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Article

Innovative Development of Circular Systems While Ensuring Economic Security in the Industry

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Abstract: This article is devoted to the formation of methodological foundations of the circular economy on the safety of industrial enterprises. The dependence of the system of economic security from the circular economy concept is implemented by the 3 R model. The model is based on the consistency of quantitative, value and normative indicators. These indicators together allow a comprehensive analysis of the dynamics and direction of the process of implementation of technologies of circular use of resources. The main factors of influence of the circular economy concept on the security of industrial enterprises are resource provision, secondary use of materials and results. To establish the sequence of analysis, we used the mathematical toolkit of factor analysis based on determining the set of factors and their forming indicators. The conducted assessment of the impact of the circular economy concept on the system of economic security of industrial enterprises allows us to state the monopoly of individual sectors of industry, and shows the overall picture of dependence without a position on the level of technology renewal and eco-innovation of production support technologies.

Keywords: innovative development; circular economy; economic security; industrial enterprises; energy efficiency; efficiency evaluation; model

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1. Introduction

Modern economic development challenges are provoked by energy crises, global migrations of population, and economic risks, often caused by military conflicts and international geopolitical transformation of the world economy. The application of innovations, energy-saving and waste-free technologies helps to minimize the negative impact of resource shortages, fossil material shortages, and spatial and temporal limitations. In addition, security challenges become the determinant of the scientific and applied search for new technologies for the use of resources and their uninterrupted circulation in production processes. This is how the requests for industrial enterprises regarding the creation of innovative materials, competitive products, and new economic tools for regulating business processes and production are formed.

Literature Review

Scientific research of modern interpretations of the economic theory of innovative development are realized in many contiguous concepts. This allows us to develop the conceptual apparatus and improve the tools of new methods and tools to ensure the development of economic systems. Taking into account the current trends in innovative modernization of industrial enterprises, there is a need to formalize the scientific basis for ensuring safety and environmental friendliness.

Studies in the development of the theory of innovation developed the so-called "neoclassics"—by G. Mensh, F. Kotler, and B. Twiss. Mensh laid down scientific principles of development through the formalization of the process of changes in the life

circular of technical means of production, which over time was transformed into the theory of technological modes [1]. The scientist–economist, continuing Schumpeter's teachings, argued that innovation occurs in times of crisis and provokes the development of the economic system; state support of basic innovation allows you to avoid innovation risks, and innovation is a source of modernization of production. Simon Kuznets researched the determinants of changes in the national income of the country. The researcher also identified the role of innovation in ensuring the development of economic systems. He argued that each new stage of development begins with a new innovation [2]. Developing these concepts, Freeman introduced and substantiated the methodological foundations of the "techno–economic paradigm" of innovation development of the economy [3]. In modern interpretations Perez develops the theory of Freeman in the concept of technological modes transformed. She described the impact of key innovations on changes in the technological stages of industrial development [4].

Modern research on innovative enterprise development is revealed in the publication by Andrew Webster and John Gardner [5]. Scientists study the perception of innovation and readiness for it. Kotenko et al. [6], and Andriushchenko et al. [7] formalized the tools for regulating innovation development through ensuring competitiveness, intellectualization, and digitalization. Also, Smerichevskyi et al. [8], Khudolei et al. [9], and Shkarlet et al. [10] devoted their research to the diffusion of innovation, institutional support, and the formation of strategic principles and guidelines. Tulchynska and Popelo [11] studied the issues of resource supply and maintaining the competitiveness of the enterprise in the implementation of innovation and investment strategies. Modernization priorities of innovative development are revealed in the publication by Revko et al. [12]. Scientists have described the institutional framework for regulation and investment mechanisms for the implementation of the modernization process. Guidelines for the development of innovations in energy saving and ecology were created in the research of Kwilinski and Kuzior [13]. Acerbi and Taisch [14], Prokhorova et al. [15], Morea et al. [16], and Zaloznova et al. [17] reveal the conditions and factors of application of circular economy innovations in industry.

In today's challenges of energy efficiency and environmental conservation, the key innovations are technologies of circular use of resources in ensuring the environmental friendliness of production. Thus, the principles of development of the concept of circular economies in the EU are developed by Fortunati et al., who identified its impact on the social responsibility of business [18]. Hartleya et al. [19] explored the imperatives and standards for implementing circular economy principles. Cainelliad et al. identified the basics of applying green innovation and supporting the implementation of environmental innovation at the level of stimulating economic processes in EU countries [20]. In the modern integration of Ukrainian science with European researchers, the results of cooperation are disclosed in the concept of strategic management of the circular economy by Kuzior et al. [21].

The Ukrainian researchers of innovative development on the basis of the circular economy include Tulchynska et al. [22], Kryvda et al. [23], and Shevchuk et al. [24]. Let us separately note the scientific achievements of scientists in the concept of circular economy. Tulchynska et al. defined the role of industrial parks and described the concepts of eco-infrastructure for innovation development [22]. The impact of industrial parks and the institutional regulation of their impact on the environment are investigated by N. Shevchuk et al. [24]. Kryvda et al. developed a methodological toolkit for analyzing the harmony of spatial development with the introduction of eco-innovations and circular economy technologies [23]. Business modeling of the conditions of application of the concept of circular economy was described by Ferasso et al., who revealed modern technologies and generalized studies of material supply, processing, and transformation of resource supply chains [25]. Kristoffersen, et al. investigated the application of digitalization technologies of production processes in industrial enterprises in the application of circular economy technologies [26].

To a lesser extent, studies of the impact of innovation on the system of economic security are presented. Tkachenko et al. [27], Gonchar [28], and Rementsov [29] can be regarded as the main scientists of this field of economics. Thus, Tkachenko et al. explore the basis of the impact of modernization and innovation on the state of economic protection of industrial enterprises [27]. Circular carbon economy (CCE) technologies also belong to green innovations and energy security of industry. A study by Latifah M. Alsarhan et al. reveals the interconnectedness between circular technologies, industrial innovation, and energy security [30]. Financial aspects of economic security are disclosed by scientists Gonchar et al. [28]. Rementsov reveals the impact of industrial production potential and technology on the economic security of enterprises [29].

2. Materials and Methods

The scientific basis of the conducted research is the methodology of the theory of innovative development, the concepts of circular economy, and economic security. The scientific research applied methods of strategic management to determine the nature of the impact of circular economy technologies on the directions of economic security. When constructing the "3 R" model to analyze resource supply, resource saving and effectiveness of using the concept of circular economy in industrial enterprises in providing the system of economic security, methods of economic and mathematical modeling were used: coordination of expert assessments, establishing their significance, ranking and analysis of the nature of deviation of indicators from the reference ones. The justification of the selected methods allows a holistic analysis of the state of the economic security system and the impact on it of the introduction of cyclical economy innovations. The specified methods made it possible to substantiate a set of indicators and their harmonization in the "3 R" model.

