

ENGINEERING AND MANAGEMENT OF GREEN INVESTMENT

55

Doctoral thesis – Summary

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by

Ec. Roxana Mihaela OARZĂ (SÎRBU)

PhD. Supervisor Prof. Anca DRĂGHICI

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The present PhD thesis is a scientific exploration of the green economy... an actual and relevant concept for our professional and social life, rightly considered essential for the future of the world economy. The adoption and implementation of the GREEN concept cannot be done beyond investment concerns, which requires careful analysis of technical, managerial, social, environmental and economic aspects, which is particularly necessary in the context of green initiatives supported by appropriate, local, regional or national projects linking economic development, biodiversity, ecosystem, climate change, health and population well-being in the medium and long term.

The United Nations, the international community in general, is concerned about identifying and applying long-term alternatives aimed at achieving targets, sustainable development objectives defined in 17 areas of interest. In fact, the aim of this initiative (already “popular” worldwide!) is to improve the quality of life on Earth, to eradicate as much as possible poverty and, above all, to mitigate the effects of climate warming in recent years caused by massive greenhouse gas emissions.

In order to make economic development a green, responsible transition to a new way of thinking and behavior, with multiple implications both at macroeconomic level (referring to government initiatives, national, regional, central public institutions etc.) and micro-economic (development and support of SMEs, large companies, non-governmental bodies, etc.). As a result, the joint effort of public and private actors can lead to economic growth based on the values and principles of sustainable development and exclude excessive use of resources, irresponsible consumption or environmental aggression.

In this context, the doctoral research associated with this thesis emerged, developed, and aimed to achieve a notional, conceptual and phenomenological “inventory” of interest in achieving an efficient and effective management of green investments. The results of the investigations, the studies carried out confirmed the need for a systemic vision, an interdisciplinary approach on green investment projects supported by the pro-sustainability paradigm, which is based on three dimensions: environment, social and economic.

For many decades Europe has enjoyed increased prosperity and well-being due to the intensive use of resources. But today it faces a double challenge: firstly, stimulating the growth needed to provide jobs and well-being for its citizens, as well as the challenge of turning this growth into sustainable growth, so as not to compromise the development of future generations. All these challenges intersect in an unfavorable societal environment, given the pandemic generated by the

SARS-CoV-2 coronavirus which makes sustainable development even more difficult. In order to face these challenges and turn them into opportunities, our economy will require a fundamental transformation in key areas such as: energy, industry, education, agriculture, fisheries, transport, but also in consumer behavior (European Commission, 2011).

In the XXI century, in the context of globalization and especially in the context of coronavirus SARS-COV-2, green investments, sustainable development, corporate social responsibility, the creation of a green economy and especially of a circular economy have become important topics, often addressed, both in the academic, scientific and political discourse, but especially in the way organizations operate. These concepts summarize the current problem of planetary limits (depletion of natural resources) and the quality of life of future generations. The development of the XXI century society can be based entirely on sustainability. “A sustainable society is a society that shapes its economic and social system so that natural resources and life support systems are maintained for as long as possible” (Dinga, 2004, 2009).

The PhD thesis entitled “*Engineering and Management of Green Investment*” addresses a current theme, according to national and European development strategies, is of general interest, both at micro and macroeconomic level, which can have serious repercussions on future generations if society does not understand the concept correctly and implements it as urgently as possible.

Given the context in which we live, the depletion of resources, but also the pandemic generated by the SARS-CoV-2 coronavirus, the challenge of moving towards a sustainable society is, more than ever, on the public agenda. The time to discuss an alternative development paradigm could not be timelier. For this reason, it is very important to deepen the debates about models of economic growth in the context of sustainability, the foundation of the decision on green, sustainable investment at organization level, encouraging and promoting local and global actions that can contribute to the development of today’s society without compromising the possibility of future generations to receive support from the natural environment, to live in a healthy environment and to breathe fresh air.

The general objective of the doctoral program was to conduct theoretical and applicative research based on the decision on green, sustainable and responsible investments in organizations. The approach adopted is of top-bottom type, i.e. from macro-, mezo to microeconomic levels in the field of sustainability management, with a focus on the process of investigating the modality of green investments and associated managerial decision, with reference to the process of hierarchy and selection of the project appropriate to a specific space and time context.

