*European Journal of Sustainable Development* (2022), **11**, 1, 212-229 ISSN: 2239-5938
*Doi: 10.14207/ejsd.2022.v11n1p212*

# The Task of "recycling-revitalization" as a Priority of Sustainable Development of Ukrainian Industrial Cities

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**Abstract**
Ukrainian industrial cities are characterized by a high level of technogenic load and pollution of the territory, which determines the priority of strengthening environmental safety in comparison with the other two components of sustainable development, ensuring social consensus and rational using of local resources. The environmental safety fortification actualizes the research of the processes of introducing of circular economy elements into production and restoration of urban territories which are occupied by industrial waste, i.e. solving the "recycling-revitalization" task in an industrial city. The general scientific and special methods of cognition have been used during the research. So, it allowed us to obtain the following results. The objective necessity and possibility of the "recycling-revitalization" task solving by Ukrainian industrial cities on the basis of the development and implementation of programs and projects, as well as the formation of eco-industrial parks has been substantiated. The experience of introducing of circular economy elements and ecological revitalization of the industrial cities' territories in Europe and the United States has been analyzed including industrial symbiosis and powers in the environmental sphere of local governments. Three approaches to the management of industrial waste in the city have been considered: production-oriented, social-oriented, marketing-oriented. It has been determined that the production-oriented approach allows to form and implement of "recycling-revitalization" task solutions within the city. The organizational and economic solutions of "recycling-revitalization" task have been presented. The organizational solutions include coordinated interaction of enterprises of the city-forming, urban maintenance and urban planning sector in the management of industrial waste. Economic solutions to the "recycling-revitalization" task involve the using of three matrix models: a model of balanced resource allocation; assessing the impact of local indicators on the integral indicator of economic efficiency; model for accounting for uncertainty and risk factors. It has been argued that a socially-oriented and marketing-oriented approach to waste management in Ukrainian industrial cities presupposes concerted actions of participants at the regional and interregional level, which requires institutional and logistical support, which should be the subject of further research

*Key Words: recycling, revitalization, sustainable development, industry, industrial cities, Ukraine, Ukrainian industrial cities, environmental safety.*

## 1. Introduction

The relevance of a coordinated solution to the task, the introduction of a circular economy elements into industrial production (recycling) and ensuring the ecological restoration of territories (revitalization) in Ukrainian industrial cities has been conditioned

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by the following circumstances: technogenic pollution of the environment occurs as in the process of production activities of city-forming enterprises of the metallurgical, coal and chemical industries and due to the constant increase in the volume of dumps of metallurgical slag, waste heaps, sedimentation tanks, which are located in the urban area. Despite the fact that in the last six years after the signing of the Ukraine-EU Association Agreement (Pleasure for the Association between Ukraine 2014), which presupposes the observance of the principles of an integrated approach to pollution prevention and control (Directive 2008/98 / EC), the implementation at the state and local level of relevant strategies, concepts and programs related to the management of industrial waste (About the Basic ambush (strategy) of the state environmental policy of Ukraine 2019, About the consolidated regional programs for industrial access to the Donetsk region for 2018-2020, About the consolidated State strategy of regional development for 2021-2027, About the grasp of the Concept of realizing state policy in the sphere of industrial communication 2019), the problem of recycling industrial waste and revitalization of the territories occupied by them continues to remain. The developers of the draft Law of Ukraine "On Waste Management" (Draft Law of Ukraine "On the management of inputs) note that about 400 million tons of waste is generated in Ukraine annually and only 6% of this waste is recycled, which is extremely low compared to the EU countries, where it is about 40%. The other is located at landfills and dumps which are more than 5 thousand which of them are overloaded on 5% and 30% do not meet environmental safety standards. And the developers of the Concept for the Implementation of State Policy in the Sphere of Industrial Pollution " draw attention to the necessity for business entities to apply the best available technologies and management methods and to achieve the maximum permissible pollution levels established in accordance with them in the framework of the implementation of the provisions of Directive 2010/75 / EU (About the grasp of the Concept of realizing state policy in the sphere of industrial communication).

Most Ukrainian industrial cities have adopted and are implementing strategies for economic and social development in accordance with the Eleven sustainable development aim "ensuring openness, safety, resilience and environmental sustainability of cities" which declared UN resolution "Transforming our world: the 2030 Agenda for Sustainable Development" dated September 25, 2015 (The transforming our world: 2030 Agenda for Sustainable Development 2015) and confirmed by the Decree of the President of Ukraine dated September 30, 2019 №722/2019 (About the Sustainable Development 2019). The priorities for sustainable urban development act as a decomposition of economic, social and environmental sub-aims which are determined by the strategy and concretized in specific programs and projects. That's why for Ukrainian industrial cities that are located in regions which are characterized by a critical and high-risk level of environmental insecurity (Gernego 2021) the priority of environmental sustainability areas in comparison with two other related social and economic areas seems reasonable. The fortification of environmental safety is inextricably linked with the solution of the "recycling-revitalization" task on the basis of coordinated actions of the enterprises of the city-forming sector, the urban services sector and the urban-planning complex located in the city. At the same time an important role plays the territorial community and its representatives such as local self-government bodies that deal with issues of local importance, including the creation of comfortable living conditions for the population on

the basis of a socio-ecological-economic approach. Based on the above, the achievement of the priority of sustainable development of the Ukrainian industrial city associated with ensuring ecological balance based on industrial waste management using elements of a circular economy and methods of revitalizing urban territories contributes to the solution of the "recycling-revitalization" task. It is necessary to have appropriate organizational and economic support for solving of the "recycling-revitalization task which determines the aim and objectives of this research, determines the methods and allows the development of appropriate tools.

