Consequently, the outcomes of the investigation may differ after the calculations of the indicators for the other 50 towns are completed, and the suggested findings should be seen as a representation of the proposed framework. Furthermore, the valuation technique for assessing the likelihood of IMC may be enhanced by broadening the range of dimensions and indicators included within those dimensions. The specified indicators for waste and social aspects were picked based on data availability. Therefore, it would be advantageous to enhance the model by incorporating project-specific indicators. Finally, the study only included two municipalities to prioritise ecologically sustainable initiatives. Moreover, the assessment of weights and risks associated with participating in IMC might encompass other municipalities, provided that these municipalities possess the necessary knowledge to analyse the four dimensions.

Green bond issuing by municipalities is common in various countries but is a new concept in Lithuania. The algorithm for decision-making in IMC for the

issuance of green bonds outlines a precise framework for successfully issuing green bonds at the municipal level in the country. The framework addresses the requirement for towns to connect the issuance with local laws and regulations. The decision-making algorithm tackles the issue highlighted by Lackowska et al. (2019) with the prolonged decision-making process and duplication of personnel and resources in IMC. Thus, it is recommended to synchronise the responsibilities of the treasury, sustainability, IT, reporting, investor relations, and legislation within the framework (International Finance Corporation, 2020). Another factor in the decision-making procedure is reaching a consensus on the green bond tracking method. One example is the administration of funds through the specified account established in Poland and France (The World Bank, 2018). The decision-making algorithm considers the elements contributing to the success and obstacles faced while issuing green bonds in Lithuania (Bužinskė & Stankevičienė, 2023). Future research can focus on testing the proposed decision-making algorithm in the selected municipalities.

3.6. Conclusions of the Third Chapter

After the empirical approbation of the Green Finance Model for the Development of Zero-Waste Cities, the following conclusions have been drawn:

1. The research finding provides an original tool that allows for the modelling of possible financing options for counties considering waste management efforts. The model also sheds light on most of the alternative financing methods for smaller issuers and proposes the strategic solution of exercising the benefits of issuing green bonds by the smaller issuers by entering into IMC.
2. The first research stage covered the assessment of alternatives for municipalities regarding the financing of green projects with a focus on zero-waste. The assessment included five scenarios, namely financing through the company's funds, bank loan, the European Union's funds, green bond issuance, and mixed financing. The analysis demonstrates that green bond issuance may serve as an alternative to other financing types. Out of the ten counties polled, six found that financing with green bonds would be a beneficial option. However, the results suggest that such financing does not always offer financial or economic advantages and needs extra funding. To address the requirement for additional money and the accompanying expenses when issuing green bonds, municipalities need to develop innovative strategic solutions. One potential solution may be to engage municipalities in inter-municipal cooperation to facilitate the green bond issuance.

3. The second stage of the research involved the analysis of success factors, benefits and challenges of issuing green bonds in Lithuania. On the success factors side, the results suggested that the issuer's reputation, good credit rating and ESG score, appropriate criteria for determining the eligibility of green projects, prioritisation of financially stable projects and procedure for assessing and opting for projects are the key components of the successful issuance of the green bonds. The research identified the main benefits of green bond issuance: currency risk management, capacity to get substantial funding required for financing environmentally sustainable projects, provision of tangible and quantitative advantages, establishing and maintaining an effective bond market, and encouragement of participation of society. The research results suggest that the current challenges associated with green bond issuance are greenwashing, the overstatement of the green bond market's significance in relation to environmental preservation, the provision of limited financial and economic advantages, and the lack of universally accepted market standards.
4. The third stage of the research corresponded to the modelling of the valuation approach of the IMC possibility. The findings suggest that the two municipalities subject to the research portray similar patterns along with the Risk-Adjusted Municipal Condition Index not approaching 1, but rather being closer to 0, meaning that both municipalities would need to implement improvements to their performance in the first place before entering into IMC. The modelling of the valuation approach of the IMC possibility filled a gap in the existing scientific literature by guiding decision-making whether to engage in IMC or not.
5. The fourth stage of the research contributed to the modelling of the strategic decision-making algorithm for inter-municipal cooperation for green bond issuance. The algorithm has been formulated based on the 12-step process: alignment of the planned activities with laws, evaluation of own performance, Evaluation of IMC possibility, appointment of roles and responsibilities in IMC, credit rating, documentation, appointment of external resources, identification of green assets, ESG, marketing, execution and reporting.
6. One of the major limitations of the study is data availability; this constraint can be observed at each stage of the research. The limitation of the analysis of success factors, benefits and challenges of issuing green bonds in Lithuania is related to the range of selected study variables, as, due to the maturity of the worldwide green bond issuance, the applicable success factors, benefits and challenges related to the green bond issuance might change. Another limitation related to the second stage of the research is the selection and the number of experts participating in the survey. As the

issuance of green bonds in Lithuania is a relatively new concept, the study results might change in the future due to the above-mentioned maturity of the subject under analysis.

7. The Lithuanian government can promote green finance and green bonds by disseminating information to various groups, raising awareness about environmental issues, emphasising the importance of green finance in environmental conservation, elucidating green finance mechanisms, detailing the advantages of issuing green bonds, and educating on how to identify greenwashing.
8. The study revealed challenges related to the computation of the weighted average cost of capital (WACC) for the instances when the company or organisation, for which WACC is calculated, is not listed. The research included the proxy calculation for the evaluation of beta, but future research can be dedicated to the establishment of other possible proxies for the calculation of beta and address the challenges of the WACC calculation.
9. Future studies could involve testing a new assessment tool for zero-waste projects to confirm their implementation. The new method proposed by Stankevičienė and Bužinskė (2023), Green EVA, can potentially be replicated for the ten counties in Lithuania.
10. The future study may also focus on the testing of the green bond issuance algorithm on the selected municipalities to replicate the proposed steps in practice and propose potential improvement initiatives for the recommended algorithm. Currently, the green bond issuance process is described in theory, and the replication of all process steps would be a valuable exercise for developing the green finance model.

General Conclusions

1. The existing theoretical concepts on economic theories, economic concepts, and methods have been systemised to define their links with sustainable development aspects, such as sustainable finance, green finance and its instruments. This process indicated a synergy between these concepts. Subsequently, green finance can be a helpful tool in promoting sustainable development and growth. The results suggested that the financial markets can help facilitate the funding of projects that are beneficial to the environment. Results also showed a gap in academic research on green finance models and their practical application, considering the evolving nature of sustainable and green financing.
2. The research offered a scenario analysis for the valuation of various methods of green project financing, which encompassed five specific scenarios: financing using the company's finances, obtaining a bank loan, accessing funding from the European Union, issuing green bonds, and employing blended financing. The proposed scenario analysis may serve as a reference for policymakers, government and municipal officials, and enterprises when considering how to structure project financing solutions.
3. The research also developed a set of success factors, benefits and challenges of issuing green bonds. The findings of this research can be advantageous for prospective green bond issuers in Lithuania and in other

countries who are interested in incorporating the main factors that lead to success and avoiding potential difficulties associated with the issuance. In addition, the above-mentioned findings can serve as a tool for the promotion of green finance instruments, particularly green bonds, and for educating the general public, investors, and issuers about green bonds.

