MINISTRY OF EDUCATION
National University of Science and Technology
POLITEHNICA Bucharest

Doctoral School of
Industrial Engineering and Robotics

Monica D. IORGA (CRĂCIUNICĂ)

DOCTORAL THESIS

Study on the implementation of innovative models for the implementation of the guarantee-return system

***Scientific Supervisor*,**
Prof. univ.dr.ing. Augustin SEMENESCU
(National University of Science and Technology POLITEHNICA Bucharest

Summary

- 2025-

Contained

Introduction

The work is structured in 2 parts, a first part in which the current state of research on waste and the return guarantee system is presented and in the second part in which the author's contributions in this field are presented.

The first chapter of the paper deals with current concerns about waste and its recovery. To begin with, some conceptual and legislative elements regarding waste and waste recovery systems are defined, a brief incursion into the history of waste management legislation is also made both at the level of Romania and at the level of the European Union. A number of topical scientific articles are also presented in which this aspect of economic and social life is analysed from a scientific perspective.

The 2nd chapter presents some solutions regarding the return guarantee system, within this chapter there is also a presentation of the return guarantee system as it is designed at the Romanian level. The main purpose of this system is to contribute to the fulfillment of the collection and recycling targets set at European level and to which Romania has acquired. The method of calculating the fulfillment of this goal is established at European level as a ratio between the total number of packages placed on the market and the total number of packages validated in the database as being returned under the return guarantee system.

The 2nd part of the paper starts with the presentation of the objective and methodology of research and development, as well as the directions in which the scientific approach is to be directed in terms of the substance of the problem, but also procedural aspects. In this context, the analysis must follow elements such as consumer perception and behavior, economic impact, system efficiency, environmental impact and sustainability, making a comparison between Romania and other countries, presenting local case studies, elements of environmental education or a legal analysis of the phenomenon.

The implementation of the Guarantee-Return System (SGR) is an essential step towards a circular economy and responsible waste management. In this context, the analysis of the quality of products and services plays a crucial role in ensuring the efficiency and sustainability of the system.

First of all, assessing the quality of product packaging is fundamental. Packaging must be made of recyclable, durable and standardised materials to enable efficient collection and recycling. Poor quality packaging can compromise the integrity of the system, increasing the rejection rate at collection points and reducing recycling yield.

Secondly, the quality of the services offered by economic operators – from traders to collection centres – directly influences the consumer's experience and their trust in the system. A prompt, clearly informed and customer-oriented service contributes to increasing the participation of the population in the packaging return process.

Based on the identified quality concepts, a qualitative research was carried out in order to identify the correlation as it is perceived among stakeholders in terms of quality and impact on the analyzed system. In order to support the results obtained by the logistic regression analysis, a series of graphical representations were made that illustrate the relationships between the dependent variable – the preference for the automated system – and the most important predictors: the perception of efficiency, the simplicity of use and the trust in the system. These scatterplot plots, accompanied by regression lines, provide an intuitive and compelling view of how users' responses are grouped and evolve according to each individual factor.

The last part of the work is dedicated to the development of a prototype system for system automation, taking into account the specific results of the statistical research carried out within the doctoral approach.

Chapter 1. CURRENT CONCERNS ABOUT WASTE AND WASTE RECOVERY

Waste management has become a central topic in the context of sustainable development, being approached both from a legal perspective and from a strategic and technological point of view. According to Romanian law, waste is defined as any substance or object that the holder throws away or has the intention or obligation to throw away. However, in a modern and sustainable vision, waste is considered secondary economic resources, reintegrable in the production circuit.

In line with European policies, Directive (EU) 2018/851 promotes a systemic approach to waste, insisting on the shift from simple disposal to sustainable material management. This transformation aims, among other things, to protect human health and the environment, reduce dependence on primary resources, boost the use of renewable energy and strengthen economic competitiveness.

In this context, waste management is defined as the set of planned actions for the collection, transport, treatment, recovery and, ultimately, disposal of waste. The focus is increasingly shifting to the valorization of residual resources and their integration into circular economic chains.

At the same time, the role of institutional and scientific actors in configuring an efficient management system is highlighted. Thus, academia, national and European legislation, regulators and the economic sector have the responsibility to cooperate in order to create sustainable, functional and innovative models.

A central point is waste prevention, which involves reducing the content of hazardous substances, decreasing emissions and maximising resource efficiency. In addition, reuse and recycling are treated as essential tools for extending the lifespan of products and recovering economic value from waste materials.

The chapter provides an extensive analysis of the methods of treating biodegradable municipal waste, the most common of which are: advanced heat treatment (pyrolysis, gasification), autoclaving, aerobic composting, anaerobic fermentation and, as a last resort, landfilling. Each of these is evaluated according to technological efficiency, environmental impact and practical applicability.

Historically, there has been a significant evolution of waste legislation, from rudimentary approaches to sophisticated prevention, recycling and recovery policies. Framework Directive 2008/98/EC, Regulation 1013/2006 on waste shipments and Directive 2019/904/EU on plastic reduction are just a few legislative milestones that underpin the current European and national regulatory framework.

The paper also explores the National Waste Management Plan in Romania, which classifies waste into 18 categories and promotes coherent policies for the period 2015–2025. It is supplemented by Law no. 211/2011 on the waste regime, transposing the relevant European directives.

In the continuation of the analysis, examples of good practices and recent scientific research on waste collection, transport, treatment and recycling are presented. Among them,

the use of artificial intelligence to optimize WEEE collection, the influence of tourism on the amount of municipal waste, as well as logistical approaches in their transport stand out.

Selective collection is illustrated by concrete examples from Romania, including the implementation of automatic collection points that reward users with vouchers. Efforts to streamline the collection of hazardous waste through mathematical models and safe handling strategies are also mentioned.

The treatment stage is approached in a complex way, including incineration, anaerobic digestion and other technologies adapted to the specifics of waste, including hazardous or nuclear waste. Recent research explores efficient and environmentally friendly methods of recovering industrial, food, ceramic or construction waste.

The paper also highlights the importance of questionnaires in waste management research, providing an empirical basis for analyzing the behavior of the actors involved (citizens, authorities, economic operators). Examples from various countries (Turkey, Spain, Italy, Brazil) demonstrate the applicability of this method in comparative and impact studies.

Finally, it is emphasized that the field of waste management is in a permanent dynamic, current research being increasingly specialized and oriented towards pragmatic, innovative and sustainable solutions. The study thus opts for an analysis focused on the five fundamental components of a waste management system: collection, transport, treatment, recycling and recovery – considered essential in the transition to a genuine circular economy.

Chapter 2. SOLUTIONS REGARDING GUARANTEE-RETURN SYSTEM

The implementation of the Guarantee-Return System (SGR) in Romania is an essential step towards aligning with European standards on responsible packaging management and reducing the impact of waste on the environment. Although the official launch of the system was planned for October 2022, repeated postponements and logistical and legislative challenges generated uncertainties regarding its operation.

The SGR involves the retention of a financial guarantee from the consumer when purchasing a packaged product, an amount that is refunded upon return of the packaging. The system involves all actors in the production and distribution chain – manufacturers, traders, consumers, collection and recycling centres – and aims to facilitate the selective collection and recycling of non-reusable glass, plastic and metal packaging.

At the base of the system is an **SGR administrator**, represented by a joint stock company, made up of associations of producers (minimum 30% market share), the Romanian state (20%) and possibly traders. The role of this administrator is to coordinate the entire activity, from the registration of packaging to the public reporting of the quantities collected and recycled. However, the involvement of the state as a shareholder has generated multiple questions regarding the responsibilities, financing and possibility of making a profit from a system built on the contribution of consumers.

Effective implementation involves building an **integrated IT system**, monthly and quarterly reporting, as well as full traceability of packaging. Producers and traders have detailed obligations regarding the records, contracting with the SGR administrator, informing consumers and complying with technical and fiscal requirements.

From **the producers'** perspective, they must:

- keep detailed accounting records,
- mark the packaging according to the rules,
- pay the guarantees and administration fees,

- concludes contracts with the SGR administrator,
- report monthly data on packaging placed and returned.

Traders, in turn, are required to:

- register in the system within 90 days from the appointment of the administrator,
- display and refund the guarantees at the return points,
- do not sell products from unregistered manufacturers,
- use the administrator's information system for reporting,
- ensure the protection of returned packaging and cooperate with control authorities.

Collection and recycling targets are progressively increasing, reaching 90% for all three materials (glass, plastic, metal) from 2025. The lack of efficient separate collection at the level of local authorities has led to Romania's poor performance in terms of municipal waste recycling, standing at a level of around 14% in 2022, compared to the European target of 50%.

The SGR is intended to be a complementary solution for achieving the European objectives, being able to bring a 7–10% increase in the recycling rate. For this, it is necessary to completely digitize the process, use GPS on collection vehicles, digital scales and real-time monitoring computer platforms.

At the European level, the SGR is already implemented in 11 member states, starting with Sweden (1984) to Slovakia (2022), with return rates between 87% and 96%. Other countries (Ireland, Greece, Poland, Austria, etc.) are in the process of preparing or expanding the system. Romania, although it has taken legislative steps, lags behind these countries in terms of infrastructure, separate collection and data transparency.

The chapter also details various **international models** of operation of the SGR:

- **Croatia**: fully functional system, including for dairy packaging.
- **Germany**: extended system, but with some exceptions; mandatory for most beverage packaging.
- **Slovakia**: recently implemented, organized through a non-profit entity.
- **Switzerland**: voluntary model, very effective.
- **France, Hungary, Poland**: in the process of regulation or piloting.

In parallel with the legal analysis, the paper proposes a **methodology for the practical implementation of an intelligent SGR**, based on:

- electronic reward systems (with MIFARE cards, PIC16F877A microcontrollers, Visual Basic applications);
- sensors for identifying recycled materials;
- Interface with databases for tracking reward points and recycled quantities.

The hardware includes specific components such as: Hitachi 2x16 LCDs, RS232 converters, MIFARE readers, all integrated into a smart recycling bin. This approach provides a concrete direction for the complete digitalisation of the process, also taking into account examples of international best practices and artificial intelligence solutions.

In conclusion, in order for Romania to achieve the recycling targets and avoid European sanctions, it is imperative not only to effectively launch the SGR, but also to integrate it with a coherent logistical, IT and public communication system. In addition, the expansion of the range of packaging included and the adoption of innovative practices, such as automatic rewarding and digital traceability, will contribute to the creation of an efficient and sustainable national model.

Chapter 3. CONCLUSIONS ON THE STATE OF PLAY OF THE GUARANTEE-RETURN SYSTEM

In the context of increasing pressures on natural resources and the need for the transition to a circular economy, the Guarantee-Return System (RMS) is an essential tool for improving packaging waste management and stimulating responsible consumer behavior. The present study addresses from a multidisciplinary and applicative perspective the challenges and opportunities associated with the implementation of this system in Romania, compared to the functional models at international level.

Conceptual and legislative foundation

First of all, the conceptual framework of the work is based on the definition of waste as a secondary resource, emphasizing the transition from the classic paradigm of elimination to one oriented towards recovery. Romanian and European legislation converge in promoting the principles of the circular economy, stipulating not only obligations regarding the collection and recycling of packaging, but also concrete performance targets. Directive (EU) 2018/851 plays a crucial role, imposing an integrated vision on materials management on Member States and promoting reuse, recycling and emission reduction as key directions.

In this framework, waste management is conceptualized as a strategic process, which integrates the collection, transport, treatment and recovery of packaging in a way that minimizes the impact on the environment and maximizes the recovery of resources. Thus, the need for coordinated interventions between institutional actors, the economic sector, the scientific community and citizens is outlined, in a joint effort to support sustainability.

The current status of the SGR in Romania

In Romania, SGR became operational as of November 30, 2023, targeting beverage packaging with volumes between 0.1 and 3 liters. Although the system is active, its implementation faces significant challenges, especially in rural areas and among small traders. The shortcomings identified include the lack of adequate infrastructure (e.g. insufficient RVMs), logistical difficulties and insufficient information of the population. However, progress has been observed in the urban environment, and the system administrator – RetuRO – has undertaken the expansion of the infrastructure and the digitization of processes.

International models and best practices

Comparatively, in countries such as Germany, Norway or Lithuania, the SGR is well consolidated, reaching collection rates of over 90%. These performances are the result of consistent investments in collection infrastructure, active citizen involvement, clear regulations and efficient partnerships between the state and the private sector. The value of the guarantee, the level of digitalization and the standardization of the system are decisive factors in their success.

International experiences show that systems managed by private entities, but publicly regulated, achieve superior results compared to exclusively public ones, due to operational efficiency and increased adaptability. At the same time, social acceptability and education campaigns have a decisive role in ensuring the active participation of consumers.

Contribution of scientific research

Research in the field of SGR is in a stage of expansion, being approached from multiple perspectives: economic, ecological, social, behavioral and technological. Economic studies focus on cost-benefit analysis, impact on SMEs and effective regulation. From an environmental point of view, the research focuses on assessing the performance of the system using methods such as LCA and estimating the impact on carbon emissions and resource consumption.

The social component is represented by the analysis of consumer behavior, psychosocial factors influencing the return of packaging and the social acceptability of the system. In parallel, technological research explores the development of automatic machines (RVMs), digital traceability codes and solutions for optimizing reverse logistics.

Research trends and insights

The emerging directions of the research include the digitalization of the SGR – with a focus on traceability through blockchain, smart codes (QR, RFID) and predictive analytics through artificial intelligence. At the same time, the interest in assessing the social impact on vulnerable categories, integrating the principles of social equity and developing participatory governance models is highlighted.

In addition, the focus will shift to the integrative analysis of the system, including in relation to other forms of collection, such as informal infrastructure or collection at the gate. The need for international harmonization of standards is outlined, as well as to strengthen the role of research in packaging design, adapted to circular requirements. In parallel, it will be essential to understand and stimulate long-term sustainable behaviors, through educational, digital and cultural tools.