## 2. Research methodology.

In the process of research, the purpose of which is the developing organizational and economic approaches of the "recycling-revitalization" task solving as a priority for the sustainable development of an industrial city, it is necessary to fulfill the following tasks:
substantiation of the objective necessity and possibility of the "recycling-revitalization" task solving to ensure sustainable development of Ukrainian industrial cities;
experience analysis of the world industrial cities in strengthening the sustainability of development through the using of elements of a circular economy and ecological revitalization of territories;
development of organizational and economic solutions of the "recycling-revitalization" task as a priority for the sustainable development of an industrial city.
During the assignments, the general scientific and special methods of cognition have been used. The system analysis presents the city as a complex organizational and economic system that unites the enterprises of the town-forming, town-servicing and town-planning sectors. The monographic method and the method of structural analysis have been used to describe the field of this research. The methods of economic analysis and grouping have been used to process statistical information on the state of environmental pollution of the city territory. The method of comparison and generalization for researching the world experience of introducing of circular economy elements and ecological revitalization of territories in the context of sustainable city development has been used. The substantiation of the possibility of its application by Ukrainian industrial cities has been carried out using the method of analogy. The development of proposals for the use of the results of the "recycling-revitalization" task solving has been carried out using the method of analogies and logical analysis. To substantiate three approaches and alternatives of the "recycling-revitalization" task solving, the method of analysis and synthesis has been used. Structural and functional analysis has been applied to substantiate organizational solutions for the "recycling-revitalization" task. Mathematical modeling made it possible to formalize the process of assessing the activities of an enterprise "with and without a project", as well as the degree of uncertainty and risk by constructing matrices. The method of analogies and logical generalization has been used when we have been formulating the conclusions and recommendations.

## 3. Research area (industrial city, sustainable development, priorities, recycling and revitalization in an industrial city)

It can be argued that a city is a complex spatial socio-economic system that includes interacting and interrelated elements based on the research of the industrial city (Forrester 1969; Mc Donald 1997; O'Sullivan 2012): population, territory, city-forming , architectural and urban planning subsystems and the sphere of life support, serving the functioning, preservation and development of the city itself. Industrial cities were formed on the principle of common natural resource potential, specialization of the economy and economic ties. The economic development of the city and the formation of its production structure and social sphere are influenced by many factors, including the location, natural and climatic conditions, the level of development of transport links, national-ethnic and cultural characteristics of the population, and the size of the city determines the specifics of management, the composition and structure of its system. life support

City-forming industries characterize the specialization of the city its place in the social division of labor its activities aimed at meeting the needs of the region and the country. The concentration of production leads to an increase in the scale of activity of the city-forming base and the consumption of resources: material, labor, financial which in turn necessitates the growth of branches of the city-serving sphere, the amount of resources that are consumed increases. The city services sector can be divided into three groups according to its functional characteristics: social services (health care, education, culture, physical culture); utilities (preservation and development of housing stock, provision of electricity, heat, drinking and household water, sewerage, landscaping, road maintenance, passenger transport); household services (communications, trade, catering). City service industries exist for the city itself, its population and produce products that are consumed locally. The harmony of the city's development is manifested in the form of complexity: the interconnection of the city-forming and urban-serving and urban-planning spheres of activity, individual industries, their components in conjunction with labor and material resources. These tasks are realized to the fullest extent through the mechanism of formation of programs for the complex economic and social development of the city. The orderliness only that constitutes the main component of the management of socio-economic processes and creates an objective basis for the comprehensive, harmonious development of the city's economy.

There are usually the following subsystems distinguished as a part of the city: demographic (population), industrial, natural environment, social, recreational, industrial and infrastructural, social and infrastructural, institutional and infrastructural, ecological, resource and spiritual environment. To increase the comfort of life of the population of the city while maintaining the stability of the natural environment and the rational use of local resources is the uniform aim for all subsystems of the city in their development. All subsystems interact with each other during the functioning and development of the city.

The concept of sustainable development has a number of features for an industrial city and it is different from that given by the researchers of sustainable development of the city presented in the works (Albayrak 2017; Batty 2013; Christopherson 2013), insofar as the technogenic and anthropogenic load on the natural environment brings to the fore the issues of environmental safety, therefore, it is not necessary to support the integrity of the natural environment, but a system of measures to restore the ecological balance based on the use of tools for recycling industrial waste and revitalizing the territories occupied by

this waste. It is the strengthening of environmental safety only that will ensure the implementation of the economic and social components of the sustainable development of an industrial city.

Recycling is aimed at the maximum possible use of primary and secondary resources in production on the territory of the city, contributing to the conservation of local resources and supporting environmental safety. (Sisoeva 2019; Mochalova 2020). Wherein production is considered in a broad sense (from the extraction or supply of a resource and ending with waste disposal). In the process of recycling the maximum possible use of the resource must be ensured with a minimum of waste that cannot be used. At the same time, the processing of secondary resources and industrial waste obtained as a result of processing the primary resource for the production of basic products helps to minimize the production of waste. From the point of view of economic feasibility, secondary resources should be used in the territory of their origin by enterprises operating in the town-forming, town-servicing or town-planning sector. It will save local resources and waste transportation costs.

The revitalization of the territories is aimed at supporting environmental safety and creating comfortable living conditions for the population based on the research of the authors (Gorblyuk 2020; Sych 2016). At the same time revitalization can be carried out comprehensively and locally in four directions: spatial, economic, social, environmental. The priority is the ecological direction of revitalization for this research.

