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PRINCIPLES OF ASSESSMENT AND MANAGEMENT APPROACHES TO INNOVATION POTENTIAL OF COAL INDUSTRY ENTERPRISES

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This paper examines problems related to forming a complex of indicators to assess innovation potential of an industrial enterprise, on the example of coal industry enterprises, and an integral indicator of innovation potential, used for comparative analysis of the state of affairs in the industry. Analysis of different approaches to defining the term «innovation potential» for industrial enterprises has been carried out; resource-based, resultative, integrative and capacitive approaches have been highlighted, the latter one based on assessment of enterprise capacities. A conclusion has been made regarding advantages of integrative approach.

Research has been made on the role of industry in the fuel and power sector of China and dynamics of industry and enterprise development in Shanxi province. Basing on suggested approach a system of assessment principles has been formulated, taking into account specific features of coal industry enterprises. Complex of indicators to assess innovation potential has been developed using expert evaluation method. An expertise procedure is proposed to assess competence of experts; results obtained from the expertise are presented. Proposed complex of indicators includes 23 parameters combined into three groups.

Testing of proposed complex of indicators has been carried out on the example of coal industry in Shanxi province (China). Application of all stated principles has been proved in the process of indicator selection, assessment and formulation of recommendations for subsequent innovation potential management of coal industry enterprises. Proposed approach to forming a complex of indicators of innovation potential for industry enterprises permits to link together the logic of innovation potential definition, formation of the system of its principles, selection of the indicators complex for assessment and subsequent innovation potential management of the enterprise.

***Key words*:** innovation potential, innovation potential management, principle component analysis, entropy method, coal industry, complex of indicators

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Introduction. Innovation potential of the enterprise is a widely used economic category. Special significance is attributed to assessing the value of innovation potential and managing its development for key industries, characterized by conservative technologies and demanding innovative changes. Great relevance of research in this field, especially related to the leading branch of Chinese fuel and power sector – coal industry – is defined, on the one hand, by the lag in innovation sphere, and on the other hand, by modernization course declared by the government of P.R. China [3].

Issues of defining and assessing innovation potential are extensively covered in works of Russian and foreign researchers [8, 9, 11, 13, 15, 17], but, despite a significant number of publications, there is no universal assessment method and not even a universal approach to defining the term «innovation potential». Meanwhile, the method of selecting a complex of indicators, defining innovation potential, has to be determined by the approach to understanding the term and by its economic sense, supported by the principles of its formation, based on systematic approach and industry-specific features of investigated enterprises.

Research method. Innovation potential of the enterprise – an integral indicator – takes into account a complex of economic, financial, technological, organizational and other factors, the impact of which is considered due to separate quantitative and (or) qualitative characteristics.

The objective of creating an integral indicator, which would reflect possibilities of a complex economic system, is to define requirements to the criterion itself (innovation potential), to the principles of its formation, but also to the indicators, based on which it is assessed. When forming a complex of indicators that will define innovation potential, it should be taken into account that

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selected indicators have to reflect the main purpose of assessment, set conditions and limitations, object characteristics, the influence of which has to be assessed, or optimized, have high sensitivity to changing conditions or results of enterprise operations.

Summarizing existing approaches to defining innovation potential, the principal ones can be distinguished:

1. Factor (resource-based) approach considers innovation potential as a multitude of enterprise resources. Assessment of innovation potential amounts to identification and assessment of these resources that can be used to implement innovations [5, 6, 15].

2. Capacitive approach considers innovation potential as an indicator reflecting capacity of enterprise to implement innovations regardless of whether these innovations have been created by the enterprise itself or bought in the form of patents, licenses and know-how [4, 14].

3. Resultative approach defines innovation potential as an indicator of how ready the enterprise is to reach set innovation objectives and is characterized by parameters that assess results of innovative operations of the enterprise [9].

4. Integrative approach implies accounting of resources characteristics as well as of indicators measuring capacities and possibilities of the enterprise to implement innovation [1, 2, 18]. This approach seems to be the easiest one and therefore has been used in our research.

The purpose of the research is to propose a method to define innovation potential of coal industry enterprise that will permit, basing on a selected approach to defining innovation potential, to form a system of assessment principles, and to identify a representative selection of indicators for assessment and subsequent management.