3. Results

Summarizing the scientific achievements on the interpretation of the concept of innovative development of circular systems, we can note the following patterns in the provision of economic security:

- when considering innovative development as a source of change, the concept of circular economy acts as a toolkit for the introduction of innovations and the process of their diffusion;
- realization of innovations in the format of ecological function occurs through technological and functional modernization of production structure and production logistics;
- the modernization process and intensity introduction of innovations lay down the basic parameters of the efficiency of implementation of circular technologies;
- the orientation of innovative development determines the scope of implementation of circular technologies;
- innovative development determines the level of accumulation and efficiency of implementation of circular economy principles, and the nature of innovations determines the structure and patterns of use of circular technologies.

Transformation and reuse of resources and materials on the basis of circular economy is influenced by modern demands and emphases on social responsibility of business in ecology and competitiveness of new products, human-centeredness in internal and external economic priorities. This provokes new challenges and imbalances, the timely identification and harmonization of which requires continuous training and skills of both personnel and technical management systems. When the concept of circular economy is implemented, the economic system has the following inherent security challenges:

- the need to find acceptable and affordable sources and forms of investment in circular production technologies;
- the long-term orientation of the economy to the development of industry provoked a structural and production crisis regarding the need for mass renewal of obsolete technology, improving quality and safety standards, competitive positions. In addition,

with globalization and the reorientation of world markets to provide services, meeting the needs of people as the main consumer, there was a problem of overproduction and subsequent unprofitability;

- the spread of information and digital communications provokes superficiality in human perception of the world around us; most purchases are made using the technology of the "Internet of things" through the mental or individual perception of the value of products. In these conditions, transport and logistics and information services constitute a large part of the value of purchased goods, which ultimately affects their dominant position in the structure of income, and hence the dominance of innovative renewal priorities.
- insufficient institutional support of the principles of circular economy at the national and regional level provokes spontaneity both in the application of innovations and in the modernization of enterprises;
- retention of orientation in the production of goods towards energy and resource consumption, low institutional support of energy-saving technologies;
- orientation in the introduction of circular technologies to external economic trends and the formation of external demand for them, which increases the cost of modernization, and reduces the rate of innovation development and their competitiveness;
- the availability of cheap labor maintains the tendency of lack of need for technological improvement, intellectualization of personnel, and production of energy-saving and environmentally friendly products;
- preservation of the raw material and industrial character of the economy, which meets the existing environmental standards, provokes low motivation for scientific research and development of a new generation of circular innovations.

The solution to these problems is possible with a thorough reform and improvement of environmental standards in national economies and their reorientation toward innovative development. In the conditions of integrated globalization and openness of world technologies and resources to circular innovations, Ukrainian industrial enterprises can be competitive in spheres of intellectual orientation that do not require large capital investments. Industrial enterprises in such challenges occupy intermediate positions—their development and modernization depend on intensification of implementation of circular technologies and innovative development of economy (Figure 1). Any sphere of industrial enterprise activity under the influence of circular economy and innovations undergoes both positive and negative changes, the coordination of which occurs in the process of modernization needs satisfaction. The precondition for the implementation of technologies of circular economy is the activation of notes on the production of environmental and energy safety needs of industrial products. An inseparable component in this process is the synergy of factors of motivation to overbuilding and modernization of management systems of industrial enterprises. Implementation of the advantages of cyclical economy requires integration of economic system, activation of financial and investment mechanisms, modernization of technical and technological support and logistic management from the position of costs and time and resources reduction.

Consequently, the conditions for the introduction of the concept of circular economy in industrial enterprises are the demands of society and individual enterprises for the transformation of resources into eco-innovations, as well as the presence of economic catalysts to accelerate these processes. In this context, the main motivators for the introduction of the concept of circular economy in industrial enterprises should be a focus on the transformation of intelligence into capitalized intellectual potential for the development and implementation of circular innovation. It will ensure the sustainability of the trajectory of innovation development through a targeted modernization process: technical, technological and logistical orientation to future circular technology. Catalysts are seen as functions to stimulate and accelerate the implementation of circular innovations. Therefore, let us describe the main catalysts and motivators for the implementation of the concept of circular economy in industrial enterprises, which will reveal the characteristics of determinism of

innovative development due to the effectiveness of the implementation of modernization potential (Figure 2) on the main objectives:

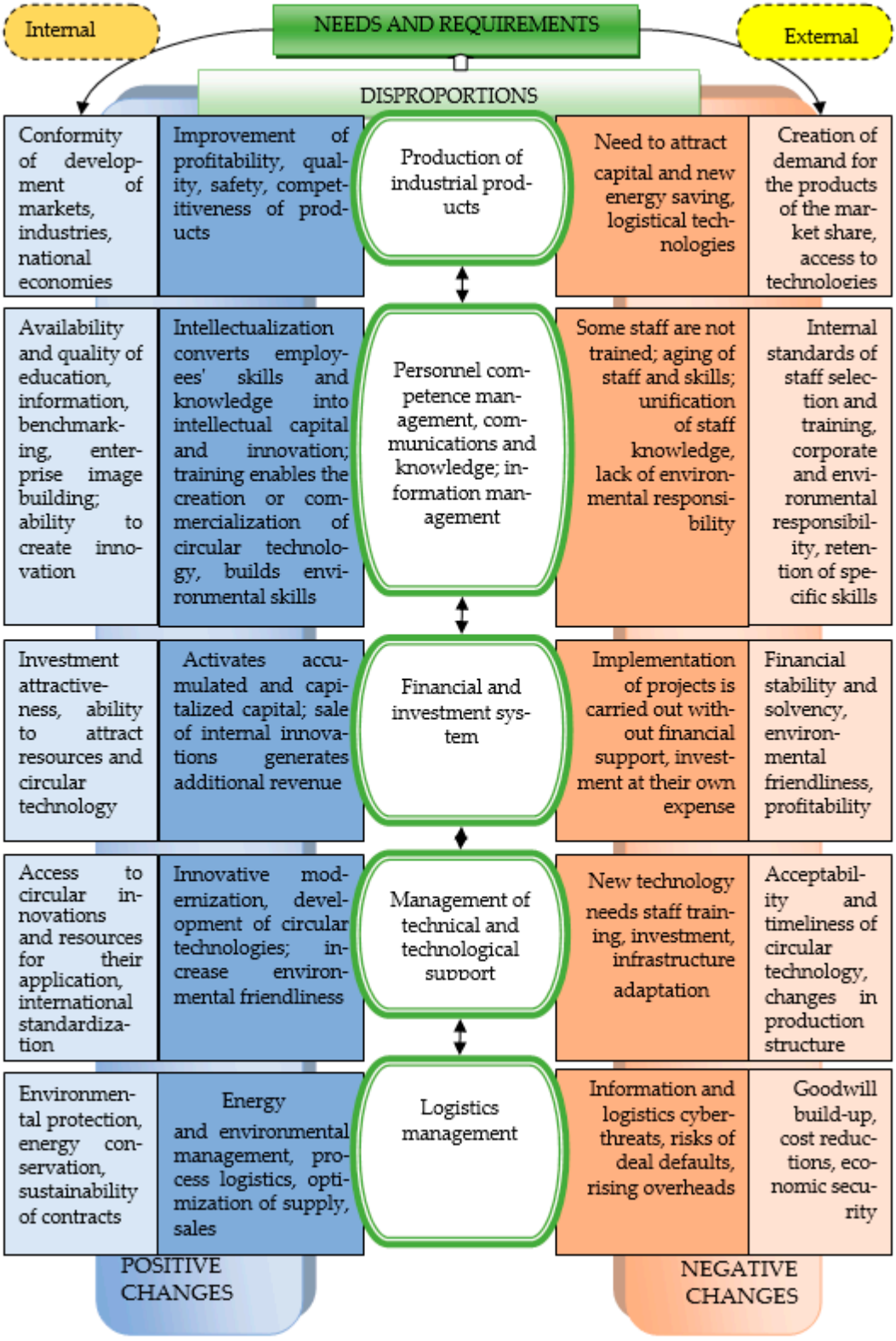

Figure 1. Disproportions between the results of implementation of the concept of circular economy in industrial enterprises.

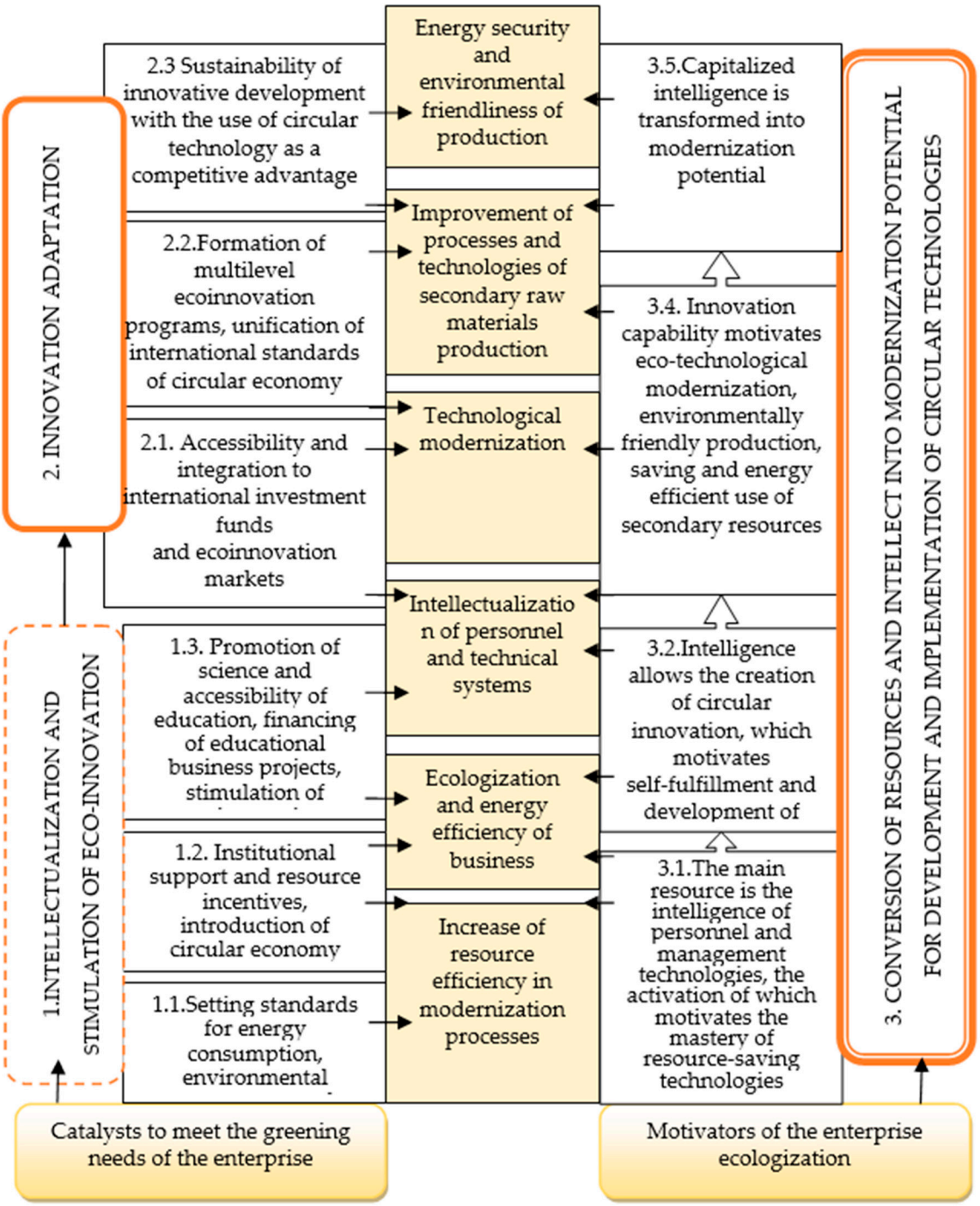

Figure 2. Catalysts and motivators for the implementation of the concept of circular economy in industrial enterprises.

First: improvement of resource efficiency of modernization;

Second: ecologization and energy efficiency of business processes;

Third: intellectualization of personnel and technical systems for mastering and application of circular technologies;

Fourth: improvement of processes and technologies to produce environmentally friendly and competitive products;

Fifth: technical and technological renewal on the principles of circular economy;

Sixth: increase in competitiveness at the expense of energy efficiency and environmental friendliness of production.

Each of the described directions of the concept of circular economy on industrial enterprises can be realized separately, but their consistency and purposefulness will ensure the unity of the vector of transformation of intelligence into innovation and intellectual capital with the subsequent positive development of the enterprise. The process of converting resources and intelligence in the internal environment is parallel to the process of innovative adaptation of the enterprise to the safe challenges described above, which depends on the influences of the external environment.

