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RESEARCH PAPER

An Integral Method of Evaluating the Innovative Capacity of Enterprises

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ABSTRACT
Innovative capacity as a potential ability of an enterprise to innovative development is manifested in the process of formation and realization of an innovative product, which can be embodied in various forms. In the article innovation capacity is considered as a complex concept that covers the innovative output of the enterprise and the reserve for providing innovative capacity, which can make the difference between the innovative capacity and the current state of the innovative output of the enterprise. In order to improve the level of management processes in the enterprise, the article improves the method of evaluation the innovative capacity, which is based on the use of a three-dimensional space model of the dependence of the innovative capacity on the level of loading vectors of technique of the enterprise (X-axis), applied innovative technologies (Y-axis) and resources (Z-axis) using AHP-model (analytical-hierarchical process model) and certain functional dependencies that indicate the state of innovative capacity of the enterprise and allow to identify the reserve for providing innovative capacity.The system of indicators designed to measure the enterprise's innovation capacity is developed on the basis of the AHP-model (analytical-hierarchical process model), which contains two levels: 1) partial indicators designed to assess the level of loading of vectors of the three-dimensional space model of the enterprise's innovation capacity; 2) generalized indicators by which the level of innovation capacity is determined. The article uses the relative weight of indicators, which is calculated by forming a matrix of judgments and evaluating the components of the vector of its priorities.

KEYWORDS: *Innovative capacity; Innovative output; Evaluation; Method; Enterprise; Three-dimensional space model; AHP-model.*

1. Introduction

1.1. Problem description

In today's dynamic environment and the widespread globalization of the global economy, it is increasingly difficult for businesses to gain and retain competitive advantages. Increasing the competitiveness of the enterprise, developing creative skills of employees, realizing the potential of researchers-innovators is possible only in the conditions of implementation of innovative processes. It requires scientific and sound approaches to managing innovation.

In the process of innovation management, it is important to identify the enterprise's ability to innovate and its ability to meet social needs through the formation and implementation of an innovative product, which can be characterized by the innovation capacity of the enterprise (I_{coe}). Innovative capacity of the enterprise as a complex of its implicit opportunities, which are in the area of applied technologies, used technique, knowledge, skills and abilities of employees, covers the innovative output of the enterprise and the reserve for providing innovative capacity. On the one hand, the innovative capacity of an enterprise is value of the innovative output (I_{ooe}) and reserve for providing innovative capacity, which depends on the state of innovative development of the enterprise. On the other hand, the reserve for

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providing innovative capacity of the enterprise distinguishes between reserve for providing innovative capacity and current state of innovative output.

As you know, identifying reserves in the activity of the enterprise, finding ways to use them effectively are one of the important tasks of economic analysis. In order to ensure the activity of finding reserves for the innovative development of the enterprise, it is necessary to provide recommendations for the evaluation of innovative capacity, the innovative output of the enterprise, which would be summarized in the integrated method of evaluation of the innovative capacity of enterprises.

1.2. Literature review

There are no publications in the economic literature on assessing the level of innovative capacity of the enterprise. It is recommended to use the AHP-method [11], the expanded enterprise development pipeline [12], the ANP-model [13], the capacity and demand analysis model [14] for the overall assessment of the enterprise capacity in literature.

Using the AHP-method [11], provides a comprehensive analysis of enterprise capacity in the following areas: the credibility of enterprise development (expressed in terms of its current, liability and quick ratio); capacity growth of the enterprise (expressed in terms of capital maintenance and appreciation and capital accumulation ratio); proportion of technical inputs (characterized by investment in R&D, training expenditure growth;); level of earnings growth (determined by the net revenue growth, operating profit, net profit growth).

The expanded enterprise development pipeline is being built by (Hubble J. and Farley D.) in the following stages: commit stage; automatic acceptance test; automatic capacity test of the enterprise and performance change detection (provides notification of changes in performance indicators); manual capacity testing; release (involves reporting by type of resources and production units–centers) [12].

The ANP-model assumes the measurement of the technological capacity of an innovative enterprise by four factors: resource foundation (sub-factors - the proportion of R&D staff involved; the average number of technological retrofitting projects completed; the average number of enterprises that have scientific and technological units; financing of scientific and technological activities; financing); R&D capability (sub-factors - R&D expenditures; technology acquisition costs; acquisition and conversion costs; full-time staff of research services); output capability (sub-factors - achievements in S&T and national prizes won; average number patent applications certified; yield ratio of new product development; content of new technology); marketing capability (sub-factors - percentage of new product sales to sales revenue; transaction value in technical market) [13].