Utilized integrative approach implies that the potential, as a capacity of the enterprise to implement innovations, is inseparable from conditions created by the environment; the system of assessment principles and complex of indicators have to consider specific features of the industry, in which the enterprise operates. Thus, innovation potential has to be defined with due account of both internal and external factors, characteristic of enterprises in a certain industry.

The difficulty of forming a complex of indicators to assess innovation potential of the enterprise is related to the fact that innovation activity is a very complex process, where not all the connections are evident and unequivocal. Impact assessment of separate parameters may require additional factor analysis. Developed complex of indicators to assess and manage innovation potential should be easy to apply in practice, transparent for analysis and if possible, exclude indicators with a significant lag between factor impact and indicator change.

The objectives of the research are to formulate principles of defining innovation potential for coal industry enterprises, taking into account selected concept of innovation potential; to determine a complex of indicators that can be used to assess the value of innovation potential of coal industry enterprises in Shanxi province (China) and to develop recommendations on how to control innovation potential.

Discussion of results obtained. The leading branch of fuel and power sector of China is coal industry; coal plays an important role in the energy balance of the country. In 2013, coal accounted for 70 % of total energy consumption in China [20], therefore economic relations that take place in the process of managing innovation potential of coal industry enterprises are a promising object of research.

Shanxi is one of the most important coal-mining provinces in China, it possesses large reserves of excellent-quality coal. The following types of coal seams are distinguished [19]:

• Seams according to their thickness: thin – from 0.5 m to 1.3 m; medium – from 1.3 m to 3.5 m; thick – over 3.5 m.

• Seams according to inclination: flat – from 0 to 25°; inclined – from 25 to 45°; steep – from 45 to 90°.

Coal extraction in Shanxi province is carried out by underground method, where the following classification of mining workings (based on their spatial position and purpose) is used:

1) workings with a direct exit to the surface (shafts, test pits, wells and tunnels);

2) workings with no direct exit to the surface (blind shafts, crossways, coal headings, inclined planes);

3) production face (place of coal or rock extraction);

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4) special chambers (pump and engine rooms, central control room, waiting chamber, health station, locomotive barn);

5) shaft insets (complex of workings near the shafts to maintain underground facilities).

Union of coal enterprises in Shanxi province currently applies three methods of coal extraction [16]:

1. Manual – has very low productivity. Currently this method is consistently replaced with mechanical one.

2. Drilling and blasting – according to current Chinese policy and regulations, this method is only applied when it is impossible to carry out mechanical development of coal seams. Drilling and blasting is a viable option for difficult geologic conditions, does not require complex equipment, but its efficiency and labor safety are quite low.

3. Mechanical extraction is a central method for coal development. It is carried out using under-cutters, cutter-loaders, systems and aggregates with movable shield support. Heading machines only mechanize the process of coal seam under-cutting with subsequent coal extraction by means of drilling and blasting. Currently more than half of all total coal amounts in Shanxi province is extracted using mechanized coal-extracting complexes.

Coal enterprises in Shanxi province increase amounts of coal extracted and sold (Table 1).

Table 1

Amounts of coal extracted and sold (Shanxi province)

Year	Coal extracted, Mt	Rate of extraction growth, %	Coal sold, Mt	Rate of sales growth, %
2011	789	–	580	–
2012	913	15.7	582	0.3
2013	960	5.1	920	58.1
2014	950	–1 %	917	–0.03

Source: http://www.stats-sx.gov.cn/tjsj/tjnj/nj2015/html/njcx.htm

According to plans of coal industry development after current reorganization, coal union of Shanxi province has to meet the following criteria:

• to reach optimal distribution of personnel and mining equipment;

• to facilitate growth of personnel qualification, which would permit to apply progressive equipment;

• to reduce lethal accidents and serious emergencies in the industry;

• to attain sustainable development of the enterprise.

An important condition needed to achieve these goals is assessment and subsequent management of innovation potential.

Suggested by the authors principles of innovation potential assessment have been developed for the abovementioned purpose of the research and specific features of research object – innovation activity of coal union in Shanxi province:

1. Principle of comprehensiveness – complex assessment of innovation potential, taking into account all significant factors, comprehensively reflected in performance indicators of the enterprise.

2. Principle of justification – scientific approach, application of objectively existing indicators.

3. Principle of systematicity – application of system approach, investigation of interconnections between external and internal (from the viewpoint of the enterprise) factors.