It should be noted that the level of innovation development in the implementation of the concept of circular economy in industrial enterprises creates conditions for economic security through the tools of institutional regulation:

- focus and scope of institutional support for innovation,
- training and scientific support and development of knowledge economy, environmental responsibility of the society,
- financing and fiscal incentives for ecological initiatives,
- integration with international investment funds and creation of conditions for attracting investors to environmental projects;
- focus on preventive strategic programming of national or territorial competitive advantages in the sphere of eco-innovative development;
- accumulation of capital provoked by demands for global eco-modernization of infrastructure—roads, bridges, pipelines, data transmission networks.
- security control over industry sectors of strategic importance and the status of "critical infrastructure" (energy, rail transport, communications), which requires monitoring of eco-innovative developments and their corresponding modernization.

So, the study of the factors showed the impact of key eco-innovations and circular technologies on economic development. Modern economic development requires the economy of energy, resources, preservation of the environment, which can be realized on the basis of circular economy technologies and eco-innovations. Consequently, the allocation of innovative development as a dominant in the processes of implementation of the concept of circular economy is appropriate and requires a more thorough formalization. Let us detail the determinism of eco-innovations of the circular concept in certain areas of activity and their impact on the economic security of industrial enterprises (Figure 3).

Innovations of circular economy in the management system of industrial enterprises should take into account the orientation of modern society towards publicity and international integration. Therefore, not only the production system is influenced, but also the organizational structure, which is rebuilt from a hierarchical model to an organic one, for approaches to communication within the team with external actors.

In the system of HR management, innovations in the formation of professional competencies and behavior regarding the ability of personnel to master eco-innovations, ensure their sustainability and corporate responsibility come to the fore. Therefore, psychological technologies are introduced in the selection and adaptation of the employee in the team. Moreover, industrial enterprises try to provide continuous professional training and formation of skills and competences for using production technologies with circular economy.

The production system of industrial enterprises requires detailed attention: implementation of innovations of circular economy determines the long-term profitability and competitiveness of both eco-products and the entire enterprise. Therefore, the relevance and timeliness of materials processing technologies, energy efficiency and environmental friendliness of production are prerequisites for functioning.

Marketing and logistics systems are supportive, but the innovativeness of circular economy technologies directly affects the competitive position in both eco-products and resource and capital markets. Modern digital systems of logistic support for economic activity concern all spheres of industrial enterprises and allow them to optimize the flows of material resources, finances, personnel and systems of processing, supply, and sales.

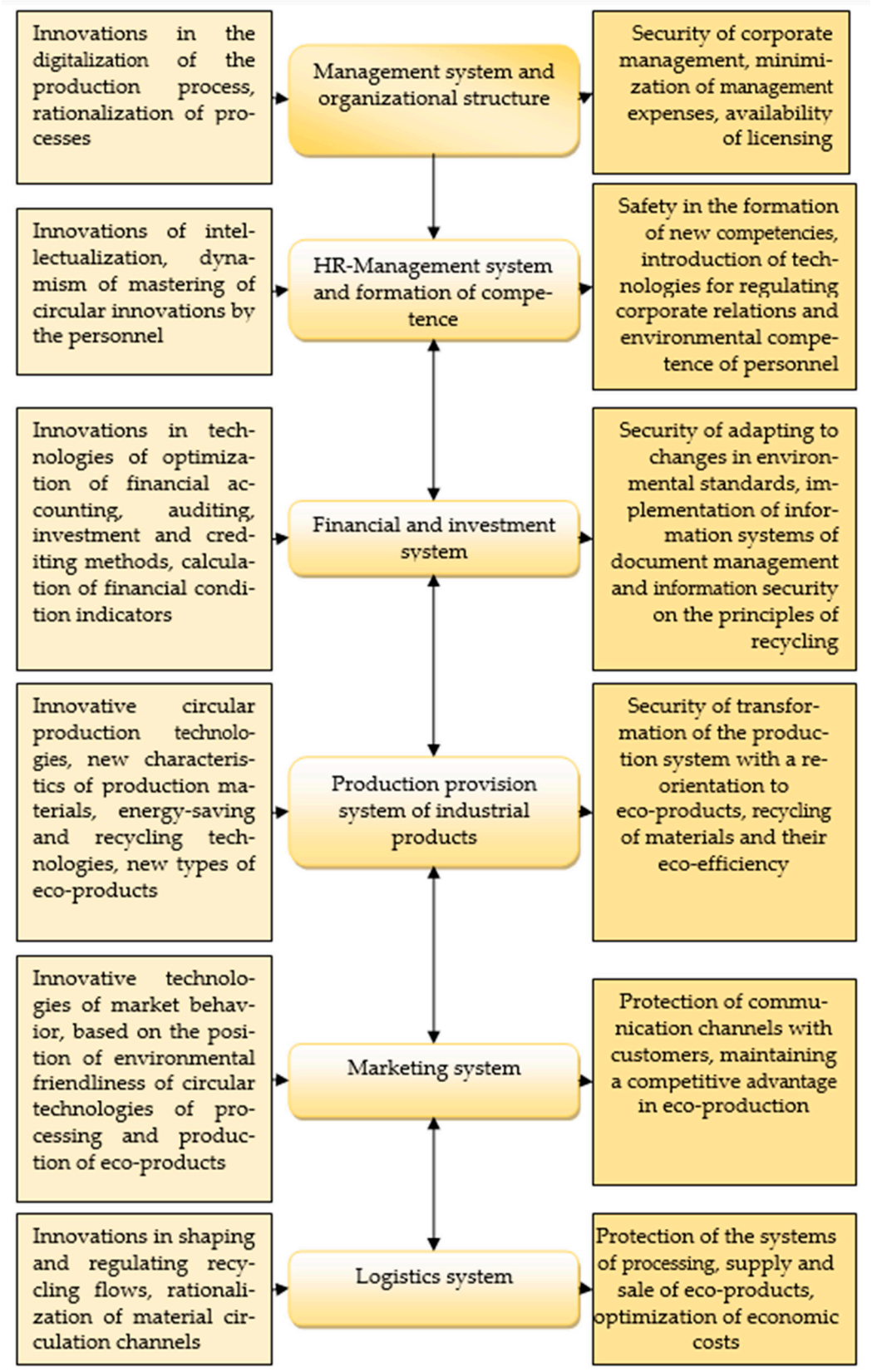

Figure 3. Determinants of implementation of circular economy innovations and their impact on economic security of industrial enterprises.

