

UDC 338.2+338.5

DOI: <https://doi.org/10.32782/business-navigator.76-56>**Rosokhata Anna**

Doctor of Philosophy (Economics), Associate Professor,
Senior Lecturer of Department of Marketing
Sumy State University

ORCID: <https://orcid.org/0000-0001-6944-1515>**Matvieieva Yuliia**

Doctor of Philosophy (Economics), Associate Professor,
Senior Lecturer of Oleg Balatskyi Department of Management
Sumy State University

ORCID: <https://orcid.org/0000-0002-3082-5551>**Bolotna Tetiana**

Bachelor's Degree Student
Sumy State University

ORCID: <https://orcid.org/0009-0009-7993-8547>**Росохата А.С.**

кандидат економічних наук, доцент,
старший викладач кафедри маркетингу
Сумський державний університет

Матвєєва Ю.А.

кандидат економічних наук, доцент,
старший викладач кафедри управління імені Олега Балацького
Сумський державний університет

Болотна Т.О.

здобувач освіти освітнього рівня «Бакалавр»
Сумський державний університет

ANALYSIS AND MULTI-CRITERIA OPTIMIZATION OF INVESTMENT SUPPORT OF THE WASTE MANAGEMENT SYSTEM FOR ENERGY¹

АНАЛІЗ ТА БАГАТОКРИТЕРІАЛЬНА ОПТИМІЗАЦІЯ ІНВЕСТИЦІЙНОГО ЗАБЕЗПЕЧЕННЯ СИСТЕМИ УПРАВЛІННЯ ВІДХОДАМИ ДЛЯ ЕНЕРГЕТИКИ

Recently, Ukraine has faced the problem of environmental pollution caused by various factors. Knowing the criticality of the situation, the Ukrainian government implemented the National Waste Management Strategy until 2030. This document outlines a detailed action plan to solve the country's waste generation and handling issues. The most useful tool for implementing this strategy is investment programs in household waste management. Although these programs are powerful tools for developing the waste management sector, they require effective control and regulation. So, a multi-criteria optimization method can be used to choose the optimal program evaluation and selection method. Additionally, to ensure the targeted use of funds, prevent corruption and abuse, and increase the efficiency of investments, some problems need a solution.

Keywords: research, waste management, environmental strategy, investment programs, household waste, financing of environmental projects, waste legislation.

У статті були дослідженні проблеми управління відходами в Україні, які стали особливо актуальні в останні роки через антропогенний вплив та індустріалізацію. Ці фактори стали основними причинами збільшення обсягів побутових і промислових відходів, забруднення ґрунтів та водойм, а також виснаження природних ресурсів. У відповідь на ці виклики, уряд України впровадив Національну стратегію управління відходами до 2030 року, яка націлена на зменшення обсягів утворення відходів та підвищення ефективності їхньої переробки та утилізації. Одним з основних інструментів реалізації цієї стратегії є впровадження

¹ The research is supported by the budget of the Ministry of Education and Science of Ukraine (research topic 0123U100112 “Post-war recovery of the energy industry of Ukraine: Optimization of waste management taking into account the health of the population, environmental, investment, tax determinants”; research topic 0122U000769 “Transfer of Green Innovations in the Energy Sector of Ukraine: A Multiplicative Stochastic Model of the Transition to a Carbon-Neutral Economy”) and the Executive Agency for Education and Culture of the European Union (Jean Monet module, project No. 101047530 “Healthy economy and policy: European values for Ukraine”)