Chapter 4. DIRECTIONS, MAIN OBJECTIVE AND METHODOLOGY OF RESEARCH AND DEVELOPMENT IN THE FIELD OF RMS

This chapter defines the strategic framework of doctoral research, delimiting the essential directions of scientific development, the fundamental objectives and the methodology related to the analysis and innovation process in the implementation of the Guarantee-Return System (RMS) in Romania.

4.1. Priority R&D directions

Starting from the analysis of the current stage of the SGR in Romania, relevant research directions are outlined, structured multidimensionally:

- **Consumer perception and behaviour**: The level of information, demographic and economic factors influencing participation (age, education, income, place of residence), financial motivations and possible obstacles in using the system are investigated.
- **Economic impact on value chain actors**: The costs and benefits for traders and producers are analyzed, as well as the potential of the SGR as a driver for the development of green industries.
- **Logistical and operational efficiency of the SGR**: The distribution of return points, accessibility, technical problems and automation potential through digital solutions (RVMs, QRs, applications) are evaluated.
- **Ecological impact and sustainability of the system**: It is estimated to reduce abandoned waste, compare it with other collection methods and reduce carbon emissions.
- **International comparison**: Romania's positioning compared to other EU states in terms of efficiency and implementation is analyzed, with a focus on good practices and cultural or legislative differences.
- **Legal-institutional analysis**: The roles and responsibilities of the institutions involved (AFM, Ministry of Environment, operators) are highlighted, as well as the legislative and bureaucratic obstacles encountered.

- **Local case studies**: Comparing implementation in large urban areas (Bucharest, Cluj, Iasi) with rural areas, investigating practical barriers and community initiatives.
- **SGR and environmental education**: The importance of information campaigns and the involvement of educational actors and the media in the formation of pro-ecological behaviors is emphasized.

4.2. Main objective of the research

The general purpose of the research is to carry out a **complex study on the efficiency, public perception and socio-economic and ecological impact of the SGR in Romania**, with a focus on identifying the determinants of success and formulating innovative models for improvement. In this regard, the aim is to:

1. Investigating the knowledge, involvement and motivation of the population regarding the SGR.
2. Assessment of the economic impact on all actors involved.
3. Analysis of the logistics efficiency and infrastructure of the SGR at national level.
4. Quantifying environmental benefits.
5. Comparison of the Romanian system with other European models.
6. Examination of the current legal and institutional framework.

These objectives will support the proposal of concrete solutions for the optimization of the SGR system, in relation to the particularities of the Romanian context.

4.3. Research and development methodology

The methodology focuses on a rigorous approach, both quantitative and qualitative. The main elements include:

- **Questionnaire applied to the general population** to assess the level of knowledge, perception, degree of involvement and receptivity towards the SGR. The sampling is statistically representative.
- **Testing specific assumptions** regarding the level of information, the perception of advantages, the impact on the environment and the openness of the population to the automated system.
- **Technological innovation**: Proposing a four-point scanning system, with sensors for identifying materials (plastic, aluminium, glass), aimed at increasing accuracy and reducing fraud, waiting time and user dissatisfaction.
- **Evaluation of the quality of the packaging and services** involved in the SGR circuit: emphasis is placed on standardization, sustainability, organization of collection centers, professionalism of the staff and effective communication with the public.

Overall, the proposed methodology ensures a comprehensive analysis of the SGR system, providing a solid basis for the development of innovative implementation models, adapted to the socio-economic and cultural realities in Romania.

Chapter 5. CENTRALIZATION OF STATISTICAL DATA ON THE PERCEPTION OF THE RETURN GUARANTEE SYSTEM AMONG THE POPULATION IN ROMANIA

The purpose of the questionnaire is to highlight the extent to which the Guarantee-Return System is known in Romania and what is the concrete way of achieving it optimally in the consumers' view.

The questionnaire must answer the following questions:

1. How well known is the Guarantee-Return System among the general population in Romania;

2. What are the advantages of using the Guarantee-Return System in an automated way in the consumer's view;
3. What is the impact on the environment in the consumer's view;
4. How receptive are consumers in Romania to the implementation of this system.

Starting from these elements, we have defined the following working hypotheses:

1. Hypothesis: A significant percentage of the general population in Romania is not familiar with the Guarantee and Return System.

a. Null hypothesis (H0): There are no significant differences in knowledge of the Guarantee and Return System among the general population in Romania.

b. Alternative hypothesis (H1): There are significant differences in knowledge of the Guarantee and Return System among the general population in Romania.

2. Hypothesis: Consumers in Romania consider that the automated use of the Guarantee and Return System has several advantages.

a. Null hypothesis (H0): There are no significant differences in the perception of the advantages of the automatic use of the Guarantee and Return System in the consumer's view.

b. Alternative hypothesis (H1): There are significant differences in the perception of the advantages of the automatic use of the Guarantee and Return System in the consumer's view.

3. Hypothesis: Consumers in Romania consider that the implementation of the automated Guarantee and Return System has a low impact on the environment.

a. Null hypothesis (H0): There are no significant differences in the perception of impact on environment from the consumer's point of view.

b. Alternative hypothesis (H1): There are significant differences in the perception of environmental impact in the consumer's view.

4. Hypothesis: Consumers in Romania are receptive to the implementation of the automated Guarantee and Return System.

a. Null hypothesis (H0): There are no significant differences in the receptivity of consumers in Romania towards the implementation of this system.

b. Alternative hypothesis (H1): There are significant differences in the receptivity of consumers in Romania towards the implementation of this system.

Representative graphs were made with the answers to the questions.