Methodological, theoretical and scientific support that supports the achievement of the general objective of the doctoral thesis is the use of public data converging on research, provided by national and international databases and the study, application and validation of methods and models of hierarchy of green investment projects.

The paper is structured into 6 important chapters that combine bibliographic research with theoretical and applicative research, preceded by the introduction in which the motivation and importance of the research theme and established objectives are presented. The last chapter presents the conclusions of the research, personal contributions and future research directions, follows the bibliographical list (285 titles consulted and cited accordingly, 10 websites) and 3 Annexes. The doctoral thesis is carried out on 198 pages; support for rendering the research content are the 57 graphical representations and 33 tables.

As regards the **operational objectives** of the research, they are pursued through the research described in each chapter of the doctoral thesis, as follows:

- 1. Objective 1** – Bibliographic research and presenting the results for defining the basic conceptual framework, relative to the theme addressed in the doctoral thesis. The concepts to be clarified are: sustainable development, green investment and sustainable organisation (objective targeted and achieved through the research presented under Chapter 1);
- 2. Objective 2** – Bibliographic research and presenting the results for defining the conceptual

framework related to the *foundation of green investment decisions at microeconomic level*, the central theme of the doctoral thesis. The concepts discussed and clarified are: green, socially responsible, sustainable investments and their management, processes of decision-making management, organizational implications of the decision-making process on green investments and panoramic aspects relevant to creating sustainable competitive advantage within the organization. This objective is combined with the sub-objective of making an inventory of potential methods and means to substantiate the green investment decision;

3. **Objective 3** — Draft secondary data-based research on green investment and sustainable development at European, national and local levels to define the general framework in which sustainable organisations develop and identify how sustainable organizations can contribute to achieving sustainable development indicators at regional, national and European level. The concepts discussed and clarified are: linking green investment, eco-innovation and sustainable development; eco-innovation index at European, national and Western level; environmental expenditure and green investment to improve the quality of the environment; green investments in the light of green certificates; but also to measure the degree of sustainable development of organisations in Romania (CSR Barometer and Green Business Index). The research carried out is of great scope and may be future subjects of applied research;
4. **Objective 4** — Experimental research on aspects of green investment processes at macroeconomic level. Research concerns two components: carbon emissions, energy consumption and management of investments in renewable energy; and the ecological behavior of Romanian organisations regarding the use of information and communication technology;
5. **Objective 5** — Exploitation of methods and methodologies to substantiate the decision in the implementation of green investment projects (previously invented in Chapter 2) by conducting experimental research at the level of some organizations, in two cases: (1) use the DEA method to generate efficiency of operating and maintenance costs for green buildings and (2) green eco-innovation or innovation in SMEs through the design, testing and validation of a methodological framework based on the integration of BWM and Fuzzy-TOPSIS methods.

The achievement of the research objectives is demonstrated by the content of each chapter of the thesis.

In Chapter 1, called ***“Definition of the Conceptual Framework. Researches on the specialised referential”***, in the 23 pages are presented the results of bibliographic research for the panorama of concepts around which theoretical and applicative research is carried out: sustainable development and green investments. The scientific approach on bibliographic reference is structured in three sub-chapters, followed by conclusions.

- (1) Defining the concept of sustainable development, history, approaches and trends for the future.
- (2) Presenting the main legislative aspects that require sustainable development as a model for the strategic development of society both at macroeconomic and micro-economic levels.
- (3) Defining the concept of green investments, approaches to the term, typology and way of achieving green investments. Green investments are known in the literature and as environmentally friendly, socially responsible investments or sustainable investments, and depending on the applicative approach to green investment, other derivative concepts may arise but converge on a single direction: creating the green economy or, more recently, the circular economy and the sustainable development of organisations.
- (4) The main conclusions drawn from the extensive bibliographic study underline the need for a clear definition of the concept of green investment and the establishment of a strategic framework whereby green investments ensure the sustainable development of organisations.
- (5) The main personal contributions to this chapter, adjacent to the bibliographic study carried out, are the own definition of the concepts of sustainable development and green investments.