4. Principle of relevance – inventory of selected indicators has to characterize innovation potential of coal industry enterprises.

5. Principle of practicability – calculation of integral indicator should be feasible not only in theory, but also in practice.

6. Principle of adaptiveness – capacity of assessment indicators and method to be adapted to changing conditions when applied at different enterprises.

7. Principle of sufficiency – capacity of indicators, used in assessment of innovation potential, to describe the object with a sufficient degree of completeness.

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8. Principle of dynamics – capacity of indicators to reflect changes within and outside coal industry.

9. Principle of measurability – requirement to indicators characterizing innovation potential to be quantitatively measurable.

10. Principle of variability – capacity of indicators complex to vary not only quantitative values, but also its composition in the course of analysis of different enterprises.

In the process of forming a complex of indicators to assess innovation potential of coal industry enterprises the following main reasons have been identified that require further innovation development of China's coal industry:

• need for further reorganization of coal industry;

• multitude of small enterprises, utilizing outdated technologies and equipment, reduce competitiveness of the industry;

• damages to the environment in the process of coal mining;

• actions of the government, aimed at environmental protection and effective use of resources;

• gradual transition to renewable energy sources.

Authors have identified specific features of coal industry enterprises that must be taken into account when assessing their innovation potential and forming a complex of indicators:

1. High capital and labor intensity of production. To facilitate innovation development, coal enterprises have to possess advanced equipment, maintained by highly qualified workforce. There is a need to improve qualification of top managers as well.

2. Rising governmental standards regarding industrial safety.

3. Specific features of Chinese state policy regarding coal industry, which sees technical borrowing as the main source of innovations.

4. Important role of coal enterprise lifecycle in the innovation process.

The initial set of indicators, applied in the research, is described in [21]. Chinese statistical office, based on analysis of innovation performance of enterprises in different regions and industry sectors, has developed an inventory of indicators that industrial enterprises could be guided by.

Application of these indicators met the requirements of variability and measurability, but their compliance with other principles had yet to be tested, as well as their adequacy regarding specifics of coal enterprises. Table 2 presents the scale that was utilized to assess competence of experts participating in the interviews.

Table 2

Criteria of expert selection

Criteria	System of assessment		
	1 point	3 points	5 points
Education level	Specialized secondary	University graduate	Postgraduate degree
Work experience in coal industry	Under 5 years	From 5 to 10 years	Over 10 years
Administrative and economic independence	Works for the organization	Familiar with the organization	Absolute independence
Experience in expert assessments	Low	Intermediate	High

Table 3

Expert qualification and opinion weights

Experts	Points	Weight of expert opinion, %
1	13	0,15
2	16	0,19
3	18	0,21
4	18	0,21
5	20	0,24
Total	85	1

To become a member of the expert group, the experts had to score 12 or more points (Table 3).

To assess the complex of indicators, a weighted mean of expert opinions has been calculated considering their qualification. The experts have been asked the following questions:

• does the indicator comply with abovementioned principles of innovation potential assessment (for each principle)?

• does the indicator take into account specific features of coal industry?

DOI: 10.18454/PMI.2017.1.131

• does the indicator reflect the principal trends in coal industry development?

Experts have evaluated each indicator on the following scale:

• 0 – indicator does not comply with suggested principle;
• 1 – indicator does not fully comply with suggested principle and can be replaced;
• 2 – indicator complies with suggested principle;
• 3 – indicator in all its fullness reflects suggested principle in action.

General rating of indicators has been calculated using weights of experts:

$$R_i = \sum_{n=1}^{N} W_n \sum_{m=1}^{M} Z_m ,$$

where R_i – rating of the indicator; i – indicator's sequence number (i = 1…23); W_n – weight of expert's opinion, %; n – number of experts, taking part in the research, n = 1…N; Z_m – score the indicator received from the expert; m – number of comparison points, m = 1…M.

The indicator remained in the inventory if its total score was no lower than 24 points. The indicator was replaced if it scored below 12 points. If the score was between 12 and 24 points, the experts were asked to compare other indicators to the one under consideration and to make a final decision. As a result, a complex has been formed that contained 23 indicators divided into separate groups and adapted to assessment of innovation potential of coal industry enterprises.