We proposed the justification of the model of influence of innovations of circular economy on the security of industrial enterprises "3 R" (Resource, Recycling, Results). The functional dependence of the economic security system on the integrated parameters in the concept of circular economy of industrial enterprises in the 3 R model is realized through the integration of the goals of energy efficiency and profitability of resource use in the formation of preventive protection (Figure 4).

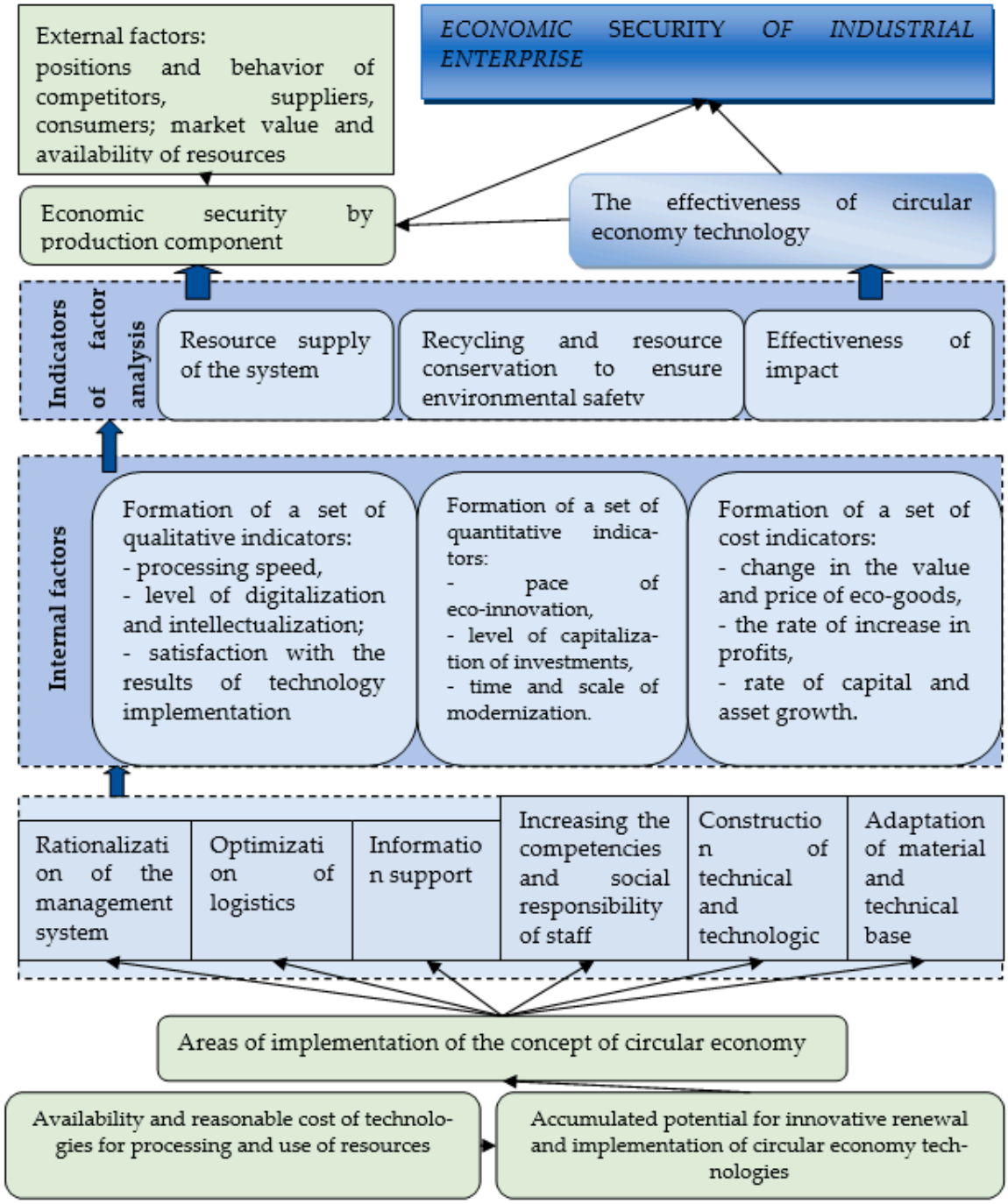

Figure 4. The "3 R" model for the integral analysis of the factor impact of the circular economy concept on the economic security of an industrial enterprise.

The main factors of influence of the circular economy concept on the security of industrial enterprises are resource provision, secondary use of materials and results:

$$f(S) = (R_s, R_c, R_e), \quad (1)$$

where $f(S)$ is the dependence function of the economic security system of the enterprise;

R_s—resource supply of the economic security system (Resource);

R_c—recycling and resource conservation for environmental safety (Recycling);

R_e—effectiveness of the impact of the circular economy concept on the level of security (Results).

In order to establish the sequence of analysis, the mathematical toolkit of factor analysis, based on the definition of a set of factors and indicators that form them, was applied. This will allow you to determine the optimized number of indicators of each group of factors and their impact on the final result. The specified functional parameters of integration impact on the system of economic security should be formally explained through the set of their indicators and coordinate their weight, correlation, etc. mathematical formulas for expediency of introduction into models. Therefore, let us first establish the basic conditions for the application of mathematical tools in the construction of the 3 R model, taking into account the need to justify the use of a set of indicators, establish their significance and consistency, expert evaluations, ranking and analysis of trends in deviations, etc.

Having explained the integrative influence of the circular economy concept on the system of economic security of an industrial enterprise, it is necessary to establish the goals of modeling: the formation and rationalization of the system of resource supply, resource saving and performance indicators, reflecting in aggregate interaction the innovativeness and environmental friendliness of industrial products in an innovative environment. Additionally, to the purpose of modeling we relate universality of model implementation to industrial companies for comparability of participants of related markets or spheres of industrial industry.

Various groups of indicators are used in economic and mathematical modeling of relative complex indicators: normative, technical or cognitive, expendable or valuable, or cost, measuring or estimating, qualitative or quantitative. For the first coordination of all indicators in the model we will use only coefficient characteristics, which will allow us to evaluate both quantitative, cost, and technical properties of the modernization process. Apply mathematical tools to compare the resulting calculated value with the reference/industry/target value and determine the weighted average arithmetic value of the indicators in a group of parameters to form a comprehensive indicator of integration impact.

These modeling conditions also include:

- the need for multiplicity of indicators (in general there should be from 10 to 30)'
- the weight of the indicators in the parameter is equal to one;
- application of expert estimates should be consistent between the opinions, which is provided by the use of concordance coefficient, as well as be within the margin of error, which is estimated on the basis of the application of mathematical tool of the standard deviation;
- benchmark/median/target values of the indicators are established.