Capacity and demand analysis is recommended to improve the activity of emergency departments of rural district general hospitals. Its purpose is to build an array of information, which was further elaborated by the Delphi Group to evaluate the organizational structure of management [14].

Also, a number of publications are devoted to determining the level of information, resource, budget (debt), financial capacity and capacity of premises at the enterprise [1-3, 6-9].

It is suggested to measure the information (channel) capacity through the upper limit of the amount of information passing through the enterprise transmission channels (in bits per second) [8]. The ecological carrying capacity of the enterprise can be measured by the following indicators: total profit, total assets, comprehensive commodity rate, material productivity, oil content in sewage, sulfide content in sewage, content of phenol in sewage, treatment rate of industrial waste water, application amount of electrical energy, comprehensive energy consumption and more. They are grouped into three dimensions: economics, environment, resources [8]. Debt capacity is the difference between budget revenues and its expenditures (excluding costs for increasing fixed asset value, expenditures for servicing existing debt for the relevant period, etc.) [7]. Resource intensity can be defined as the ratio of the cost of natural resources per unit of gross value added [6]. The components of resource intensity are nature-intensive, labor-intensive, material-intensive, energy-intensive of the products, etc. [3]. The capacity of the premises of the enterprise as a physical property of the content can be determined on the basis of the regulatory period of storage of cargoes taking into account various factors (addition, uneven loading of the warehouse, etc.) or due to the number of cargo places [1, 2].

A three-dimensional model of economic space was used to formulate an integrated method for evaluating enterprise innovation capacity, as recommended in [11]. It allows to represent the innovative capacity of the enterprise as a multi-vector space model, where the X-axis is responsible for the applied innovative technique, the Y-axis is the technologies at the enterprise, and Z characterizes its resources (Fig. 1).

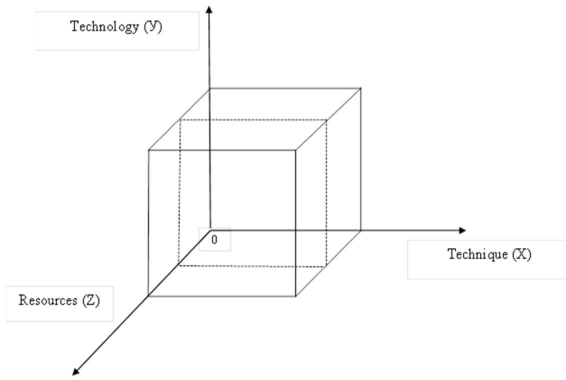

Fig. 1. A three-dimensional space model designed to evaluate the innovation capacity of the enterprise

The following three-dimensional model contains the following correspondences: the OX-axis indicates the level of technique at the enterprise in terms of innovation; the OY-axis is responsible for the level of technology of the enterprise and its compliance with the goals of innovative development; the OZ-axis characterizes the level of enterprise resource availability. Each of the vectors of the three-dimensional model characterizes the level of development of its components (load indicators), and the innovation capacity of enterprises can be measured by calculating the parameters of the vector model, which consists of three indicators.

AHP-method involves determining the level of innovative capacity of the enterprise by the formula [11]:

$$\mathrm{I}_{coe} = \sum_{i=1}^{3} w_i * C_i \qquad (1)$$

where w_i – the weights of indicators intended for estimation of innovative capacity of the enterprise; C_i – values of indicators intended for estimation of innovative capacity of the enterprise (vectors of technology, technique, resources, Fig. 1);

In order to determine the weights of indicators intended for estimation of innovative capacity of the enterprise (w_i) expertly formed matrix of judgments:

$$\begin{pmatrix} 1 & 2 & 6 \\ 0{,}5 & 1 & 0{,}33 \\ 0{,}17 & 3 & 1 \end{pmatrix} \qquad (2)$$

When forming a matrix of judgments, experts are guided by the following rating scale [11]:

$$\begin{cases} 1 - \mathit{elements\ are\ equally\ important}; \\ 3 - \mathit{element\ i\ is\ slightly\ important\ than\ j}; \\ 5 - \mathit{element\ i\ is\ obviously\ important\ than\ j}; \\ 7 - \mathit{element\ i\ is\ intensely\ important\ than\ j}; \\ 9 - \mathit{element\ i\ is\ extremely\ important\ than\ j}; \\ 2,4,6,8 - \mathit{means\ the\ value\ of\ adjacent} \\ \mathit{judgment\ respectively}. \end{cases}$$

Based on the identified elements of the matrix of judgments (2), the components of the priority vector (weights of indicators w_i) are evaluated, which is summarized in Table. 2 [15].