4. The research offered a set of indicators for the assessment of the possibility of inter-municipal cooperation. The set of these indicators incorporated the evaluation of financial, solvency, social, and environmental factors. The set of these indicators was integrated into the model for the valuation of the possibility of inter-municipal cooperation, considering the potential threats involved in the collaboration between municipalities. The set of indicators for the assessment of the possibility of inter-municipal cooperation and the valuation of the possibility of inter-municipal cooperation may serve as a beneficial tool for legislators aiming to foster collaboration between counties and municipalities to enhance the provision of services to the wider community.
5. The research developed an algorithm for green bond issuance by municipalities in inter-municipal cooperation for the sustainable development of zero-waste cities. Municipalities can get advantages from the suggested algorithm by following a well-defined pathway and explicit procedures that outline the roles and responsibilities of the stakeholders engaged in the process of issuing green bonds.
6. The empirical research targeted Lithuania's counties. The findings indicated that green bonds may potentially be an alternative to finance environmentally sustainable projects. Among the ten surveyed counties, six correspond to favourable financing through green bonds. Nevertheless, the findings indicate that this type of financing may not consistently provide financial or economic benefits and requires further money. Based on these findings, the inter-municipal cooperation possibility has been assessed based on the set of indicators for the assessment of the inter-municipal cooperation possibility and its valuation approach for Vilnius and Tauragė counties. Both counties are expected to improve their performance before engaging in cooperation. The research identified six factors for the successful issuance of green bonds, five benefits, and four main challenges. The research results were incorporated into the green bond issuance algorithm to form a 12-step procedure.

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

Papers in the Reviewed Scientific Journals

Bužinskė, J., & Stankevičienė, J. (2023). Analysis of success factors, benefits, and challenges of issuing green bonds in Lithuania. *Economies*, *11*(5), 143. https://doi.org/10.3390/economies11050143

Bužinskė, J., & Stankevičienė, J. (2023). Decision-making algorithm for the issuance of the green bonds by municipalities in inter-municipal cooperation in Lithuania. *Economies*, *11*(12), 287. https://doi.org/10.3390/economies11120287

Papers in Other Editions

Stankevičienė, J., & Bužinskė, J. (2023) Green EVA as a tool for the determination of the Green Economic Value Added of the environmentally-sustainable projects. In Business transformation in uncertain global environments: 16th annual conference of the EuroMed Academy of Business. https://emrbi.org/wp-content/uploads/2024/03/euromed2023-book-of-proceedings-2023-10-26_compressed.pdf

Stankevičienė, J., & Bužinskė, J. (2021). Trends of municipal waste flows, composition, treatment in Lithuania and its regions. In International Scientific Conference "Contemporary Issues in Business, Management and Economics Engineering 2021" . https://doi.org/10.3846/cibmee.2021.599.

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Summary in Lithuanian

Įvadas

Problemos formulavimas

XXI amžių žmonija pasitiko su neįtikėtinais inžinerijos pasiekimais, inovacijomis ir technologine pažanga. Šis technologinis proveržis daro įtaką mus supančiai aplinkai, kuriai gresia degradacija, todėl žmonijos gyvenamoji aplinka patiria sunkumų.

Palyginti su praėjusiais dviem dešimtmečiais, su klimatu susijusių nelaimių dažnumas padidėjo beveik dvigubai (United Nations Office for Disaster Risk Reduction, 2021). Pasaulio ekonomikos forumas (World Economic Forum, 2021) pateikia pagrindinių pasaulinių rizikų stebėjimus pagal tikimybę ir poveikį. Kalbant apie tikimybės dimensiją, svarbu paminėti, kad aplinkosauginė rizika, pavyzdžiui, ekstremalios oro sąlygos, stichinės nelaimės ir klimato nepakankamumas, nuo 2014 m. patenka į didžiausių rizikų penketuką. Klimato kaitos poveikis jau yra akivaizdus – jį liudija stiprėjantys orų reiškiniai, tokie kaip karščio bangos, intensyvios liūtys, potvyniai ir sausros. Šie reiškiniai kelia didelį pavojų žmonių sveikatai, saugumui, gerovei, pragyvenimo šaltiniams, maisto ir vandens ištekliams, infrastruktūrai ir ekonomikos plėtrai (Steg, 2023). Mokslininkai bando įvertinti aplinkos pokyčių poveikį ekonomikai. Pavyzdžiui, Sachs et al. (2019) apskaičiavo, kad dėl visuotinio atšilimo gali būti patirta ekonominių nuostolių, kurie sudaro 5–20 % pasaulio BVP. Kiti aplinkos pokyčių poveikio ekonomikai pavyzdžiai aprašyti disertacijos 1.2 skyriuje. Galima daryti išvadą, kad didžiulė destrukcija ir padariniai, atsirandantys dėl katastrofiškų įvykių kintant klimatui, trukdytų pasiekti darnaus vystymosi tikslus (United Nations Office for Disaster Risk Reduction, 2021; Wen et al., 2023).

Viena iš pasaulinių aplinkosaugos problemų – atliekos. Šalies lygmeniu savivaldybės dažnai yra atsakingos už tvaraus ir veiksmingo atliekų tvarkymo organizavimą. Tačiau savivaldybės neretai susiduria su sunkumais skirstant lėšas atliekų tvarkymo projektams.

Mokslininkai (Liberati & Marinelli, 2021) nustatė, kad egzistuoja žaliųjų finansų spraga, kuri apibrėžia nepakankamus finansinius išteklius, skiriamus žaliosioms investicijoms, o tai trukdo ekonomikai pereiti prie ekologiškai tvaresnės struktūros. Taip pat, nepaisant to, kad mokslinėje literatūroje pateikiami skirtingi požiūriai į savivaldybių bendradarbiavimą, trūksta įrodymų apie savivaldybių bendradarbiavimą taikant žaliųjų finansų priemones. Minėtos spragos koreliuoja su tyrimo problema – tiek mokslinėje literatūroje, tiek praktikoje trūksta bendradarbiaujančioms savivaldybėms taikytino efektyvaus žaliųjų finansų modelio, skirto aplinką tausojantiems ir žaliesiems projektams, susijusiems su komunalinių atliekų mažinimu, orientuojantis į „nulinių atliekų“ principus, finansuoti.

Disertacijos aktualumas

Daugelis mokslininkų prognozuoja, kad komunalinių atliekų kiekis pasaulyje tik didės (Kaza et al., 2018). Komunalinės atliekos sudaro apie 10 % visų ES susidarančių atliekų (Europos Komisija, 2023), tačiau jos yra vienas iš sunkiausiai tvarkomų atliekų srautų dėl mišrios sudėties, didelio skaičiaus šios rūšies atliekų teršėjų ir atsakomybės už šio atliekų srauto tvarkymą fragmentiškumo. Didelę komunalinių atliekų dalį sudaro pakuočių atliekos, turinčios didelį apykaitos potencialą. Neseniai paskelbta ataskaita parodė, kad Lietuva nevykdo (1) atliekų perdirbimo ir paruošimo pakartotiniam naudojimui ir (2) pakuočių perdirbimo tikslų (Europos Komisija, 2023). Šie rezultatai reiškia, kad, neįdiegus papildomų priemonių, Lietuvai gresia pavojus nepasiekti 2030 m. tikslo – 60 proc. komunalinių atliekų paruošti pakartotiniam naudojimui ir perdirbimui.

Tyrimo objektas

Žaliųjų finansų modelis, skirtas finansuoti aplinką tausojančius ir žaliuosius projektus, tvariai miestų be atliekų plėtrai.

Disertacijos tikslas

Disertacijos tikslas – sukurti ir empiriškai išbandyti žaliųjų finansų modelį, kurį taikant būtų priimami racionalūs ekonominiai sprendimai, skirti tvariai miestų be atliekų plėtrai.

Disertacijos uždaviniai

Disertacijos tikslui pasiekti, buvo iškelti šie uždaviniai:

1. Išanalizuoti mokslinius literatūros šaltinius, susijusius su žaliųjų finansų koncepcija bei komunalinėmis atliekomis siekiant išnagrinėti žaliųjų finansų taikymą komunalinių atliekų tvarkymo kontekste ir apibrėžti teorinę disertacijos struktūrą.
2. Sukurti ir metodologiškai pagrįsti žaliųjų finansų modelį, kuris leistų savivaldybėms išnaudoti žaliųjų finansų potencialą finansuojant „nulinių atliekų“ projektus, skirtus tvariai miestų be atliekų plėtrai.
3. Nustatyti ir įvertinti žaliųjų obligacijų emisijos sėkmės veiksnius, naudą ir iššūkius.

