CIRCULAR MODELS OF RESOURCE CYCLES: ESSENCE AND FEATURES

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Abstract: *Ensuring sustainable development of economic systems requires the introduction of organizational and management and environmentally safe technologies, circular models of resource cycles aimed at reducing the negative impact on the environment. This corresponds to the concepts of sustainable development, circular economy, green economy, etc. This is also confirmed by advanced world experience, which shows that increasing the level of environmental safety of the national economy can be achieved by introducing conceptually new management tools based on integrated (combination of systemic, process, situational, functional) approaches, concepts of "lean" production, closed-loop economy, sustainable development. As a result of the study, it was established that the key goal of the transition to a circular economy is to change the paradigm of development of society and the economy (production, consumption, energy-efficient, marketing, etc.), rethinking value-added chains and developing circular models of resource cycles that must meet modern requirements and challenges in the global world.*
In view of this, the article reveals the relationship between the concepts of "circular model" and "resource cycle" based on bibliometric analysis using VosViewer software. The essence of the term "resource cycle" is clarified. The features of the circular model of resource cycles are determined. It is proved that at present it is necessary to look for innovative tools and implement fundamentally new approaches to the organization of economic activity. Circular economy is recognized as an effective way of doing business and a key mechanism for the development and implementation of circular models of resource cycles and business strategies in the context of global transformations.

Key words: *circular economy, linear economic model, circular model, resource cycle, circularity of resources, anthropogenic impact on the environment, sustainable development.*

JEL: A20, Q20, Q28

1. Introduction.

At the current stage of human development, the economy is becoming a factor of direct impact on the natural environment. This situation arose as a result of economic development focused on meeting the needs of humanity while ignoring the need to ensure environmental neutrality of production and consumption, which, given the inconsistency of natural and economic resource cycles and the limited availability of natural resources, determines significant negative qualitative and structural changes in the environment (Kyzym et al., 2023a). It is worth noting that large-scale climate change, limited availability or shortage of many natural resources for doing business in the global world, and their irrational use over time have led to the need to restructure economic models (Kyzym et al., 2023b). That is, modern economic conditions require an accelerated transition to a new model – a closed-loop economy (Dzwigol, Kwilinski et al., 2021a, 2021b; Ganea et al., 2022; Kyzym et al., 2024). Today, this model of economic development has received recognition and support in many countries of the world through political decisions, plans and practical actions. The circular economy is based on the

example of a closed cycle of substances in nature and aims to maximize the value of raw materials and products until the end of their use. The transition to such a system will have not only environmental, but also economic and social benefits due to job creation, cost savings and prevention of environmental pollution.

According to the study by the international consulting company KPMG "Future State 2030", climate change and the shortage of natural resources are recognized as global megatrends of the near future. And among the seventeen UN Sustainable Development Goals, seven are aimed at overcoming environmental problems.

Therefore, in the conditions of the Fourth Industrial Revolution, in order to ensure sustainable development of the world, the paradigm of the production model is changing: from linear to cyclical. From the point of view of R. Bradley et al. (2018), a linear economy, which is focused only on consumption, leaves behind economic, environmental and social problems. The circular economy, a new economic structure, can be combined with elements of sustainable production based on the 6Rs to alleviate these problems by establishing a closed flow of materials. By implementing the prospects of the circular economy, the recycling of resource flows is maximized, which provides economic and environmental benefits by minimizing waste (Solis et al., 2021).

According to experts, the abandonment of traditional production and consumption systems based on the principle of "use resources – produce products – dispose of waste" will allow to obtain a potential economic benefit of 4.5 trillion US dollars by 2030.

According to T. Shevchenko (2019), in the context of a circular economy, the development of resource cycles takes on a new meaning - preserving the gradually created value of the material, product and its parts. The development of the structure of resource cycles occurs through the reconstruction of existing cycles, as well as the formation of new ones. Resource cycle segmentation could become an effective tool for measuring progress in approaching a circular economy through the study of structural changes in the resource cycles of the territory caused by the closure and slowdown of material loops.