Tab. 1. Calculation of the weights of indicators intended for estimation of innovative capacity of the enterprise (w_i)

	$w_{i,j}$	Elements of the judgment matrix			Average geometric elements	Evaluation of components of the priority vector (weight of indicator w_i)
		w_1 Resources	w_2 Technology	w_3 Technique		
Elements of the judgment matrix	w_1 Resources	1	2	6	2,29	0,63
	w_2 Technology	0,5	1	0,33	0,55	0,15
	w_3 Technique	0,17	3	1	0,80	0,22
	Total				3,64	1

As a generalization of the results of expert evaluation, calculate the maximum eigenvalue of the judgment matrix (λ_{max}) by using formula (Mahas, 2014):

$$\lambda_{max} = \sum_{i=1}^{n}\left(w_i \times a_{ij}\right), \quad (3)$$

where a_{ij} − elements of the judgment matrix.

This value is used to calculate the consistency index of judgments (CI):

$$CI = \frac{\lambda_{max}-1}{n-1}. \quad (4)$$

The basis of application of the AHP-method in determining the integral level of innovative capacity of the enterprise is a two-level (hierarchical) system of indicators by which the evaluation process takes place (Fig. 2).

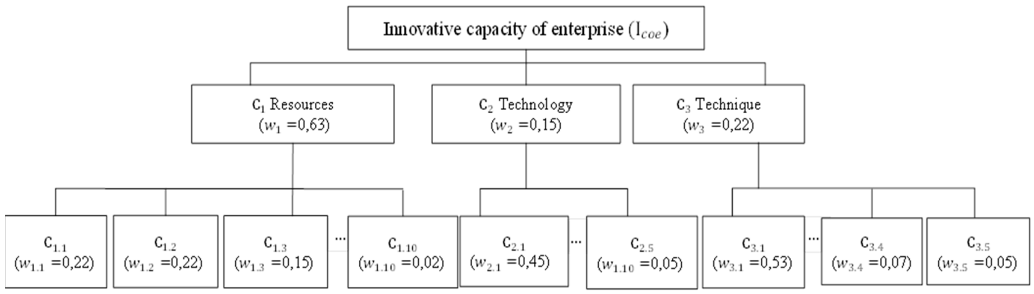

Fig. 2. AHP-model of evaluation of innovative capacity of the enterprise

The procedure for determining the weight of its elements (the weight of indicator w_i) is described above.

2. Results and Discussion

To evaluate the innovative capacity of the enterprise and identify the reserves for its provision we recommended the following steps (Fig. 3):

1. Defining the purpose and tasks of analyzing the innovative capacity, output of the enterprise and identifying reserves for their provision;
2. Information support of the process of analyzing the innovative capacity, innovative output of the enterprise and identifying reserves for their provision;
3. Selection of methods intended for estimation of innovative capacity and innovative output of the enterprise, search of reserves for their provision;
4. Calculation of the innovative capacity of the enterprise (I_{coe});
5. Determination of the level of innovative output of the enterprise (I_{ooe});
6. Comparison of the actual state of the enterprise's innovation capacity and its (I_{ooe}). If $I_{coe} > I_{ooe}$, the reserve for providing the innovative capacity of the enterprise is determined. Otherwise ($I_{coe} = I_{ooe}$), there is no reserve for providing innovative capacity of the enterprise, innovative capacity of enterprises is fully used in the activity of enterprises;
7. Generalization of the results of the analysis, formation of management decisions regarding the use of the identified reserves for providing innovative capacity of the enterprise.