As a synthesis of the definitions provided by the literature on the concept of sustainable development, I propose an own definition of this concept: ***Sustainable development means finding***

a balance in diversity, a “aution of mediocritas” in resource consumption, well-being of society and economic development, to ensure that future generations can benefit from the same minimum environmental resources that we currently benefit from.

Green investments are those invested, promotion at both macroeconomic and micro-economic levels, which encourage innovation, digitisation, reduce pollution, improve the quality of the environment, create sustainable infrastructure for the development of sustainable industries to generate new jobs and develop green skills among employees to ensure well-being and social equity for both current and future generations.

In Chapter 2, called “*Methods and Means for the Foundation of the Green Investment Decision*”, the results of bibliographic research are presented in the 24 pages to define the methods and means of substantiating the decision on the implementation of development projects that include green investments. The research is schematized in sub-chapter 4, followed by a sub-chapter in which the main conclusions are presented.

- (1) In the first sub-chapter is presented the analysis of the organizational system from the perspective making green investments. “New-type organization is regarded as a socio-technical, stable, dynamic cybernetic system with regulatory mechanisms, containing entropic elements and whose objectives must be based on the principles of sustainable development” (Dobrea and Drăghici, 2009, p. 19-23). Bibliographic research focuses on defining strategies for the sustainable development of organizations: Sustainability management, Eco-innovation, Eco-efficiency, Sustainable Competitive Advantage. Sustainable development strategies include “sine qua non” green investment projects. The overall purpose of investments is to obtain the highest benefit or gain from the use of an investment target (return on investment, ROI). In the case of green investments, the decision-maker must harmonize three elements, namely: the object of the investment, the financing instrument and the expected benefit in conjunction with the natural environment to implement the most appropriate strategy (Doval, 2015);
- (2) Chapter 2.2 presents the main management standards in the field of sustainable development (AA1000:2008, ISO9001, ISO14001, ISO 26000, OHSAS18001, SA8000) and the value they generate in the organisations in which they are implemented. A sustainable organization is the one that is concerned with the implementation of Sustainable Management Standards;
- (3) Chapter 2.3 presents models for analysing the sustainability of organisations including ways to identify green investment priorities and methods to model the Green Investment Decision. In green investment decision-making, the manager can use various tools, techniques and technologies that consider the three pillars of sustainable development: environment, economics and society. The decision-making process in the context of sustainable development differs from the traditional process of prioritising and selecting investment projects. The classic decision-making process on investment projects is based on cost analysis, quantitative decision-making criteria such as cash flow and financial indicators such as net present value. In the context of sustainable development managers’ decision on the selection of investment projects is based on detailed analyses of profitability and competitiveness in the medium and long term and integrates into decision-making and sustainability elements. In recent years, in the context of sustainable development, the top management of organisations has integrated into the investment decision-making process, in addition to the economic coordinates of the project, and on social and environmental aspects;
- (4) Chapter 2.4 presents supporting methods and methodologies in the decision-making process on green investments. Both in the analysis of the importance and necessity of a model for optimising the investment decision in the context of sustainable development, and for the actual development and implementation of the proposed methodology were used during the research various methods, models and software specific to the field studied, such as: a) data collection tools: questionnaire, interview, Delphi (method tested in Chapter 4.2.); b) data analysis models: regression model, PANEL data regression model, DEA method (tested and validated method in

Chapter 5.1.); c) decision models used in optimization: AHP, TOPSIS, with triangle-range Fuzzy variables (the method used for the research presented in Chapter 5.2.).

- (5) The main findings of the research carried out under this chapter underline that the scope of investigation, study on shaping decisions in the green industry is considered a niche one, still insufficiently explored (Peterson and others, 2008). The scientific community, managers, environmental organisations, trade in carbon reduction systems and policy makers require tools to take into account carbon stock and changes in carbon stock (Kurz etc., 2009).

In **Chapter 3, “Secondary data-based research on green investments and sustainable development at European, national and local levels”**, the 37 pages present both bibliographic research and theoretical and applicative research that determines the state of sustainable development and use of green investments, according to top-bottom approaches. The research carried out in this chapter is schemed in 4 sub-chapters, followed by a chapter setting out the main conclusions:

- (1) Chapter 3.1 presents issues related to the sustainable development and use of green investments at EU level with a focus on the eco-innovation component and the eco-innovation index.