4. Išbandyti pasiūlytą savivaldybių bendradarbiavimo galimybės vertinimo modelį ir parengti pasiūlymus dėl tolesnės šio modelio plėtros.
5. Sukurti žaliųjų obligacijų išleidimo, savivaldybėms bendradarbiaujant tarpusavyje, algoritmą, skirtą finansuoti savivaldybių atliekų mažinimo ir (ar) atliekų kontrolės projektus.

Tyrimų metodika

Tyrimo objektui tirti buvo pasirinkti šie tyrimo metodai:

1. Sisteminė ir mokslinės literatūros analizė bei interpretavimo ir konceptualizavimo metodai naudojami žaliosios ekonomikos ir žaliųjų finansų sąvokoms tirti.
2. Prognozavimo metodai ir eksponentinis išlyginimas, skirtas atliekų tendencijoms Lietuvos apskrityse prognozuoti, bei atliekų tendencijų prognozių patikimumo statistinė analizė.
3. Ekspertų interviu buvo pasirinkti siekiant surinkti kokybinius vertinimus, susijusius su žaliųjų obligacijų emisija ir savivaldybių bendradarbiavimo galimybe.
4. Daugiakriterinis sprendimų priėmimo metodas, analitinės hierarchijos procesas, skirtas ekspertų apklausai analizuoti.

Darbo mokslinis naujumas

Žaliųjų finansų modelio teorinio ir empirinio tyrimo mokslinis naujumas:

1. Sukurtas žaliųjų finansų modelis, skirtas tvariai miestų be atliekų plėtrai. Jis apima žaliųjų obligacijų išleidimo sėkmės veiksnių analizę, savivaldybių bendradarbiavimo vertinimo rodiklių rinkinį ir žaliųjų obligacijų išleidimo algoritmą.
2. Sukurtas žaliųjų obligacijų išleidimo sėkmės, naudos ir iššūkių rodiklių rinkinys. Jis leidžia pritaikyti žaliųjų obligacijų išleidimo algoritmą.
3. Sukurtas savivaldybių bendradarbiavimo vertinimo rodiklių rinkinys. Šie rodikliai padėjo pagrindą siūlomam integruotam modeliui – pagal riziką pakoreguotam savivaldybių būklės indeksui, leidžiančiam įvertinti savivaldybių bendradarbiavimo galimybes, remiantis finansiniu, mokumo, socialiniu ir aplinkosauginiu vertinimu. Modelyje atsižvelgiama į galimą riziką, susijusią su savivaldybių bendradarbiavimu.

Darbo rezultatų praktinė reikšmė

Tyrime pateikiami pagrindiniai sėkmingos žaliųjų obligacijų emisijos veiksniai kartu su jos nauda ir bendrais iššūkiais. Šio tyrimo rezultatai gali būti naudingi potencialiems žaliųjų obligacijų emitentams, politikos formuotojams, norintiems populiarinti žaliąsias finansines priemones, pat gali šviestimo tikslais apie ekologiškas finansines priemones ir jų taikymo galimybes.

Siūlomas savivaldybių bendradarbiavimo galimybių vertinimo metodas yra vertinimo įrankis, padedantis savivaldybėms, svarstančioms galimybę suvienyti jėgas siekiant mažinti komunalinių atliekų kiekį. Siūlomas žaliųjų obligacijų išleidimo algoritmas gali pasitarnauti kaip aiškus kelrodis žaliųjų obliagcijų išleidimo procese dalyvaujančioms šalims.

Ginamieji teiginiai

1. Žaliosios finansinės priemonės – žaliosios obligacijos – gali būti alternatyvus finansavimo būdas, skirtas aplinkosaugos požiūriu tvariems projektams finansuoti. Toks finansavimas dažnai neduoda finansinės ir (arba) ekonominės naudos ir reikalauja papildomo finansavimo. Šios problemos gali būti įveiktos savivaldybėms bendradarbiaujant tarpusavyje.
2. Žaliųjų finansų modelis gali būti taikomas savivaldybių siekiant tvarios miestų be atliekų plėtros.
3. Siekiant sėkmingo žaliųjų obligacijų emitentų bendradarbiavimo, reikia įvertinti bendradarbiavimo galimybes, atsižvelgiant į perspektyvinius rezultatus, kurie grindžiami susijungiančio emitento finansinės, mokumo, socialinės ir aplinkosauginės veiklos vertinimu.

Darbo rezultatų aprobavimas

Disertacijos tyrimų rezultatai buvo skleisti penkiose publikacijose recenzuojamuose mokslo leidiniuose: 2 - tarptautiniame recenzuojamame mokslo žurnale, įtrauktame į Scopus duomenų bazę (Bužinskė & Stankevičienė, 2023, Bužinskė & Stankevičienė, 2023), ir 3 – tarptautinių konferencijų pranešimuose (Stankevičienė & Bužinskė, 2023; Stankevičienė & Bužinskė, 2021; Bužinskė & Stankevičienė, 2021). Autorė skaitė tris pranešimus trijose mokslinėse konferencijose:

1. Tarptautinė mokslinė konferencija „Šiuolaikinės verslo, vadybos ir ekonomikos inžinerijos aktualijos 2021“, 2021 m., Vilnius, Lietuva.
2. Tarptautinis mokslinis forumas „Šiuolaikinės ekonomikos, technologijų ir švietimo tendencijos“, 2021 m., Tbilisis, Gruzija.
3. Verslo transformacija neapibrėžtoje globalioje aplinkoje: 16-oji metinė EuroMed verslo akademijos konferencija, 2023 m., Vilnius, Lietuva.

Doktorantūros studijų metu įvyko vienas mokslinis vizitas:

1. Drezdeno technikos universitetas, Atliekų tvarkymo ir žiedinės ekonomikos institutas, Vokietija, 2021 m. rugsėjis – 2022 m. gegužė.

Autorė taip pat skaitė keturis pranešimus doktorantūros seminaruose Vilniaus Gedimino technikos universitete, vieną pranešimą Vokietijos federalinio aplinkos apsaugos fondo seminare, Vokietijoje, ir du pranešimus Drezdeno Technikos universitete, Atliekų tvarkymo ir žiedinės ekonomikos institute, Vokietijoje, seminaruose.

Disertacijos struktūra

Disertaciją sudaro įvadas; trys skyriai su atitinkamomis išvadomis; bendrosios išvados; literatūra; autoriaus publikacijų sąrašas; disertacijos santrauka lietuvių kalba. Bendra disertacijos apimtis yra 163 puslapiai, disertacijoje pateikta 18 paveikslų, 45 lentelės, 48 sunumeruotos formulės ir 278 literatūros šaltiniai.

1. Žaliųjų finansų koncepcijos teorinė analizė

Klimato kaitos ir aplinkosaugos iššūkių problemos paskatino ekonomikos teorijų, politikos, finansavimo metodų ir aplinkosaugos vertinimo bei valdymo metodų ekspertų bendradarbiavimą. Šiuo bendradarbiavimu siekiama aplinkosauginės, ekonominės ir socialinės naudos, remiant tvarumo darbotvarkę (1.2 pav.). Dvi su klimato sritimi susijusios ekonomikos teorijos yra aplinkos ekonomika ir ekologinė ekonomika. Aplinkosaugos ekonomikoje ekonominės idėjos taikomos sprendžiant aplinkosaugos ir gamtos išteklių problemas, o ekologinė ekonomika nagrinėja ekonominės veiklos ir biologinių sistemų, apimančių gyvybę, sąveiką (Harris ir Roach, 2021).