Figure 5.1.
Graph of answers to question 1

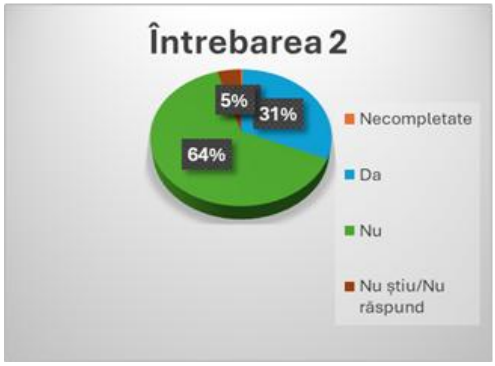

Figure 5.2.
Graph of answers to question 2

Figure 5.3.
Graph of answers to question 3

Figure 5.4.
Graph of answers to question 4

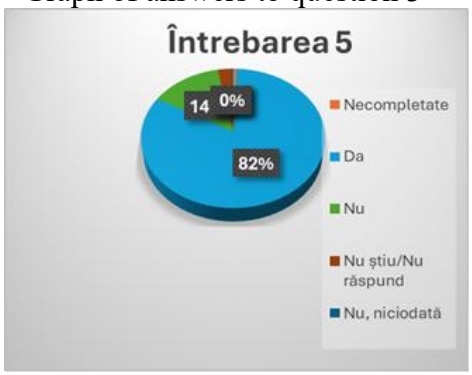

Figure 5.5.
Graph of answers to question 5

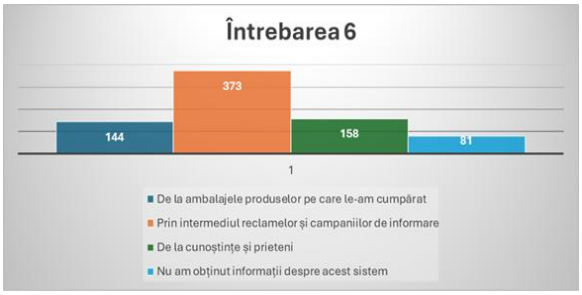

Figure 5.6.
Graph of answers to question 6

Figure 5.7.
Graph of answers to question 7

Figure 5.8.
Graph of answers to question 8

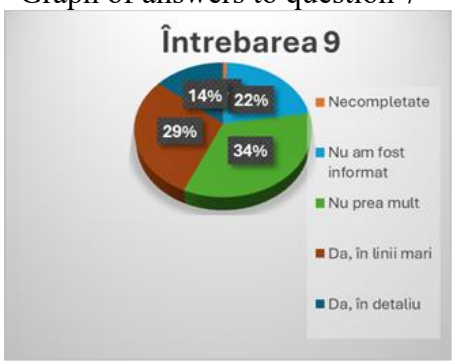

Figure 5.9.
Graph of answers to question 9

Figure 5.10.
Graph of answers to question 10

Figure 5.11.
Graph of answers to question 11

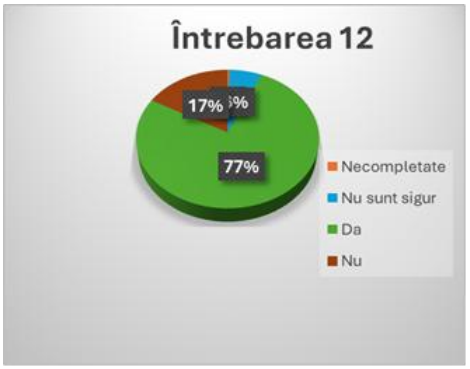

Figure 5.12.
Graph of answers to question 12

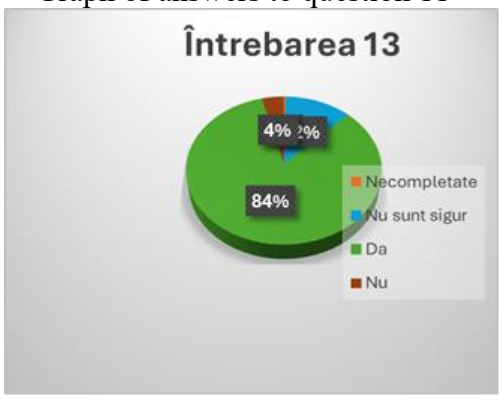

Figure 5.13.
Graph of answers to question 13

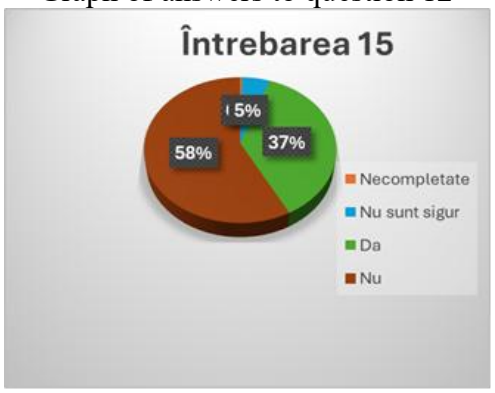

Figure 5.15.
Graph of answers to question 15

Figure 5.16.
Graph of answers to question 16

Figure 5.17.
Graph of answers to question 17

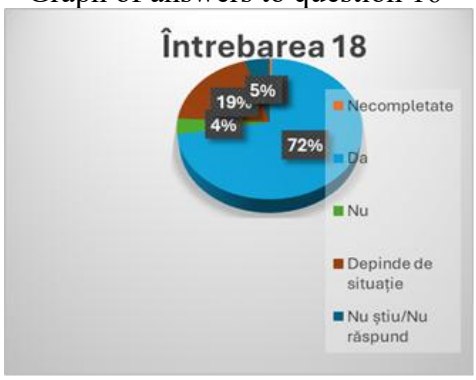

Figure 5.18.
Graph of answers to question 18

Figure 5.19.
Graph of answers to question 19

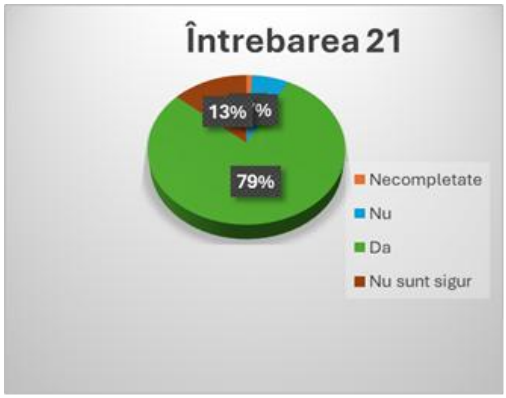

Figure 5.21.
Graph of answers to question 21

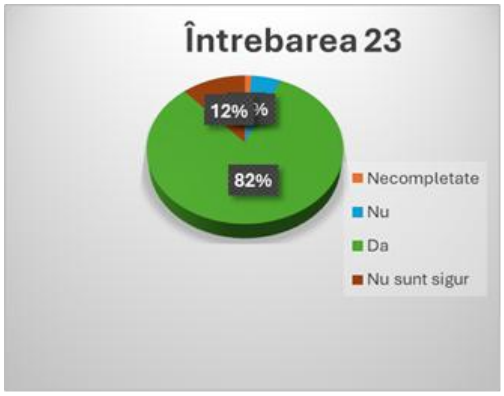

Figure 5.23.
Graph of answers to question 23

Figure 5.24.
Graph of answers to question 24

Figure 5.25.
Graph of answers to question 25

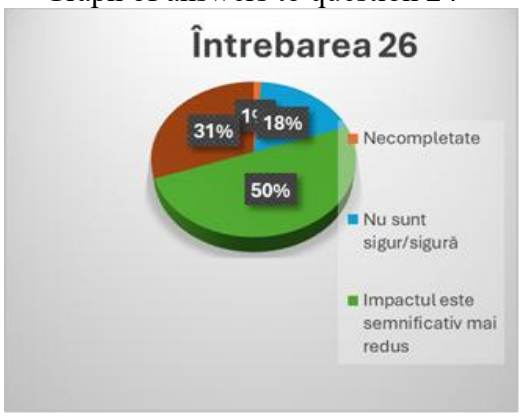

Figure 5.26.
Graph of answers to question 26

Figure 5.27.
Graph of answers to question 27

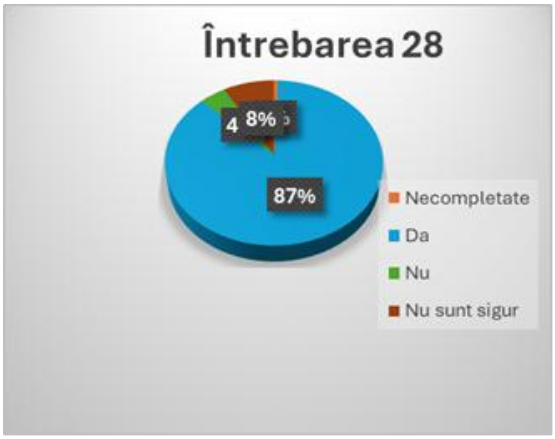

Figure 5.28.
Graph of answers to question 28

Figure 5.29.
Graph of answers to question 29

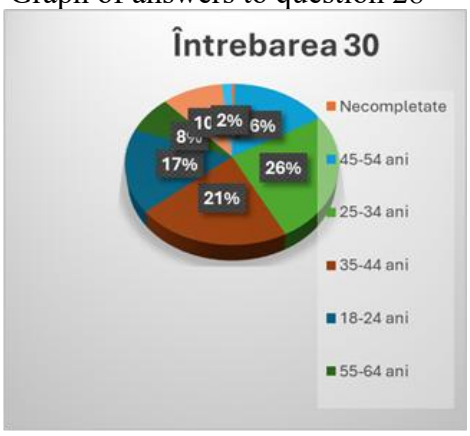

Figure 5.30. Graph of answers to question 30

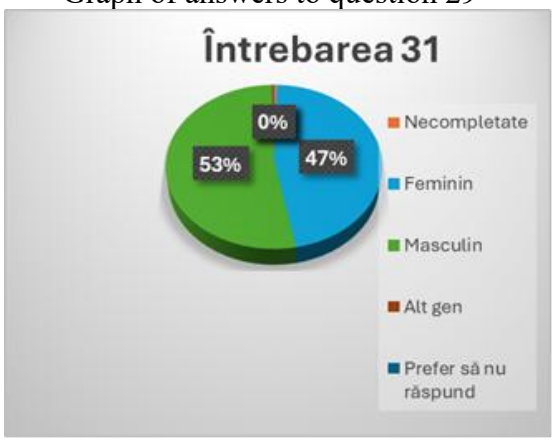

Figure 5.31.
Graph of answers to question 31

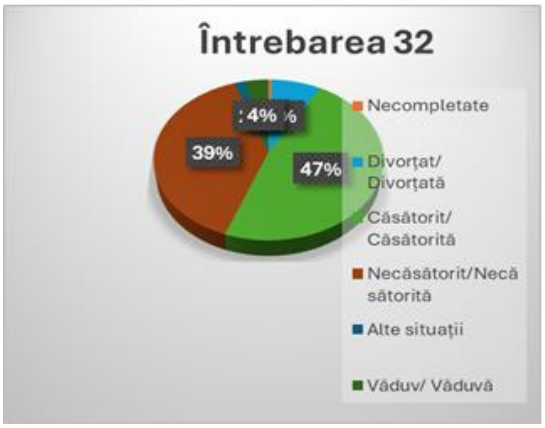

Figure 5.32.
Graph of answers to question 32

Figure 5.33.
Graph of answers to question 33

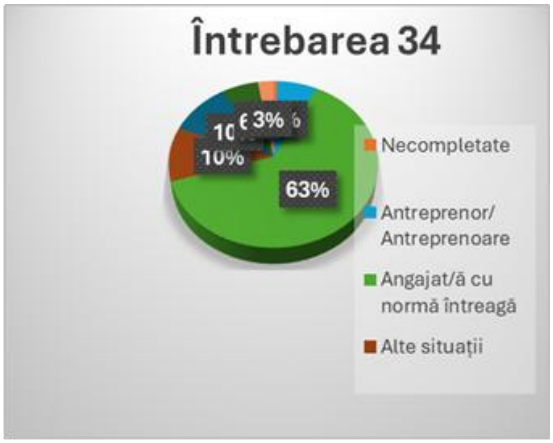

Figure 5.34. Graph of answers to question 34

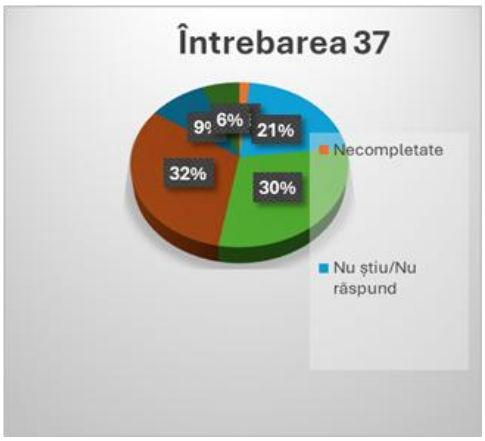

Figure 5.35. Graph of answers to question 37

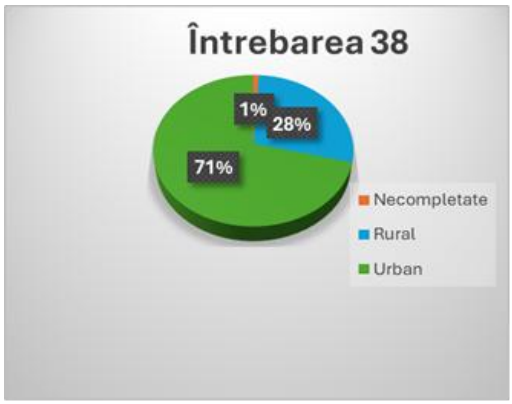

Figure 5.36. Graph of answers to question 38

Figure 5.37. Graph of answers to question 39

Chapter 6. ANALYSIS OF THE REPRESENTATIVENESS OF THE SAMPLE AND VERIFICATION OF RESEARCH HYPOTHESES

Chapter 6 of the thesis focuses on the scientific validation of the research through a detailed statistical analysis, meant to demonstrate the representativeness of the sample used and to verify the hypotheses formulated regarding the perception of the adult population in Romania on the Guarantee-Return System (SGR).

With a sample of **604 respondents**, the research targets the adult population of Romania (estimated at approximately 15 million people). A **margin of error of ±3.99% was calculated**, with a **confidence interval of 95%,** indicating high **representativeness**. Subgroups were also analysed by **age, gender and income**, highlighting a balanced coverage for most demographic categories, with a slight under-representation of the 65+ age segment and people with incomes below the minimum wage.

Four essential hypotheses were statistically tested using the **Chi-square test (χ^2):**

1. **The degree of familiarity of the population with the SGR**;
2. **Perception of the advantages of system automation**;
3. **Assessment of the impact of the SGR on the environment**;

4. **Consumers' receptivity to the implementation of the system**.

For each hypothesis, the **p-values were > 0.05**, which indicates **the lack of significant differences** between the responses of the analyzed categories and, implicitly, a high degree of homogeneity of perceptions at the population level.

Based on the analysis, it appears that **most respondents are familiar with the SGR**, recognize **the advantages of automation**, perceive the system as having a **positive impact on the environment** and show a **favorable receptivity** to its adoption.

In conclusion, the research validates that the SGR is positively perceived by the Romanian public, and the rigorous statistical analysis provides **a solid foundation for public policy recommendations**. The results support the need **to strengthen infrastructure**, **optimize the logistics process** and **awareness campaigns** to achieve the ambitious collection and recycling targets set at national and European level.

To calculate the sample, we considered Romania's adult population of 15 million people using the formula:

$$Marja\ de\ eroare\ (ME) = Z \times \sqrt{\frac{p(1-p)}{n}} \times \sqrt{\frac{N-n}{N-1}}$$

Where

Z = 1.96 (for a 95% confidence interval)

P = 0.5 (conservative value for maximizing the margin of error)

n = sample size

N = total adult population of Romania (15 million)

Starting from the margin of error formula, we make the calculations for the representativeness of the sample of 604 responses received to the questionnaire applied.

Total population (N): 15,000,000 (estimated adult population of Romania)

Sample size (n): 604 respondents (number of responses received)

Confidence Level (Z): 1.96 (corresponds to a 95% confidence interval)

Estimated proportion (p): 0.5 (conservative value for maximizing margin of error)

Margin of error (ME): 3.99% (± 3.99%)

Confidence interval: [46.01%, 53.99%].

This result indicates that the collected responses are representative of the entire adult population of Romania, with high accuracy.

In the study, in order to better highlight the elements of representativeness, we made the representativeness calculations for the age, gender and income subgroups.

Representativeness by age groups:

Table 6.1. Analysis of representativeness by age groups

Age group	Sample Size	Margin of error (ME)	Confidence Interval
25-34 years old	156	7.85%	[42.15%, 57.85%]
35-44 years old	129	8.63%	[41.37%, 58.63%]
18-24 years old	102	9.70%	[40.30%, 59.70%]
45-54 years old	97	9.95%	[40.05%, 59.95%]

65+ years	61	12.55%	[37.45%, 62.55%]

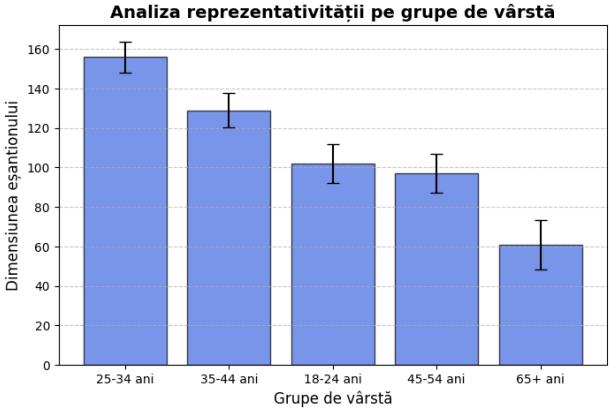

Figure 6.1. Analysis of representativeness by age groups

We can see that the 25-34 and 35-44 age groups have a good representativeness, with a margin of error below 9%, and for 65+ years, the margin of error of 12.55% suggests that this segment is underrepresented in the sample.

Gender representativeness:

Table 6.2. Analysis of gender representativeness

Gender	Sample Size	Margin of error (ME)	Confidence Interval
25-34 years old	321	5.46%	[44.54%, 55.46%]
35-44 years old	283	5.86%	[44.14%, 55.86%]

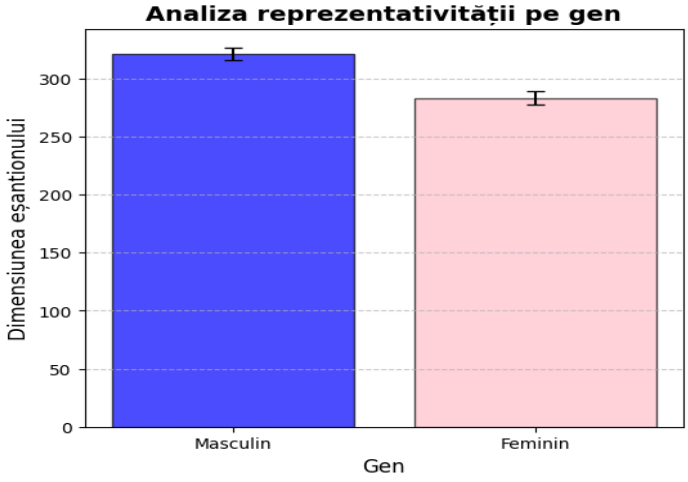

Figure 6.2. Analysis of gender representativeness

Both groups have a margin of error below 6%, which indicates good representativeness.

Table 6.3. Analysis of representativeness by income categories

Income interval	Sample Size	Margin of error (ME)	Confidence Interval
Below the minimum wage	98	9.89%	[40.11%, 59.89%]
Above the minimum wage	201	6.92%	[43.08%, 56.92%]

Above the national average	174	7.51%	[42.49%, 57.51%]
I don't answer	131	8.52%	[41.48%, 58.52%]

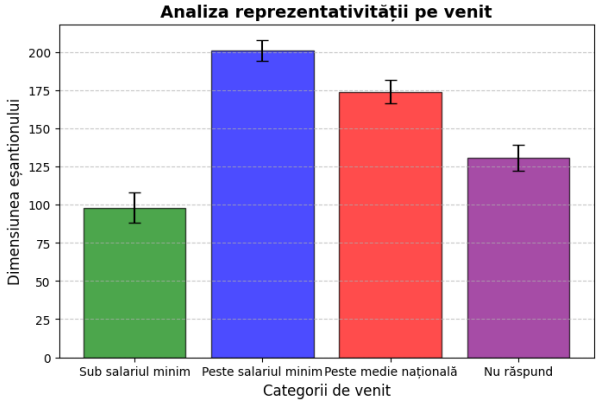

Figure 6.3. Analysis of representativeness by income groups

Regarding the representativeness analysis, we can say that the sample is representative of the adult population of Romania, with a general margin of error of 3.99%, the gender is well balanced, with an almost equal representativeness between men and women. The 25-44 age groups are well represented, but people over 65 are underrepresented. Average and above-average incomes are well captured, but those with incomes below the minimum wage are underrepresented.

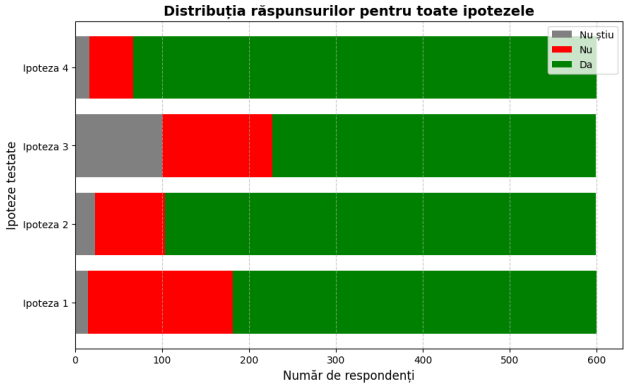

Figure 6.8. Centralized graph of the distribution of responses in the case of the 4 hypotheses

The expected frequencies are calculated so that each category has a balanced distribution based on the available data. Since we have only one sample and the categories are independent, the expected frequencies are equal to those observed:

$$E = O$$

$$\chi^2 = \sum \frac{(O-E)^2}{E} = \frac{(533-533)^2}{533} + \frac{(51-51)^2}{51} + \frac{(16-16)^2}{16}$$

$$\chi^2 = 0$$

In conclusion:

$\chi^2 = 0.0$

P = 1.0

Again, the final result does not indicate significant differences.