The main compromise in the management of industrial waste using elements of a circular economy should be achieved by choosing between the cost of recycling waste and thereby preventing or reducing the level of formation of industrial waste dumps and the cost of revitalizing the territory occupied by industrial waste dumps. It is explained by the fact that within the framework of the urban economic complex, which unites enterprises on a certain territory, the problem is solved in a closed system. If there is more industrial waste than the city can consume on its territory, the problem is solved in an open system, i.e. the possibilities of using waste on the territory of the region are considered - a regional program for the management of industrial waste, or in neighboring regions on the basis of interregional programs and projects for the management of industrial waste. At the same time, an important role belongs to the choice of an alternative between the processing of industrial waste at the places of their origin or at the places of their consumption and the sale in the regions of Ukraine and abroad.

An alternative arises between the reclamation of dumps and their development in the case of accumulation of industrial waste dumps. In this case calculations are performed "with a project and without a project." In addition to economic calculations, organizational decisions are justified on the basis of considering the interests of the project participants. It also evaluates the impact of the project on the ecological situation in the city, both in terms of the load on the natural environment and in terms of the comfort of living of the population on the basis of relevant indicators.

Currently, it is required to develop strategic and tactical solutions aimed at comprehensively achieving the tasks of sustainable development of an industrial city in the socio-ecological and economic aspect, considering the priority of using elements of industrial waste recycling and revitalization of the territory to strengthen the level of environmental safety. To substantiate these decisions, an appropriate scientific and

methodological support is required, the results of the development of which are presented in the next section.

## 4. Research results.

### 4.1. Objective necessity of the practice of the "recycling-revitalization" task solving the leadership of Ukrainian industrial cities.

The necessity of the "recycling-revitalization" task solving by Ukrainian industrial cities is due to a critical and highly risky environmental situation in a third of the regions of Ukraine, including Luhansk, Kherson, Lviv, Zaporizhzhia, Donetsk regions as evidenced by research data (Gernego 2021).

There are industrial cities in these regions which have an atmospheric pollution index exceeding the maximum permissible norms during 2016-2020 according to the calculations and observations of the Central Geophysical Observatory (CGO) by Boris Sreznevsky. (Table 1). These are the cities of Dnipro, Zaporizhzhia, Kamyansk, Kramatorsk, Krivuy Rig, Lisichansk, Mariupol, Rubizhne, Slavyansk.

**Table 1.** Dynamics of the air pollution index in industrial cities of Ukraine 2016-2020.

| **Cities** | **2016** | **2017** | **2018** | **2019** | **2020** |
|---|---|---|---|---|---|
| Dnipro | 13,9 | 13,9 | 15,1 | 17,2 | 14,1 |
| Kamensk | 10,5 | 13,5 | 13,1 | 14,3 | 14,8 |
| Odessa | 11,2 | 11,5 | 12,5 | 14,4 | 12,7 |
| Slavyansk | 10,1 | 10,3 | 8,5 | 6.1 | 4,8 |
| Kramatorsk | 10,1 | 8,5 | 8,2 | 7,5 | 7,5 |
| Kherson | 9,9 | 7,3 | 7,3 | 10,5 | 8,2 |
| Lisichansk | 9,5 | 8,2 | 7,5 | 6,5 | 5,5 |
| Mikolaev | 8,9 | 9,3 | 9,8 | 13,7 | 9,2 |
| Lutsk | 8,8 | 9,2 | 10,3 | 7,7 | 6,8 |
| Krivuy Rig | 8,7 | 9,0 | 10,4 | 9,6 | 9,6 |
| Mariupol | 8,6 | 15,5 | 15,8 | 17,9 | 15,7 |
| Kyiv | 8.1 | 9,1 | 10.4 | 9,6 | 9,6 |
| Rubizhne | 8,0 | 7,4 | 7,5 | 7,2 | 6,2 |
| Zaporizhzhia | 8,0 | 7,5 | 7,4 | 8,0 | 8,0 |
| Uzhgorod | 7,5 | 7,4 | 6,7 | 6,1 | 5,7 |
| Rivne | <7,0 | 7,5 | <7,0 | 7,5 | <7,0 |
| Lviv | <7,0 | <7,0 | 7,5 | 7,1 | 6,9 |
| Kremenchuk | <7,0 | <7,0 | 7,1 | <7,0 | 6,9 |
| Cherkasy | <7,0 | <7,0 | <7,0 | 7,4 | 7,3 |

*Source: compiled by the authors based on* (Camp of the new natural environment in the territory of Ukraine)

Such cities as Mariupol, Kamensk, Zaporizhzhia and Kramatorsk have been leading in terms of soil pollution over the past 6 years: in 2016 - Mariupol; 2017 - Kamensk; 2018 and 2019 - Zaporizhzhia and Mariupol; 2020 Mariupol and Kramatorsk. (The camp of the new natural environment in the territory of Ukraine 2021).

The solution of this situation is facilitated by the development and implementation of strategies, programs and projects for the management of industrial waste at the regional and city level. An example is the Regional Program for Industrial Waste Management in Donetsk region in 2018-2020. The results of the implementation are presented in table. 2.