Mokslininkai (D'Amato et al., 2017, 2019) analizavo žaliosios ekonomikos, bioekonomikos ir žiedinės ekonomikos skirtumus bei nustatė šių sričių sąsajas. Šiame kontekste žiedinės ekonomikos sąvoka susijusi su nuolatiniu ir cikliniu gamybos procesu. Kita vertus, bioekonomikoje akcentuojamas biologinių pakaitalų naudojimas gamybos sąnaudoms ir produktams. Žalioji ekonomika taip pat apima sprendimų įgyvendinimą atsižvelgiant į gamtą. Pagrindinė bioekonomikos sudedamoji dalis yra biotechnologijų pažanga (Birner, 2018). Bioekonomikos ir žiedinės ekonomikos darna skatina pramonės simbiozę. Be to, žaliosios ekonomikos ir žiedinės ekonomikos koreliacija grindžiama efektyviu išteklių naudojimu. Žaliosios ekonomikos ir bioekonomikos sąvokos apima platesnę sritį nei žiedinės ekonomikos sąvokos (Birner, 2018). Pasak mokslininkų (Shachi et al., 2021), ryšys tarp bioekonomikos ir žiedinės ekonomikos pasireiškia bendru tikslu – tvarkyti atliekas ir skatinti pakartotinį išteklių naudojimą.

Acar ir Yeldan (2019) pažymėjo, kad žaliosios ekonomikos sąvoka atsirado 1989 m., tačiau didelio dėmesio ji sulaukė tik po 2008 m. krizės, kuri paskatino ieškoti alternatyvių ekonomikos augimo būdų. Žalioji ekonomika laikoma priemone tvaraus vystymosi problemoms spręsti. Ji siūlo įvairią veiklą kaip kompromisą siekiant tvaraus vystymosi tikslų (Merino-Saum et al., 2018). Žaliosios ekonomikos ir darnaus vystymosi tikslų (DVT) ryšį nustatė Žaliosios ekonomikos veiksmų partnerystė (angl. Partnership for Action on Green Economy (PAGE)). Žaliosios ekonomikos pažangai įvertinti PAGE naudoja rodiklių rinkinį, kuris vėliau susiejamas su atitinkamais DVT (Merino-Saum et al., 2018; PAGE, 2017). Žalioji ekonomika palengvina ekonomikos pokyčius, didindama informuotumą apie aplinkosaugos problemas, gebėjimą prisitaikyti prie klimato kaitos ir atsparumą (Cai & Guo, 2021). Žalioji ekonomika atlieka svarbų vaidmenį švelninant ir kontroliuojant aplinkosaugos problemas ir kartu didinant socialinę gerovę (Acar & Yeldan, 2019). Žaliosios ekonomikos sąvoka nustato ryšį tarp finansinės aprėpties ir žaliojo finansavimo principų. Manoma, kad abu šie principai prisideda prie žaliojo ir integracinio augimo plėtros. Finansinė aprėptis palengvina informacijos ir sandorių sąnaudų skirtumų mažinimą, taigi skatina veiksmingą išteklių paskirstymą ir naudojimą (Wang et al., 2022). Pagrindinis žaliosios ekonomikos tikslas – tuo pat metu mažinti klimato kaitą ir švelninti pavojus aplinkai, kartu didinant visuomenės gerovę. Žalioji ekonomika kartu su žaliaisiais finansais prisideda prie darnaus vystymosi, nes padeda spręsti dabartinius ir būsimus sunkumus (Yang et al., 2022).

Metodai, padedantys taikyti aplinkosaugos ir ekologijos ekonomiką, apima išteklių naudojimo efektyvumą, perdirbimą, pakartotinį naudojimą, atkūrimą ir žaliosios infrastruktūros plėtrą. Bendros vertinimo priemonės, taikomos taikant aplinkosaugos ir ekologijos ekonomiką, yra sąnaudų ir naudos analizė (SNA), gyvavimo ciklo vertinimas (GCV),

gyvavimo ciklo sąnaudų analizė (GCSA), medžiagų srautų analizė (MSA), stochastinis ribinis metodas (SRM), socialinis gyvavimo ciklo vertinimas (SGCV).

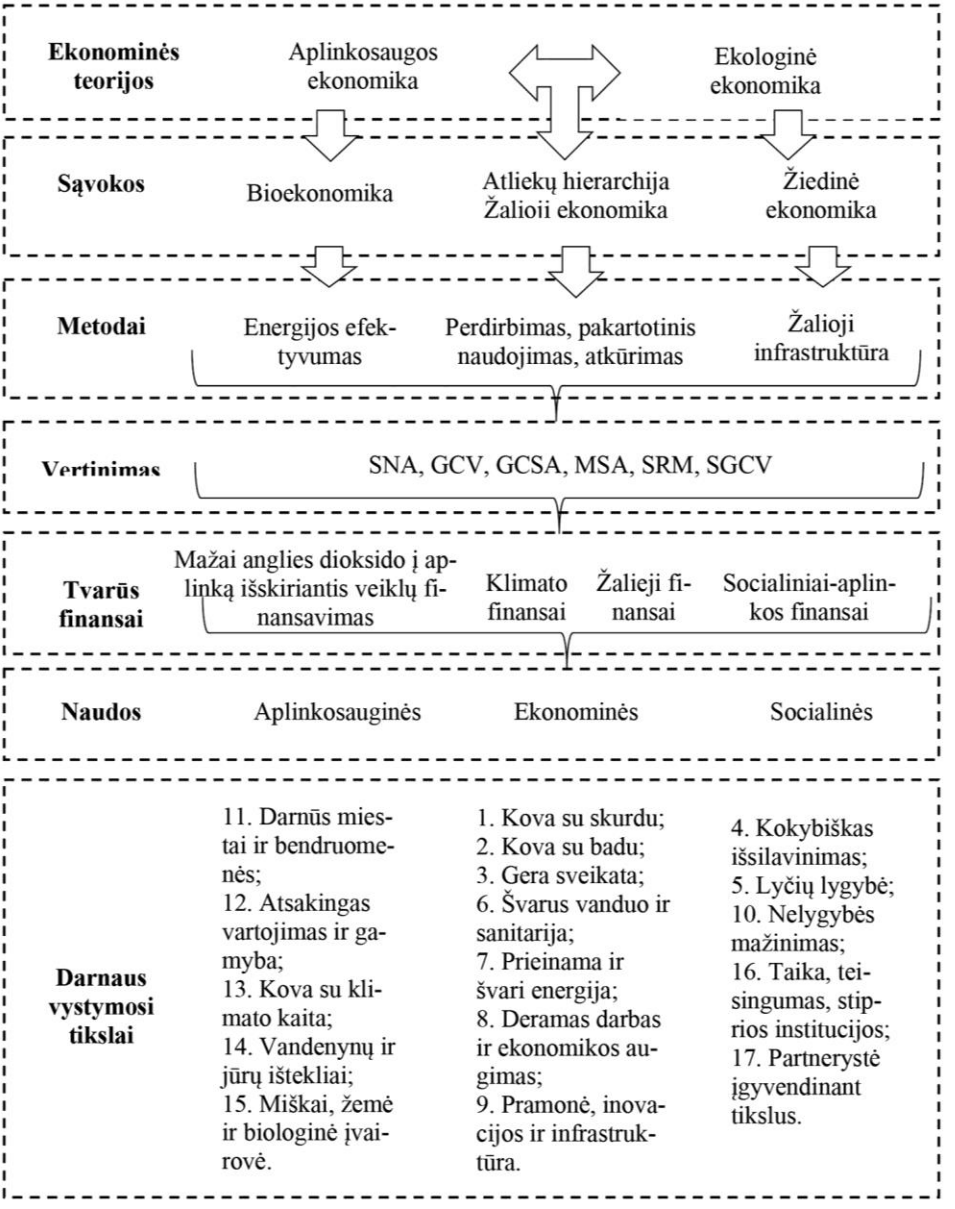
Migliorelli (2021 m.) apžvelgė tvarių finansų sistemą, nagrinėdamas jos *mikro-*, *mezo-* ir *makro-* aspektus. Mikrolygmeniu tvarių finansų sistema apima tvarių prekių ir paslaugų kategorizavimą ir nustato jų veiklos gaires. Mezolygmeniu tvarių finansų sistema apima visos pramonės standartų nustatymą. Vyraujančios normos apima socialiai atsakingą investavimą (SRI) ir investavimą į aplinką, socialinę sritį ir valdymą (ESG), taip pat poveikio finansavimą ir investavimą.