The process of describing the economic–mathematical model of factor analysis for integration influence of the concept of circular economy on the system of economic security of the enterprise includes many consistent steps.

At the first stage of modeling the factor influence of the circular economy concept on the system of economic security of an enterprise, let us form a list of the main indicators for each parameter.

First, we refer to the indicators of the resource support of the implementation of the technology of circular economy of the enterprise as:

- investment rate;
- modernization rate;
- the dynamics of the cost of innovation activities of the enterprise;
- the dynamics of the change in the rate of capitalization of the enterprise;
- the change in the duration of the innovation and investment process.

Secondly, the enterprise's resource-saving indicators are next:

- resource intensity;
- change in duration mastering the technology of secondary processing of materials;
- the level of digitization of technologies;
- level of activation of intellectual potential;
- share of staff competencies in the workforce.

The next group of effectiveness indicators includes:

- the scale of application of circular economy technology (the share of coverage of the technical–technological and material–technical base of the enterprise);
- rate of change in production potential value;
- profitability of the implementation of innovative investment technologies of the circular economy;
- profitability of the investment activity;
- change in the market share of ecological goods.

The second stage of formalizing the model is to establish the significance of the indicators in the evaluation system (Table 1). At this stage, the tools of expert evaluations are used and a number of requirements for the relevance of the results are satisfied:

- values of indicators are assigned in the range of 0–1;
- sum of evaluations of indicators in one parameter should be equal to one (100%);
- evaluation results must be consistent and reliable;
- we will take the number of score variations in accordance with the results obtained, setting the step for assigning values at 5 units.

The experts' cognitive thinking as of the date of the assignment (2021) was evaluated. The experts were Ukrainian scientists and businessmen.

Consistency of expert evaluations is established by applying the coefficient of concordance. At the same time, a value of the coefficient of concordance close to 1 is acceptable, and less than 0.4 is unacceptable. Formula:

$$w = \frac{12\sum \Delta^2}{n^2(m^3 - m)} \quad (2)$$

where n is quantity surveyed experts;

m—quantity of variations in the obtained values of the indicators;

Δ—deviation.

The deviation by the average sum of ranks is found by the formula:

$$\overline{\sum p} = n \times (m + 1)/2 \quad (3)$$

To calculate the consistency of the specialists' statements, the rank gradation of their evaluations is made (Tables 2–4). We assign ranks to the obtained assessments in the range from 1 to 9 (which corresponds to the number of assessment ranges with a step of 5 points).

Table 1. Determination of the significance of the indicators in the "3 R" model using expert tools, %.

Indicators	Expert Evaluation											Total Rank
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
1. Resource supply:	25	25	20	30	20	20	25	30	20	35	20	23.6
1.1. investment rate	15	25	30	20	20	25	20	20	25	25	20	22.3
1.2. modernization rate	20	20	40	25	30	25	20	40	15	25	25	25.9
1.3. dynamics of the cost of innovation activities of the enterprise	30	20	10	20	25	30	20	10	30	10	20	20.5

Table 1. *Cont.*

Indicators	Expert Evaluation											Total Rank
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
1.4. dynamics of the change in the rate of capitalization of the enterprise	25	15	10	25	10	10	20	15	20	10	20	16.4
1.5. change in duration	10	20	10	10	15	10	20	15	10	10	15	13.2
Total weight, h. unit.	100	100	100	100	100	100	100	100	100		100	90.9
2. Recycling and resource conservation:	40	40	40	35	40	35	40	45	35	20	40	37.3
2.1. resource intensity	25	25	25	20	15	15	25	20	25	35	25	23.2
2.2. quickness of technology adoption	20	15	20	15	25	20	20	20	20	30	20	20.5
2.3. level of technology digitalization	15	15	15	10	20	20	15	15	15	10	20	15.5
2.4. level of intellectual potential activation	25	25	25	30	20	30	25	30	25	10	25	24.5
2.5. share of staff competencies in the workforce.	15	20	15	25	20	15	15	15	15	15	10	16.4
Total weight, h. unit.	100	100	100	100	100	100	100	100	100	100	100	100.0
3. Effectiveness:	35	35	40	35	40	45	35	25	45	45	40	39.1
3.1. scale of technology application	20	15	25	25	25	30	25	25	5	5	15	19.5
3.2. rate of change in production potential value	20	25	15	20	20	30	25	30	25	25	15	22.7
3.3. profitability of technology implementation	20	25	30	25	20	10	25	20	25	35	30	24.1
3.4. profitability of investment activities	15	25	15	15	20	15	20	20	35	15	20	19.5
3.5. change in market share of ecological goods	25	10	15	15	15	15	5	5	10	20	20	14.1
Total weight, h. unit.	100	100	100	100	100	100	100	100	100	100	100	100.0
Total weight of the parameter, h. unit	100	100	100	100	100	100	100	100	100	100	100	

Table 2. Rank gradation of evaluation of the indicators' significance in the parameters of the factor influence of resource supply on economic security.

Indicators	Expert Evaluation											Total Rank	Δ	Δ^2
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1.1.	7	5	4	6	6	5	6	6	5	5	5	60	27	729
1.2.	6	6	2	5	4	5	6	2	7	5	5	53	20	400
1.3.	4	6	8	6	5	4	6	8	4	8	6	65	32	1024
1.4.	5	7	8	5	8	8	6	8	6	8	6	75	42	1764
1.5.	8	6	8	10	8	8	6	8	8	8	7	85	52	2704
														$\sum\Delta^2 = 6621$

Table 3. Gradation of rank estimates of the significance of the indicators in the parameters of the factor impact of resource saving.

Indicators	Expert Evaluation											Total Rank	Δ	Δ^2
	1	2	3	4	5	6	7	8	9	10	11			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
2.1.	5	5	5	6	7	7	5	6	5	5	5	61	28	784
2.2.	6	7	6	7	5	6	6	6	6	4	6	65	32	1024
2.3.	7	7	7	8	6	6	7	7	7	8	6	76	43	1849
2.4.	5	5	5	4	6	4	5	4	5	8	5	56	23	529
2.5.	7	6	7	5	6	7	7	7	7	7	8	74	41	1681
														$\sum\Delta^2 = 5867$

Table 4. Gradation of rank estimates of the significance of the indicators in the parameters of the factor impact of performance.