інвестиційних програм у сфері управління побутовими відходами. У статті детально проаналізовано існуючі інвестиційні програми, методи їхньої оцінки та відбору, запропоновано метод багатокритеріальної оптимізації, який дозволить визначити найбільш значимі та корисні програми для фінансування. Було проведено порівняльний аналіз успішних інвестиційних програм, що дозволило виявити ключові фактори, які сприяють їхній ефективності. Особлива увага приділена питанням фінансування заходів у сфері управління відходами, де зазначено, що інвестиційні програми можуть стати повноцінним джерелом фінансування. Досліджуються алгоритми подання, погодження та затвердження інвестиційних програм відповідно до наказу Міністерства розвитку громад, територій та інфраструктури України від 18 жовтня 2023 року. В статті також висвітлюється механізм контролю за виконанням цих програм, встановлений постановою Кабінету Міністрів України від 7 липня 2023 року, що передбачає моніторинг виконання програм та аналіз їхніх результатів. На основі проведеного аналізу було розроблено рекомендації щодо удосконалення процесу вибору, затвердження та контролю інвестиційних програм у сфері управління відходами. Запропоновані рекомендації можуть бути використані для підвищення ефективності системи фінансування екологічно спрямованих заходів, що сприятиме досягненню європейських стандартів екологічної свідомості в Україні. Перспективи подальших досліджень полягають у розробці критеріїв для багатокритеріальної оптимізації інвестиційних програм з метою створення прозорого та ефективного механізму їхнього впровадження.

Ключові слова: дослідження, управління відходами, екологічна стратегія, інвестиційні програми, побутові відходи, фінансування екологічних проєктів, законодавство у сфері відходів.

Statement of the problem. In recent years, the problem has become particularly challenging in Ukraine and globally. Due to industrialization, intensive use of fuel and energy resources, and increased emissions into the atmosphere, the volume of waste is growing, which results in soil and water pollution and a general decline in the quality of life of the population.

In this regard, the Government of Ukraine has set out to develop and implement a systematic approach to solving this problem. It launched the National Waste Management Strategy until 2030, which aimed not only at reducing waste generation but also at increasing the efficiency of its recycling and reuse. One of the main tools for implementing the strategy is the implementation of investment programs in the household waste management field.

Investment programs introduced in this area play an essential role in financing waste processing and recycling. However, despite the significant potential of these programs, there are several challenges and problems related to the need to find a methodology for selecting the most relevant and useful programs for their financing, which can lead to a loss of funds due to financing of less profitable investment programs from the point of view of waste management. In addition, there are several problems with their effective control, regulation and monitoring. Risks of corruption, shortcomings in identifying potential investors, and the lack of a comprehensive approach to attracting investment are the main obstacles to achieving the strategic goals.

Analysis of recent research and publications. Ecology, environmental investment and investment in innovation are leading topics in the scientific research of experts around the world. Not only because of its relevance and significance in the context of global climate change but also because of the opportunities to introduce the latest technologies and modernize existing processes that can fundamentally change our understanding of sustainable development, this area attracts deep interest. It has also gained wide resonance in the Ukrainian scientific community. The issue is studied by such academics as Lyulyov O. [1–4], Letunovska N. [4], Pimonenko T. [1–6; 8], Ziabina E. [2; 6], Chygryn O. [1; 5], Kvilinsky O. [2; 3; 6],

Sager L. [7], Kazimirova V. [7], Leonov S. [8], Bilan Y. [8], Štreimikiene D. [8], Mentel G. [8].

Formulation of the research task. The purpose of the study is to analyze the current waste management policy and methods of its financing on the example of investment programs, to conduct research on the algorithm for submitting, approving and implementing investment programs and, on this basis, to provide recommendations for improving the choice by multi-criteria optimization, approval and control of investment programs.

Summary of the main research material. On November 8, 2018, the Cabinet of Ministers of Ukraine issued a resolution "On Approval of the National Waste Management Strategy in Ukraine until 2030" the purpose of which is to reduce the amount of waste generation and increase the efficiency of its processing and reuse. This strategy is aimed at creating the necessary preconditions for improving the living standards of the population through the implementation of a systematic approach to waste management at the national and regional levels. The resolution also sets out specific goals for the disposal of each type of waste to achieve this goal.

According to the resolution, there are the following types of waste that need to be disposed of: household waste, industrial waste, construction and repair waste, hazardous waste, agricultural waste, and specific types of waste [9]. According to Article 33 of the Law of Ukraine "On Waste Management": "Financing of activities in the field of waste management is carried out at the expense of waste generators and owners. Funds from the state and local budgets, environmental protection funds, voluntary contributions from enterprises, institutions, organizations, citizens of Ukraine and their associations, as well as other sources not prohibited by law may be used to finance measures in the field of waste management" [10]. Accordingly, investment programs can become a full-fledged source of funding for waste management.