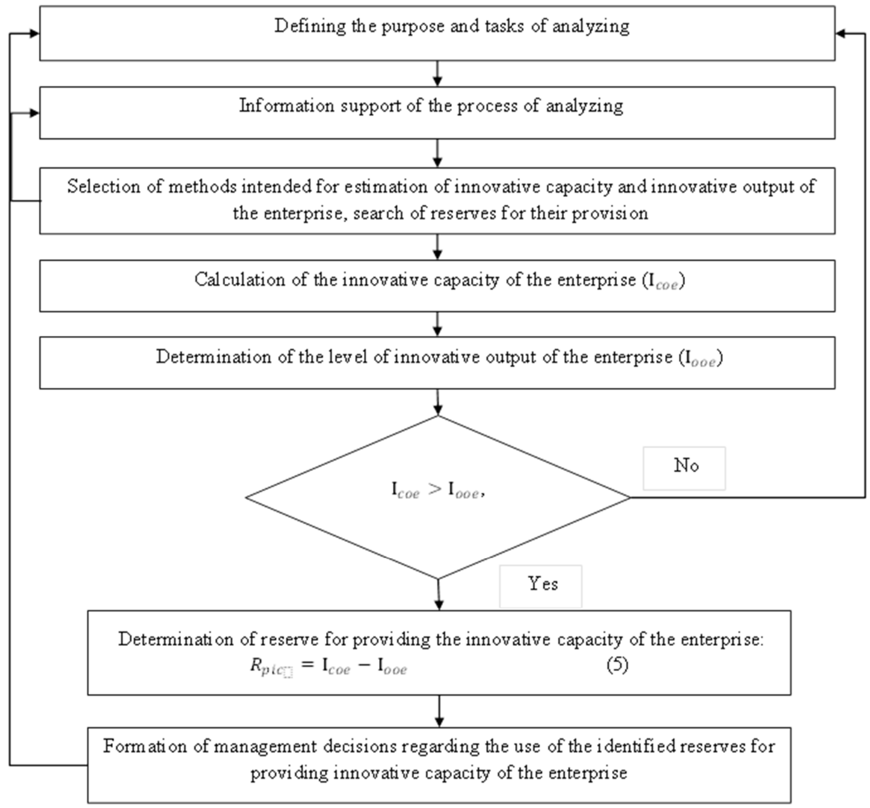

Fig. 3. Stages of evaluation of innovative capacity, innovative output of the enterprise and identification of reserves for providing innovative capacity

Innovative capacity is a complex property of an enterprise, depending on the technology of the enterprise, its availability of resources (qualification of personnel and the level of other types of resources - material, financial, information), available technique, etc. We presented it as a multi-vector model of three-dimensional space (Fig. 1). To measure each of the vectors of the three-dimensional model for evaluating the enterprise's innovation capacity, we recommend a system of indicators (Table 2), which is structured using the AHP-model (Fig. 2) [3, 6, 8, 10, 11, 13, 17-19, 21, 22, 24].

Tab. 2. Indicators intended for evaluation of the innovation capacity of the enterprise

Priority vector and their weight	Indicators	Item
Resources (0,63)	The share of complexity of innovative products in the total complexity of products of the enterprise	C_{11}
	Growth of average output of innovative products per employee	$C_{1.2}$
	The share of employees of a company with a high level of competence (compliance profile of competencies)	$C_{1.3}$
	An absolute increase of profitability of innovative activity	$C_{1.4}$
	Financial independence ratio (FI)	$C_{1.5}$
	Turnover ratio during the development and production of innovative products	$C_{1.6}$
	Coverage ratio	$C_{1.7}$
	Material intensity of innovative products	$C_{1.8}$
	Capital productivity	$C_{1.9}$
	Capacity of channels of information transfer of the enterprise	$C_{1.10}$
Technology (0,15)	Growth rate of expenses on the acquisition of technology	$C_{2.1}$
	Increase in the value of implemented patent licenses	$C_{2.2}$

	The share of the enterprise's costs for the legal protection of technologies	$C_{2.3}$
	The level of productivity of enterprise technologies	$C_{2.4}$
	Rate of financial return of technology of the enterprise	$C_{2.5}$
Technique (0,22)	The pace of change in the number of projects for technical re-equipment of the enterprise	$C_{3.1}$
	Index of capital investments in updating of fixed assets of the enterprise	$C_{3.2}$
	Efficiency Index (EI) of introduction of new equipment	$C_{3.3}$
	The level of spending on the development of new equipment, social activities and labor protection	$C_{3.4}$
	Coefficient of renewal of fixed assets	$C_{3.5}$

The weighting of the indicators intended for estimating the loading level of each of the vectors of the recommended three-dimensional model is determined according to the procedure of application of the AHP-method described above [25-27]. For each matrix of judgments, maximum eigenvalue of the judgment matrix and consistency index of judgments are determined, on the basis of which the reliability of the results of expert analysis is determined [28].

