The state and dynamics of the intellectual infrastructure of technological development of industrial enterprises: methodological tools for assessing sustainability

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Abstract. The article presents the results of research in the field of formation of methods of organization of intellectual infrastructure of technological development of industrial enterprises, focused on methodological issues of measuring and assessing its sustainability. The relevance of the research is due to modern trends in the intellectualization of the economy under the influence of technological processes of digitalization, which determine the need for the formation of new infrastructure institutions necessary to solve modern problems of technological development in industry. As a result of this research stage, the structural characteristics and parameters that determine the state and dynamics of the intellectual infrastructure of technological development of industrial enterprises have been clarified, which allowed us to offer methodological tools for assessing the state of stability of the intellectual infrastructure and the prospects for its positive dynamics focused on the digital transformation of business processes of industrial production. Thus, as structural elements that determine the organizational level of the intellectual infrastructure of technological development of industrial enterprises, the following are defined: the level of material resources used in the production of products; the availability of logistics routes; the environmental impact of the results of resource processing, including the cost of disposal of residues; the state of fixed assets. The author's approach to the assessment of the intellectual infrastructure of technological development of industrial enterprises has been developed, based on the identification of key elements of the studied infrastructure, classification of resource blocks, justification of indicators and factors of resource components that affect the stability of the intellectual infrastructure of technological development. This approach makes it possible to develop and improve methodological tools for analytical assessment of the organizational level of stability of the intellectual infrastructure of technological development, identifying trends in its dynamics, as well as controlling unacceptable deviations.

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1 Introduction

In the conditions of a difficult economic situation caused by the pandemic, many enterprises are forced to suspend their activities. Operating ones incur additional costs for ensuring the safety of personnel. The superiority of using a sustainable intellectual infrastructure for technological development in production is becoming increasingly obvious, since the intellectual infrastructure for technological development as an innovative process entails a reduction in the share of human participation in production chains, resulting in reducing the number of personnel required for production. However, even at this stage, within an individual enterprise, the choice of an intellectual infrastructure as an investment object is a non-trivial task. An effectively directed intellectual infrastructure for technological development based on certain "growth points" contributes to greater stability of the enterprise; increase its competitiveness and the profitability of its products.

A similar situation is observed at the industry level. Investments in the intellectual infrastructure for technological development have a different degree of profitability depending on the enterprise – the object of investment, due to the specific characteristics of each economic entity.

Moreover, it is important to consider the optimal investment object also in the division on a territorial basis. Many factors influencing such a choice depend on the physical location of the enterprises under study. To understand which investment object gives the greatest innovative result, it is necessary to calculate the potentials of the intellectual infrastructure for technological development of such objects. Each economic entity has its own specific characteristics, which are mainly in the internal environment in relation to the enterprise. When viewed at scales up to the meso level, the external ones are very similar [1-3].

Since information about external factors influencing on the intellectual infrastructure potential in technological development is available to both the enterprise itself and any other entities, their assessment is also possible by a wide range of interested economic agents. Moreover, the influence of environmental factors on the intellectual infrastructure potential in technological development is common for all enterprises in the industry, given the similarity of the chosen assessment methodology [4-9].

Another feature of the environmental factors is the lack of a relationship between the influence of factors and progress of innovative development of intellectual infrastructure. This study determines the point of view where the intellectual infrastructure potential in technological development is an indicator considered at each individual moment of time. It does not depend on the degree of progress along the innovation path, but on the factors influencing it.

2 Materials and methods

The conceptual principles of the theories such as intellectualization of the economy, institutional economics, innovation and technological management served as scientific research methods. The analysis method allows identifying and investigating individual components of the intellectual infrastructure for technological development to determine the basic characteristics of the intellectual infrastructure potential in technological development. The method compares the scales of technological development at industrial enterprises containing an innovative component of intellectual infrastructure. Classification and grouping methods justify the structures and the element-by-element composition of the intellectual infrastructure potential in technological development. The modelling method is aimed at visualizing and studying various states of intellectual infrastructure evaluation for technological development using the means of mathematical construction of the dependence

of factors and indicators on the state of the enterprises under study. A normative approach is necessary to assess the influence importance of factors, taking into account the weight coefficients on the target value of the indicator under study. The process approach builds a logical chain of actions and links for formalizing the processes of evaluating the intellectual infrastructure potential in technological development.