For this reason, it is proposed to consider the procedure for the development, approval and approval of investment programs in the field of household waste management, approved by the order of the Ministry of Community Development, Territories and Infrastructure of Ukraine on 18th of October 2023, the order "On Approval of the

Procedure for the Development, Approval and Approval of Investment Programs of Business Entities in the Field of Household Waste Management" [11; 12]. In general, it can be divided into 4 stages: development, approval, approval and publication of the investment program (Figure 1).

Also, the resolution dictates a strict structure of the investment program in order to analyze it more clearly and to investigate whether the enterprises developing investment programs adhere to it. Let's look at Table 1, where we analyzed the following two investment programs:

The investment program for household waste management of the Putivl Housing and Maintenance Office for 2024–2025 [13].

The Investment Program of GRINERA Boryslav Limited Liability Company for 2024 [14].

The investment program is approved by an authorized body, which is the executive authority of a village, town or city council, which sets tariffs for the recovery and disposal of household waste in accordance with the Laws of Ukraine "On Local Self-Government in Ukraine" and "On Waste Management". Also, since July 7, 2023, the Cabinet

of Ministers of Ukraine has approved the Procedure for Monitoring the Implementation of Investment Programs in the Field of Household Waste Management.

It specifies that this Procedure establishes a mechanism for monitoring the implementation of investment programs in the field of household waste management. The control is carried out by authorized institutions at the municipal level to monitor the implementation of the programs. Business entities are obliged to submit reports on the implementation of investment programs within the established timeframe, which contain information on the costs and results of the measures taken. The authorized institution reviews the submitted materials and draws up an act on the results of the program implementation, which expresses conclusions on the accuracy and completeness of the measures taken [12].

At this stage, we propose to apply the multicriteria optimization method [15]. There are multiple reasons for this. First, waste management is a complex and multifaceted issue that requires consideration of numerous interrelated factors, such as economic, environmental and social aspects.