Tvarių finansų sistemos makrolygmuo apima platesnį tvarumo politikos kūrimą ir įgyvendinimą. Šis lygmuo apima finansinių sprendimų ir darnaus vystymosi tikslų (DVT), Paryžiaus susitarimo, atsakingos bankininkystės bei ekologijos ir klimato kaitos finansavimo integraciją.

Tvarūs finansai – tai visapusiškas požiūris, apimantis įvairias finansavimo strategijas, kuriomis siekiama atsižvelgti į aplinkos, socialinius ir valdymo veiksnius, kartu skatinant ekonominės vertės kūrimą (Sachs et al., 2019). Finansavimo metodus, specialiai sukurtus darniam vystymuisi skatinti, galima suskirstyti į penkis atskirus tipus (Kahlenborn et al., 2017; Migliorelli & Dessertine, 2019; Migliorelli, 2021). Mažai anglies dioksido į aplinką išskiriančių technologijų finansavimas padeda mažinti klimato kaitą. Mažo anglies dioksido kiekio finansavimas skirtas finansuoti iniciatyvoms, kuriomis siekiama mažinti šiltnamio efektą sukeliančių dujų (ŠESD) išmetimą (Sachs et al., 2019). Klimato kaitos finansavimas pirmiausia susijęs su pastangų prisitaikyti prie klimato kaitos parama. Klimato kaitos finansavimu siekiama skirti finansinių išteklių programoms, kurios konkrečiai skirtos klimato kaitai švelninti ir prie jos prisitaikyti, taip skatinant perėjimą prie dekarbonizuotos ekonomikos (Sachs et al., 2019). Klimato finansai pirmiausia susiję su aplinkos ir ekologijos išsaugojimu. Tai reiškia, kad projektams, kurie gali kelti grėsmę aplinkai, neskiriama jokia finansinė parama. Šiuo atveju aplinkosaugos problemos suvokiamos kaip finansinė rizika.

Pagrindiniai aplinkosauginiai privalumai apima klimato kaitos poveikio mažinimą, biologinės įvairovės valdymą ir išteklių naudojimo optimizavimą. Ekonominė nauda apima didesnę ekonominę plėtrą ir didesnį inovacijų diegimą. Socialinė nauda apima sveikatos sutrikimų, susijusių su nepalankiomis aplinkos sąlygomis, mažėjimą, geresnes gyvenimo sąlygas ir didesnes užimtumo galimybes. Aplinkos, ekonominė ir socialinė nauda gali būti tiesiogiai susieta su atitinkamomis darnaus vystymosi tikslų (DVT) kategorijomis.

Remiantis S1.1 pav. pateikta schema, galima teigti, kad viena iš tvaraus finansavimo sudedamųjų dalių yra žalieji finansai. Žaliųjų finansų priemonės yra glaudžiai susijusios su finansų rinkomis, kur finansų rinkos atlieka lemiamą vaidmenį finansuojant siektinus vystymosi tikslus (Siracusa, 2021). Finansų rinkos yra kaip informacijos šaltinis politikos formuotojams, kad jie galėtų priimti pagrįstus ekonominius ir valdymo sprendimus.



S1.1 pav. Ryšys tarp ekonomikos teorijų ir koncepcijų, tvaraus finansavimo mechanizmų ir darnaus vystymosi tikslų (parengta autorės, remiantis Birner (2018), D'Amato et al. (2017, 2019), D'Amato & Korhonen (2021), Khoshnava et al. (2019), Loiseau et al. (2016)

Žalieji finansai, gerai žinomas būdas tvariai plėtrai skatinti, smarkiai išpopuliarėjo pasaulyje ir sulaukia vis didesnio dėmesio (Bai & Lin, 2024). Nors žaliųjų finansų sektorius smarkiai išsiplėtė, tai vis dar gana naujas terminas, neturintis visuotinai priimto apibrėžimo (Lazaro et al., 2023). Nors yra daug terminų ir reikšmių, daugelis siūlomų žaliųjų finansų apibrėžčių apibūdina įvairias finansines priemones ir programas, kuriomis siekiama remti darnų vystymąsi ir kurios apima tiek finansinius, tiek nefinansinius subjektus (Maria et al., 2023).

Daugelis autorių (Alsmadi et al., 2023; Cheong et al., 2020; Ehlers & Packer, 2017; Fatica et al., 2019; Gilchrist et al., 2021; Inderst et al., 2012; Löffler et al., 2021; Migliorelli & Dessertine, 2019; Sangiorgi & Schopohl, 2023; Tripathy et al., 2020; Ye & Rasoulinezhad, 2023) pripažįsta, kad žaliosios obligacijos yra fiksuoto pajamingumo finansinės priemonės, naudojamos siekiant gauti lėšų aplinkosaugos projektams. Žaliosios obligacijos naudojamos aplinką tausojančioms iniciatyvoms, kuriomis siekiama tvarios žaliosios ekonomikos tikslų, finansuoti (Adekoya et al., 2021). Žaliųjų obligacijų rinkos tikslas – gauti finansavimą projektams, kurie atitinka aplinkosaugos (E), socialinius (S) ir valdymo (G) standartus (Ribeiro, 2023). Žaliosios obligacijos naudojamos reikalavimus atitinkantiems projektams, kurie yra specialiai sukurti siekiant klimato kaitos švelninimo ir prisitaikymo prie klimato kaitos tikslų, taip pat kitų aplinkosaugos tikslų, finansuoti arba refinansuoti (Organisation for Economic Cooperation and Development, 2023). Žaliosios obligacijos yra esminės priemonės finansuojant perėjimą prie mažo anglies dioksido kiekio technologijų ekonomikos ir skatinant tvarų vystymąsi (Cheng et al., 2024). Žaliųjų obligacijų rinka smarkiai išaugo: nuo 37 mlrd. dolerių 2014 m. iki 487,1 mlrd. dolerių 2022 m., o iki 2030 m. prognozuojamas augimas iki 914,4 mlrd. dolerių (Cheng et al., 2024).

2. Žaliųjų finansų modelio, skirto tvariai miestų be atliekų plėtrai, formulavimo metodika

Žaliųjų finansų modelis, skirtas miestų be atliekų plėtrai, grindžiamas S2.1 pav. pavaizduotu keturių etapų procesu. Pirmasis žaliųjų finansų modelio, skirto miestų be atliekų plėtrai, etapas grindžiamas žaliųjų projektų finansavimo galimybių modeliavimu. Šio etapo tikslas – išanalizuoti galimus alternatyvius žaliųjų projektų finansavimo būdus, daugiausia dėmesio skiriant „nulinėms atliekoms“. Analizei taikomi šie metodai: grynoji dabartinė vertė, vidinė grąžos norma, naudos ir sąnaudų santykio analizė, žaliojo kapitalo vidutinė svertinė kaina ir žaliojo progreso apskaičiavimas.

Antrasis tyrimo etapas skirtas žaliųjų obligacijų emisijos Lietuvoje sėkmės veiksniams, naudai ir iššūkiams analizuoti. Šio etapo analizė grindžiama ekspertų interviu, o vėliau gautų atsakymų analizė atliekama taikant analitinį hierarchijos procesą.