However, as studies show, 61% of companies did not have sufficient training and awareness of employees regarding the efficient use of resources (Hernandes de Paula e Silva et al., 2024).

Thus, the outlined topic of this study is relevant and requires further thorough scientific development. Therefore, the purpose of this article is to identify the relationship between the concepts of "circular model" and "resource cycle" based on bibliometric analysis using VosViewer software, as well as to clarify the essence of the term "resource cycle" and define the features of the circular model of resource cycles.

2. Basic content.

In the last decade, the concept of a circular economy or a closed-loop economy has been actively discussed by government officials, scientists, educators, experts, entrepreneurs, and representatives of public organizations. According to supporters of this concept, circular growth will help overcome the climate crisis and promote the development of an inclusive green economy. The very definition of this type of economy was formulated in their study in 2019 by experts from the University of Oxford (Haney et al., 2019), based on a series of interviews conducted with participants of the Platform for Accelerating the Circular Economy (PACE). The interviewed experts mostly agreed that the closed-loop economy is a regenerative type of economy that aims to preserve as much value as possible from products, their components, and materials, whose growth is not stimulated and does not depend on the use of limited resources. In essence, this type of economy is considered as a new trajectory of society's development towards sustainability and resilience (Khaustova & Reshetnyak, 2023).

As the analysis shows, there are many interpretations of the concept of "circular economy" in the literature. It is worth noting that there are significant differences between different views on the circular

economy. Thus, researchers have identified 114 different definitions (Kirchherr et al., 2017) and 38 different options for preserving value, such as reduction, reduction, recycling (Reike et al., 2018).
Therefore, based on the generalization of existing scientific approaches to defining the circular economy, they are conventionally systematized into the following groups: section of the economy; paradigm; strategy; model; system; environmental opportunity; recycling technology; tool of the "green" economy; type of economic activity (Trushkina, 2021; Trushkina & Prokopyshyn, 2021). Under the circular economy, it is proposed to consider the modern paradigm of the development of economic systems; the strategic direction of sustainable development; an economic model based on circular models of resource cycles and technologies for processing industrial waste in order to achieve sustainable functioning of the national economy. At the same time, the circular economy should be considered as a promising model that will become the basis of the next link in the chain of economic evolution (Kyzym et al., 2023a). It should be noted that the theory of resource cycles is included in the circle of scientific interests of scientists and specialists (Bradley et al., 2018; De Angelis & Feola, 2020; Hernandes de Paula e Silva et al., 2024; Schwarz et al., 2024; Solis et al., 2021; Tian et al., 2022; van Stijn A. et al., 2021). And as P. Shyshchenko & O. Havrylenko (2020) note, the theory of resource cycles serves to find ways of coordinated, harmonious development of natural and technological processes.
The relevance of the topic, which is associated with the development of the concept of a circular economy and the formation of circular models of resource cycles, is confirmed by the results of the bibliometric analysis. According to the title of the article, abstract, keywords "Circular model" or "Circular Models" and "Resource Cycle", which are placed in the international database Scopus, 628 documents were obtained for 1995-2025. When forming the sample, restrictions were made: only published scientific articles were taken.
A quantitative analysis of the formed sample of 628 scientific articles showed that by 2015 the level of publication activity was quite low. On average, the growth rate of the number of publications was 40.4% for 2015-2024. At the same time, it can be assumed that by the end of 2025 there will also be a trend of increasing the number of publications on the specified topic compared to previous years. According to preliminary estimates, the annual growth rate of the number of publications for 2015-2025 will be 27.7%.
As the analysis shows, the main organizations involved in solving the selected problem are Ministry of Education of the People's Republic of China (14 documents), CNRS Centre National de la Recherche Scientifique (12), Technical University of Denmark (9), Chinese Academy of Sciences (9), Parthenope University of Naples (9), Norges Teknisk-Naturvitenskapelige Universitet (8), Tsinghua University (8), ETH Zürich (8), Alma Mater Studiorum Università di Bologna (8), Lunds Universitet (8 documents). При цьому здебільшого такі роботи публікують науковці з China (105 documents), Italy (86), United Kingdom (67), Spain (59), Germany (58), United States (55), Netherlands (42), Sweden (29), France (26), Australia (25 documents). In Ukraine, 7 scientific articles were found using the specified search criteria.
The following keywords are mostly used in the publications: Circular Economy (398 documents), Life Cycle (219), Sustainable Development (172), Recycling (159), Life Cycle Assessment (135), Environmental Impact (135), Life Cycle Analysis (121), Sustainability (119), Waste Management (90), Economic Aspect (63), Environmental Economics (57), Life Cycle Assessment (LCA) (53), Decision Making (51), Climate Change (50), Environmental Management (44), Greenhouse Gases (36), Material Flow Analysis (34), Carbon Footprint (33), Business Models (33), Environmental Sustainabilit (28), Environmental Protection (27), Innovation (26), Carbon Emission (25), Energy Efficiency (24), Resource Efficiencies (22), Energy Utilization (22), Resource Use (19), Industrial Economics (19), Resource Management (18), Resource Recovery (17), Circular Business Models (16), Renewable Energy Resources (12), Natural Resource (12), Sustainable Production (11), Energy