**Table 2.** Results of implementation of the Regional Industrial Waste Management Program in Donetsk region in 2018-2020.

| **Industry** | **Waste type** | **Implemented by** | **Amount of funding** | **Result** |
|---|---|---|---|---|
| Metallurgy | Recycling blast furnace, converter, open-hearth slag, reuse of metallurgical sludge in sinter production | Close shareholder partnership Metallurgical plant "Azovstal" и Close shareholder partnership Metallurgical plant by Ilych (Mariupol city) | 1066,2 million UAH | Processed 13.1 million tons of waste and withdrawn 0.81 million tons of raw materials |
| Coal mining | Recycling of coal enrichment wastes with the removal of coal concentrate | Private shareholder partnership "DTEK Oktyabrskaya COF" (Dobropillya city) | 3, 3 million UAH | Processed 76.76 thousand tons of waste and withdrawn 25.98 thousand tons of coal concentrate |
| Chemical | Improving the processing of chemical waste | Close shareholder partnership "Avdiyivsky coke plant" (Avdiivka city) | 2, 5 million UAH | |

*Source: compiled by the authors based on* (About the news of the 2020 regional programs)

The specialists of the Ecology and Natural Resources Department of the Donetsk Regional State Administration note that the results of the implementation of the Regional Program and its methodological support will be considered when developing the Regional Waste Management Plan in the Donetsk Region for the period up to 2030. Similar regional plans have already been adopted or are under development in practically all regions of Ukraine including critically and highly environmentally unsafe ones. Regional plans for waste management in general and industrial waste in particular are specified in programs and projects that are implemented at the city level.

It is proposed to use both restrictive instruments in regional plans for the implementation of industrial waste management tasks, related to bringing Ukrainian legislation in the environmental sphere to European standards, and stimulating instruments, including the creation of eco-industrial parks, the use of public-private partnerships and corporate social responsibility mechanisms. Currently, Ukraine is modernizing the legislative framework

for the creation of industrial parks based on the principles of industrial symbiosis and industrial ecology. Wherein the process of justifying the creation of industrial and eco-industrial parks in cities and regions of Ukraine is underway. At the same time, in the old industrial regions the possibilities of transferring existing facilities of industrial zones to the principles of circularity with the provision of benefits and preferences for investors, which are used in industrial and eco-industrial parks are being considered. These issues should be resolved by coordinating the interests of all participants in the process of supporting and strengthening the ecological balance of the urban area. And local governments should initiate and organize the implementation of projects and programs within the framework of the "recycling-revitalization" task solving as evidenced by the positive experience of industrial cities in the world within their competence related to solving problems of local importance.

### 4.2 The experience of the world industrial cities in strengthening the sustainability of development through the introduction of a circular economy elements and ecological revitalization of territories

The introduction of elements of a circular economy in the industrial cities of the European Union is inextricably linked with the implementation of the concept of industrial symbiosis. Industrial symbiosis allows not to destroy or accumulate excess resources (waste) generated during one production process but to use them in another production process. (Chertow 2016) As a result, synergy is ensured, which increases economic benefits and reduces the pressure on the territorial ecosystem. (Preobrazhensky 2020). The concept of industrial symbiosis is implemented in the formation of industrial and eco-industrial parks, which is a network of enterprises interacting with each other in order to improve the economic and environmental condition based on the exchange of energy and materials. (Chertow 2016). At the same time, closed cyclic systems are formed that use by-products of production, generate a minimum of waste and save natural resources. This is how the factories operate in the most famous eco-industrial park Kolundborg (Denmark), which received the 2018 Gothenburg Sustainability Prize. Due to the industrial symbiosis of enterprises of four industries (energy, oil refining, pharmaceuticals and production of construction materials) and the recycling of their industrial waste, the annual cost savings in Kolundborg park amounted to 24 million euros. (Utkina 2020). At the same time, special attention should be paid to the participation of the municipality in the activities of the eco-industrial park and in the construction of a heating distribution network that uses steam from the power plant. An interesting approach is to consider the local characteristics of industrial ecology for the formation of quasi-models of the closed-cycle economy, which is used in the Hungarian industrial park. (Nagypál 2020). Also, worth noting is the quasi-model of industrial symbiosis of the largest US nuclear power plant Palo Verde on the use of wastewater from the municipality of the city of Tanapaca for cooling the plant. Thus, a closed loop of the city water supply and sewerage system is realized. of the city of Tanapaka It should be noted that the basis of projects implemented within the framework of eco-industrial parks and quasi-models of the economy of a closed and industrial symbiosis is the mechanism of public-private partnership, which has features of use in the field of environmental safety associated with the presence or absence of certain powers of local governments in environmental sphere. (Kaletnik 2021).

As for the revitalization of urban territories, for the purposes of this study, the experience of old industrial cities in Europe and the USA, in particular Pittsburgh, Detroit, Manchester, Liverpool, Lille, Turin and the cities of the Ruhr region, is interesting, which was summarized in the monograph. (Starodubrovskaya 2011; Tarasova 2017) The authors of the monograph state the fact that the successful implementation of the revitalization process in Pittsburgh is largely due to the fact that the main organizers are local authorities. They establish partnerships with businesses, which allows them to use their financial resources widely enough to invest in the development of urban infrastructure. It is equally important to prioritize the solution of environmental problems associated with a decrease in the technogenic and anthropogenic load on the environment, which stimulates the development of the environmental technology industry. The experience of the cities of the Ruhr region is complemented by the presence of initiatives for the development of projects on the part of commercial companies, non-profit organizations and ordinary residents, as well as the organization of the implementation of these projects on the basis of attracting investment resources. In this case, the state administration and local self-government bodies play a coordinating role.

It is necessary to state the following based on the considered experience of industrial cities of the world in solving problems of industrial waste recycling and ecological revitalization of territories. It is advisable to consider both the possibilities of interaction between the enterprises of the city-forming one the urban service and urban planning sector on the principles of industrial symbiosis, and the availability of the possibility of expanding the powers in the environmental sphere of local self-government bodies when developing projects.