Trečiasis žaliųjų finansų modelio, skirto miestų be atliekų plėtrai, etapas skirtas savivaldybių bendradarbiavimo galimybėms, siekiant išleisti žaliųjų obligacijų emisiją, skirtą žaliesiems projektams finansuoti, daugiausia dėmesio skiriant „nulinių atliekų“ principams, įvertinti. Trečiajame etape siūlomas naujas vertinimo metodas, skirtas savivaldybių bendradarbiavimo galimybėms, siekiant efektyvaus bendradarbiavimo tarp mažesnių emitentų, pavyzdžiui, mažesnių Lietuvos savivaldybių, įvertinti. Siūlomas vertinimo metodas grindžiamas bendradarbiaujančių savivaldybių finansinės, mokumo,

socialinės ir aplinkosauginės būklės vertinimu bei finansinės būklės indekso ir pagal riziką pakoreguoto savivaldybės būklės indekso vertinimu.

ETAPAS	I ETAPAS	II ETAPAS	III ETAPAS	IV ETAPAS
	Žaliųjų projektų finansavimo galimybių modeliavimas	**Žaliųjų obligacijų išleidimo sėkmės veiksnių, naudos ir iššūkių nustatymas**	**Savivaldybių bendradarbiavimo galimybių įvertinimas**	**Savivaldybių žaliųjų obligacijų emisijos modeliavimo algoritmas**
TIKSLAS	Pademonstruoti žaliųjų projektų finansavimo alternatyvas, orientuotas į tvarią miestų be atliekų plėtrą	Išskirti sėkmės veiksnius, naudą ir iššūkius, susijusius su dabartinėmis žaliųjų obligacijų emisijomis	Suformuluoti keturmatį savivaldybės veiklos vertinimo metodą	Apibrėžti žaliųjų obligacijų emisijos procesą, remiantis ankstesnių pakartotinių tyrimų etapų rezultatais.
METODAI	Žaliasis progresas; Žalioji VSKK; Kaštų–naudos analizė; Scenarijų analizė	Ekspertinė apklausa; Analitinės hierarchijos procesas	Ekspertinė apklausa; Finansiniai, mokumo, atliekų, socialiniai rodikliai; Pagal riziką pakoreguotas savivaldybių būklės indeksas	Rezultatų, gautų iš 2 ir 3 etapų, sinergija; Geriausia rinkos praktika, susijusi su vaidmenimis ir atsakomybėmis
REZULTATAI	Žaliosios obligacijos pripažįstamos kaip galimas žaliųjų projektų, orientuotų į „nulines atliekas“, finansavimo būdas	Sėkmingos žaliųjų obligacijų emisijos kriterijai	Įvertinta bendradarbiaujančių savivaldybių finansinė, mokumo, socialinė ir aplinkosaugos būklė	Suformuluotas savivaldybių žaliųjų obligacijų išleidimo procesas savivaldybėms bendradarbiaujant tarpusavyje, nustatyti savivaldybių vaidmenys ir atsakomybės
SVARBA	Siūloma žaliųjų projektų skirtingų finansavimo būdų scenarijų analizė	Sukurtas žaliųjų obligacijų emisijos sėkmės veiksnių, naudos ir iššūkių rinkinys	Nustatytas savivaldybių bendradarbiavimo galimybių vertinimo rodiklių rinkinys	Pasiūlytas žaliųjų obligacijų išleidimo procesas savivaldybėms, bendradarbiaujančioms tarpusavyje ir siekiančioms tvarios miestų be atliekų plėtros

S2.1 pav. Žaliųjų finansų modelio, skirto miestų be atliekų plėtrai, bendra apžvalga (parengta autorės)

Paskutinis tyrimo etapas skirtas žaliųjų obligacijų išleidimo algoritmui modeliuoti siekiant sėkmingai išleisti žaliųjų obligacijų emisiją. Šiame tyrimo etape apibendrinami ankstesnių tyrimų rezultatai, gauti iš tyrimo metodikos I, II ir III etapų, ir pasiūlomas

dvylikos žingsnių procesas, skirtas savivaldybių žaliųjų obligacijų emisijai, vykdomai bendradarbiaujant tarp savivaldybių.

Išsami visų keturių tyrimo etapų seka kartu su analizės procesų bei pritaikytais vertinimo metodais pateikiama S2.1 lentelėje. Išsamus formulių paaiškinimas pateiktas 2 skyriaus skirsniuose.

S2.1 lentelė. Žaliųjų finansų modelio, skirto miestų be atliekų plėtrai, etapų formavimas (parengta autorės)

Etapas	Proceso seka	Pritaikytas vertinimo metodas
I etapas	Duomenų rinkimas	Atliekų tvarkų centrų finansinėse ataskaitose pateikiamos informacijos apie atliekų tvarkymo projektus rinkimas
	Tyrimo prielaidų ir scenarijų rengimas	Penkių finansavimo scenarijų rengimas ir tyrimo prielaidų formulavimas
	Grynoji dabartinė vertė (GDV)	$NPV = CF_0 + \sum_{t=1}^{n} \frac{CF_n}{(1+r)^n}$
	Vidinė grąžos norma (VGN)	$0 = NPV = CF_0 + \sum_{t=1}^{n} \frac{CF_n}{(1+IRR)^n}$
	Ekonominė grynoji dabartinė vertė (EGDV)	$ENVP{=}PV(B){-}PV(C)$
	Ekonominė vidinė grąžos norma (EVGN)	$B_0 - C_0 + \frac{B_1 - C_1}{(1+ERR)} + \frac{B_2 - C_2}{(1+ERR)^2} + \cdots + \frac{B_T - C_T}{(1+ERR)^T} = 0$
	Naudos ir sąnaudų santykis	$B/C = \frac{PV(B)}{PV(C)}$
	Žaliasis progresas	$Žaliasis\ Progresas = \frac{WCEE_t - WCEE_{t-1}}{WCEE_{t-1}}$
	Žalioji vidutinė svertinė kapitalo kaina	$\left[\frac{E}{E+D}\right]K_e + \left[\frac{D}{E+D}\right]k_d(1-t_c)(1+GP) = WACC$
II etapas	Ekspertinė apklausa	Apklausos klausimų formulavimas bei ekspertinio vertinimo rezultatų rinkimas
	Analitinės hierarchijos metodo taikymas	Matricos sudarymas $C = [C_{ij}]_{nxn} \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{21} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix}$
		Tarpusavio verčių vertinimas $R = \left[\frac{1}{C_{ij}}\right]_{nxn} \begin{bmatrix} \frac{1}{C_{11}} & \frac{1}{C_{12}} & \frac{1}{C_{13}} \\ \frac{1}{C_{21}} & \frac{1}{C_{22}} & \frac{1}{C_{23}} \\ \frac{1}{C_{31}} & \frac{1}{C_{32}} & \frac{1}{C_{33}} \end{bmatrix}$