Resource (11), Economic System (11), Circularity (11), Carbon Cycle (11), Mineral Resources (10), Conservation Of Natural Resources (10), Business Model (10), Business Cycle (10 documents).
Based on the results of the analysis of coincidences and closeness of the relationship of 411 keywords of the selected sample of publications, a network visualization map was constructed (*Figure*). It consists of 7 clusters. Based on the constructed terminological map of categories and the selected most significant keywords related to the issues of building circular models of resource cycles, it can be stated about the multidimensionality and cross-dependence of the studied areas, since there are numerous connections between the terms, as well as their high prevalence in research.

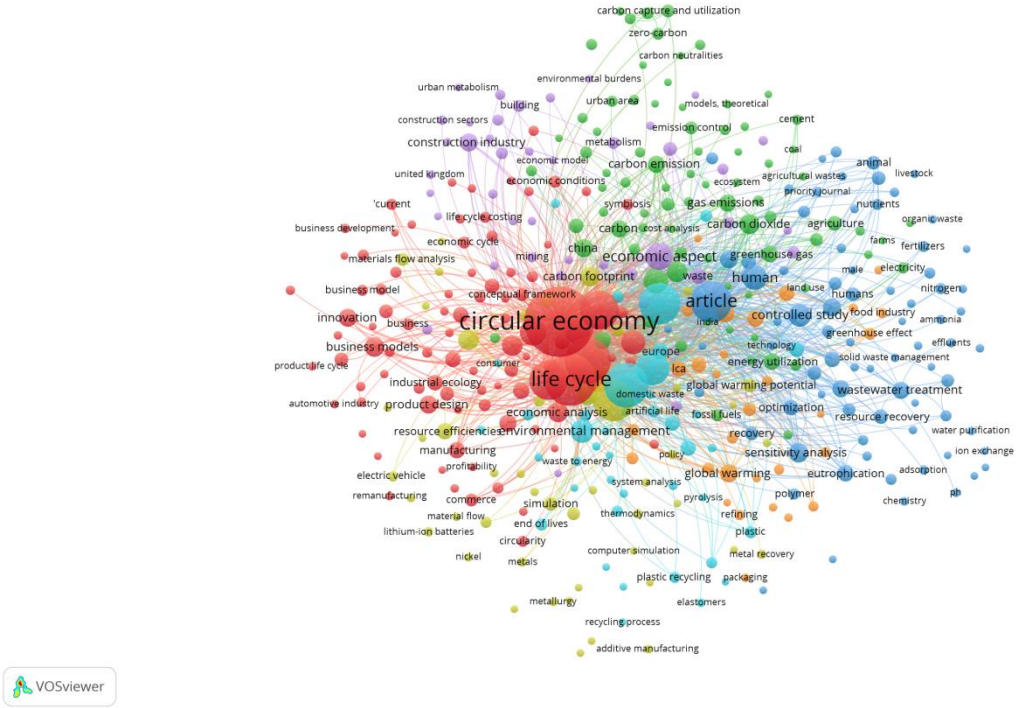

Figure. Map visualization of bibliometric analysis of publications devoted to the issues of building circular models of resource cycles (content aspect)