### 4.3. Organizational and economic solutions of the "recycling-revitalization" task in the Ukrainian industrial city

It should be emphasized that management decisions must meet such requirements as:
compliance with the current legislation and the provisions of the statutory documents of the enterprise;
the presence in the text of the decision of a clear targeting and targeting;
conformity of the form to the content;
inadmissibility of contradictions to oneself or to a previously made decision;
considering the possibility of technical, economic and organizational feasibility of the solution;
availability of parameters of external and internal control of the implemented solution;
assessment of the risk of negative consequences of the decision taken during its implementation (Melnikova 2007). Let us consider the substantiation of organizational and economic solutions of the "recycling-revitalization" task on the example of metallurgical production waste management - blast furnace slag. There are three main approaches to the process of industrial waste management in the city:
production-oriented,
involving the processing and use of blast-furnace slags within the city by enterprises socially oriented, involving the free use of blast-furnace slags on the territory of the region;
marketing-oriented, involving the sale of blast-furnace slags both domestically and abroad.

For a socially-oriented approach mainly organizational solutions are developed, considering the needs and possibilities of using waste by infrastructure on the territory of the region without preliminary processing. The marketing-oriented approach is characterized by the formation of mainly economic decisions related to the assessment of the cost of shipping and transportation of waste to the customer, considering the logistics features described in this article. (Boychenko 2018). The production-oriented approach is based on the adoption and implementation of both organizational and economic decisions related to the peculiarities of using the elements of recycling production by city-forming enterprises and the readiness of enterprises of the urban service and urban planning sector to establish production cooperation links for waste processing and reduce the level of their disposal in dumps.

Proceeding from the fact that the interaction of the city-forming metallurgical enterprises operating on the principles of recycling is primarily associated with the use of non-traditional sources of heat and electric energy by enterprises of the urban service sector, it does not in any way affect the approach used in the formation of decisions. Thermal and electric power is used by urban heat supply, electric transport and street lighting companies. As for other types of waste, their use in urban economy and construction refers to the issues of ensuring sustainable development of the territory in terms of supporting environmental safety. That's why the enterprises of the city-forming sphere of the economy (in particular, road facilities and landscaping) act as consumers of waste in the form of blast-furnace slags as an accompanying result in the production of metal using elements of a circular economy.

The use of slag, its processing or sale refers to the issues of strengthening environmental safety as a component of sustainable economic development. This conclusion is based on the authors' research (Sysoeva 2019; Mochalova 2020) on the relationship between the goals and objectives of the circular economy, the green course and sustainable development. It should be noted that although the production of slag occurs in the process of metal production on the principles of a circular economy, the processing and sale of slag has nothing to do with ensuring the circularity of metallurgical production. This concerns the circular functioning of the economy of a certain territory, in particular, a closed-cycle city where metallurgical production is located. Therefore, the processing and marketing of slag as industrial waste should be considered in the context of the circular development of the territory. So, the principles of a circular economy in industrial production relate directly to the production process and the processing of associated waste in a given production cycle, since they aim to reduce the formation of dumps by maximizing waste processing. As for waste in dumps, this is not a task of a circular economy but of sustainable development of the territory in terms of ensuring environmental safety and reducing man-made load by reducing harmful emissions. The territory Circular functioning and the green course is aimed at the use of non-traditional sources of energy and building materials which reduces the need to use minerals and natural resources from deposits located in the city (Mochalova 2020).

The existence of industrial waste dumps blast furnace slag influences both the ecological situation and the comfort of the population. That's why the community and local self-government bodies (LSG) can have three options for actions in relation to the producer of industrial waste: neutral (state regulation); moderate (regulation through local taxes and

discharges, fines, benefits and preferences); radical (closure of production, re-profiling and development of other more environmentally friendly industries)
As for the moderate position of the local self-government bodies and the community in relation to industrial waste - they proceed from the following. The production of waste such as blast furnace slag depends on the production of the metal. And the production of metal is determined by the needs of the market. So, with the extensive option, the production of slag is directly proportional to the fulfillment of orders for the production of metal and is determined by the standards; with the intensive approach, the production of waste may be lower than the standard. It is the specified volume of slag that is subject to management as industrial waste: disposal, processing or sale. It considers the fact that:
the decision to "dispose of waste" depends on the volume of waste, taxes on them and the cost of renting a land plot where they are stored;
the decision to "sell waste" depends on the demand and the cost of transportation (transportation costs);
the decision to "recycle waste" depends on the need for recycled slag in the city or region (in road facilities or construction).
From the point of view of a systematic approach, it is necessary to consider the management of all types of metallurgical production wastes, assess the demand for them, identify the reasons for the low demand for certain types of waste, in particular blast furnace slag, and justify the directions of their stimulation both on the part of state authorities and on the part of local authorities. self-government, including tax regulation of investment activities, state and regional programs for the revitalization of territories, as well as mechanisms of public-private partnership and corporate social responsibility.
Blast furnace slags are currently circulating in the Ukrainian and international market segments. The turnover of blast-furnace slags in the international market segment involves the establishment of contractual relations with foreign partners for the export of raw materials, which are regulated by the rules of international trade. In the Ukrainian segment of the blast-furnace slag market, direct and indirect participants in business relations should be identified. It should be considered that the use and processing of blast furnace slag includes three main areas. These directions are:
preparation of granulated slag for road construction;
production of cement, concrete, fertilizers, slag wool, slag pumice;
formation of construction details. (Kocheshkova 2020)
Direct participants in the process of production, processing and using of blast-furnace slags are: producers - metallurgical enterprises, processors - enterprises of the building materials industry and enterprises for the production of fertilizers; consumers - construction and agricultural enterprises. The state, local governments, logistics firms, banks and resellers are indirect actors. Each of the participants pursues their own interests which must be agreed upon in the process of entrepreneurial activity. In particular, the interest of the state and local authorities in the development of entrepreneurship in the processing of blast-furnace slags is due to both the possibilities of increasing the revenues of budgets of different levels; creation of new jobs; saving local natural resources in the production of building materials (sand, gypsum, stone, etc.), and increasing environmental safety by reducing the anthropogenic load on the territory and population during the development of dumps.