3 Results

The initial position of the methodology development is to determine the specific features of the intellectual infrastructure potential in technological development at industrial enterprises. For example, one of the first signs is a significant level of material resources used in the production. This is because the result of production processes is a material product. Also related to this is the peculiarity of the need for the availability of logistics routes for the transportation of material products and raw materials. Another distinctive feature associated with the first one is the impact on the environment, since production involves the physical processing of resources, thus, energy costs and the disposal of residues. Another feature is the requirement of a significant mass of fixed assets consisting of buildings, machine tools, equipment [10]. Other signs can also be included. A more complete list looks as follows: logistics routes: the development of the labour market; the availability of basic resources (electricity, water, production resources); the possibility of recycling residues, reducing emissions; a significant number of fixed assets; investment attractiveness.

Studying the specific features of the intellectual infrastructure potential in technological development, it is necessary to examine its structures. There is an approach, the proponents of which assume the division of the intellectual infrastructure potential in technological development into three parts: resource, internal and effective. As seen from the above specific features, the resource component is the most significant for the analysis, because in one way or another they are connected with it. Logistics directly depends on the availability of logistics routes, as well as transport hubs and the state of the infrastructure. The labour market is nothing more than the availability of a sufficient number of required human resources, including specific qualifications. This also puts forward demands for the level of specialists in the region, as well as their education. The availability of basic resources is directly related to the level of economic development of the region, the presence of other industries in it. The possibility of recycling residues and reducing emissions also depends on the infrastructure, the requirements of local regulations. A significant number of fixed assets requires updating, replacement and repair. A necessary element is the availability of material and technical support for the innovation process, for example, experimental design laboratories, testing ranges, etc. All this is also based on the qualification of service personnel and the development of the region. Investment attractiveness, in turn, is largely determined by the totality of all influencing factors. However, from the point of view of the enterprise itself, it is enough to refer to the availability of financial resources. Thus, it can be concluded that in this case the resource component is the most significant for analysis. In the field of necessary and available resources, as well as ensuring access to them, there is one of the key differences between organizations belonging to different economic spheres.

There are successful examples of classification of the resource component at industrial enterprises in the scientific literature [11]. Thus, the resource component at an industrial enterprise can be divided into the following elements: material and technical; information; financial; human.

Each of the above elements participates in the formation of the of the intellectual infrastructure potential in technological development, which leads to the absence of the possibility of their exclusion. However, it is impractical to consider all resources in one group from the point of view of the representativeness of factor analysis. Thus, the most logical

way is to keep the structure dictated by the resource classification and extrapolate it to the assessment of the intellectual infrastructure potential in technological development. However, this should be done with certain changes, since this classification is not detailed enough, and in one way or another, it does not fully correspond to the goals of assessing the intellectual infrastructure potential in technological development.

For example, the above classification does not take into account organizational and managerial resources. Although partially integrated into human resources, they should be allocated as a separate category, since they imply the entire complex of organizational and managerial measures. A similar remark can be made about intellectual resources. According to the classification above, they are also included in the human resources. But the analysis of such factors as the number of patents acquired, or indicators characterizing the diffusion of innovations in general, is lost. Material and technical resources also contain too many categories to be analysed separately.

From the above, it can be concluded that the intellectual infrastructure potential in the technological development at an industrial enterprise is a complex system with multidirectional relationships. However, its general structure is quite clearly visible. The potential of the intellectual infrastructure for technological development consists of six main components: intellectual, organizational and managerial, production, financial, raw materials, and environmental. Moreover, the intellectual component, in turn, is divided into scientific and technical, and personnel.

Developing a methodology for assessing the potential of the intellectual infrastructure for technological development, first, it is necessary to determine its structure, as the basis for it. The most appropriate structure of the intellectual infrastructure potential in technological development is a tree - like structure, where the first-order element is the potential of the intellectual infrastructure for technological development. The second-order elements are its resource components divided into external and internal environments, aggregated in accordance with the above classification. Their more detailed classification is the third-order elements. Accordingly, the fourth-order elements are indicators characterizing a particular block of resources, and they are factors influencing the potential of the intellectual infrastructure for technological development. A visual demonstration of this structure is shown in Figure 1.