Source: built on the basis of data from the Scopus scientometrics database using the VOSviewer program.

It is worth emphasizing that the problem of the exchange of substances between nature and the economy was first studied by I. Komar. He defined resource cycles as a set of transformations and spatial movements of a certain substance or group of substances that occur at all stages of its use by humans, including preparation for exploitation, extraction from the environment, processing, consumption and return to the environment (Shevchenko, 2019). That is, the exchange of substances between society and nature has a pronounced polycyclic nature, and the general flow of substances in the "nature – society – nature" system can be divided into separate resource cycles. At the same time, each cycle has a number of accompanying and additional subcycles that develop on the basis of diversified use of the main resource (Shevchenko, 2019).
Over time, resource cycles develop, which means a change in their structure (Chen & Graedel, 2012). In the context of a circular economy, the development of resource cycles includes not only a change in territorial structures, but also their qualitative transformation according to three criteria: elimination of toxic and harmful substances/materials in production; maximum replacement of non-renewable resources with renewable ones; reduction of waste to zero (Shevchenko, 2019).

The resource cycle can be divided into two main segments: 1) "transformation of a mineral into a material" (mining – processing – enrichment); 2) "transformation of a material into a product" (production – use – production").
According to T. Shevchenko (2019), the resource cycle is a set of transformations and spatial movements of a certain substance or group of substances that occur at all stages of its use by humans. Resource cycles bring materials and energy to the human economy. After extraction, processing and consumption, resources undergo various recovery cycles, such as repair, reuse, recycling, etc. (Antikainen et al., 2018; Ghisellini et al., 2016). After the end of their useful life, resources return to nature through incineration and dispersion in the atmosphere, through landfilling, or through release into the environment (Krausmann et al., 2018; Martinez-Alier, 2021a; Rammelt, 2020).
Considering all of the above, the global economy currently sustainably uses only about 8% of the total resource volume (Haas et al., 2020; Haigh et al., 2021), so humanity may face critical resource shortages and exceed key ecosystem limits in the coming decades (Bihouix, 2014; Herrington, 2021; Turner, 2014).
In his thesis, M. Calisto Friant (2022) follows the value preservation options (also called R-hierarchy, R-imperatives or simply R) established by D. Reike, W. Vermeulen & S. Witjes (2018), namely: R0 rejection, R1 reduction, R2 reuse/resale, R3 repair, R4 recovery, R5 recycling, R6 reuse, R7 material recycling, R8 energy recovery, R9 mineral re-extraction.
The concept of a circular economy involves the involvement of natural resources in the economic resource cycle in an amount sufficient to ensure the growth of scale and environmental neutrality of economic activity by increasing the rational use of natural resources, creating closed resource cycles in the spheres of production and consumption, and creating a waste disposal industry. Therefore. Creating an environmentally neutral economic model requires structural changes in certain resource cycles, increasing the rationality and efficiency of resource use, which will also lead to changes in the defining features of the economic model (Kyzym et al., 2023a).
The scientific work (Kyzym et al., 2023a) considers three types of economic resource cycles, which are distinguished depending on the specifics of different economic models, namely: open (typical of pre-industrial economies); open with elements of closed (industrial economy); closed (circular, cyclical or closed-loop economy).
As noted by scientists P. Shyshchenko & O. Havrylenko (2020), resource cycles are somewhat similar to natural ones, since they are part of a single natural resource cycle that occurs in different environments: natural and socio-economic. However, a distinctive feature of the resource cycle is its open nature, that is, the formation of a mass of waste at all stages – from extraction to the final use of a natural substance. It is estimated that from each ton of extracted resource, on average, only 5 to 15% reaches the finished product, the rest goes to waste.
Scientists interpret the resource cycle as a set of transformations and spatial movements of a certain substance or group of substances at all stages of their use by humans within the social link of the global circulation of these substances. Typically, the resource cycle includes the following phases: discovery of natural resources; preparation of natural resources for exploitation; extraction of natural resources from the natural environment; processing of natural resources; consumption of natural resources by humans; return of waste to nature (Shyshchenko & Havrylenko, 2020).
Based on the generalization of existing theoretical approaches to the essence of resource cycles, the following definition can be given: a resource cycle is a chain of sectoral transformations of resources, the analogue of which is the chain of creation of added value.
As a result of the study, it was established that the systemic features of circularity are: a closed resource cycle; climate neutrality of the resource cycle. The criteria for assessing the key characteristics of the degree of achievement of the circular economy include: compliance of the resource cycle model of a certain sector with the requirements of the circular approach; compliance