Based on the content of the proposed indicators (Table 2) and methods of their calculation and synthesis, we can recommend the following steps in calculating the level of innovative capacity of the enterprise I_{coe}, Fig. 3):

– formation of an array of input data to calculate the indicators of the second level of the hierarchy of the AHP-model of estimation of innovative capacity of the enterprise (Fig. 2) according to the defined vectors of the three-dimensional model (vector of resources, technique and technology, Fig. 1);

– calculation of indicators of the second level of the hierarchy of the AHP model (Table 2);

– generalization of indicators of the second level of the hierarchy of the AHP-model, using formula (1), obtained values of indicators of the second level and their weight. The order of weight determination is the same regardless of the level of studied AHP-model indicators;

– determination of the integral level of the innovative capacity of the enterprise I_{coe}) according to formula (1), applying the weighting of partial indicators of the level of loading vectors and the results of the generalization obtained in the previous stage [26].

From estimation of innovative capacity of enterprise (I_{coe}) we will pass to determination of level of innovative output (I_{ooe}). To evaluate the innovative output of the enterprise (I_{ooe}) should be guided by the same procedure and set of indicators that are recommended in determining the level of innovation capacity of the enterprise (I_{coe}). However, if the determination of the level of innovation capacity (I_{coe}) should set economically acceptable (normative) values of indicators, then the measurement of innovative capacity is based on the use of actual (current values) of indicators.

In the process of evaluation, there is also a need to calculate the growth rate of enterprise innovative output ($G_{r\_iooe\ i/i-1}$). In order to do this, use the formula:

$$G_{r\_iooe\ i/i-1} = \frac{I_{ooe\,i}}{I_{ooe\,i-1}}, \qquad (5)$$

where $I_{ooe\,i}$, $I_{ooe\,i-1}$ – the innovative capacity of the enterprise in the current and the previous period, respectively [29].

To analyze the level of innovation capacity of enterprises, we use the steps recommended above. Based on the economically permissible (normative) values, which are established by expert means, we calculate the level of innovative capacity of the enterprise (Table 3) [30].

Substitute obtained in table. 3 values of the level of loading vectors (C_i) of the three-dimensional model, intended to estimate the innovative capacity of the enterprise in formula (1):

$$I_{coe} = 0{,}63 \times 0{,}8683 + 0{,}15 \times 0{,}2965 + 0{,}22 \times 0{,}8282 = 1{,}095.$$

3. Experimental

Let's evaluate the innovative output of the enterprise. As a base, was selected company «Svitovyr», which specializes in innovative energy projects. In order to do this, we will use the financial and management reporting data of the enterprise [28].

Tab. 3. Calculation of the level of innovative capacity of the enterprise using economically permissible (normative) values of partial indicators

Item C_{ii}	Economically permissible (normative) values	Weight	Levels of loading vectors C_i
$C_{1.1}$	0,6	0,22	0,8683
$C_{1.2}$	0,02	0,22	
$C_{1.3}$	0,8	0,15	
$C_{1.4}$	5	0,13	
$C_{1.5}$	0,5	0,09	
$C_{1.6}$	2,5	0,07	
$C_{1.7}$	1,5	0,04	
$C_{1.8}$	0,4	0,03	
$C_{1.9}$	4	0,02	
$C_{1.10}$	5	0,02	
$C_{2.1}$	0,2	0,45	0,2965
$C_{2.2}$	0,6	0,22	
$C_{2.3}$	0,15	0,18	
$C_{2.4}$	0,5	0,09	
$C_{2.5}$	0,05	0,05	
$C_{3.1}$	1,1	0,53	0,8282
$C_{3.2}$	0,12	0,26	
$C_{3.3}$	1,05	0,18	
$C_{3.4}$	0,25	0,07	
$C_{3.5}$	0,15	0,05	

Having worked out an array of input data, the expert group calculated the indicators intended to determine the level of innovation capacity of the enterprise on the basis of «Svitovyr» LLC (Table 4).