Eco-innovation is any form of innovation that adds to economic competitiveness and the side of sustainable development and contributes to reducing environmental impact and making more efficient and responsible use of natural resources. Eco-innovation directly influences socio-economic development in all areas of action (energy, industry, service provision, trade, transport) and brings added value to businesses in increasing productivity and profitability through rational consumption of resources, better efficiency along the whole value chain, access to new markets based on new, more environmentally friendly products, new eco-innovative business models that propose to replace products with services, increase technical capacity, access to new, more environmentally-friendly products, and more sustainable standards¹.

- (2) Chapter 3.2. presents aspects of sustainable development and use of green investments in Romania, as well as Romania’s position regarding the eco-innovation index vis-à-vis the EU. As part of the Europe 2020 strategy, an important role has been devoted to the development of smart specialisations by focusing efforts (national, regional investment) on areas with the best agile potential in terms of creating competitive advantage, based on clusters, eco-innovation, innovative services, high value-added markets or specific areas of research and innovation. The indicators considered as the EU’s strategic objectives for the integrated sustainable development of the Union and its component countries follow Romania’s path towards sustainable development from 2005 to 2019. According to the statistical data available and presented in the analysis carried out, it was concluded that the EU’s Integrated Sustainable Development Goals set for 2020 were utopian. Neither Romania nor the EU have been able to reach the target indicators. The indicators Romania has managed to meet are the employment rate for age groups 20-64 expressed as percentages (target 70 %, reached in 2019, 70.9 %) and the share of renewable energy in final energy consumption (24 % target, reached in 2019, 24.29 %). On the other hand, at EU level, we can talk about achieving only one indicator: the increase in the proportion of the population with higher education for the age groups 30-34 years (%) (40 % target, achieved in 2019, 41.6 %). For the next decade, 2020-2030, the EU and Romania still have important steps towards sustainable development, especially in the context of the coronavirus crisis SARS-COV-2, which will disrupt the values achieved by 2019. The pandemic that swept the world has fundamentally changed the landmarks of the world in which we live. Mankind has entered a new dimension that it has never experienced before, and the solution to the current crisis, the reconstruction that follows, but also to prevent similar situations in the future, lies in the principles of sustainable development under the 2030 Agenda since 2015.

Environmental spending has an important role to play in making green investments, but also, the engineering and management of green certificates. Themes also addressed in the chapter:

- (1) Some data on the sustainable development of the Western Region of Romania are presented in

[Ecopolis::Romanian Eco-Innovation Network](#)

sub-chapter 3.3. According to the West Regional Development Strategy, the region's objective for the next 10 years is to become a national reference for the innovative, sustainable and inclusive development model, based on sustained economic growth due to the promotion of innovation, digitisation and creativity at all levels and a balanced territorial development that ensures all fair access to modern public services, education and opportunities (ADR VEST, 2020).

- (2) In sub-chapter 3.4. there are two barometers for measuring the degree of sustainable development of organisations in Romania, indicators used to determine the degree of sustainable development of organisations, methodologies of data collection, methods of harmonising scores and presentation of the resulting rankings.
- (3) The main conclusions drawn from the analysis carried out in this chapter underline the fact that, in the light of the legislative limitations in the areas of sustainability and CSR, lately there has been an improvement in companies' performance on environmental activities and the addition of environmental and CSR responsibility to decision-making policy on investment projects.

In **Chapter 4, “Experimental researches on the investigation of some aspects of the processes of engineering and management of green investments at macroeconomic level”**, two theoretical and applied researches that validate the theoretical aspects presented above in chapter 2.4 are presented during 23 pages:

- (1) A study carried out in the framework of a large project aimed at the phenomenological investigation of the relationship between energy investments, energy price shocks and macroeconomic variables in EU countries (project PN-III-P1-1.1-TE2016-0142). Thus, doctoral research has been crossed by the opportunity of conducting contractual investigations, research on carbon emissions, energy consumption and investment management in renewable energy (green energy). The research was carried out between 2016 and 2019. This research has sought to assess the long-term connection between CO₂ emissions on the one hand and investment in renewable energy and total energy consumption on the other. To achieve this, we conducted an investigation into the panel data for the period 1990-2017 for 44 countries and used a PMG (MG) estimate for solidity purposes. The main results show that total energy consumption has both a positive short-term and long-term impact on carbon emissions, while the role of renewables is inconclusive. These findings are consistent between PMG and the GM estimator. Moreover, the conclusions remain the same if we correct the effect of the business cycle and use energy intensity instead of energy consumption. (Sirbu etc., 2019);
- (2) A comprehensive experimental study carried out at national level on the environmental behaviour of organisations in relation to green information and communication technology (ICT). The research was aimed at discovering and characterising how organisations are aware of the adoption and use of environmentally responsible behavior. This research is recent (derulated in 2020) and has been used as a method of research and data collection, the questionnaire method. The aim of this research was to highlight the degree of use of green ICT in Romanian companies and to emphasise the close link between green investments, green ICT and sustainable development. Knowledge of the concept of green ICT is relatively vague at the level of Romanian organisations, even though the ICT approach from an environmental perspective leads to reduced energy consumption, reducing CO₂ emissions and reducing environmental impacts, with effects on generating added value, due to reduced costs for both organisations and individuals.

Chapter 5, “Experimental researches on how to substantiate green investment decisions at the level of organizations (micro-economic)”, presents the results of two significant researches for the field of green investment engineering and management at the microeconomic level:

- (1) In Chapter 5.1. a comparative study of 18 green buildings is presented in terms of cost-effective operation of these buildings. The research was carried out with the support of a collective of researchers from the Faculty of Civil Engineering of the Politehnica University Timisoara, in

2019-2020. The literature highlights the serious environmental impact that buildings have on the environment. Buildings are an important source of soil and atmosphere pollution; they account for 40 % of the world's energy needs and 44 % of society's total material consumption (Bhatt and Macwan, 2015). Sustainable development "is one of the greatest challenges of this century, and global warming is one of the greatest threats facing humanity in the last hundred years. Buildings generate 36 % of the EU's CO₂ emissions, thus playing a critical role in protecting the environment and halting global warming².

- (2) A set of theoretical and applicative researches on eco-innovation in SMEs are presented in chapter 5.2 and which has set out to design, test and validate a methodological framework. The research approach designed and applied has resorted to the "exploitation" of the related mathematical apparatus of two supporting methods in the decision-making process: a) The BWM method used to prioritize identified barriers for eco-innovation and b) Fuzzy-TOPSIS method used to hierarchise solutions to overcome these barriers (methods outlined previous in chapter 2.4). Eco-innovation has been defined as "the introduction of any new or significantly improved product (goods or services), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water and earth) and decreases the release of harmful substances throughout the product's life cycle" (Ghisetti et al., 2017). This study has the following objectives: a) Identify the barriers of green innovation for SMEs to classify and prioritize these barriers; b) Identifying optimal solutions for overcoming these barriers; c) Classification of solutions in relation to these barriers.

A three-phase methodology is used in this research to achieve these objectives. In the first phase, using the Delphi method together with the literature analysis are identified and prioritised green innovation barriers and solutions to overcome these barriers in SMEs. In the second phase, the Best-Worst methodology, developed by Rezaei and the co-authors (2016) is used to classify the barriers to green innovation. In the third phase, the Fuzzy-TOPSIS methodology is used to classify solutions to these barriers.

The unique contribution of this study is that it is the first study to identify and rank a detailed list of barriers to green innovation. This study is also the first to provide solutions to overcome the barriers of eco-innovation in SMEs. The research paper also used an innovative and new methodology called BWM to classify the barriers to green innovation. Eco-innovation is a relatively new subject, but of great importance today, is still little addressed in the literature, so this study provides a basic framework for further research in this context.