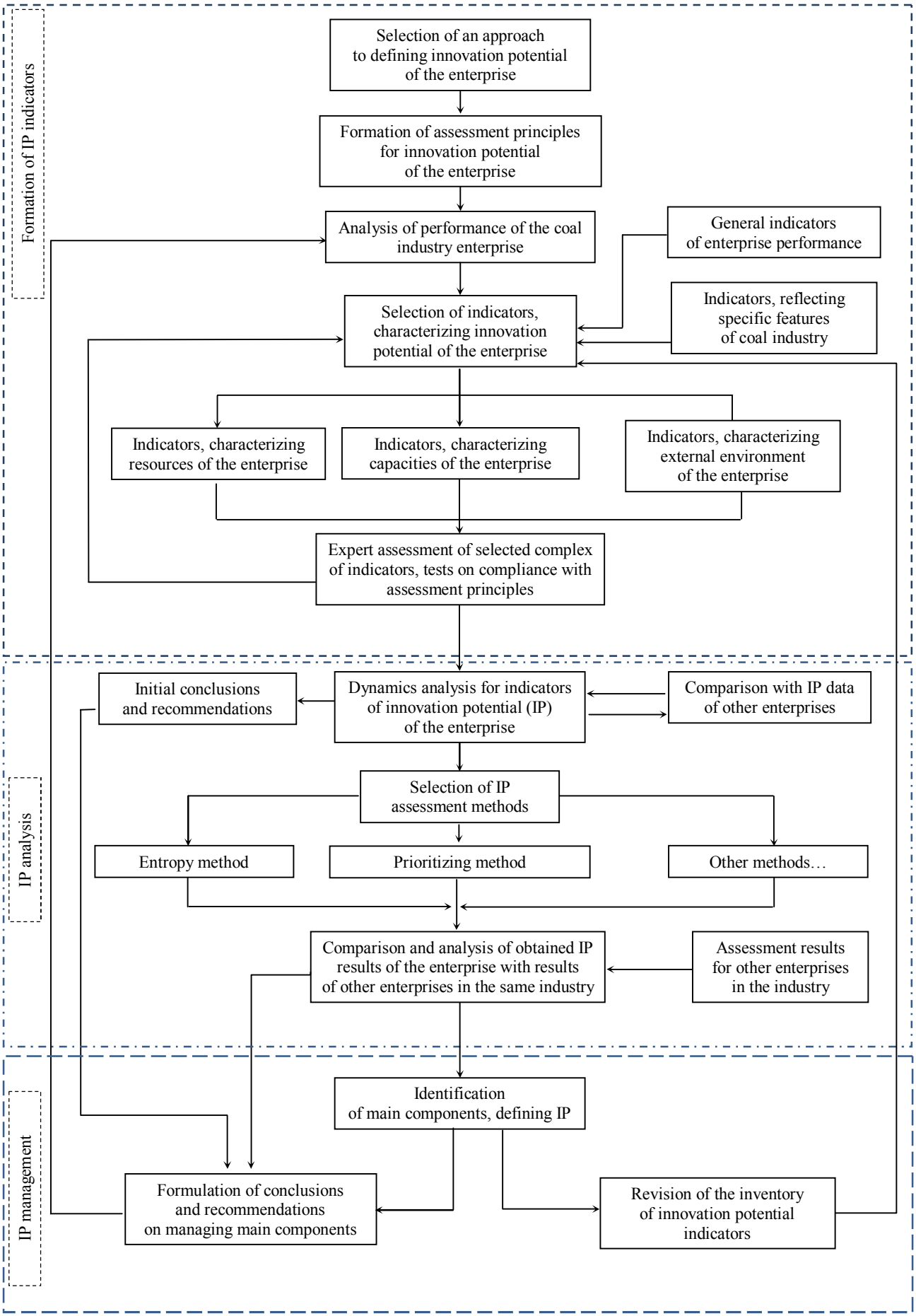
Indicators of internal environment are divided into two sub-groups that characterize the enterprise from the viewpoint of present internal resources to carry out innovation activity ($P_1 – P_8$) and from the viewpoint of capacities to implement innovations with limited resources ($P_9 – P_{19}$) (Table 4). The second group contains indicators of external environment of the enterprise.