Entrepreneurship in the processing and use of blast furnace slags can be organized both by metallurgical enterprises based on the diversification of production and the implementation of territorial development projects using the mechanisms of corporate social responsibility and public-private partnerships as well as by enterprises of the building materials or fertilizers industry. At the same time, benefits and preferences can be obtained in the process of taxation or when calculating rent for plots under slag dumps when implementing environmental projects, attracting environmental investments or introducing environmental innovations. The development and implementation of state, regional and city programs for the management of industrial waste and revitalization of the territory also contributes to the development of entrepreneurship in the field of processing blast-furnace slags and the development of their dumps.

It is advisable to form economic solutions of the "recycling-revitalization" task within the framework of a production-oriented approach based on the use of the following matrix models. The matrix model is a rectangular table, the elements of which, in accordance with a certain economic content, reflect the relationships between the components of the control object, and their values are calculated according to the rules established in matrix theory. In the matrix model, in numerical or relative terms, production and economic relationships are reflected within a given object and outside it. The model combines balances of production costs and balances of resource allocation. The basic rule of matrix modeling is that the totals of rows and columns must be equal. From an economic point of view, this equality is interpreted as a balance of value: the value of distributed and accumulated goods and services is equal to the value of production costs plus newly created value. These conditions are met by the matrix model - the interindustry balance, which is developed in kind and in value terms. The interindustry balance scheme includes a synthesis of two tables, one of which characterizes the structure of production costs in the context of individual types of products, and the other characterizes the distribution structure. The interindustry balance in physical terms consists of two sections: sources of formation of product resources; directions of use of product resources for current production consumption and for final consumption. The interindustry balance in value terms consists of four sections: intra-industrial relations of the modeled system; primary costs of resources entering the system from the outside (model input); results of production activities (model output): the processes of redistribution of newly created value within the system, determined during the formation of the matrix model.

The static interindustry balance model assumes that the volumes of industrial consumption are directly proportional to the volumes of production of products of consuming industries, and the coefficients of proportionality are the coefficients of direct costs. Also, the same product is produced by only one industry. The matrix model of the norms (coefficients) of direct costs is a system of equations with one unknown, which has a matrix of coefficients and the property of balance due to the presence of one linearly dependent equation and, in general form, is an input-output balance the interindustry balance scheme in vector-matrix form

$$X = AX + Y, \qquad \text{[formula 1]}$$

where A – matrix of direct costs coefficients;
X – output column vector;

Y – final product column vector.

This system of equations requires the presence of two known quantities in each equation x and y to solve. However, it is possible to compose a system of equations with one unknown, which has a complete matrix of coefficients and balance properties. Such a system of equations is presented by Sh. Hoshimura in his work "Theory of reproduction and capital accumulation" (Hoshimura 1978).

The system of equations has the property of being balanced due to the presence of one linear-dependent equation. Sh. Hoshimura proposes to solve this system of equations by the method of determinants based on the formalization methods used in linear algebra. The method of determinants has advantages in comparison with the traditional ones and allows: to consider all the components of expanded reproduction; after minor transformations of the production matrix, construct the distribution matrix; one resource at a time, which is specified, determine the needs for other resources; evaluate the economic growth of the system in terms of quantitative and qualitative parameters (Melnikova 2007).

The interaction of enterprises of the town-forming, town-servicing and town-planning sectors is described by the resource-communication model. It involves the performance of production and economic functions in the management process and ensures the formation of both economic and organizational decisions.

The production function is usually described by the Cobb-Douglas production function, which displays the relationship between the maximum volume of product produced and the physical volume of factors of production at a given level of technical knowledge. The production function with this technology has properties that determine the relationship between the volume of production and the number of factors used. Production functions are different for different types of production, but they all have common properties. Two main properties can be distinguished: there is a limit to the growth of the volume of output, which can be achieved by an increase in the cost of one resource, all other things being equal; there is a certain complementarity of the factors of production, but without a decrease in the volume of output, a probable and definite interchangeability of these factors of production is possible. For the release of a product, various combinations of resources can be used, which provides the possibility of producing a product using less capital or more labor input, and vice versa. However, there is a limit to how much labor can be replaced by more capital so that production is not reduced. (Modern management: an encyclopedic reference book 1997). It is advisable to supplement the specified production function with an economic one, which can be described by the function of transaction costs. At the same time, the structuring of transaction costs depends on the differentiation of costs and the search for information, which leads to changes in the production function depending on the information resource. In addition, it is necessary to introduce constraints in the model related to the peculiarities of resource integration and technology constraints.

An important component of the balanced development of an enterprise is the assessment of the efficiency of production and economic activities based on the use of an assessment of the influence of factors on the integral indicator of the efficiency of activities. It is reflected in the matrix model of production and economic activity, presented in Fig. 1.

It consists of 4 blocks and is built on the principles of systemic and factor analysis. This model includes the following indicators: integrated assessment (Ie), resource intensity (Re), costs per 1 UAH. products (Ce), resource turnover (Or), working capital utilization factor (Kz), material consumption (Me), working capital turnover (Os), energy intensity (Ee), salary intensity (Ze), labor intensity (Te), average salary (Cz), depreciation for 1 UAH, production (Am), capital intensity (Fe)) and the coefficient of depreciation of fixed assets (Ki).