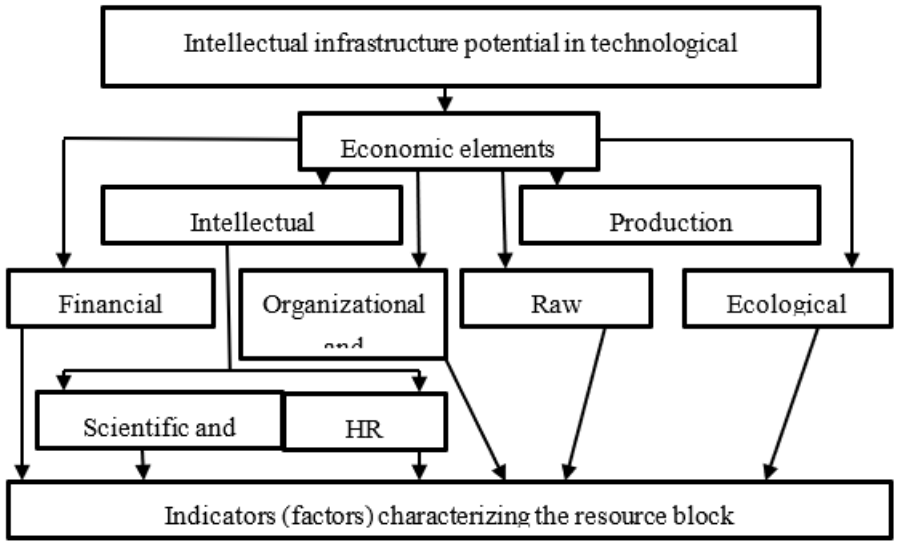

Fig.1. Structure for assessing the intellectual infrastructure potential in technological development. Compiled by the authors.

Thus, the universal method of assessing the potential of the intellectual infrastructure for technological development is a method, the result of which is an integral indicator. For each of the intellectual and technological environments, external and internal, it in this case also consists of six other integral indicators characterizing each individual component of the intellectual infrastructure potential in technological development and implying the result of assessing indicators of the last order. Such approach provides a detailed analysis of changes in the intellectual infrastructure potential in technological development in the context of enlarged groups of factors, as well as with details up to individual indicators [12].

However, these factors are not static, so it is impossible not to recognize the concept of changing the object of analysis when conducting the procedure for assessing the potential of the intellectual infrastructure for technological development at the enterprise, depending on the goals. Thus, if it is necessary to identify and calculate the real level of the intellectual infrastructure potential for technological development at an enterprise, the object of analysis is the system considered above. It calculates separately the elements of the main indicator, which provides flexibility of the approach depending on the goal [13].

Moreover, as it was already proved above, it is impossible to form a model for assessing the potential of the intellectual infrastructure for technological development without taking into account the belonging of factors to the internal or external environment of the enterprise. Since the result of developing a list of influencing factors and indicators directly depends on the degree of their universality, it is possible to build a recommendation assessment model for environmental factors. For the factors of the internal environment, the model is exclusively indicative in conducting the assessment procedure.

To measure the integral indicator characterizing each component of the intellectual infrastructure potential in technological development, changes in the coefficients included in it should be calculated. However, due to the specific features of a particular enterprise, these coefficients can be adjusted in accordance with the degree of their importance as part of the integral indicator using weighting coefficients. Taking into account the above, it is possible to calculate an integral indicator reflecting the state of each of the integral elements of the intellectual infrastructure potential in technological development as:

$$\boldsymbol{PI} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} (\boldsymbol{w_i} \times \boldsymbol{\delta_i}) / \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{w_i} \quad (1)$$

where: PI is an integral indicator, an element of the intellectual infrastructure potential for technological development; w_i is the weighting factor for the indicator i; δ_i is the value for the indicator i; i is the found indicators included in the current block of economic indicators in accordance with the resource classification.