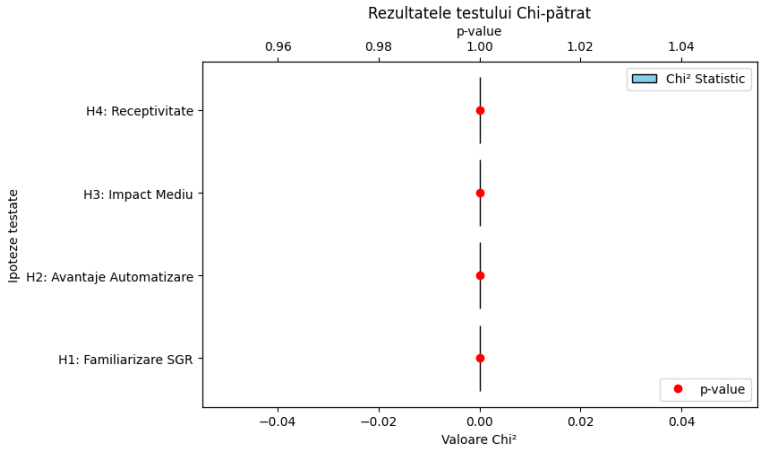

Figure 6.9. Chi-square test results

Figure 6.9 shows the results of the Chi-square test applied to assess the relationship between demographic variables and respondents' attitudes towards the Guarantee and Return System (SGR). On the vertical axis are listed the tested hypotheses, and on the horizontal axis are the Chi-squared and p-values associated with each hypothesis, in which the blue bars (Statistical Chi-square) – indicate the variations of the tested hypotheses and the red dots (p-value) – show the statistical significance.

the impact of the implementation of European and national regulations regarding the Guarantee-Return System in Romania. The hypotheses tested were 4 in number and referred to the familiarization with the Guarantee and Return system, the advantages that the automation of such a system generates, the reduction of the environmental impact and the receptivity of buyers to such a system.

The analyzed studies confirm the efficiency of the SGR in reducing packaging waste and promoting recycling, but also the need for continuous adjustments to improve the system. As the SGR system strengthens in Romania, further studies are needed to assess the long-term impact on the recycling rate, consumer behaviour and its economic sustainability.

The effective implementation of the SGR depends on cooperation between the government, retailers, producers and consumers, and public policies must be adapted to support a functional and efficient system.

The statistical analysis indicates that the sample used is representative of the adult population of Romania, with an acceptable margin of error and an adequate confidence interval. The Chi-square test applied to the hypotheses did not reveal statistically significant differences between the analyzed categories, which suggests that the respondents' perceptions are homogeneous regarding the Guarantee-Return System. Hypothesis testing was done using the Chi-square test (χ^2), individually for each of the 4 hypotheses. All 4 hypotheses have been confirmed.

Chapter 7. QUALITY STUDIES WITH AN IMPACT ON THE RETURN GUARANTEE SYSTEM

Chapter 7 of the doctoral thesis analyzes the decisive role of quality in the efficient implementation of the Guarantee-Return System (RMS), providing a theoretical and applicative framework for the evaluation of the products, works and services (P/L/S) involved in this process. The conceptual construction of the chapter is based on two essential analytical tools:

the quality loop and **the quality circle diagram**, which allow a systematic examination of how user requirements, design and execution correlate within the RMS.

The quality loop is approached as an integrative model that runs through the entire life cycle of a P/L/S – from marketing and design, to manufacturing, distribution and post-use – highlighting the impact of each stage on the overall performance of the system. In the context of the RMS, this approach allows the identification of the critical factors that influence operational success: packaging quality, collection infrastructure, logistical efficiency, but also the consumer experience at the return points.

The conceptual model of the quality loop has as its specificity the separate (individual) consideration of the contributions of the different phases of the loop. Also, the order of approach of these phases is correlated with the order of the algorithm for the design and development of a P/L/S.

Thus, the first phase (stage) of the quality loop is "Marketing" – this being a decisive stage for the success of the product.

The argumentation of the decisive importance of this first phase of the quality loop lies mainly in the following 2 aspects:

- A marketing and a scientific and qualitative market research ensures a good reception (reception) of the respective product in the market (correct segmentation of the market, including from the point of view of the category of customers to whom P/L/S is addressed).
- An important database is established on the technical characteristics and performances necessary for the respective product in terms of the "expressed and implicit needs" of the customers, the true arbiters and judges of the quality of the product.

The 2nd phase of the quality loop "Conception, design and development of P/L/S" has a very important weight in the final quality. This is especially evident in new or upgraded P/L/S.

Similar to the medical saying "prevention is easier than to treat and cure", paying due attention to this 2nd phase of the quality loop minimizes the expense caused by possible repairs after execution.

Thus, it is recognized that about 80% of the causes of scrap (defects) derive from design and only about 20% from manufacturing.

In the conception and design phase, the following are established:

- The optimal construction solution.
- The nature and characteristics of the raw materials and materials required (including specific consumption).
- The requirements and characteristics of the machinery, tools, devices and verifiers (SDV-istics) related to the execution.

Another argument that reflects the importance of the conception, design and development phase of the product is that one of the most effective methods of improving quality, namely the "Value Analysis" targets precisely this phase (conception and design).

In the same context, it is considered that if it is not designed correctly with the product, the quality will not be achieved during manufacturing. Example: the "cartridge" in any drawing of an execution project has several headings, including "Material Type". In the unfortunate case where the material is not chosen correctly (and foreseen) from the conception and design phase, the manufacture (actual execution) cannot give the respective P/L/S the prescribed quality.

The importance of the conception and design phase also lies in the fact that the decisions and solutions adopted in this phase can only be changed during the execution phase (actual manufacturing) with the consent of the designer (derogations are required from the project, derogations that must be approved by the designer – for example, the change of the material, in the absence of the one provided for in the first project).

The main elements characteristic of phase 3 of the quality loop (Supply) are presented below:

- Study of the supplier market and its dynamics (any change in the supplier market must be analysed and interpreted).
- The quality of the contracts consists in the provision of rationally and judiciously staggered delivery terms, in direct correlation with the needs of the technological process.
- Selection of raw materials, materials, etc. primarily on qualitative criteria and the optimal quality/price ratio (maximum).

The main feature of the 4th phase of the quality loop, "Manufacturing Preparation" is to ensure the conditions, both in terms of Human Resources and Fixed Assets (Machinery, Aggregates, Tools, Devices) necessary to carry out all operations (stages) of the technological flow at the prescribed technical and technological parameters.

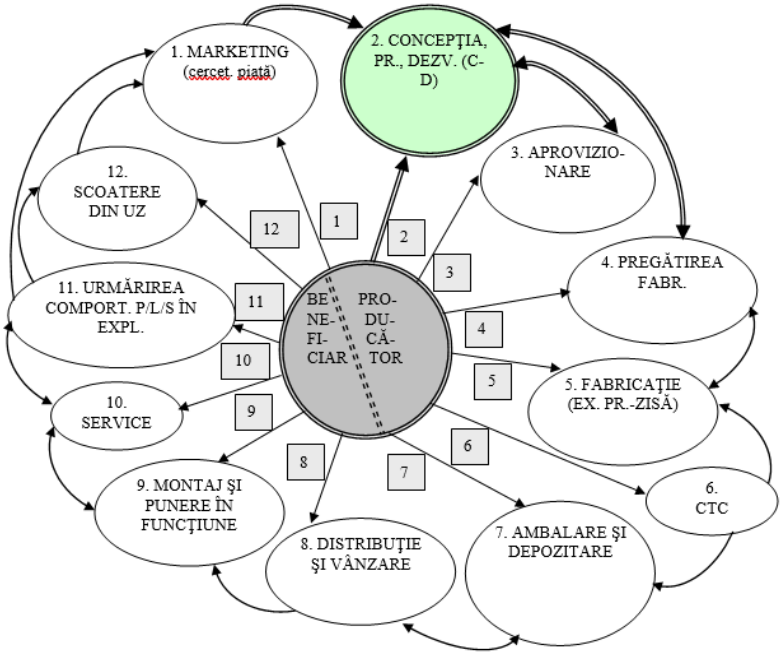

Figure 7.1. The conceptual model of the quality loop of a P/L/S

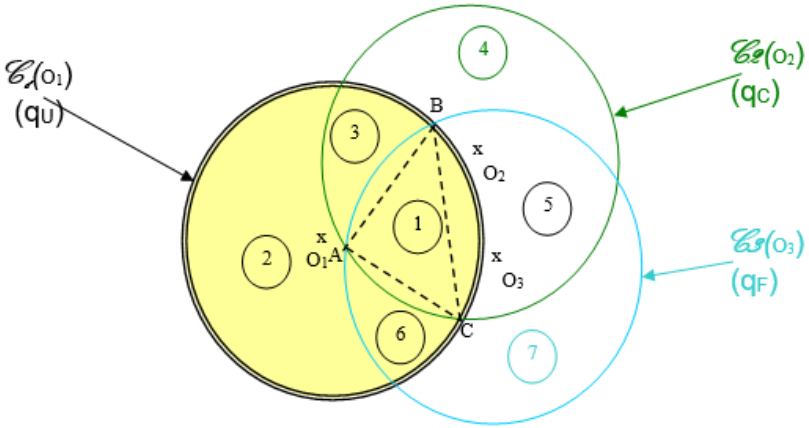

Figure 7.3. Quality Circles Diagram

The specific characteristics of each non-compliance area are summarised in Table 7.1.

Table 7.1. Characteristics of the non-conformance zones in the quality circle diagram

Crt. No.	Area No.	Name of the area	Characteristics of the area	Observations
1.	(1)	***Conformal quality (optimal area)***	*Customers' requirements* are *fully designed and implemented*	TOTAL *quality*
2.	(2)	*Unmet* customer *requirements*	The requirements expressed by customers are *undesigned and unfulfilled*	Total lack *of quality* (P/L/S *"harmful")*
3.	(3)	Defective area *(non-conformities)*	Customer requirements were designed, but not realized	Products with *defects in workmanship ("quasi-scrap")*
4.	(4)	The area *of unnecessary quality*	Features *designed without customer demand or realization*	Possibly *to make a prototype (or small series) for testing the market*
5.	(5)	The area *of excess quality (overquality)*	Features *designed and executed, but not required by customers*	*Market testing and "education" – conquering new market segments and eliminating competition*
6.	(6)	The area *of "wonders" (fortuitous, or deliberate)*	Required quality, *not designed*, but achieved	*The execution saved the design*
7.	(7)	The "*quality waste" area*	Qualities *not required* by customers, *not designed, but realized*	*Unjustified production costs*

Chapter 8. STUDY ON THE DEFINING ELEMENTS OF QUALITY IN THE FIELD OF AUTOMATIC SYSTEMS SGR

Chapter 8 marks the culmination of the scientific approach undertaken within this thesis, proposing a series of **innovative models** for the implementation of the Guarantee-Return System (RMS) in Romania. These models are built on the basis of a systemic and multidimensional analysis, integrating the data obtained from empirical research, the theoretical conclusions formulated in the previous chapters, as well as the best European and international practices.

The foundation of these proposals is represented by the need **to adapt the SGR to the national specificity**, both from a cultural, logistical and technological point of view. A **flexible**

but rigorous framework is thus proposed to allow the system to evolve in clearly defined stages, with quantifiable objectives and permanent monitoring mechanisms.

The general model of the SGR is dissected into essential components – design, collection, reverse logistics, reimbursement, education and feedback – each approached through the **prism of the principles of total quality**, **circular economy** and **sustainable efficiency**. Four major directions of innovation are identified:

1. **Digitalization of the SGR** – by implementing QR codes, mobile applications and real-time traceability systems, it facilitates the efficient management of returned packaging, reduces fraud and optimizes reverse logistics.
2. **Automation of collection points** – the proposal to expand the use of RVM (Reverse Vending Machines) equipment, adapted also for rural areas, contributes to standardizing the population's access to the return infrastructure.
3. **Integration into a centralized IT system** – which allows real-time data analysis, dynamic adjustment of logistics flows and generation of performance reports for all entities involved (retailers, manufacturers, authorities).
4. **The educational-participatory model** – a systemic approach to consumer involvement, through constant information campaigns, educational games, loyalty and reward programs, but also by creating a civic culture of ecological responsibility.

The chapter also proposes a **conceptual map for gradual implementation**, starting with the optimization of the pilot areas and the controlled expansion of the system according to the recorded performances. It is also recommended to establish a **public audit and transparency mechanism**, which allows for the continuous and corrective evaluation of the functioning of the system.

Finally, it is stated that the success of any SGR model depends on the **synergy between infrastructure, technology, regulation and citizen behavior**, and Romania has the potential to create an efficient and adapted system, with regional reference value.

It is important to note that **this analysis does not imply a causal relationship**, but only one of association. Also, applying the Pearson coefficient to ordinal or coded data simplifies reality and may omit non-linear relationships, but provides a useful framework for initial interpretation and directing more in-depth statistical analyses.

In conclusion, the use of the Pearson correlation coefficient in this research allowed the identification of **significant relationships between the main dimensions of user perception**, contributing to a better understanding of how they interact with the Guarantee-Return System. The results provide valuable support for applied recommendations on improving the system, increasing participation and building public trust.