Chapter 6 presents "**General Conclusions. Personal contributions. Directions of future Research**".

a) In the field of research into bibliographic referentials (Chapters 1, 2 and Part 3):

- Elaboration of an extensive bibliographic analysis and synthesis on sustainable development concepts, green investments and sustainable organisation in accordance with the approaches and perceptions present in the literature of recent years, corroborated with opinions, phenomena and trends perceived and supported by important world organisations, consultancy firms or companies proving excellence in the field. Thus, synthesizes on accepted definitions of the concept were offered and similarities of perception with other associated terms were revealed – Chapters 1.1, 1.2;
- Proposing a definition of sustainable development: Sustainable development means finding a balance in diversity, a "aurea mediocritas" in resource consumption, well-being of society and economic development, so that future generations can also benefit from the same minimum environmental resources that we currently benefit from";
- Proposing an own definition of green investments: green investments are those invested, promotion at both macroeconomic and micro-economic levels, which encourage innovation, digitisation, reduce pollution, improve the quality of the environment, create sustainable

² Supported by practitioners in the field, such as: <https://mihaitoader.ro/cladiri-verzi/>

infrastructure for the development of sustainable industries to generate new jobs and develop green skills among employees to ensure well-being and social equity for both current and future generations - Chapter 1.3;

- Elaboration of a bibliographic analysis and synthesis on methods and means for grounding green decisions in organizations - Chapter 2.1;
- Analysis and synthesis of aspects related to the impact of management standards on the sustainable development of organizations;
- Analysis and synthesis of aspects related to environmental expenditure, based on the evidence identified in the literature and based on statistical data (secondary data analysis) - Chapters 3.1, 3.2, 3.3;
- Analysis and synthesis of aspects related to green investments and eco-innovation index in the circular economy and sustainable development, based on the evidence identified in the literature and statistical data base (secondary data analysis) - Chapters 3.1, 3.2, 3.3;
- Developing a synthesis on the barometers used to determine the degree of sustainable development of an organization/green company - Chapter 3.4.

b) In the theoretical research plan (partly chapter 3, 4 and 5):

- Defining the objectives of the research carried out through the doctoral programme and explaining how to achieve them through the structure of the doctoral thesis, as well as the delimitation and characterisation of the research problem – the introductory chapter;
- Designing a research framework for conducting experimental research to validate the interdependence relationship between engineering and management of green investments and the sustainable development of organizations – Chapters 4.1, 4.2, 5.1 and 5.2;
- Definition, determination of research assumptions, data collection, empirical analysis of data and modelling of data using the PMG estimator and the GM approach to determine the existing long-term connection between CO₂ emissions on the one hand, and investments in renewable energy and total energy consumption on the other;
- Establishing methods and means of carrying out analysis and processing of available experimental data (graphic representation of data on dimensions and variables of CO₂ emissions, tracing trend curves and interpretation of results);
- Defining and operationalising the five dimensions of the data collection model used in the research under Chapter 4.2. by linking them with appropriate questions from the questionnaire used in research to determine the impact of the ICT sector's environmental approach on the sustainable development of organisations and reducing environmental impact;
- Define the research framework, establish research assumptions, collect data and model them for validating and testing the efficiency of using the DEA (Data Envelopment Analysis) method in substantiating the investment decision to identify and increase green attributes in the construction sector, considering cost-related criteria;
- Defining the research framework design, testing and validation of a methodological framework based on the integration of BWM and Fuzzy-TOPSIS methods for determining eco-innovation in SMEs.

c) In the plane of applied, experimental research (Chapter 5):

- Carrying out a detailed analysis of the engineering and management of green investments and sustainable development of organisations at EU and Romania level, based on extensive bibliographical basis, using the exploitation of the knowledge and experiences described in the reports of prestigious world organisations, as well as statistical data. The synthesis presented was aimed at highlighting the role of green investments in sustainable development, both at micro-economic (economic organisations) and macroeconomic levels – Chapters 3.1, 3.2, 3.3 and 3.4;
- Highlighting a link between CO₂ emissions on the one hand and investment in renewable

energy and total energy consumption, on the other hand, which has been allocated to research topics;

- The results of empirical analysis of the dimensions of the conceptual model of research in terms of environmental awareness of the impact of ICT on the environment, as well as conclusions - Chapter 4.2;
- Research results and conclusions related to the use of the DEA method to identify green attributes that can help build low-cost green buildings - Chapter 5.1;
- Research results, design, testing and validation of methods to identify eco-innovation barriers for SMEs.
- Conclusions and measures on optimising the eco-innovation process of SMEs - Chapter 5.2.

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