To assess the importance of the factors influence, in addition to the approach involving the use of weighting factors, it is proposed to use a normative approach. In this case, corresponding to the goal value, a coefficient of 1 is assigned to the indicator. If it exceeds the goal, the coefficient is 1.25. In addition, in the converse case it is 0.75, respectively. Thus, the result of the product of individual quantitative assessments of the included coefficients is the integral indicator for each component of the intellectual infrastructure potential in technological development of the internal intellectual and technological environment. In this case, the structural element of the intellectual infrastructure potential in technological development is determined by the formula:

$$\boldsymbol{Ij} = \left(\frac{\mathbf{P_{j1}}}{\mathbf{E_{j1}}} * \frac{\mathbf{P_{j2}}}{\mathbf{E_{j2}}} * \ldots * \frac{\mathbf{P_n}}{\mathbf{E_n}} \right) \quad (2)$$

where: I is an integral indicator for the studied element of the intellectual infrastructure potential for technological development; Pj is the result of assessing the j-th of the studied indicators; Ej is the established standard/maximum value for the j-th indicator.

In view of the need to combine the integral indicators, characterizing the state of the intellectual infrastructure potential for technological development, into a single indicator, it is necessary to determine how this can be done. The approach reflected by the formula (3) is the most appropriate:

$$\boldsymbol{Ij = \sqrt[n]{t_{i-1}^{n} t_i}} \quad (3)$$

where: ti is i-th coefficient of the assessment system; n is the number of analyzed indicators.

Thus, the integral indicator of the intellectual infrastructure potential in technological development is calculated by the formula:

$$\mathbf{IP} = \sqrt[3]{\boldsymbol{I_{sci}}^{\boldsymbol{\alpha 1}} \boldsymbol{I_{org-mang}}^{\boldsymbol{\alpha 2}} \boldsymbol{I_{pers}}^{\boldsymbol{\alpha 3}} \ldots} \quad (4)$$

where: I_{sci}, $I_{org\text{-}mang}$, I_{pers}, etc are integral indices for the components of the intellectual infrastructure potential in technological development, α1, α2, α3 are the significance coefficients for the indicators determined by the expert method.

The interpretation of the obtained integral indicator for the potential of the intellectual infrastructure for the technological development at the enterprise is performed on a scale based on the Harrington desirability function as the most applicable for multiparametric tasks [14]. The applied parameters for this function are shown in Table 1.

Table 1. Harrington desirability function.

Linguistic assessment	Intervals of values for the desirability function d(x)
Excellent	1.0 - 0.80
Good	0.79 - 0.63
Acceptable	0.62 - 0.37
Low	0.36 - 0.20
Bad	0.19 - 0.00

The intellectual and technological environment is divided into an external environment in relation to the enterprise, and an internal one. The internal environment means a system of intra-company relations, connections formed by the state of the elements in the enterprise's intra-organizational system and effecting its activities. In turn, the external intellectual and technological environment is divided into a macro-environment (factors making indirect impact on the organization), and a microenvironment (factors making direct impact on the conditions of the organization's activities and their result) [15].

To assess the potential of the intellectual infrastructure for technological development based on the internal environment, with certain changes depending on the specialization of the economic entity that is the object of assessment, it is possible to apply the methodology described above. However, it is not applicable for assessing the potential of the intellectual infrastructure for technological development of the enterprise's external environment due to the nature of the indicators used.

A suitable method for assessing is a methodology based on the grouping of indicators characterizing the influencing factors in such a way that each group evaluates a certain aspect of the implementation of the system: the resource part of the process; the implementation of the process; the results of activities; interaction with society [16].

Taking the region as a system in which the embodied mechanisms of economy development associated with innovation based on the above methodology, the authors propose the following groups of indicators. They are assessment of the scientific and educational complex (SEC) potential (I1), assessment of the resource base potential for intellectual and technological process (I,2), assessment of

the potential of possible innovation outcomes (I,3), and assessment of changes in the level of life through innovation (I,4).