<table>
<tr><td colspan="16">Analyzed period</td></tr>
<tr><td rowspan="2"></td><td colspan="2" rowspan="2"></td><td>Ie</td><td>Re</td><td>Ce</td><td>Or</td><td>Kz</td><td>Me</td><td>Os</td><td>Ee</td><td>Ze</td><td>Te</td><td>Cz</td><td>Am</td><td>Fe</td><td>Ka</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr>
<tr><td>B</td><td colspan="2"></td><td colspan="3">BLOCK 1</td><td colspan="8">BLOCK 2</td></tr>
<tr><td>a</td><td>Ie<br>Re<br>Ce</td><td>1<br>2<br>3</td><td colspan="3" rowspan="2">a change in the integral indicator due to a change in resource intensity and costs for 1 UAH products</td><td colspan="8" rowspan="2">assessment of the efficiency of using production resources and financial results of production, reserves for achieving the desired level of profit</td></tr>
<tr><td>s</td></tr>
<tr><td>e</td><td colspan="2"></td><td colspan="3">BLOCK 3</td><td colspan="8">BLOCK 4</td></tr>
<tr><td></td><td>Or<br>Kz<br>Me<br>Os<br>Ee<br>Ze<br>Te<br>Cz<br>Am<br>Fe<br>Ka</td><td>4<br>5<br>6<br>7<br>8<br>9<br>10<br>11<br>12<br>13<br>14</td><td colspan="3">change in resource intensity due to changes in the use of fixed assets, working capital and wages</td><td colspan="8">absolute change in the initial indicators and calculation of their influence on the level of use of working capital and funds for labor remuneration, the amount of depreciation deductions per unit of production</td></tr>
<tr><td>p</td><td colspan="2"></td><td colspan="3">BLOCK 3</td><td colspan="8">BLOCK 4</td></tr>
<tr><td>e</td><td>Or<br>Kz<br>Me<br>Os<br>Ee<br>Ze<br>Te<br>Cz<br>Am<br>Fe<br>Ka</td><td>4<br>5<br>6<br>7<br>8<br>9<br>10<br>11<br>12<br>13<br>14</td><td colspan="3">change in resource intensity due to changes in the use of fixed assets, working capital and wages</td><td colspan="8">absolute change in the initial indicators and calculation of their influence on the level of use of working capital and funds for labor remuneration, the amount of depreciation deductions per unit of production</td></tr>
<tr><td>r</td><td colspan="2"></td><td colspan="3">BLOCK 3</td><td colspan="8">BLOCK 4</td></tr>
<tr><td>i</td><td>Or<br>Kz<br>Me<br>Os<br>Ee<br>Ze<br>Te<br>Cz<br>Am<br>Fe<br>Ka</td><td>4<br>5<br>6<br>7<br>8<br>9<br>10<br>11<br>12<br>13<br>14</td><td colspan="3">change in resource intensity due to changes in the use of fixed assets, working capital and wages</td><td colspan="8">absolute change in the initial indicators and calculation of their influence on the level of use of working capital and funds for labor remuneration, the amount of depreciation deductions per unit of production</td></tr>
<tr><td>o</td><td colspan="2"></td><td colspan="3">BLOCK 3</td><td colspan="8">BLOCK 4</td></tr>
<tr><td>d</td><td>Or<br>Kz<br>Me<br>Os<br>Ee<br>Ze<br>Te<br>Cz<br>Am<br>Fe<br>Ka</td><td>4<br>5<br>6<br>7<br>8<br>9<br>10<br>11<br>12<br>13<br>14</td><td colspan="3">change in resource intensity due to changes in the use of fixed assets, working capital and wages</td><td colspan="8">absolute change in the initial indicators and calculation of their influence on the level of use of working capital and funds for labor remuneration, the amount of depreciation deductions per unit of production</td></tr>
<tr><td></td><td colspan="2">15</td><td colspan="14">general change in the integral indicator by factors</td></tr>
</table>

*Fig. 1. Matrix for a comprehensive assessment of the effectiveness of production and business activities*

The integral indicator is calculated by the formula:

$$Ie = 1 - \frac{Me + Ee + Ам + Ze}{Fe + Kz + Ze + Ee} \quad . \qquad \text{[formula 2]}$$

The indicators of this matrix are calculated by the formulas:

$$\Delta y_i^a = \Delta a \cdot \frac{1}{b^1}; \qquad \Delta y_i^b = \Delta b \cdot \frac{a^0}{b^0 b^1}, \qquad \text{[formula 3]}$$

where Δyi - change of the i-th private indicator of assessment;

Δa - change in the value of the indicator in the numerator;

Δb - change in the value of the indicator in the denominator;

a0,b0,b1 – the value of these indicators, respectively, in the baseline and reporting periods.

As a result of establishing formalized links between the indicators of each block and between the blocks of the system, the influence of a change in each of them on the subordinate indicator is assessed. The matrix presents relative indicators characterizing the

two sides of production efficiency (cost effectiveness and resource use). They reveal the proportions of production, establish links between the indicators of the production system and allow you to determine the change in some particular indicators as a result of changes in others.

It should be noted that the economic assessment of the efficiency of production activities should be complemented by an environmental assessment, the indicators of which and their interpretation are presented in the research (Rekova 2021). The results of the environmental assessment can influence the establishment of appropriate restrictions in both production and management.