Figure 8.6. Matrix of SGR correlations

Figure 8.6 shows **the Pearson correlation matrix** visually in the form of a heatmap. Based on this visualization, we can draw the following general conclusions:

- **Clear Cluster Between Efficiency, Simplicity and Preference for Automation**

There is a coherent area of strong positive correlations between these three dimensions. This confirms that positive perceptions of the efficiency of the SGR system directly contribute to the feeling of simplicity and determine a greater preference for the use of the automated version.

- **Trust in the system is backed by Simplicity**

The visible correlation between "Trust" and "Simplicity" suggests that users gain confidence in the system when they perceive it as easy to understand and use. The chart underscores this consistent positive relationship.

- **Difficulties in understanding are isolated**

The cell corresponding to the variable "Difficulties in understanding" shows values close to zero in relation to the other dimensions, indicating that the reported difficulties do not directly affect perceptions of efficiency, simplicity or confidence. Visually, these areas are almost neutral on the map.

- **Information has an ambiguous role (limited data)**

The correlations with the variable "Information" are either weak or completely absent, signaling either a difficult coding or a lack of conscious impact by respondents on other perceptions.

- **Visual consistency between high values**

Dark colors in the upper area of the diagonal (deep red for positive correlations) provide an intuitive representation of significant connections, while light blue or gray squares indicate weak or absent relationships.

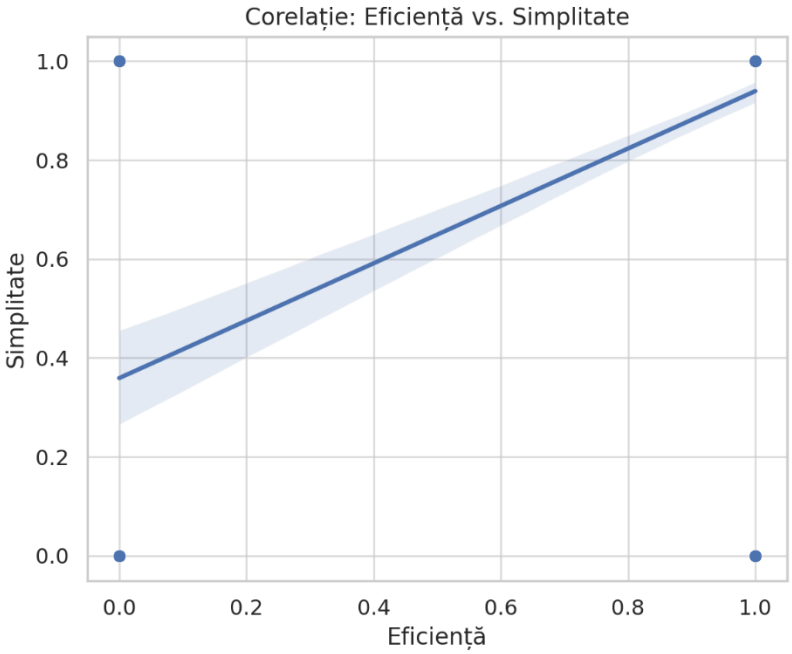

Figure 8.7. The correlation between efficiency and simplicity of use

The graph illustrates very clearly the correlations between:

1. **Efficiency and Simplicity** – a positive and robust linear relationship;
2. **Simplicity and Preference for automation** – clear correlation, indicating the impact of simplicity on the choice of automated system;
3. **Efficiency and Preference for automation** – moderate but still significant correlation.

Chapter 9. SOLUTION FOR OPTIMIZING THE COLLECTION EQUIPMENT WITHIN THE SGR

The implementation of the Guarantee-Return System does not only imply a legislative regulation and a sustainable economic model, but also an efficient technological support. An essential role in the operation of this system is **played by automated collection equipment**, also known as **RVMs (Reverse Vending Machines).** These devices are a clear example of the **integration of technology into green infrastructure**, allowing the automatic collection, identification, validation and rewarding of the user for returned packaging

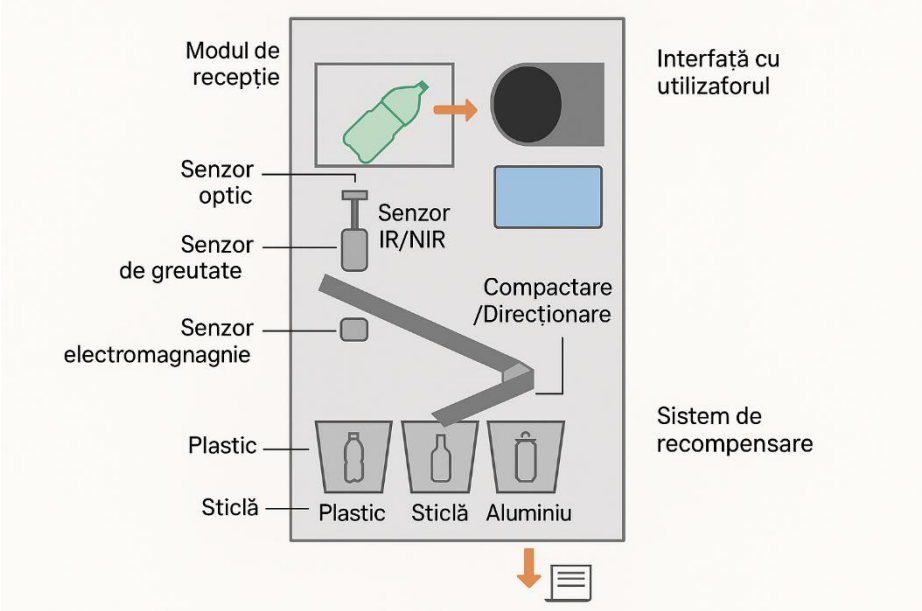

Figure 9.1. Technical sketch of an RMS

As can be seen from Figure 9.1. The practical operation of the equipment involves several stages.

The operation of an automated equipment for the collection of recyclable packaging begins when the user inserts a container into **the receiving module**. This is a compartment equipped with proximity sensors that:

- detects the inserted object,
- automatically activates internal systems,
- and triggers the analysis and sorting sequences.

Chapter 10. STRUCTURED INTERVIEW FOR MERCHANTS' PERCEPTION OF THE PROPOSED SOLUTION

Within scientific research, qualitative data collection methods play an essential role in the deep understanding of social, behavioral and organizational phenomena. Among these methods, the structured interview is one of the most rigorous and controlled forms of researcher-respondent interaction. Widely used in the social sciences, in marketing research, in the analysis of public policies or in the evaluation of projects, the structured interview stands out for its ability to produce comparable, coherent and goal-oriented data.

For a deeper and more intuitive understanding of the opinions expressed by traders during the structured interview regarding the automated solution proposed within the Guarantee-Return System (RMS), a series of graphic representations were made that summarize the most relevant answers obtained. These graphs not only provide an overview of the distribution of responses, but also highlight the prevailing trends, the level of familiarity, the perceived barriers and the degree of openness towards the adoption of RVM (Reverse Vending Machine) equipment.

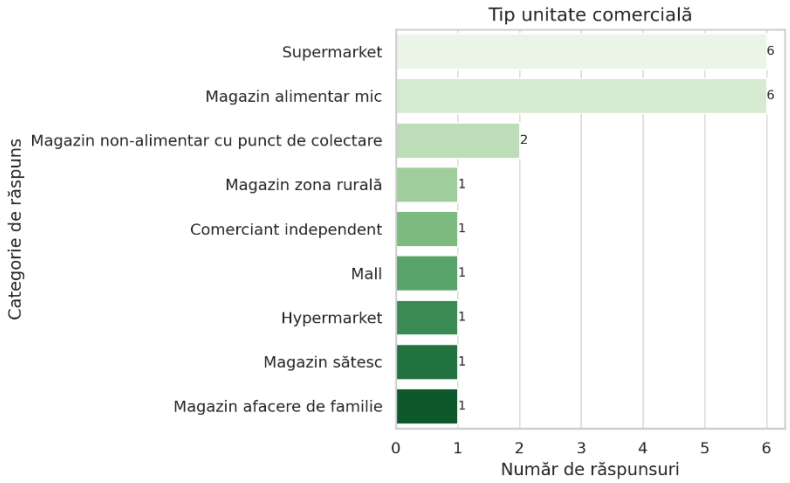

Figure 10.1. Type of business unit

Through figure 10.1, the typological diversity of the participating commercial units is captured. There is a preponderance of supermarkets and small grocery stores, these being categories of economic operators directly involved in the management of warranty packaging.

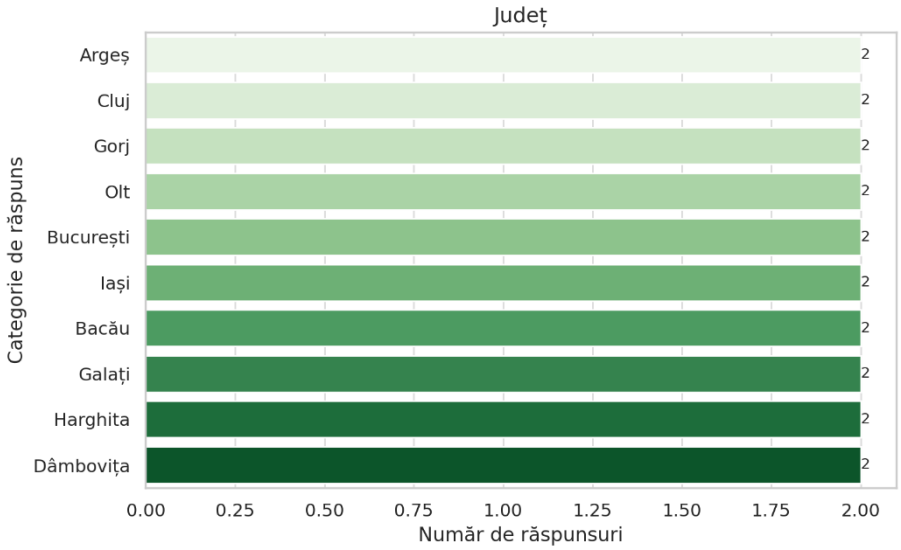

Figure 10.2. Respondents' county of residence

The geographical distribution, illustrated in Figure 10.2, confirms that the responses were collected from a geographically dispersed sample, covering ten counties from different regions of the country, with a higher density in Cluj and Argeș counties.

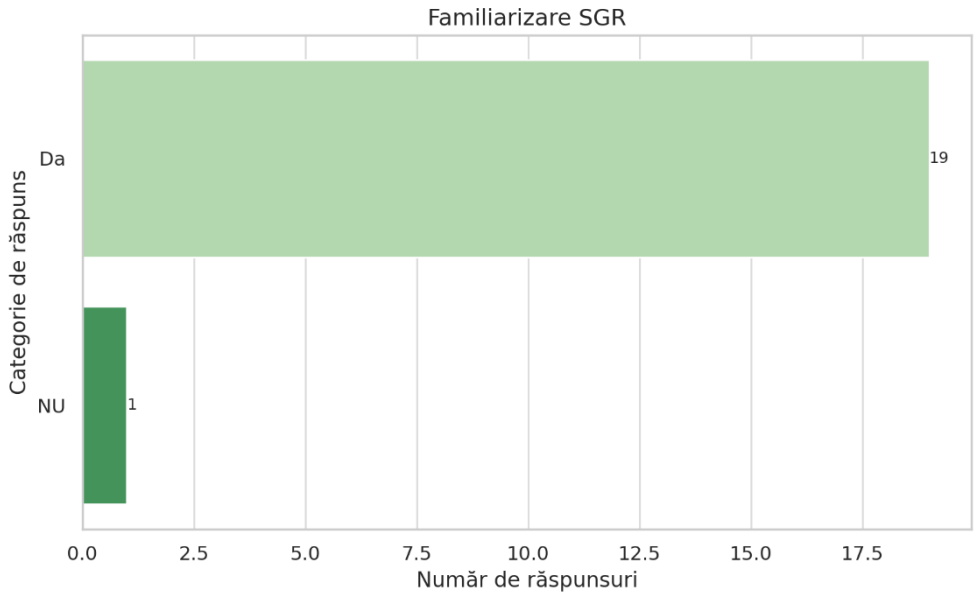

Figure 10.3. Familiarization with the SGR

Next, the graph on the level of familiarity with the SGR shows that most respondents are already aware of the existence and functioning of this system.

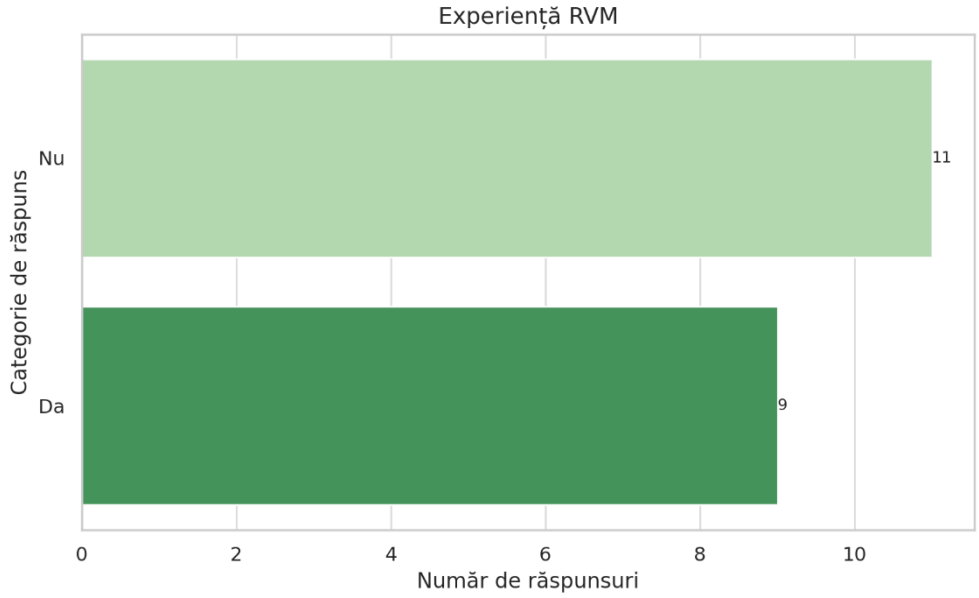

Figure 10.4. Experience in using RVM

Also, a significant part of them had the opportunity to interact with RVM automated equipment, either as traders or as simple users, which gives them a practical perspective on the advantages and limitations of the technology.