S2.1 lentelės pabaiga

Etapas	Proceso seka	Pritaikytas vertinimo metodas
		Normalizavimas $$X_{ij} = \frac{C_{ij}}{\sum_{i=1}^{n} C_{ij}} \begin{bmatrix} X_{11} & X_{12} & X_{13} \\ X_{21} & X_{22} & X_{23} \\ X_{31} & X_{32} & X_{33} \end{bmatrix}$$
		Kriterijų svorių nustatymas $$W_{ij} = \frac{\sum_{j=1}^{n} X_{ij}}{n} \begin{bmatrix} W_{11} \\ W_{12} \\ W_{13} \end{bmatrix}$$
		suderinamumo koeficientas $$CR = \frac{CI}{RI}$$
III etapas	Duomenų rinkimas	Atrinktų savivaldybių finansinių, aplinkosauginių ir socialinių duomenų rinkimas
	Ekspertinė apklausa	Apklausos klausimų formulavimas bei ekspertinio vertinimo rezultatų sisteminimas
	Finansinių, mokumo, socialinių ir aplinkosauginių sąlygų vertinimas	Vertinimas pritaikant metodus, skirtus finansiniams, mokumo, socialiniams ir aplinkosauginiams veiksniams apskaičiuoti
	Finansinės būklės indeksas	Atrinktų savivaldybių finansinės būklės indekso apskaičiavimas; Finansinės būklės indeksas = $w_1*DI_1+w_2*DI_2+\cdots+w_n*DI_n$
	Pagal riziką pakoreguotas savivaldybių būklės indeksas	Atrinktų savivaldybių pagal riziką pakoreguotas būklės indekso apskaičiavimas; Pagal riziką pakoreguotas savivaldybių būklės indeksas = $w_1*DI_1*R_1+w_2*DI_2*R_2+\cdots+w_n*DI_n*R_n$
IV etapas	Žaliųjų obligacijų išleidimo algoritmo formulavimas	Savivaldybių žaliųjų obligacijų išleidimo savivaldybėms bendradarbiaujant tarpusavyje algoritmo formulavimas remiantis ankstesniais tyrimo etapų rezultatas

Išsamus taikomų metodų paaiškinimas pateikiamas kituose antrojo skyriaus poskyriuose. Kiekviename poskyryje pateikiama išsami tyrimo metodika ir atitinkama kiekvieno taikyto metodo skaičiavimo seka.

3. Empirinis žaliųjų finansų modelio, skirto tvariai miestų be atliekų plėtrai, patvirtinimas

Pirmasis tyrimo etapas apėmė savivaldybių žaliųjų projektų finansavimo alternatyvų vertinimą, daugiausia dėmesio skiriant „nulinių atliekų“ projektams. Buvo vertinami penki scenarijai: finansavimas įmonės lėšomis, banko paskola, Europos Sąjungos lėšomis, žaliųjų obligacijų išleidimas ir mišrus finansavimas. Rezultatai rodo, kad iš 10 tirtų apskričių

6 pasižymi palankiomis finansavimo per žaliąsias obligacijas sąlygomis, tačiau ne visada šis finansavimo metodas yra finansiškai palankus.

Antrajame tyrimo etape buvo analizuojami žaliųjų obligacijų emisijos Lietuvoje sėkmės veiksniai, nauda ir iššūkiai. Rezultatai parodė sekančius sėkmės veiksnius: emitento reputacija, geras kredito reitingas ir ASV (ESG) balas, patikimi žaliųjų projektų tinkamumo kriterijai, finansiškai stabilių projektų prioretizavimas, projektų vertinimo ir atrankos tvarka. Tyrimo metu taip pat nustatyta, kad pagrindiniai žaliųjų obligacijų emisijos privalumai yra valiutos rizikos valdymas, gebėjimas gauti reikiamą finansavimą, reikalingą aplinkosaugos požiūriu tvariems projektams finansuoti, apčiuopiamos ir kiekybinės naudos suteikimas, veiksmingos obligacijų rinkos sukūrimas ir palaikymas, visuomenės dalyvavimo skatinimas. Tyrimo rezultatai parodė, kad dabartiniai su žaliųjų obligacijų emisija susiję iššūkiai yra „žaliųjų smegenų plovimas“, žaliųjų obligacijų rinkos reikšmės aplinkosaugai pervertinimas, ribotos finansinės ir ekonominės naudos teikimas, visuotinai priimtinų rinkos standartų nebuvimas.

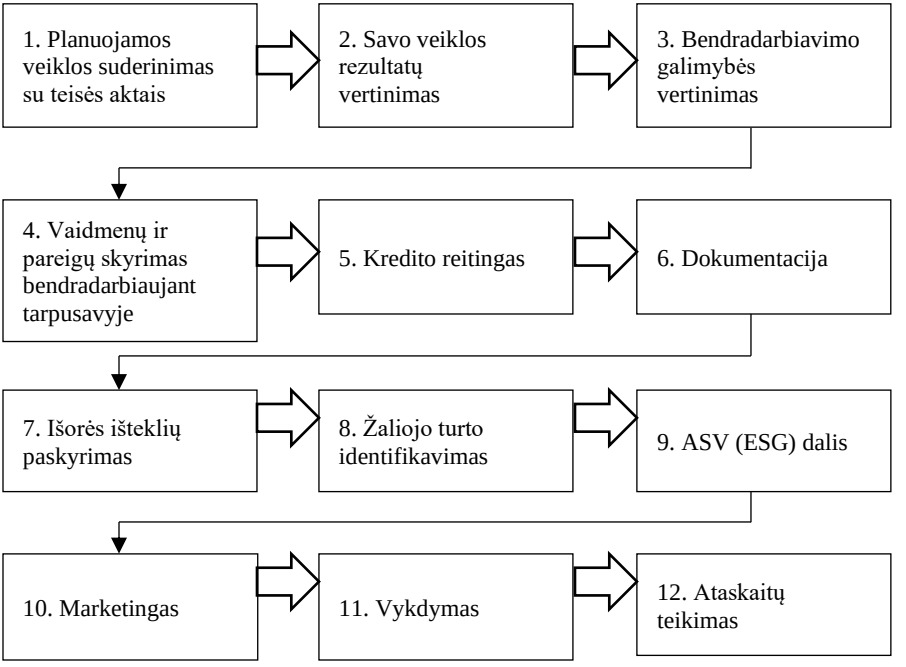
Trečiasis tyrimo etapas buvo skirtas savivaldybių bendradarbiavimo galimybių vertinimo metodui modeliuoti. Išvados rodo, kad abiejų tyrime dalyvavusių savivaldybių rodikliai yra panašūs, o pagal riziką pakoreguotas savivaldybės būklės indeksas nesiekia 1, bet yra artimesnis 0, o tai reiškia, kad abi savivaldybės, prieš pradėdamos bendradarbiauti tarp savivaldybių, pirmiausia turėtų pagerinti savo būklę.

Ketvirtasis tyrimo etapas padėjo modeliuoti žaliųjų obligacijų išleidimo algoritmą savivaldybėms bendradarbiaujant tarpusavyje išleidžiant žaliąsias obligacijas. Algoritmas buvo suformuluotas remiantis 12 žingsnių procesu (žiūrėti S.3.1 pav.). Išsamus kiekvieno etapo paaiškinimas, įskaitant esminius pasirinkimo momentus:

1. Planuodamos išleisti žaliųjų obligacijų emisiją, savivaldybės turi atsižvelgti į teisinius reikalavimus ir vietinius apribojimus. Pagrindiniai veiksniai, kuriuos reikia išnagrinėti, yra teisinis reikalavimas savivaldybėms išleisti obligacijas, kaip numatyta teisės aktuose, arba derybų planavimo dėl obligacijų išleidimo su atitinkamais valdžios subjektais tvarka.
2. Vėlesni veiksmai apima savo veiklos įvertinimą ir galimybės bendradarbiauti su kita savivaldybe apsvarstymą. Tai galima padaryti taikant šiame darbe pasiūlytą vertinimo metodą.
3. Kai vertinimo rezultatai teigiami ir miestai nusprendžia įsitraukti į bendradarbiavimą dėl žaliųjų obligacijų išleidimo, būtina sudaryti abipusį susitarimą dėl kiekvienos savivaldybės vaidmenų ir įsipareigojimų. Kitas svarstytinas aspektas – sutarimas dėl žaliųjų obligacijų stebėsenos metodikos. Kitas aspektas, į kurį reikia atkreipti dėmesį, yra sutarimas dėl asmenų, kurie bus atsakingi už žaliųjų obligacijų prospekto patvirtinimą.
4. Būtina nustatyti žaliąjį turtą arba „nulinių atliekų“ projektą, kuris bus finansuojamas iš pajamų, gautų iš žaliųjų obligacijų emisijos. Labai svarbu pažymėti, kad savivaldybės aplinkosauginio tvarumo vertinimas šiame etape nėra tinkamas rodiklis.
5. Būtina paskirti išorės suinteresuotąsias šalis, įskaitant banką emitentą, išorės auditorių, antrosios nuomonės teikėją ir reitingų agentūrą.
6. Reikia parengti reikiamus dokumentus, susijusius su žaliųjų obligacijų emisija. Galima paminėti žaliųjų obligacijų prospektą, išsamaus patikrinimo ataskaitą,

audituotas finansines ataskaitas kartu su jų paskelbimu ir sandorio dokumentaciją. Labai svarbu atkreipti dėmesį, kad žaliųjų obligacijų prospektas turi turėti atitinkamus Lietuvos finansų priežiūros institucijos ir pačių savivaldybių patvirtinimus.