Business management involves the selection of appropriate forms of communication ties and relations based on information support, management of flows of production, economic, financial information necessary for effective functioning and development. At the same time, it is very important to determine the degree of reliability of expectations based on external information and analysis of external influences, which requires the use of methods for assessing the risk of economic activity and making appropriate decisions on its management. In this case, the criterion for managing uncertainty is not a decrease in risk, but an increase in the efficiency of decisions. To assess the effectiveness of decisions based on the interaction of levels of uncertainty and the nature of management activities, it is advisable to use matrix (4), in which the nature of management is represented by rows, and by columns - the degree of uncertainty in the formation of management decisions. The degree of uncertainty in the formation of management decisions is a scale. However, it is advisable to distinguish four discrete levels for convenience, two limiting levels - low and ultra-high and two intermediate ones - medium and high, that is

$P = \{P_1, P_2, P_3, P_4\}$,

where P1 - low level does not affect the typical procedures for the formation of the management decisions; P2 - the middle level requires a revision of the existing procedures for the formation of management decisions; P3 - high level provides for the development of new procedures for the formation of management decisions; P4 - an ultra-high level of uncertainty implies the replacement of almost all existing procedures in the formation of management decisions.

The degree of possible implementation of the solution depends on both the nature of the control and the level of uncertainty:

$$R = R(U, P)$$

or in matrix form:

$$R = \left(R_{ij}\right)_{\substack{i=1,\ldots,4;\\ j=1,\ldots,4}} = r\left(U_i, P_j\right)_{\substack{i=1,\ldots,4;\\ j=1,\ldots,4}}, \qquad \text{[formula 4]}$$

where

$U = (U_1, U_2, U_3, U_4)$ – nature of management (routine, stable, corrective, innovative).

Each element of the matrix (4) determines the degree of efficiency of decisions. The matrix represents the conditions for preparing effective solutions and shows the possibilities for their implementation. To reduce uncertainty and risk, it is advisable to use both traditional

methods, in particular, functional-cost analysis and innovative management methods (situational centers) that provide forecasting of the results of decisions made. Functional-cost analysis allows you to combine the functional features of resources with the valuation of operating, material, investment assets of participants and the risk of financial losses from their imbalance. Situational centers accumulate tools for collecting and analyzing information, forecasting tools and building possible development models and visual presentation of results in a form that will be most convenient and useful for project managers (Melnikova 2007). The main components of the situational center are the means of dynamic (simulation) modeling, which make it possible to calculate the possible consequences of different scenarios of the development of events. The use of the presented matrix models in combination with the mechanism of resource-communication interaction allows making reasonable economic decisions on the problem of "recycling revitalization" both locally by the project participants and in a complex temporary coordination center, which can be formed to organize the implementation of the project. Since the socially-oriented and marketing-oriented approach involves the export of blast-furnace slags outside the urban area, which in turn requires the availability of appropriate institutional and logistical support, allowing the establishment and implementation of projects at the regional and country level as a whole. At the same time, it is advisable to integrate the task of "recycling-revitalization" with the tasks of the waste management subsystem at the regional and city level, which should be the subject of further research.

## 5. Conclusions and recommendations

Industrial cities have features that must be considered when choosing priorities for their sustainable development. These features are associated with a high technogenic load that negatively affects the environment and the generation of industrial waste. That's why the strengthening of environmental safety is a priority compared to the economic and social components of sustainable development and involves of the "recycling-revitalization" task solving associated with the use of elements of the circular economy for the management of industrial waste and the restoration of urban areas occupied by dumps of this waste.

Based on the analysis of the environmental situation in Ukrainian industrial cities and an assessment of the possibility of using the world experience of waste recycling and revitalization of territories in sustainably developed cities, methodological approaches have been formulated and tools have been proposed to form organizational and economic solutions of the "recycling-revitalization" task. At the same time, it is considered that in the management of industrial waste on the principles of circularity, there are three alternatives: recycling and using in the city; implementation of social projects of intermunicipal and interregional cooperation; sale within the country or abroad. If it is not possible to implement the indicated alternatives, then industrial waste ends up in dumps and subsequently an ecological revitalization of the territory is required. At the same time, the cost of ecological revitalization of the territory occupied by industrial waste may be higher than the cost of equipment for waste recycling. It is necessary to consider this contradiction when developing programs and projects for industrial management.

The objective necessity of the "recycling-revitalization" task solving is due to both the difficult environmental situation in the industrial cities of Ukraine and the opportunities associated with the formation of industrial and eco-industrial parks, the use of the principles of industrial symbiosis and industrial ecology in the management of industrial waste. The experience of industrial cities in Europe and the United States testifies to the need for coordinated actions of urban economy enterprises on the principles of industrial symbiosis as a condition for ensuring circular production and the leading role of local governments as an organizer of the territory revitalization process in the environmental aspect.

Organizational solutions of the "recycling-revitalization" task are to ensure the coordination of the actions of the project participants - the enterprises of the city-forming, urban service and urban planning sector when choosing the alternative "processing and use of industrial waste in the city territory". Economic decisions are associated with the use of three matrix models (a matrix of resource allocation, a matrix for assessing the influence of factors on the integral indicator of efficiency, a matrix of compliance of the type of management with the level of uncertainty of decisions made), as well as the mechanism of resource-communication interaction for organizing production and management. The alternative associated with the implementation of social projects of intermunicipal and interregional cooperation involves the use of mechanisms of public-private partnership and corporate social responsibility on the part of town-forming enterprises. The alternative associated with the sale of industrial waste within the country or abroad "involves marketing research and the formation of schemes of transport routes. Detailed development of these alternatives presupposes the availability of appropriate institutional and logistical support, which should be the subject of further research.

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