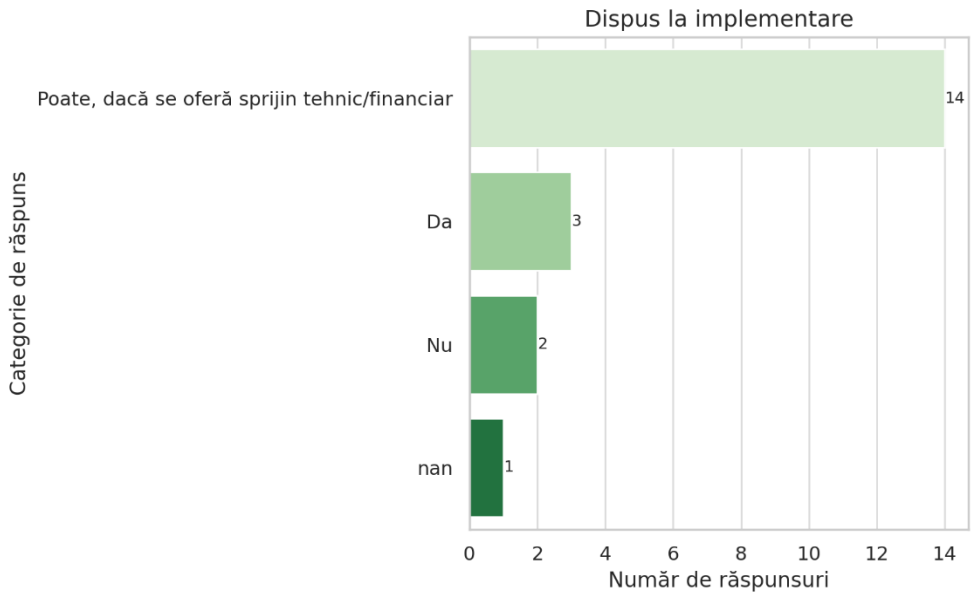

Figure 10.5. Willingness to implement the proposed solution

Another relevant aspect is reflected in the graph dedicated to the availability of merchants to implement the proposed solution. Although one party openly declares that it would adopt such equipment, others condition the decision on adequate technical and/or financial support. This nuance is essential in outlining a realistic plan for implementing the system.

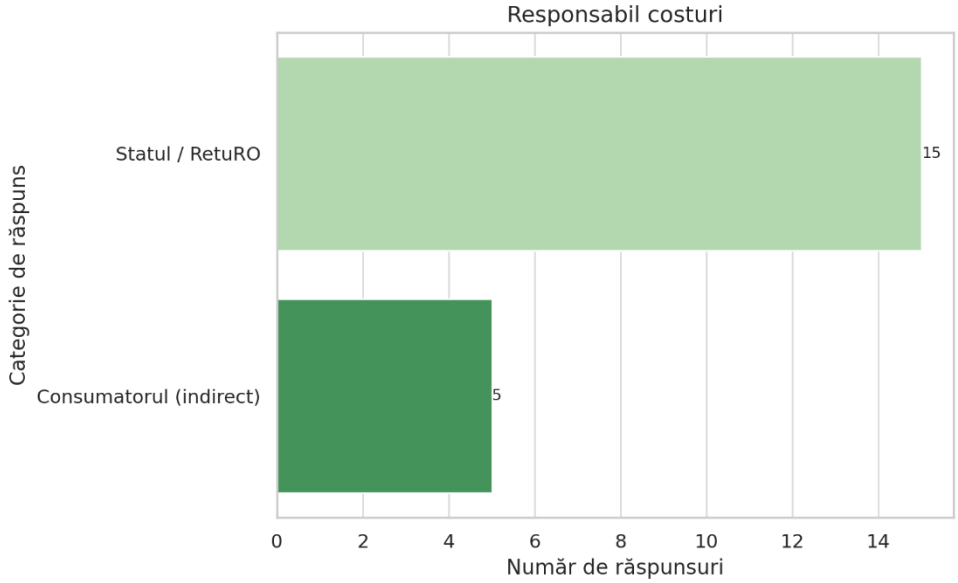

Figure 10.5. Responsibility for the cost of implementation

Regarding the responsibility charged for the costs of acquiring and maintaining the equipment, the answers converge almost unanimously towards the idea that these expenses should be borne by authorities or entities such as RetuRO. This opinion is significant and must be taken into account in the public financing policies of the SGR infrastructure.

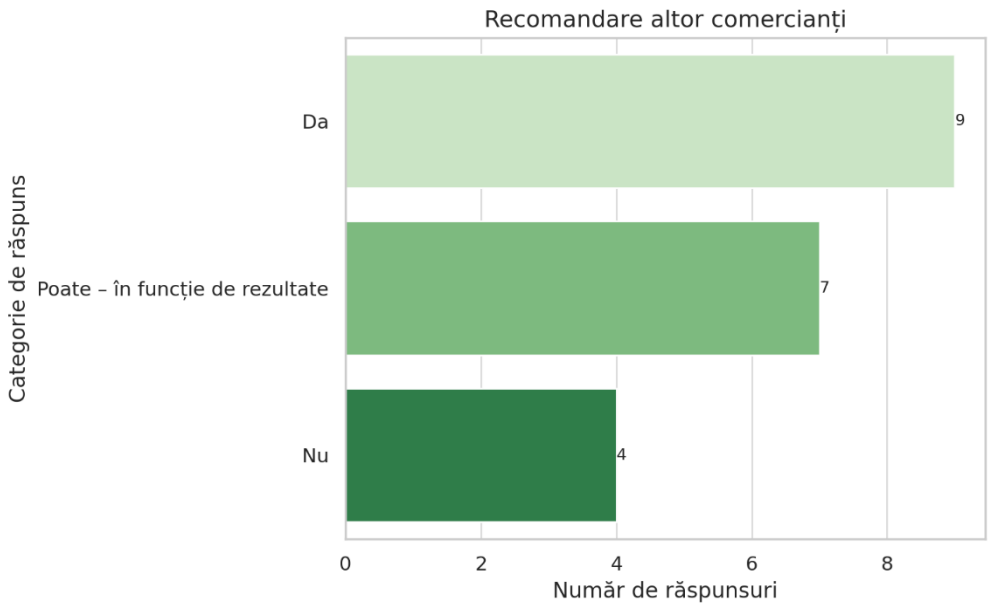

Figure 10.6. Recommending the new solution to other merchants

On the other hand, the degree of recommendation of this solution to other traders is generally positive, but not without reservations. The graphs show a minority that shows reluctance, most often justified by costs or a lack of complete information on the functioning of the system.

Finally, there is a notable consensus on the importance of the processing time of each package, with all respondents pointing out that this indicator is vital for customer satisfaction and process efficiency.

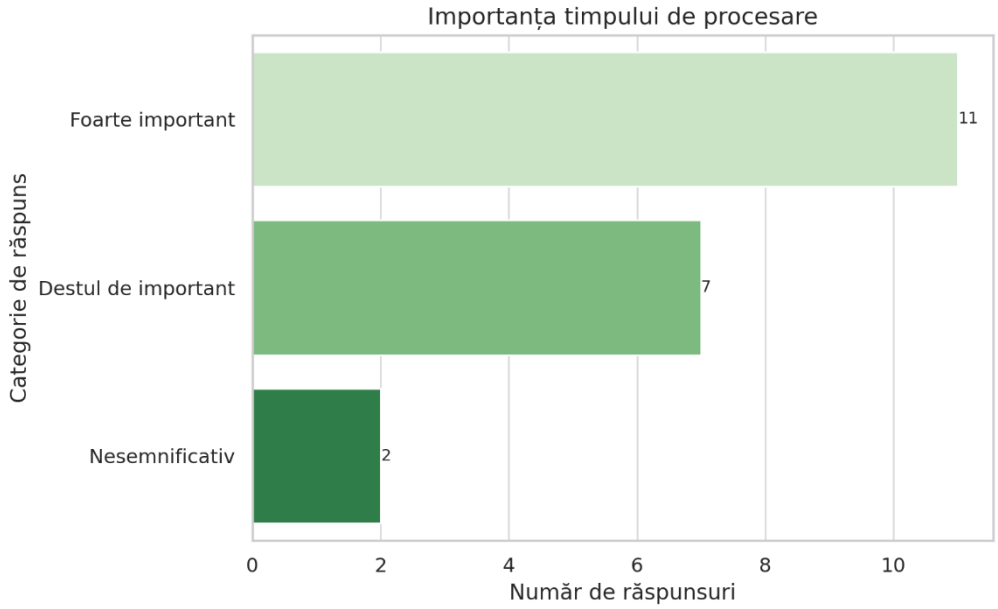

Figure 10.7. The Importance of Processing Time

Therefore, these graphical representations provide a solid visual basis for interpreting qualitative responses and allow a nuanced understanding of the positioning of merchants in relation to the digitization and automation of the collection infrastructure within the SGR.

Chi-square analysis demonstrated that the type of business unit does not significantly influence the intent to recommend automated equipment to other traders. This finding has several important strategic implications:

1. Promotion campaigns should not be differentiated according to the format of the store, but rather according to the level of information and the specific needs of each merchant.
2. Recommendations can come from any segment, and merchants in rural areas or small stores can be as influential and receptive as those in malls or hypermarkets.
3. It is advisable to identify merchants from various types of establishments who have had positive experiences and to be transformed into ambassadors of the project – precisely to cover the full spectrum of commercial formats.

In conclusion, the lack of a significant association between the type of unit and the recommendation of the RVM solution shows us that the perception is determined by deeper factors, such as trust in the system, the functionality of the equipment and the support offered in the implementation process – and not only by the operational specifics of each business.

Chapter 11. FINAL CONCLUSIONS AND ORIGINAL CONTRIBUTIONS TO THE IMPROVEMENT OF THE EQUIPMENT USED IN THE GUARANTEE-RETURN SYSTEM

(1) Important conclusions have been drawn from the analysis of the current state of the Guarantee-Return System, which are presented in Chapter 3. We mention here among the most important are those related to the actual implementation but also the research directions. Thus, research on the Guarantee-Return System is in an active stage of development, focused on evaluating efficiency, adopting new technologies and understanding consumer behavior. However, there is still a need for in-depth studies on the local adaptation of the system, long-term sustainability and social impact.

In recent years, research on SGRs has seen a significant increase, due to the pressure imposed by Green Deals, EU recycling targets and legislative changes. The field is inter/multidisciplinary, being approached from economic, environmental, technological, behavioral and public policy perspectives.

The academic interest in the SGR is solid and growing, reflecting the complexity and importance of this mechanism in the transition to a circular economy. The studies contribute not only to improving the technical performance of the system, but also to understanding the socio-economic and environmental impact, providing essential support for decision-makers and industry

(2) Taking into account the data and conclusions of the analysis of the current state of the Guarantee and Return System, the research and development directions as presented in § 4.1 were considered to be topical. A first fundamental direction concerns the perception and behavior of consumers towards the SGR. It is essential to understand to what extent citizens are informed about the functioning of the system, what motivates them to participate and what barriers they encounter. Demographic factors – such as age, education level, income or residence environment (urban/rural) – have a significant influence on participation and attitudes. Also, financial motivations, often cited as key incentives, are worth evaluating to see

if they are sufficient or need to be supplemented with other types of rewards. At the same time, the obstacles reported by users – from the lack of infrastructure to the complexity of the return procedure – must be analyzed and quantified in order to adapt the system to the real needs of the population.

Another strategic dimension of the research is the economic impact of the SGR on the economic actors involved – from retailers and producers, to logistics operators. A detailed analysis of how the SGRs affect the operational costs of these entities is required, as well as the identification of financial benefits and constraints. The system can also be perceived as an opportunity for the development of recycling infrastructure and for boosting green industries, which opens up a promising framework for applied research in the economy and sustainable entrepreneurship.

From a functional perspective, it is crucial to investigate the logistical and operational efficiency of the system. The network of return points must be evaluated not only quantitatively – by number and geographical coverage – but also qualitatively, in relation to accessibility, equipment and processing capacity. Technical challenges in the collection and sorting of packaging, as well as the frequency of reported problems in the use of equipment, are other topics that require rigorous documentation. At the same time, the role of technology – from automation and intelligent scanning, to dedicated mobile applications – must be analyzed in the context of streamlining operations and improving the user experience.

Another level of research refers to the ecological impact of the implementation of the SGR, from the perspective of reducing abandoned waste and carbon emissions. Through measurements and simulations, resource savings, pollution reduction and indirect benefits on public health and biodiversity can be estimated. In parallel, it is useful to compare the SGR system with other selective collection models, such as voluntary collection or 'door-to-door' take-back systems, in order to highlight the relative effectiveness of each approach.

Inevitably, the implementation of the SGR in Romania must also be put in an international comparative perspective. Studies that analyze Romania's positioning in relation to other countries in the European Union offer not only a picture of the gaps, but also the opportunity to take over good practices from functional systems. Whether it is the success of the German model, the flexibility of the Estonian system or the legislative adaptations in the Nordic countries, each example can provide valuable lessons. Cultural and legislative differences also need to be taken into account, as they profoundly influence the level of participation and the recovery rate of packaging.