Indicators	Expert Evaluation											Total Rank	Δ	Δ^2
	1	2	3	4	5	6	7	8	9	10	11			
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
3.1.	6	7	5	5	5	4	5	5	5	9	7	63	30	900
3.2.	6	5	7	6	6	4	5	4	5	5	7	60	27	729
3.3.	6	5	3	5	6	8	5	6	5	2	4	55	22	484
3.4.	7	5	7	7	6	7	6	6	2	7	6	66	33	1089
3.5.	5	8	7	7	7	7	9	9	8	6	6	79	46	2116
														$\sum\Delta^2 = 5318$

Average sum of ranks

$$\overline{\sum p} = 11 \times (5+1)/2 = 33$$

The coefficient of concordance for the indicators of the resource provisioning parameter:

$$w = \frac{12 \times 6621}{11^2 \times (5^3 - 5)} = 0.9119$$

The coefficient of concordance for the indicators of the resource-saving parameter:

$$w = \frac{12 \times 5867}{11^2 \times (5^3 - 5)} = 0.8081$$

The coefficient of concordance for the performance parameter indicators:

$$w = \frac{12 \times 5318}{11^2 \times (5^3 - 5)} = 0.7325$$

Consequently, the calculations showed the acceptability of the set of selected indicators and their significance in the model, as well as the consistency of expert evaluations. The consistency of the expert study falls into the range of 1–0.4, so we can reasonably assert the economic feasibility and mathematical consistency of the proposed model, since all these indicators reflect the positive impact on the efficiency of application of circular economy technologies to increase the level of economic protection. That is why Kendall's methodology is sufficient for formalization of the final model. This excludes the need

to use mathematical tools for Spearman's model, which allows us to identify mutually exclusive indicators.

The third stage of the analysis of the economic security system under the influence of the implementation of circular economy technologies consists in the establishment of the benchmark/median/target values of the selected indicators. Since all the proposed indicators for each parameter reflect the relative dynamics of change, we will consider their growth as a positive assessment, and the benchmark value will be greater than unity.

In the next step, we formalized the formulas for the evaluation of the integrated impact. To present the results of the selection of indicators for the formalization of mathematical tools for the visualization of formulas in the 3 R model, the authors have provided Formulas (4)–(6). The formulas are interpreted on the basis of linguistic interpretations. Applying the obtaining the significance of the parameters, we will describe the formula as follows:

$$S = R_s \times q_s + R_c \times q_c + R_e \times q_e = R_s \times 0.236 + R_c \times 0.373 + R_e \times 0.391 \quad (4)$$

where R_s is the parameter of the resource impact of the circular economy technologies on the increase in economic security of the enterprise;

q_s—the significance of the parameter of the resource impact of the circular economy technologies;

R_c—the parameter of resource saving;

q_c—the significance of the parameter of resource saving;

R_e—efficiency parameter;

q_e—the significance of the efficiency parameter.

Recycling processes, as described above, is based on monitoring the dynamism of innovation–investment renewal and the duration of the process and is calculated by the formula:

$$R_s = \sum_{i=1}^{n} \frac{Pi}{Pe} \times q_i = \frac{I}{I_e} \times 0.232 + \frac{Tm}{Tm_e} \times 0.205 + \frac{Tc}{Tc_e} \times 0.155 + \frac{Kk}{Kk_e} \times 0.245 + \frac{TI}{TI_e} \times 0.164 \quad (5)$$

where *Pi*—value of the indicators of recycling at the enterprise;

Re—the reference value of indicators;

i—number of indicators in the parameter;

I—investment rate;

Tm—rate of modernization;

Tc—the dynamics of the cost of innovation activities of the enterprise;

Kk—the dynamics of the change in the rate of capitalization of the enterprise;

TI—change in the duration of the innovation and investment process.

Resource saving at an industrial enterprise in the processes of economic security due to the application of circular economy technologies is found by the formula:

$$R_c = \sum_{i=1}^{n} \frac{Cy_i}{Cy_e} \times q_i = \frac{R}{R_e} \times 0.223 + \frac{Tt}{Tt_e} \times 0.259 + \frac{D}{D_e} \times 0.205 + \frac{IK}{IK_e} \times 0.164 + \frac{HR}{HR_e} \times 0.132 \quad (6)$$

where Cy_i—indicators of resource saving at the enterprise;

Cy_e—reference values of resource-saving parameter;

i—number of indicators in the parameter;

R—resource intensity of the innovation and investment process;

Tt—the rate of conquering of a new market or technology;

D—level of digitalization;

IK—level of activation of intellectual potential;

HR—the share of competent personnel in the total number of employees.

The effectiveness of the introduction of technologies of the circular economy of the enterprise, further determining the market share and market position in the coverage of eco-innovations and eco-products, we calculate by the formula:

$$R_e = \sum_{i=1}^{n} \frac{E_i}{Ee} \times q_i = \frac{K}{K_e} \times 0.195 + \frac{Tp}{Tp_e} \times 0.227 + \frac{Pr}{Pr_e} \times 0.241 + \frac{IP}{IP_e} \times 0.195 + \frac{M}{M_e} \times 0.141 \quad (7)$$

where *Ei* are indicators of the efficiency of implementation of circular economy technologies at an enterprise;

Ee—reference values of performance indicators;

i—number of indicators in the parameter;

K—scale of modernization (share of coverage of the enterprise assets);

Tp—the rate of configuration of the value of the company's potential;

Pr—profitability of implementation of innovation and investment projects;

IP—profitability of investment activity;

M—change in market share.

To form the final formula for determining the state of the economic security system of an enterprise by factor analysis of the impact of circular economy technologies, it is necessary to determine a formalized set of calculations of intermediate indicators, reflecting general economic processes, but having sectoral features. The calculation of indicators is based on the financial and analytical reporting of enterprises of the infrastructure sphere. The 3 R model allows us to describe the dependence of the economic security system on the parameters of the introduction of circular economy technologies through the consistency of quantitative, value and normative indicators. This enables a comprehensive analysis of the dynamics, value, and strategic orientation of the process of implementing technologies of circular use of resources. At the same time, the main purpose of factor analysis of the integration impact of the circular economy concept is to determine the state of the enterprise's economic security system, the nature and trends in its changes. In the last step of the simulation, it is advisable to gradate quantification of the criteria of the impact of technologies of circular use of resources on security, which will further allow applying the developed 3 R model in the strategic analysis of enterprises. To meet the strategic objectives of eco-modernization, we will consider two descriptive characteristics: sufficient or insufficient impact on the state of security of the system of economic security, performed through the system of meeting the conditions:

$0 < S < 1$—insufficient influence of circular economy technologies to improve the protection of the economic security system of industrial enterprises;

$S > 1$—sufficient integrative influence of circular economy technologies, which provides the increase in the efficiency of the economic security system of the industrial enterprise.