Tab. 4. Calculation of the innovative capacity level of «Svitovyr» LLC using the actual values of partial indicators in 2016-2018

Item	Actual values of partial indicators			Weights	Levels of loading vectors C_i		
C_{ii}	2016	2017	2018		2016	2017	2018
$C_{1.1}$	0,86	0,89	0,91	0,22			
$C_{1.2}$	-0,328	0,138	-0,346	0,22			
$C_{1.3}$	0,65	0,7	0,8	0,15			
$C_{1.4}$	4,8	-27,6	22,8	0,13			
$C_{1.5}$	-0,329	-0,273	-0,293	0,09			
$C_{1.6}$	1,120	2,057	2,03	0,07			
$C_{1.7}$	0,6250	0,7060	0,7506	0,04			
$C_{1.8}$	0,4	0,32	0,36	0,03			
$C_{1.9}$	4,157	7,122	11,822	0,02			
$C_{1.10}$	0,195	0,079	0,104	0,02	1,011	-2,955	3,603
$C_{2.1}$	-0,34	1,14	-0,64	0,45			
$C_{2.2}$	0,00	0,00	0,00	0,22			
$C_{2.3}$	0,04	0,05	0,03	0,18			
$C_{2.4}$	-0,27	-0,16	0,14	0,09			
$C_{2.5}$	0,63	0,39	0,81	0,05	-0,1386	0,5271	-0,2295
$C_{3.1}$	0	0	0	0,53			
$C_{3.2}$	6,13	-0,58	-0,82	0,26			
$C_{3.3}$	1,09	1,00	1,05	0,18			
$C_{3.4}$	0,01	0,01	0,02	0,07			
$C_{3.5}$	0,22	0,12	0,05	0,05	1,8017	0,0359	-0,0203

The value of the load level of the vectors of the three-dimensional model (C_i) (Table 4) will be used to evaluate the innovative output of «Svitovyr» LLC using formula 1. The results are summarized in Table. 5.

Tab. 5. Calculation of innovative output of «Svitovyr» LLC in 2016-2018

Indexes	Calculation	Value
$I_{ooe_{2016}}$	$0{,}63 \times 1{,}011 + 0{,}15 \times (-13{,}86) + 0{,}22 \times 1{,}8017$	0,877
$I_{ooe_{2017}}$	$0{,}63 \times (-2{,}955) + 0{,}15 \times (0{,}5271) + 0{,}22 \times 0{,}0359$	-1,741
$I_{ooe_{2018}}$	$0{,}63 \times 3{,}603 + 0{,}15 \times (-0{,}2295) + 0{,}22 \times (-0{,}0203)$	2,209

Taking into account the obtained values of innovative output of «Svitovyr» LLC in 2016-2018, we calculate the indicator of growth of innovative capacity of the enterprise. In 2016, the equality of $I_{coe} > I_{ooe}$ is satisfied. Thus, the reserve for providing innovative capacity (R_{pic}) of «Svitovyr» LLC in 2016 is:

$$R_{pic_{2016}} = 1{,}095 - 0{,}877 = 0{,}218.$$

In 2017, the condition of $I_{coe} > I_{ooe}$ is also fulfilled, the reserve for providing innovative capacity of «Svitovyr» LLC is in 2017: $R_{pic_{2017}} = 1{,}095 - (-1{,}741) = 2{,}836$

We also define the coefficient of growth of innovative output (formula 6):

$$G_{r\_iooe\ 2017/2016} = \frac{2{,}836}{0{,}218} = 13{,}009.$$

In 2018, the condition $I_{coe} > I_{ooe}$ is not fulfilled. This requires a revision of the economically permissible (normative) values of the indicators intended to calculate the innovative capacity of «Svitovyr» LLC in 2018.

4. Conclusion

The theoretical bases of the innovative capacity of the enterprise were developed in the article, which allowed it to be considered as the sum of the components of the innovative output of the enterprise and the reserve for providing the innovative capacity.

In order to evaluate the level of innovative capacity of the enterprise, the article improves the method based on the use of the three-dimensional space model of the dependence of the innovative capacity on the level of loading vectors of the technique of the enterprise (X-axis), applied innovative technology (Y-axis) and resources (Z-axis). AHP-model (analytical-hierarchical process models) was used to form an integral method for evaluating innovative capacity. The applied functional dependencies of the used model indicate the state of innovative capacity of the enterprise and allows to identify the reserve for providing innovative capacity.

The developed AHP-model (analytical-hierarchical process model) contains two levels of indicators (partial - intended for estimating the level of loading of the vectors of the three-dimensional model of the spatial state dependence of the innovative capacity of the enterprise and generalized ones, which determine the level of innovative capacity) intended for measuring the innovation capacity, using the relative weight of the indicators established by forming a matrix of judgments and evaluating the components of the vector of its priorities.

The application of the integral method of estimating the innovative output of the «Svitovyr» LLC in the dynamics allowed to identify the reserves for providing the innovative capacity of the enterprise and the growth rate of the innovative output.

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