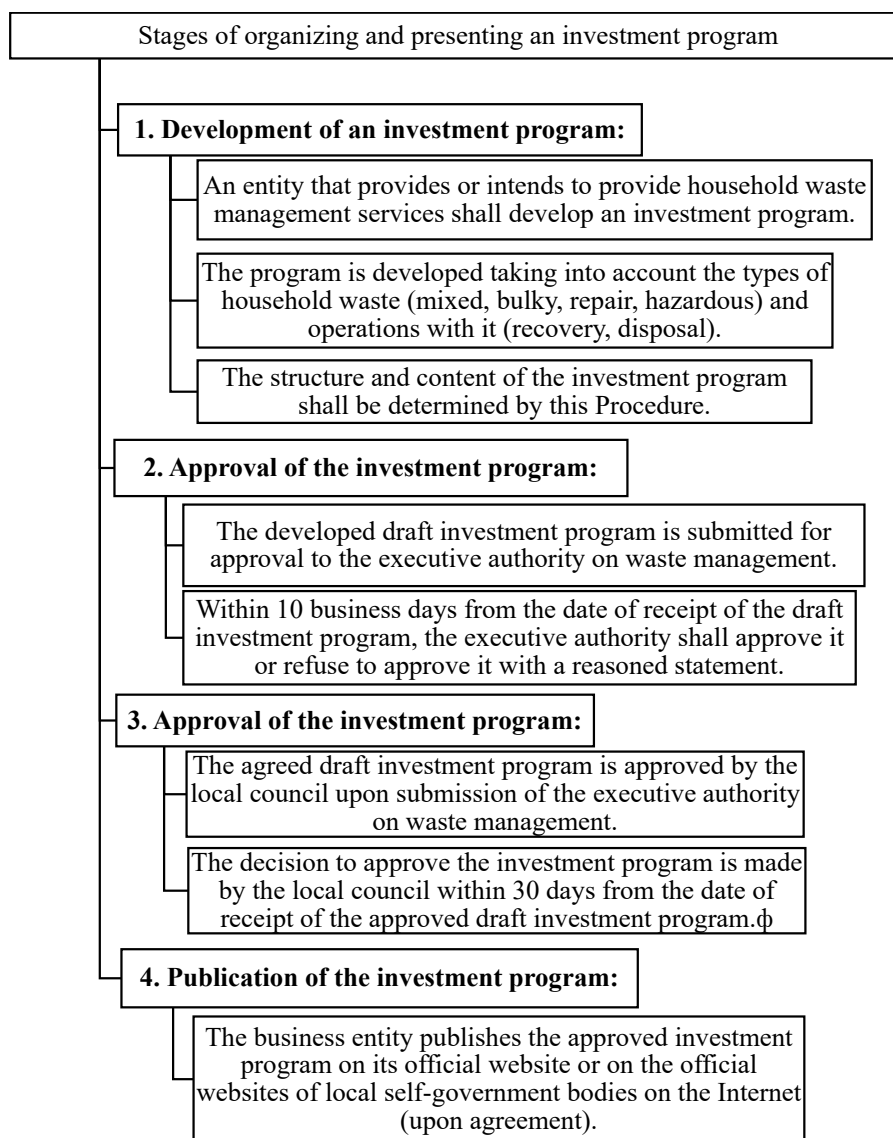


Figure 1. Stages of organizing and presenting an investment program

Comparative table of investment programs

Name of the structure requirements	Investment program 1	Investment program 2
Cover sheet in the form	+	+
Content of the investment program	+	+
The information card of the business entity to the investment program in the form	+	+
The financial plan of using funds to implement the investment program	+	+
The use of funds for the implementation of the investment program	-	+
The financial plan of using funds for the implementation of the investment program and their accounting in the tariff structure for 12 months, in the following forms	-	+
The explanatory note with some structural elements	+	+
The description of the investment program activities for the planned and forecast periods, with some mandatory information	-	+
Additional documents if you plan to attract or receive a loan or credit to finance the investment program activities as of the date of the investment program development	-	+

Source: created by the authors based on [11–14]

Traditional investment appraisal methods that focus on a limited number of criteria often fail to capture the full range of impacts and consequences adequately. This method allows for a wide range of criteria to be considered simultaneously, thus providing a comprehensive and accurate analysis of investment programs.

Secondly, the multicriteria optimization method provides considerable flexibility in selecting and changing criteria, which is extremely important in a dynamic environment where political, economic and environmental circumstances can change rapidly. It allows investment strategies to flexibly adapt to new challenges and opportunities, increasing their relevance and effectiveness.

Thirdly, the method supports transparency and validity of the decision-making process. It allows for clear identification and justification of priorities, which is essential for attracting investors and securing support from the public and government organizations.

Thus, the choice of an investment program for adoption is determined by a comparative assessment of the experimental options by their characteristics. In this regard, there is a need to use a multi-criteria decision-making method that excludes the influence of each criterion on the objective function, along with the values of the intervals of acceptable values of each criterion on the choice of an acceptable investment program option (objective function). To exclude the influence of units of measurement of the investment program utility indicators, a normalization operation was performed, which allows the conversion of the values of quality indicators into dimensionless values ($f_j \rightarrow f_j$). Before performing such an operation, you need to determine:

1) maximum (f_j^+) and minimum (f_j^-) j-th criterion for the investment programs under study (x_i);

- 2) the optimal value j-th criterion by the following rule:
- if the evaluation criterion f_j tends to the minimum value ($f_j^{opt} \rightarrow \min$), so $f_j^{opt} = f_j^-$;
 - if the evaluation criterion (f_j) tends to the maximum value ($f_j^{opt} \rightarrow \max$), to opt $f_j = f_j^+$.