of the physicochemical properties of the remainder of the transformed basic resource with the possibilities of their accumulation in the environment.

3. Conclusions.

Currently, the issues of reducing waste, increasing resource efficiency and product sustainability are recognized as extremely urgent worldwide. This can be achieved by implementing circular resource cycle models. Recycling materials and products for use in a circular mode will contribute to the innovative development of various sectors of the economy. The transition to a more circular economy can increase competitiveness, stimulate innovation, accelerate economic growth and create jobs (700 thousand jobs in the EU alone by 2030). To this end, the European Union aims to build a circular and climate-neutral economy by 2050 (European Parliament, 2023).

From a macroeconomic perspective, a circular economy investment strategy could lead to a 10% reduction in the cost of raw materials and a 7% increase in GDP in the European Union by 2030 compared to a business-as-usual model (Ellen MacArthur Foundation, 2017). However, such a leap in development undoubtedly requires strategies that are focused on the specific potential of the economy, as well as the appropriate infrastructure and administrative capacity. An important long-term opportunity for the circular economy is the reduction of direct and indirect environmental costs. Direct costs are associated with waste management. However, indirect costs of natural resource use are also relevant. On a global scale, according to estimates by the International Group of Experts on Resources within the framework of the United Nations Environment Programme, these costs amount to up to 2.4 trillion US dollars (Trushkina, 2021). In addition, it should be emphasized that the development of the circular economy contributes to the social effect by creating jobs. According to a study by the European Commission (European Commission, 2018), depending on how waste is processed, different numbers of jobs can be created: for 10 thousand 1 tonne of used products can create one job from incineration, six from landfill, 36 from recycling and up to 296 from recovery and reuse.

Research published by the International Resources Group shows that using the world's natural resources wisely and efficiently today means that the next generation will receive annual economic benefits of 2 trillion dollars by 2050, while offsetting the costs of ambitious climate action (UNEP, 2017).

The world's population is expected to grow by 28% and is projected to use 71% more resources per capita by 2050. Without urgent efficiency measures, global annual use of metals, biomass, minerals such as sand and other materials will increase from 85 billion tonnes to 186 billion tonnes by 2050. That is, the report suggests that while investments in ambitious climate action would lead to a 3.7 percent drop in global GDP per capita by 2050, these costs to the economy could be offset by more efficient resource use (UNEP, 2017).

In addition to the economic benefits, the analysis also shows that resource efficiency and climate action would reduce global resource use by about 28 percent in 2050 compared to current trends. For the G7 countries, resource efficiency combined with ambitious climate action would increase gross domestic product by 600 billion dollars in 2050 (600 dollars per person, or 1 percent) (Ekins et al., 2017).

A potential avenue for further research is to develop a theoretical framework for the circular economy approach.

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