Table 4

Indicators of internal and external environment proposed by the experts

Internal environment				External environment	
Indicator	Internal resources	Indicator	Capacities to implement innovations	Indicator	Expert suggestions
P_1	Expenses on environmental protection	P_9	Share of advanced production equipment	P_{20}	Share of own capital in R&D
P_2	Accepted patent applications from the enterprise	P_{10}	Costs of innovation implementation in the gross sales of the enterprise	P_{21}	Share of bank loans in financing R&D
P_3	Number of invention patents	P_{11}	Intensity of investment in research and development (R&D)	P_{22}	Intensity of state investments in R&D
P_4	Return on total assets	P_{12}	Growth of R&D expenses	P_{23}	Level of industrial co-operation in R&D
P_5	Expenses on health and safety	P_{13}	Expenses on technology transfer and modernization		
P_6	Return on costs	P_{14}	Share of personnel working in R&D		
P_7	Level of workforce qualification	P_{15}	Percentage of expenses on personnel training		
P_8	Costs of 1 t of coal	P_{16}	Share of investment in new equipment		
		P_{17}	Percentage of modern equipment installation		
		P_{18}	Coefficient of modern technology implementation		
		P_{19}	Probability of R&D success		

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Method of innovation potential management for coal industry enterprises

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Method of suggested approach to forming a complex of indicators to assess and manage innovation potential of coal industry enterprise is presented in the figure.

The novelty of proposed circuit (see figure) is in complex approach to managing innovation potential: definition of the term «innovation potential», formation of system of principles with due consideration of selected approach, assessment of complex of indicators and subsequent management of the process. Method and suggested principles comply with selected integrative approach, selection of another one can lead to their revision.

After formation of the complex of indicators, an analysis of innovation potential of a coal enterprise in Shanxi province has been carried out. Quantitative assessment has been done using methods of parameter entropy and prioritizing. To compare the results, two enterprises of Chinese coal industry have been chosen – «Hebei» and «Shandong». Choice of «Hebei» and «Shandong» was dictated by similar regional economic conditions, the same legal form (large state-owned enterprises), close characteristics of extracted coal, geographical proximity of the regions, comparable amounts of coal extraction. Consistent results obtained confirmed adequacy of selected complex of indicators.

Quantitative assessment of innovation potential of the enterprise is a foundation for further managerial decisions, aimed at its development. An algorithm has been developed to control innovation potential based on identification of the most informative parameters using principle component method [6].

All suggested principles of formation of innovation potential have been implemented in our research (Table 5).

Table 5

Implementation of suggested principles in assessment of innovation potential

Principle	Way of implementation
Comprehensiveness	In the system of indicators of innovative potential for coal industry enterprises
	In complex analysis of all existing performance indicators for Chinese coal industry enterprises and in the procedure of forming the most representative selection
Justification	Inclusion of parameters, considered in Chinese system of statistics, and justification of their inclusion in the inventory of indicators
Systematicity	By way of using distinguished important factors, characterizing interaction of Chinese coal industry enterprises with external environment of business procedures, examination of internal environment elements in their inter-connection and identification of corresponding indicators to characterize these inter-connections as well
Relevance	Consideration of specific features of coal industry in China in the process of indicator selection
Practicability	Development of formulas to define all the indicators, needed for the calculation of integral indicator
Adaptiveness	Utilization of principle component method to define the most important indicators for each enterprise
Sufficiency	Apply procedures of forming the most representative selection
Dynamics	Application of suggested method to calculate integral indicator considering time dynamics of separate indicators
Measurability	In the procedure of selecting indicators and utilization of entropy and prioritization methods to calculate integral indicator of innovative potential
Variability	In the procedure of justified selection of indicators, characterizing the level of innovative potential, and using method of calculation for the integral indicator with due account of time dynamics of separate indicators

Conclusion. Proposed approach allowed to link together the logic of innovation potential definition, formation of the system of its principles, selection of the indicators complex for assessment and management.

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The work is distinguished by valid and justified application of all abovementioned principles in the process of selecting indicators as well as in assessing the level of innovation potential and subsequent drawing of recommendations on managing innovation potential. In the opinion of authors, suggested approach is quite flexible and can be adapted to assessment and management of innovation potential of enterprises in other industries as well. Further research in this field would allow to develop a universal approach to assessment of innovation potential of enterprises in different industrial sectors, making such results comparable to each other.

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