Striving for the optimal value j-th criterion ($f_j^{opt} \rightarrow \min$; $f_j^{opt} \rightarrow \max$) is taken into account when choosing formulas 1; 2 for the standardization operation.

$$f_i(x_i) = \begin{cases} \frac{f_i(x_i) - f_j^-}{(f_j^+ - f_j^-)}, \text{ if } f_j^{opt} \text{ max} & (1) \\ \frac{f_j^- - f_i(x_i)}{(f_j^- - f_j^+)}, \text{ if } f_j^{opt} \text{ min} & (2) \end{cases}$$

$f_i(x_i)$ – is the value of the j-th criterion in the normalized form for the i-th option; $f_i(x_i)$ – is the value of the j-th criterion for the i-th option in the corresponding units of measurement; $[f_j^+; f_j^-]$ – is the range of permissible values of the j-th criterion of investment programs in waste management that are compared with each other.

After the normalization operation, we calculated the values of the objective function (φ) for each investment program (x_i).

The choice of the most useful investment program is defined by determining the compliance with the conditions of the greatest approximation of its objective function [$\varphi(x_i)$] to the objective function of the 'ideal' investment program (the one that meets all the necessary requests) [$\varphi(x_0)$], which is equal to zero. Consequently, the smaller the value of the investment program's objective function $\varphi(x_i)$ in the range of criteria values, the better the program's performance. The data obtained for the purpose of further selection of the optimal investment program for adoption are presented in Table 2 with a two-way alternative-criterion classification, which indicates the criteria f_j and characterizing the performance of the investment program: A_j – in quantitative scales and in a dimensionless form.

There are 10 criteria, which are divided into three main blocks (structure, financial results, and possible benefits from the investment program), which can be further subdivided into several criteria. Thus, the first block of criteria "structure" consists of 3 A_j – criteria, each of which is divided into three more:

- 1) Design: title page; contents; information card.
- 2) Financial indicators: financial plan for the use of funds for the implementation of the investment program; Use of funds for the implementation of the investment

program; Financial plan for the use of funds for the implementation of the investment program and their consideration in the tariff structure for 12 months.

3) Specialization: explanatory note; description of investment program activities for the planned and forecast periods; additional documents in case of planning to attract or receive a loan or credit to finance the investment program activities as of the date of the investment program development [9–12]. These are the indicators of the first one that were chosen for multi-criteria optimization, as they are mandatory components of the investment program. The next second block of criteria, Financial Results, was formed based on commonly used financial indicators for investment evaluation and consisting 4 points: Net Present Value (NPV, UAH thousand), Profitability Index (PI, units), Payback Period (PP, months), and Internal Rate of Return (IRR, %). They are necessary because the investment program involves financial investments and considering these indicators is important before its adoption and financing.

The last third block of criteria, "Possible benefits of the investment program," also includes 3 points: Volume

of recycled waste (thousand kg), Volume of incinerated waste (thousand kg), and Volume of waste disposed of in designated areas (thousand kg). They were taken from the national statistics report "Waste Management by Classification Groupings of the State Waste Classifier in 2020" to make forecasts of how the implementation of the investment program could lead to changes in statistics, to establish how many units of benefit the investment program could bring if it is adopted [16].

In order to test the multi-criteria optimization approach, we chose to conduct this analysis for two investment programs (Table 1).

The investment program for household waste management of the Putivl Housing and Maintenance Office for 2024–2025 (Inv. 1) [13].

The Investment Program of GRINERA Boryslav Limited Liability Company for 2024 (Inv. 2) [14].

A ranking of 10 criteria was established for these two investment programs in the comparative assessment of the research results, and the analysis revealed that the second investment program is more favorable for adoption (Table 2, 3) according to these criteria.

Table 2

The results of the values of the objective functions $\varphi(x_1)$ $\varphi(x_2)$ when choosing the optimal investment program for its further adoption