In addition to the international comparison, a legal-institutional analysis of the domestic regulatory framework is also necessary. Research in this direction can target the role played by institutions such as the Ministry of Environment, the Environmental Fund Administration or authorized economic operators. Legislative and bureaucratic challenges, delays in implementation, overlapping competences and compliance with European directives are essential topics for clarifying and making the system more efficient.

A complementary and extremely valuable approach is that of local case studies, which allow the investigation of differences in implementation and participation between large urban areas (such as Bucharest, Cluj or Iasi) and rural or isolated communities. Qualitative research can bring to light aspects that are difficult to quantify statistically: lack of local interest, transport difficulties, cultural barriers or low involvement of local administration. Also, the identification of community initiatives – whether of NGOs or groups of volunteers – can highlight models of good practice that can be replicated on a national scale.

(3) In relation to the current stage and the directions of research and development regarding the Guarantee-Return System, it was determined as the main objective of the research and development activity within the doctorate (see and § 4.2) to analyze the

efficiency, public perception and socio-economic and environmental impact of the Guarantee-Return System in Romania, in order to identify the main factors influencing the success of its implementation and to formulate directions for improvement.

In order to achieve the general objective of evaluating the Guarantee-Return System (RMS) in Romania, the research proposes a complex approach, structured in several specific directions. First of all, the level of information, the degree of participation and the motivations of consumers will be analyzed, along with the perceived barriers in the use of the system. Secondly, the economic impacts on the actors involved – traders, producers, distributors and authorities – will be investigated in terms of the associated costs, benefits and challenges.

On the operational level, the functioning of the system will be analyzed from a logistical point of view, with a focus on the efficiency of the infrastructure and possible regional malfunctions. In parallel, the research aims to quantify the environmental benefits of SGR, including reducing abandoned waste and increasing recycling. A comparative component will aim to relate the Romanian model to other European systems, in order to identify good practices and adaptable solutions. Last but not least, the legislative and institutional framework governing the SGR will be analyzed, highlighting the strengths and possible inconsistencies.

By integrating these directions, the research aims to provide a coherent overview of the SGR and to substantiate viable recommendations for improving the functioning of the system, for the benefit of society and the environment.

(4) The relevant conclusions regarding the doctoral research and development activity for the achievement of its main objective, in relation to the methodological references (see § 4.3), are as follows.

Highlighting the extent to which the Guarantee-Return System is known in Romania and the optimal methods of implementation from the consumers' perspective by answering a series of questions such as:

- How well is the Guarantee-Return System known among the general population in Romania?
- What are the perceived advantages of the automatic warranty return system from the consumer's perspective?
- What is the perceived impact on the environment from the consumer's perspective?
- How receptive are Romanian consumers to the implementation of this system?

Based on these elements, the working hypotheses were defined

In order to improve the system, we started from a theoretical analysis of the aspects regarding the quality of products and services, in general, the quality of the automatic guarantee-return system, in particular.

The implementation of the Guarantee-Return System (SGR) is a key element in the transition to a circular economy and in promoting responsible waste management. In this context, the analysis of the quality of the products and associated services becomes essential to guarantee the efficiency and sustainability of the system.

Also, the quality of the services provided by the economic actors involved – from traders to collection centres – has a direct impact on the user experience and on consumers' trust in the SGR mechanism. Well-organized services, informed staff and clear communication with users contribute significantly to increasing the population's involvement in the packaging return process.

The implementation of the SGR in Romania represents an important step in aligning with the European strategies on the circular economy. As the system develops, a rigorous assessment of its impact on consumer behaviour, economic efficiency and operational sustainability is essential. This research aims to analyze the representativeness of the sample used to measure the perception of the adult population towards the SGR, to validate the

hypotheses formulated and to provide a clear picture of the effectiveness of this system in Romania.

The analyzed studies confirm the efficiency of the SGR in reducing packaging waste and promoting recycling, but also the need for continuous adjustments to improve the system.

As the SGR system strengthens in Romania, further studies are needed to assess the long-term impact on the recycling rate, consumer behaviour and its economic sustainability.

The statistical analysis indicates that the sample used is representative of the adult population of Romania, with an acceptable margin of error and an adequate confidence interval. The Chi-square test applied to the hypotheses did not reveal statistically significant differences between the analyzed categories, which suggests that the respondents' perceptions are homogeneous regarding the Guarantee-Return System. Hypothesis testing was done using the Chi-square test (χ^2), individually for each of the 4 hypotheses. All 4 hypotheses have been confirmed.

The analysis carried out highlights the importance of a well-structured guarantee-return system to improve recycling rates and the efficiency of packaging collection. Integrating it into municipal waste management strategies requires careful coordination between authorities, retailers and consumers to maximise the benefits and reduce the costs associated with implementation.

The scientific importance of this doctoral thesis is supported by the contributions made to the statistically representative analysis of the level of consumer involvement in the return guarantee system

The practical importance of this doctoral thesis lies in the fact that it addresses a major topical topic in the context of the transition to a circular economy: the analysis of the Guarantee-Return System (SGR) in Romania. At a time when the responsible management of packaging waste has become not only a legal requirement, but also an ecological emergency, the implementation of an efficient SGR system is one of the most concrete solutions for reducing pollution, recovering resources and educating the civic behavior of consumers.

This research provides a significant practical contribution both for decision-makers and for the economic actors involved – traders, producers, public authorities and logistics operators – as it provides a comprehensive, empirically substantiated diagnosis of the functioning of the system and the perceptions of users. In addition, by highlighting the challenges encountered in its implementation and the regional or structural differences, the paper has the potential to contribute directly to the improvement of public policies in the field of environment and to the optimization of the institutional architecture that supports the functioning of the SGR.

At the same time, the importance of the theme derives from its interdisciplinary character. The Guarantee-Return System is not just a logistical tool, but a complex mechanism involving economic, social, ecological and legislative dimensions. Analyzing this system in depth means understanding the interaction between consumer behavior, the efficiency of the collection infrastructure, financial sustainability and compliance with European regulations. In this regard, the doctoral thesis proposes not only a theoretical analysis, but also a series of applicable recommendations, with immediate relevance for the authorities and the business environment.

By identifying good international practices and adapting them to the national specificity, the research acquires a strategic dimension, providing a valuable guide for strengthening a functional, accessible and accepted SGR system by society. Last but not least, this paper contributes to the development of the academic literature in Romania in the field of environmental policies and waste management, filling a significant gap in terms of the rigorous analysis of the implementation of the SGR in the Romanian space.

Thus, the practical importance of the theme lies in its ability to provide concrete solutions and support the construction of a sustainable packaging management model, with long-term positive effects on the environment, economy and civic culture.

The implementation of the Guarantee-Return System does not only imply a legislative regulation and a sustainable economic model, but also an efficient technological support. An essential role in the operation of this system is played by automated collection equipment, also known as RVMs (Reverse Vending Machines). These devices are a clear example of the integration of technology into green infrastructure, allowing the automatic collection, identification, validation and rewarding of the user for returned packaging.

The built system involves two major advantages: reducing the processing time of returned packaging and improving economic efficiency by decreasing the cost of return and increasing consumer compliance as a result of reducing time. Decreasing the time to identify the type of packaging based on the built-in camera system is an optimized variant of the current solutions for implementing the Guarantee-Return System, and the large-scale implementation of such a mechanism can determine major advantages at the level of the entire economic gear.

Given that environmental care is a priority at the level of the European Union and beyond, we consider such an approach to encourage the circular economy to be appropriate.

The originality of the analysis is given by the unitary vision in which the doctoral research was constituted, which started from the statistically representative analysis of the consumers' perception of the implementation of the Guarantee-Return System, given that it is recently introduced in our country.

Based on the answers received to the questionnaire applied, an improved equipment for taking over the packaging subject to this system was designed, equipment for which the software was also developed to allow the practical implementation of the solution. A qualitative study was also carried out among the traders, to inventory their receptivity to the implementation of the proposed solution.

In the perspective of consolidating an efficient Guarantee-Return System (RMS) adapted to contemporary realities, future research directions must address not only the logistical and behavioral components of the system, but also the opportunities offered by emerging technologies. One of the most promising directions is undoubtedly the integration of Artificial Intelligence into the technical architecture of return equipment. The use of machine learning algorithms, advanced visual recognition and behavioral prediction systems could radically transform the way packaging subject to return is collected, identified and sorted.

Thus, an entire branch of applied research in the field of intelligent automation is taking shape, which aims to develop equipment capable of recognizing the packaging material (PET, aluminum, glass), detecting possible contamination or fraud attempts and interacting with users through intuitive interfaces, including voice or based on mobile applications. RVM equipment could in the future become smart nodes in an interconnected collection and recycling network, where data is analyzed in real time, and maintenance or redistribution interventions are automatically planned based on predictive algorithms.

However, this technological approach should not be separated from the behavioural dimension. Another important research direction is predictive modeling of consumer behavior, in order to understand and anticipate their reactions to different measures – be they financial, educational or logistical. Using advanced statistical models, combined with empirical data, distinct user profiles can be identified, such as enthusiastic participants, conditional skeptics or chronic non-participants, which would allow the design of much more targeted and effective communication and intervention strategies.

In addition to behavioral analysis, it is also necessary to deepen the economic component by developing extensive cost-benefit analysis models. Such research could include, in addition to direct financial calculations, social and environmental impacts – such as savings

made in the public sanitation sector, reduction of expenditure associated with pollution or indirect public health benefits. In this sense, the SGR system must be seen as an integral part of a circular economic ecosystem, whose effects extend far beyond the physical collection of packaging.

Another relevant direction is related to the sustainability assessment of the entire recycling chain, through the application of Life Cycle Assessment. This would make it possible to estimate the real environmental impact of each stage – from the transport of packaging, the energy consumption of RVM equipment to the recovery of the resulting materials. Such an approach could highlight not only the benefits, but also potential areas of inefficiency or hidden ecological contradictions.

Research should also address the issue of technological interoperability. In an increasingly digitized society, the integration of the SGR system with mobile applications, payment platforms and digital reward systems becomes a necessity. This opens up a fertile field for studies on the digitization of the recycling process, the gamification of participation (through rankings, badges or ecological challenges) and the development of personal accounts through which users can track their contribution to protecting the environment.

Also in the sphere of the near future are comparative research at international level, which can highlight the cultural, legislative and institutional differences between the Romanian model and other successful European systems. These studies would allow the adaptation of good practices to the national specificity, contributing to the refinement of public policies and to the overcoming of cultural or administrative obstacles.

Finally, a particularly sensitive but increasingly topical aspect is the analysis of the ethical implications of the implementation of advanced technologies. Future research needs to answer questions such as: is video surveillance at points of return acceptable? How is users' personal data protected? What degree of transparency is required in the operation of decision algorithms? Thus, an interdisciplinary approach is required, in which digital ethics, consumer rights and technological engineering collaborate in a coherent and balanced framework.

In conclusion, the future research directions in the field of SGR are not limited to refining an administrative mechanism, but propose a rethinking of the entire collection and recycling system in an intelligent, adaptive and sustainable key. The implementation of Artificial Intelligence is not just an exercise in technological innovation, but an essential step in the evolution towards an efficient, transparent and citizen-centric system – a system in which the environment, economy and technology harmonize in the service of a cleaner future.

Bibliography

1. LAW no. 211 of 15 November 2011 (republished) on the waste regime. Published in the Official Gazette no. 220 of 28 March 2014.
2. Robles I., O'Dwyer E., Guo M., (2020), *Waste-to-Resource value chain optimisation: Combining spatial, chemical and technoeconomic aspects* available at https://www.x-mol.com/paper/1253723937566515200.
3. Haas M., Galler R., Scibile L., Benedikt M., (2020), *Waste or valuable resource — a critical European review on re-using and managing tunnel excavation material, Resources,* Conservation and Recycling, Volume 162, 105048.
4. Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste.
5. BASEL CONVENTION on the Control of the Transportation of Hazardous Wastes and Their Disposal across Borders, published in Official Gazette No. 18/26 Jan. 1991 http://www.cdep.ro/pls/legis/legis_pck.htp_act_text?idt=28032
6. De Vega C. A., Ojeda-Benítez S., Ramírez M. E., (2008), Solid Waste Characterization Recycling Potential for a University Campus, Waste Management, 28 Suppl 1:S21-6, PubMed.
7. Annual Report 2010 - The State of Environmental Factors in Romania, Chapter 6 Waste Management, p. 143-16, https://www.wall-street.ro/files/143775-395.pdf.
8. Mateescu C., Băran G., Constantinescu I., *New trends in the treatment and energy recovery of biodegradable municipal waste*, National Institute for Research and Development for Electrical Engineering ICPE-CA Bucharest, "POLITEHNICA" University of Bucharest https://www.inginerie-electrica.ro/acqu/pdf/2008_9.pdf.
9. Centralized medical waste treatment system https://www.gient.net/medical-waste-autoclave/.
10. Johnson A., Eastern Metropolitan Regional Council, (2007), *The Development of Waste Management Law,* available at: https://www.iswa.org/uploads/tx_iswaknowledgebase/538338_Paper.pdf in English.
11. Rathje W., Murphy C., (2001), *Rubbish! The archeology of garbage*, second edition The University of Arizona Press, Tucson.
12. United Nations Framework Convention on Climate Change, (2008), *Kyoto Protocol Reference Manual.* United Nations Framework Convention on Climate Change, Available at: http://unfccc.int/kyoto_protocol, in English.
13. Vienna Convention on the Protection of the Ozone Layer http://publications.europa.eu/resource/cellar/607feb06-39d3-11ea-ba6e 01aa75ed71a1.0020.02/DOC_1.
14. Directive 2008/98/EC of 19 November 2008 on waste and repealing certain Directives. https://www.greenresources.ro/wp-content/uploads/2020/08/directiva-2008-98-ce-19-nov-2008-forma-sintetica-pentru-data-2020-06-05.pdf.
15. Regulation (EC) no. 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste.
16. Commission Decision of 3 May 2000 replacing Decision 94/3/EC establishing a list of waste pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Directive 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste (notified under document number C(2000).
17. Directive 1999/31/EC on landfills.

18. Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).
19. Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC.
20. Directive 2012/19/EU on waste electrical and electronic equipment.
21. Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the environmental impact of certain plastic products.
22. Căilean (Gavrilescu) D., Teodosiu C., (2016), *An assessment of the romanian solid waste management system based on sustainable development indicators, Sustainable Production and Consumption,* Volume 8, p. 45-56.
23. NATIONAL PLAN for waste management of 20 December 2017, Published in the Official Gazette no. 11 bis of 5 January 2018.
24. The Law on Community Services of Public Utilities no. 51/2006.
25. Communication from the Commission on technical guidance on the classification of waste (2018/C 124/01), EUR- Lex https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018XC0409%2801%29.
26. NATIONAL PLAN for waste management of 20 December 2017, Published in the Official Gazette no. 11 bis of 5 January 2018.
27. ORDER no. 1121/2006 of 4 July 2006 on the application of International Financial Reporting Standards.
28. Association of Development Intercommunity Dobrogea https://www.adidobrogea.ro/reciclarea-deseurilor/despre-deseuri/.
29. Smart collection station https://www.sigurec.ro/ro/solutiile-sigurec/sigurec-prime.html .
30. Nowakowski P., Szwarc K., Boryczka U., (2020), *Combining an artificial intelligence algorithm and a novel vehicle for sustainable e-waste collection,* Science of The Total Environment, Volume 730, 138726.
31. Greco G., Cenciarelli V. G., Allegrini M, (2018), *Tourism's impacts on the costs of municipal solid waste collection: Evidence from Italy, Giulio Greco, Velia Gabriella Cenciarelli, Marco Allegrini,* Journal of Cleaner Production Volume 177, p. 62-68.
32. Farrokhi - Asl H., Makui A., Ghousi R., Rabbani M., (2020), *Developing a hazardous waste management system with consideration of health, safety, and environment,* Computers & Electrical Engineering, Volume 82, 106553.
33. Ministry Environment and Changes Climate http://www.mmediu.ro/beta/domenii/gestionarea-deseurilor/transport-depozitare-incineration/.
34. DECISION No. 1061 of 10 September 2008 on the transport of hazardous and non-hazardous waste on the territory of Romania.
35. Asefi H., Shahparvari S., Chhetri P.,(2019) *Integrated Municipal Solid Waste Management under uncertainty: A tri-echelon city logistics and transportation context,* Sustainable Cities and Society, Volume 50.
36. Nowakowski P., Szwarc K., Boryczka U., (2020), *Combining an artificial intelligence algorithm and a novel vehicle for sustainable e-waste collection,* Science of The Total Environment, Volume 730, 138726.
37. Lella J., Mandla V. R., Zhu X., (2017), *Solid waste collection/transport optimization and vegetation land cover estimation using Geographic Information System (GIS): A case study of a proposed smart-city, Sustainable Cities and Society,* Volume 35, p. 336-349.
38. Huber F., Blasenbauer D., Mallow O., Lederera J., Winter F., Fellnera J,(2016), *Thermal co-treatment of combustible hazardous waste and waste incineration fly ash in a rotary kiln, Waste Management,* Volume 58, p. 181-190.
39. Gao A., Tian Z., Wang Z., Wennersten R., eSun Q., (2017) *Comparison between the*

Technologies for Food Waste Treatment, Energy Procedia, Volume 105, p. 3915-3921.
40. Theodosiou A., Jones A.N., Burton D., Powell M., Rogers M., Livesey V.B., (2018), *The complete oxidation of nuclear graphite waste via thermal treatment: An alternative to geological disposal,* Journal of Nuclear Materials, Volume 507, p. 208217.
41. Daigo I., Kiyohara S., Okada T., Okamot D., Goto Y., (2018), *Element-based optimization of waste ceramic materials and glasses recycling,* Resources, Conservation and Recycling, Volume 133, p. 375-384.
42. Kalinowska - Wichrowska K., Pawluczuk E., Boltryk M, (2020), *Waste-free technology for recycling concrete rubble concrete,* Construction and Building Materials, Volume 234, 117407.
43. Guo L., Wu D.Q., (2017), *Study of recycling Singapore solid waste as land reclamation filling material,* Sustainable Environment Research, Volume 27, Issue 1, p. 1-6.
44. Xevgenos D., Papadaskalopoulou C., Panaretou V., Moustakas K., Malamis D., (2015) *Success Stories for Recycling of MSW at Municipal Level: A Review,* Waste Biomass Valor, 6, p. 657-684.
45. Mwanza B. G., Mbohwa C., Telukdarie A., (2018), *Levers Influencing Sustainable Waste Recovery at Households Level: A Review*, Procedia Manufacturing, Volume 21, p. 615-622.
46. Cristobal J., Caldeira C., Corrado S., Sala S., (2019), *Techno-economic and profitability analysis of food waste biorefineries at European level,* Science of The Total Environment, Volume 693, 133516.
47. van Herpen E., van Geffen L., Nijenhuis-de Vries M., Holthuysen N., van der Lans I., Quested T., (2019), *A validated survey to measure household food waste,* MethodX, Volume 6, p. 2767-2775.
48. Derqui B., Grimaldi D., (2020), *Data on the sustainability profile and food waste management in primary and secondary schools: The case of the Catalonia region in Spain, Data in Brief*, Volume 28, 104825.
49. Yildiz N.D., Yilmaz H., Demir M., Toy S., (2011), *Effects of personal characteristics on environmental awareness; a questionnaire survey with university campus people in a developing country, Turkey,* Scientific Research and Essays Vol. 6(2), p. 332-340.
50. Desa A., Abd Kadir N.B., Yusooff F., (2012), *Waste education and awareness strategy: towards solid waste management (SWM) program at UKM*; Procedia - Social and Behavioral Sciences, Volume 59, p. 47-50.
51. A. Semenescu (coordinator), O.R.Chivu, A. Ioana, M.C.Costoiu, D.F. Marcu, C.A. Barbu, "STATISTICS IN ENGINEERING AND ECONOMICS"-, Ed POLITEHNICA Press, 2018, 233 p. ISBN 978-606-515-796-5.
52. Adrian IOANA, Augustin SEMENESCU, Dragos Florin MARCU, Alexandru GHIBAN, Alina Nicoleta COLAN, Quality Management. Theory and Applications. Matrix Rom Publishing House, COD CNCSIS 39, Bucharest, ISBN 978-973-755-894-7, 318 pages, 2013.
53. Mihnea COSTOIU, Augustin SEMENESCU, Adian IOANA, Dragos Florin MARCU, Catalin BARBU Economic and Financial Analysis - Theory and Applications, Matrix Rom Publishing House, COD CNCSIS 39, ISBN 978-606-25-0196-9, Bucharest, 179 pages, 2015
54. Ioana, A., Semenescu, A., Marcu, D., The Basics of Management. Theory and Applications, Matrix Rom Publishing House, COD CNCSIS 39, Bucharest, ISBN 978-973-755-761-2, 251 pg, Bucharest, 2011.
55. Bethlehem, J., Biffignandi, S., & Rossi, G. (2017). Handbook of Web Surveys. Wiley.
56. Pew Research Center. (www.pewresearch.org) - Trusted source for opinion polls and topical surveys in various fields.
57. Gallup (www.gallup.com) - One of the most well-known polling institutes, it provides

relevant data and analysis in the political, economic and social fields.
58. American Association for Public Opinion Research (AAPOR) (www.aapor.org) - A professional organization dedicated to the study of polls and opinion polls.
59. European Society for Opinion and Marketing Research (ESOMAR) (www.esomar.org) - A global association that promotes market research and opinion polls.
60. Field, A. (2018). Discovering Statistics Using IBM SPSS Statistics. SAGE Publications Ltd. - This book provides a comprehensive introduction to applied statistics, focusing on the use of IBM SPSS Statistics software in data analysis.
61. Agresti, A., & Finlay, B. (2019). Statistical Methods for the Social Sciences. Pearson. - This book is an excellent resource for understanding the basic principles of statistics in the social sciences.
62. Levin, J. R., Fox, J., & Forde, D. R. (Eds.). (2016). Elementary Statistics in Social Research. Pearson. - This book is suitable for beginners and provides a clear and accessible introduction to statistics, with examples from social research.
63. Diez, D. M., Barr, C. D., & Çetinkaya-Rundel, M. (2014). OpenIntro Statistics. OpenIntro, Inc. – This book is freely available and provides an introduction to modern statistics, including concepts and examples relevant to current research.
64. Fowler Jr., F. J. (2013). Survey Research Methods (4th ed.). Sage Publications, Inc.
65. Groves, R. M., Fowler Jr., F. J., Couper, M. P., Lepkowski, J. M., Singer, E., & Tourangeau, R. (Eds.). (2009). Survey Methodology (2nd ed.). Wiley.
66. Lavrakas, P. J. (Ed.). (2008). Encyclopedia of Survey Research Methods. Sage Publications, Inc.
67. Saris, W. E., & Gallhofer, I. N. (Eds.). (2014). Design, Evaluation, and Analysis of Questionnaires for Survey Research (2nd ed.). Wiley
68. Adrian IOANA, Augustin SEMENESCU, Monica IORGA (CRĂCIUNICĂ), Claudiu NICOLICESCU, Bianca Cezarina ENE, Daniela Ionela JUGANARU, Dumitru DEONISE, Costin Alexandru DEONISE, Florin-Ștefan PETCU, "Quality Management. Theory and Applications. Second Ed. – revised and improved", Printech Publishing House, Bucharest (forthcoming).
69. Ioana, A., Semenescu, A., Marcu, D., Ghiban, A., Alina Nicoleta Colan, "Quality Management. Theory and Applications". Matrix Rom Publishing House, Bucharest, ISBN 978-973-755-894-7, 318 pages, 2013.
70. Ioana, A., Semenescu, A., Preda, C.F., Marcu, D., "The Basics of Management. Theory and Applications, Second Edition Revised and Improved", Matrix Rom Publishing House, Bucharest, ISBN 978-973-755-761-2, 342 pg, Bucharest, 2012.
71. Ioana, A., Semenescu, A., Preda, C.F., "Strategic Management. Theory and Applications". Matrix Rom Publishing House, Bucharest, ISBN 978-973-755-8268, 204 pg, Bucharest, 2012.
72. Adrian IOANA, Daniela TUFEANU, Dragos Florin MARCU, Bogdan FLOREA, Daniela Alice LUTA, Bianca Cezarina ENE, Daniela Ionela JUGANARU, Roxana Marina SOLEA, "Historical and Educational Aspects of Discoveries and Inventions that Revolutionized Mankind", EUROPEAN JOURNAL OF MATERIALS SCIENCE AND ENGINEERING (EJMSE), Volume 6, Issue 3, 2021: 131-135 www.ejmse.ro | ISSN: 2537-4338, doi:10.36868/ejmse.2021.06.03.131, 2021.
73. Florin-Ștefan Petcu, Adrian Ioana, Claudiu Nicolicescu, Monica Iorga (Crăciunică), Bianca Cezarina Ene, and Dumitru Deonise "Aspects Regarding the Analysis and Quantification of the Quality of Products, Works and Services (II)" article in progress in the journals ACTA TECHNICA NAPOCENSIS – Series: APPLIED MATHEMATICS, MECHANICS AND ENGINEERING and REVISION OF UNCONVENTIONAL TECHNOLOGIES
74. Timoteo, M; Lourenço, E; Broached, AC; Domenico, L; da Silva, J; Oliveira, B; Barbosa,

R; Montemezzi, P; Mourão, CFDB; Olej, B; Alves, G, "Digital Management Systems in Academic Health Sciences Laboratories: A Scoping Review" , HEALTHCARE, ISSN 2227-9032, 2021, Volume, 9, Issue, 6, Pages, 222 - 286, WOS:000666094800001

75. Doringer, S, "'The problem-centred expert interview'. Combining qualitative interviewing approaches for investigating implicit expert knowledge" , INTERNATIONAL JOURNAL OF SOCIAL RESEARCH METHODOLOGY, ISSN 1364-5579, 2021, Volume, 24, Issue, 3, Pages, 265 - 278, WOS:000539973000001
76. Van Wart, M; Roman, A; Wang, XH; Liu, C, "Operationalizing the definition of e-leadership: identifying the elements of e-leadership" , INTERNATIONAL REVIEW OF ADMINISTRATIVE SCIENCES, ISSN 0020-8523, 2019, Volume, 85, Issue, 1, Pages, 80 - 97, WOS:000461564700006
77. Van Wart, MM; Roman, A; Wang, XH; Liu, C, "Integrating ICT adoption issues into (e-)leadership theory" , TELEMATICS AND INFORMATICS, ISSN 0736-5853, 2017, Volume, 34, Issue, 5, Pages, 527 - 537, WOS:000401386000011
78. . Ji, XY; Ye, H; Zhou, JX; Deng, WL, "Digital management technology and its application to investment casting enterprises" , CHINA FOUNDRY, ISSN 1672-6421, 2016, Volume, 13, Issue, 5, Pages, 301 - 309, WOS:000389837200001
79. Li, WZ; Liu, KC; Belitski, M; Ghobadian, A; O'Regan, N, "e-Leadership through strategic alignment: an empirical study of small- and medium-sized enterprises in the digital age" , JOURNAL OF INFORMATION TECHNOLOGY, ISSN 0268-3962, 2016, Volume, 31, Issue, 2, Pages, 185 - 206, WOS:000378667700007
80. Voce, J, "Reviewing institutional policies for electronic management of assessment" , HIGHER EDUCATION, ISSN 0018-1560, 2015, Volume, 69, Issue, 6, Pages, 915 - 929, WOS:000354292400003