These requirements are key when making decisions about the introduction of circular economy technologies with the use of qualitatively new resource-saving or commercialization eco-innovations.

Investigating in more detail the state of the economic security system of industrial enterprises according to the indicators of resource supply, resource saving and effectiveness of the circular economy concept using the "3 R" model, it can be stated, that the monopoly position on the markets of industrial products in certain territories (PJSC "AvtoKrAZ", JSC "Bohdan" Motors, SE "KAZ "AVIACON", SE "Kharkiv Machine Building Plant" "FED", SE "Odessa Aviation Plant", PJSC "Motor Sich" do not affect the overall evaluation results (Table 5). The surveyed enterprises are the components of the industrial sector of Ukraine and are located on the territory under the control of the government. The results of the strategic analysis of the economic security system according to the "3 R" model of each of the studied enterprises showed the dependence on the existing business environment, the level of personnel competence, the dynamics of eco-innovation implementation and investment support. It should also be noted that the impact of circular economy technologies on the level of economic security is directly proportionally correlated with the dynamics of the performance of innovation development in the time range. For example, in the analysis of the profile of JSC "Bohdan Motors" we see low values of effectiveness along with monopolization of the market of certain types of products (cars), and for both indicators we observe a decrease in values in 2018. The same patterns are observed in the analysis of the

values of the assessed indicators for SE "Kharkiv Machine-Building Plant" "FED", the only difference is that the drop in values at this enterprise occurred in 2017. Interdependence of the values of the indicators is also observed at the enterprises of the aviation industry PJSC "Motor Sich", SE "KAZ "AVIACON", SE "Odessa Aviation Plant": the peak values of the indicators occur during periods of growth in the production of aviation equipment and components and, accordingly, the profitability of enterprises. In addition, we can note the dependence of indicators on the volume of investments made, which directly affects the resource ratio.

Table 5. Evaluation of the impact of the introduction of circular economy technologies on the level of the economic security system of industrial enterprises using the "3 R" model.

Enterprises	Period of Analysis					Dynamics of Indicator Change, 2020/2016
	2016	2017	2018	2019	2020	
1	2	3	4	5	6	7
JSC "Bohdan Motors"						
The level of economic security	1.62	1.75	1.20	1.23	1.26	1.62
- resource supply	0.48	0.59	0.06	0.05	0.07	0.48
- recycling	0.219	0.249	0.279	0.314	0.335	0.219
- effectiveness	0.93	0.91	0.86	0.87	0.85	0.93
SE Kharkiv machine-building plant "FED"						
The level of economic security	1.81	1.36	1.73	2.20	2.06	1.14
- resource supply	0.42	0.21	0.54	0.41	0.55	1.29
- recycling	0.927	0.423	0.694	1.119	0.998	1.08
- effectiveness	0.46	0.73	0.49	0.67	0.52	1.13
PJSC "Motor Sich"						
The level of economic security	0.782	1.185	1.169	1.065	1.168	1.494
- resource supply	0.212	0.204	0.179	0.104	0.091	0.430
- recycling	0.330	0.353	0.355	0.291	0.317	0.962
- effectiveness	0.24	0.628	0.636	0.670	0.760	3.165
SE KAZ "AVIAKON"						
The level of economic security	0.959	0.947	1.277	0.552	12.572	13.116
- resource supply	0.351	0.398	0.379	0.051	0.771	2.195
- recycling	0.077	0.076	0.474	0.005	5.929	76.688
- effectiveness	0.530	0.473	0.424	0.497	5.872	11.080

The conducted assessment of the impact of the circular economy concept on the system of economic security of industrial enterprises allows us to state the monopoly of individual sectors of industry and shows the overall picture of dependence without position on the level of technology renewal, eco-innovation of production support technologies.

The results are derived on the basis of theoretical statements, applied modeling and calculations on the basis of factual data of the enterprises' activity. The obtained results help to make managerial decisions on the implementation of innovative technologies of circular economy and ensuring the required level of economic security.

4. Discussion

The research is based on the actualization of energy security risks of industry. Innovative technologies of the circular economy act as a tool for ensuring economic security. Zero-waste industry and recycling allow saving not only resources, but also energy. There-

fore, in conditions of energy threats, the use of circular technologies will ensure not only economic security, but also the competitiveness of eco-innovations and eco-products. The key competitive advantages and non-pecuniary guarantees are resource supply, resource saving and industrial effectiveness.

The conducted calculations allow us to draw conclusions about the diversity and mandatory implementation of circular economy technologies at the industrial enterprises of Ukraine. Solutions can also be implemented in other countries. Considering the activity and market position of each industrial enterprise in the context of ensuring the effectiveness of the impact of eco-technologies on the system of economic security and innovative development, we trace the lack of motivation to activate the available resource opportunities and use the monopoly position in the market of certain industrial products. Therefore, we will direct further research to the formalization of tools for strategic management of eco-innovation activity of industrial enterprises.

The availability of circular economy technologies and their impact on the competitive status of industrial enterprises is becoming a key safety factor. Strategic guidelines for the effectiveness of the application of circular economy innovations become priorities for modernization and reconstruction. Therefore, it is expedient to develop the topic of the conducted research in order to find new innovations in the circular economy. Adjustment of the level of resource provision, resource conservation and profitability should be applied in strategic security management. The energy security of industrial enterprises is based on the security of the application of circular economy technologies. Therefore, further research on the formation of the decision-making system must be coordinated with the system of the proposed indicators and implement monitoring systems. Strategizing this process will promote timely harmonization of directions of improvement of circular economy technologies, opportunities of intellectualization of innovative development, eco-innovation, formation of systems of personnel, financial and logistical support of economic security. The formation of the information content of the necessary indicators will provide a timely assessment of economic risks. The identification and structuring of economic and energy threats is a necessary condition for predicting changes in the trends of innovative technologies of a cyclical economy.

5. Conclusions

The application of the "3 R" model will allow the enterprise to determine the directions of economic security due to the implementation of technologies of circular use of resources.

The conducted substantiation of the methodological tools made it possible to formalize the authors' approach. Analysis of the impact of circular economy technologies on the level of security of an industrial enterprise according to the authors' "3 R" approach reveals management opportunities for minimizing the risks of resource provision, resource conservation and profitability. Approbation of the approach at Ukrainian enterprises reflected the impact of circular economy technologies on the level of security. In further research, the obtained results allow the formation of strategies for energy security.

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