Alternatives	Criteria A_j													
	Design (%) A_1		Financial indicators (%) A_2		Specialization (%) A_3		Net present value, NPV (thousand HRY) A_4		Profitability index, PI (units) A_5		Payback period, PP (months) A_6		Internal rate of return on investment, IRR (%) A_7	
	f_1	f_1	f_2	f_2	f_3	f_3	f_4	f_4	f_5	f_5	f_6	f_6	f_7	f_7
Control (x_1)	100	1	33,3	0	33,3	0	60	0,5	3	0,2	36	0,5	13	0,075
Inv. 1 (x_2)	100	1	33,3	0	33,3	0	40	0,3	5	0,4	24	0,3	22	0,3
Inv. 2 (x_3)	100	1	100	1	100	1	50	0,4	7	0,6	12	0,1	34	0,6
f_j^+	100		100		100		100		10		60		50	
f_j^-	33,3		33,3		33,3		10		1		6		10	
$f_j(x^u)$		1		1		1		1		1		1		1
f_j^{opt}	100 (max)		100 (max)		100 (max)		10 (min)		10 (max)		6 (min)		50 (max)	

Table 3

The results of the values of the objective functions $\varphi(x_1)$ $\varphi(x_2)$ when choosing the optimal investment program for its further adoption (Continuation)

Alternatives	Criteria A_j						Values of the objective functions $\varphi(x_j)$	Rank
	Expected volume of utilized waste (thousand kg) A_8		Expected volume of waste incinerated (thousand kg) A_9		Expected volume of waste disposed of in specially designated areas (thousand kg) A_{10}			
	f_8	f_8	f_9	f_9	f_{10}	f_{10}		
Control (x_1)	2	0,1	3	0,5	2	0,25	3,125	2
Inv. 1 (x_2)	4	0,3	2,5	0,4	1,4	0,1	3,1	3
Inv. 2 (x_3)	6	0,5	1,3	0,17	1,2	0,05	5,42	1
f_j^+	10		5		5			
f_j^-	1		0,5		1			
$f_j(x^u)$		1		1		1		
f_j^{opt}	10 (max)		0,5 (min)		1 (min)			

Let's detail the indicators that led us to this conclusion: Inv. 2. Has first rank and $\varphi(x_1) = 5,42$, the control investment program was ranked second with an indicator of $\varphi(x_1) = 3,125$, Inv. 1 was ranked third with an indicator of $\varphi(x_2) = 3,1$ and turned out to be the least favorable for adoption.

In general, such an approach as multi-criteria optimization can become a universal method of selecting investment programs for adoption and further financing. The proposed criteria for optimization can be used or modified depending on the objectives of the investment program selection and other variables. The multi-criteria optimization method of investment programs applied to assess the investment support of the waste management system in Ukraine can be used in further research for several important purposes.

In addition to the multi-criteria optimization method, the following measures were proposed to improve the existing development system, coordination, approval of investment programs and their control.

It is necessary to create a single database with information on approved investment programs so that interested parties can participate in their financing and the procedure is transparent, which will help prevent corruption.

In particular, the electronic database can be integrated with the existing Prozzoro platform or have a similar structure, functionality and online monitoring system for the implementation of investment programs. The database should contain information on: a) approved investment programs, which should contain all the items listed in Table 1; b) terms of participation in the financing of investment programs; c) algorithm of organization and presentation of investment programs, including the steps

described in Figure 1; d) criteria for selecting investment programs for further work with them; e) authorized persons directly involved in the acceptance of investment programs.

The platform should be accessible to business entities that submit investment programs, executive authorities on waste management, local governments, the public, the media, investors, and scientific institutions. It is necessary to ensure the transparency of the system.

Conclusions. In summary, investment programs in the field of waste management are one of the tools for providing funding for waste treatment and disposal. It can be much more effective, but several opportunities for improvement have been identified in terms of evaluating and monitoring the implementation of these programs. The identified opportunities highlight the need to implement and improve the existing system. The main challenges that could be addressed include the difficulty of defining criteria and methods for selecting investment programs, the risks of corruption, and the lack of a comprehensive approach to attracting investment. Suggested opportunities include the use of multi-criteria optimization as a method of evaluating an investment program and the introduction of an electronic database.

Further research is planned to focus on improving mechanisms for controlling and regulating investment programs, which will reduce corruption risks and increase the transparency of the use of funds. Special attention will be paid to the development of a single database for all investment programs, which will facilitate better monitoring and evaluation of their effectiveness. It is also planned to focus on developing and improving the criteria for multi-criteria optimization, which will reduce the risk of using funds for unprofitable investment programs.

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