7. Svarbus žaliųjų obligacijų emisijos etapas – kredito reitingo gavimas. Iš pradžių savivaldybė turi pasirinkti kredito reitingų agentūrą ir pateikti galutiniam kredito reitingui įvertinti reikalingą informaciją.
8. ESG komponentas apima žaliųjų obligacijų sistemos sukūrimą ir antrosios šalies nuomonės gavimą iš pasirinkto vertintojo.



S.3.1 pav. Savivaldybių žaliųjų obligacijų išleidimo algoritmas savivaldybėms bendradarbiaujant tarpusavyje (parengta autorės)

9. Rinkodara yra labai svarbus sėkmingos žaliųjų obligacijų emisijos etapas. Iš pradžių būtina surengti neviešą platinimą, skirtą tik pasirinktiems investuotojams, siekiant gauti jų nuomonę dėl žaliųjų obligacijų išleidimo. Todėl kruopščiai paruošiami ir vėliau rengiami pristatymai investuotojams.
10. Vykdymo etapas apima tokią veiklą, kaip kainų nustatymas ir galutinių žaliųjų obligacijų emisijos sąlygų parengimas. Šis etapas taip pat apima obligacijų pajamų paskirstymo ir paraiškos įtraukti į biržos prekybos sąrašus pateikimo grafiko nustatymą.

11. Ataskaitų teikimas yra baigiamasis žaliųjų obligacijų išleidimo procedūros etapas. Savivaldybėms svarbu sukurti lėšų panaudojimo stebėjimo ir ataskaitų teikimo tvarką.

Savivaldybės, atsiželdamos į savivaldybių žaliųjų obligacijų išleidimo algoritmo žingsnius, galės efektyviau planuoti resursus bei numatomas veiklas žaliųjų obligacijų iųleidimo procese.

Bendrosios išvados

1. Esamos teorinės koncepcijos apie ekonomikos teorijas, ekonomines sąvokas ir metodus buvo susistemintos, siekiant apibrėžti šių ekonomikos teorijų sąsajas su darnaus vystymosi aspektais, tokiais kaip darnūs finansai, žalieji finansai ir jų priemonės. Šis procesas parodė, kad tarp minėtų sąvokų egzistuoja sinergija, todėl žalieji finansai gali pasitarnauti skatinant tvarų vystymąsi ir augimą. Rezultatai parodė, kad finansų rinkos gali padėti palengvinti aplinkai naudingų projektų finansavimą. Rezultatai taip pat parodė, kad, atsižvelgiant į kintantį tvaraus ir ekologiško finansavimo pobūdį, egzistuoja žaliojo finansavimo modelių ir jų praktinio taikymo akademinių tyrimų spraga.
2. Tyrimo metu buvo pasiūlyta scenarijų analizė, skirta įvairiems žaliųjų projektų finansavimo būdams įvertinti, kuri apėmė penkis konkrečius scenarijus: finansavimas naudojant įmonės lėšas, banko paskolos gavimas, Europos Sąjungos finansavimas, žaliųjų obligacijų išleidimas ir mišrus finansavimas. Siūloma scenarijų analizė gali pasitarnauti kaip orientyras politikos formuotojams, vyriausybės ir savivaldybių pareigūnams bei įmonėms, svarstančioms, kaip struktūrizuoti projektų finansavimo sprendimus.
3. Atlikus disertacinį tyrimą taip pat parengtas žaliųjų obligacijų išleidimo sėkmės veiksnių, naudos ir iššūkių rinkinys. Šio tyrimo rezultatai gali būti naudingi būsimiems žaliųjų obligacijų emitentams Lietuvoje ir kitose šalyse, kurie suinteresuoti įtraukti pagrindinius sėkmę lemiančius veiksnius ir išvengti galimų su emisija susijusių sunkumų. Be to, minėtos išvados gali pasitarnauti kaip žaliųjų finansinių priemonių, ypač žaliųjų obligacijų, populiarinimo ir visuomenės, investuotojų bei emitentų švietimo apie žaliąsias obligacijas priemonė.
4. Tyrimas pasiūlė rodiklių rinkinį savivaldybių bendradarbiavimo galimybėms vertinti. Į šių rodiklių rinkinį įtrauktas finansinių, mokumo, socialinių ir aplinkosauginių veiksnių vertinimas. Šių rodiklių rinkinys buvo integruotas į savivaldybių bendradarbiavimo galimybės vertinimo modelį, atsižvelgiant į galimas grėsmes, susijusias su savivaldybių bendradarbiavimu. Savivaldybių bendradarbiavimo galimybių vertinimo rodiklių rinkinys kartu su savivaldybių bendradarbiavimo galimybių vertinimu gali būti naudinga priemonė įstatymų leidėjams, siekiantiems skatinti apskričių ir savivaldybių bendradarbiavimą, kad būtų pagerintas paslaugų teikimas platesnei bendruomenei.
5. Tyrimo metu buvo sukurtas savivaldybių žaliųjų obligacijų išleidimo algoritmas, skirtas padėti savivaldybėms bendradarbiauti tarpusavyje siekiant tvarios miestų be atliekų plėtros. Savivaldybės gali gauti naudos iš pasiūlyto algoritmo, jei vadovausis aiškiai apibrėžtu keliu ir aiškiomis procedūromis, kurios apibrėžia

žaliųjų obligacijų emisijos procese dalyvaujančių suinteresuotųjų šalių vaidmenis ir atsakomybę.

6. Atliktas Lietuvos apskričių empirinis tyrimas. Tyrimo rezultatai parodė, kad žaliosios obligacijos potencialiai galėtų tarnauti kaip alternatyvus tvarių projektų finansavimo būdas. Iš 10 tirtų apskričių 6 pasižymi palankiomis finansavimo per žaliąsias obligacijas sąlygomis. Vis dėlto išvados rodo, kad šis finansavimo būdas gali ne visada duoti finansinės ar ekonominės naudos ir reikalauja papildomų lėšų. Remiantis šiomis išvadomis, savivaldybių bendradarbiavimo galimybių vertinimo rodiklių rinkiniu ir jo vertinimo metodu, buvo įvertintos Vilniaus ir Tauragės apskričių, kuriose abiejose veiklos rezultatai iki bendradarbiavimo veiksmų turėtų būti pagerinti, tarpžinybinio bendradarbiavimo galimybės. Tyrimo metu nustatyti šeši sėkmingos žaliųjų obligacijų emisijos veiksniai, penki privalumai ir keturi pagrindiniai iššūkiai. Minėti tyrimo rezultatai buvo įtraukti į žaliųjų obligacijų emisijos algoritmą ir sudarė 12 žingsnių procedūrą.

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GREEN FINANCE MODEL FOR THE SUSTAINABLE DEVELOPMENT OF ZERO-WASTE CITIES

Doctoral Dissertation

Social Sciences,
Economics (S 004)

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ŽALIŲJŲ FINANSŲ MODELIS TVARIAI MIESTŲ BE ATLIEKŲ PLĖTRAI

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