Thus, the aggregate integral indicator for the intellectual infrastructure potential in technological development and the external environment in this case are calculated as the arithmetic mean of the indicators given by the four groups.

However, if this classification is accepted, it is impossible to compare the result of evaluating environmental factors with the one of applying the methodology for the factors of the internal intellectual and technological environment at the enterprise. While maintaining the same list of components of the six elements, the only way to extrapolate the principle of combining the internal factors to the external ones is possible with a few exceptions. Within these groups, all indicators should also be normalized, since here statistical data are dealt for several time intervals. To do this, the following is used:

$$\boldsymbol{k_{ij} = (x_{ij} - x_{ij}^{min})/(x_{ij}^{max} - x_{ij}^{min})} \quad (5)$$

where k is the coefficient, i is the number of the indicator grouping, j is the number of the indicator within the i-th group.

A number of indicators in the range from 0 to 1 and reflecting the average values for each necessary indicator is a result of this operation. To find an average integral indicator within each element of the intellectual infrastructure potential in technological development, it is necessary to use a statistical formula:

$$\boldsymbol{I_i = (k_{i1} * k_{i2} * \cdots * k_{in})} \quad (6)$$

Thus, the method implies the consistent implementation of a number of steps:

– To determine specific features of the industry, taking into account territorial ones.
– To identify the significance of the resource components of the intellectual infrastructure potential in technological development based on specific features (separately for the internal and external intellectual and technological environment).
– To make a list of indicators (factors) for each components of the intellectual infrastructure potential for technological development (separately for the internal and external intellectual and technological environment).
– To choose an approach to their assessment. So, weight coefficients can be used. It is possible to normalize the values of the selected indicators and analyze deviations from the norm using the described normative approach and formula (2), or to use a more flexible approach to normalization and formula (5).
– To calculate integral indicators of the intellectual infrastructure potential in technological development, using the formula (1) if the approach with the assignment of weighting coefficients was used, or the formula (6) if the normative approach was used.
– To assess the achieved values of the resource components for the potential of the intellectual infrastructure for technological development based on the Harrington desirability function.
– To calculate the integral indicator of the intellectual infrastructure potential in technological development using the formula (4). The analysis and assessment of the obtained result is similar to 6.

4 Discussion

The proposed methodological approach for creating a multi-factor model of several levels with the calculation of integral indicators shows the specific features of the industry identified according to the algorithm. This approach allows specifying the resource components that are the elements of the intellectual infrastructure potential in technological development. The

following step is to determine the list of indicators that characterize each component of the intellectual infrastructure potential in technological development. First, the list of factors for the internal environment should be defined. We start with the organizational and managerial component.

Undoubtedly, most manufacturing companies invest substantially in increasing the number of product types and developing the existing assortment of products by means of research and development. It is also necessary to adjust the assortment to the requirements of customers. The performance criterion for such activities is the customer's attitude to the manufactured product. In other words, a new product cannot be declared as an innovative solution if it is not accepted by the client and is not included in the product assortment [8]. Consequently, it is important to analyze changes in the product assortment for the two subsequent comparative periods. To achieve this, the total number of product types for the current and previous periods is compared to clarify the renewal coefficient of the product assortment. The formula for calculating the coefficient is as follows:

$$\Delta \boldsymbol{PP} = \begin{cases} \frac{(PT_t^n - PT_{t-1}^n)}{PT_{t-1}^n} \end{cases} \tag{7}$$

$$\text{If } \mathbf{PT_t^n \geq 2 \times PT_{t-1}^n} \text{ then } \mathbf{PT_{t-1}^n = 1, otherwise \ if \ PT_t^n < PT_{t-1}^n \ then \ PT_{t-1}^n = 0}$$

where**:** $\boldsymbol{PT_t^n}$ is the number of items in the assortment at time t; $\Delta\mathbf{PP}$ is the assortment innovativeness coefficient.

If the number of product types doubled between the two periods, this ratio would be 100%. However, more than twofold increase in the number of products as compared to the previous year results in a value greater than 100%. The result can be corrected to 100% by setting the scale between 0 and 1. In the opposite case, the number of product types may decrease during the considered periods. This decrease results in a negative value of this function, but corrected to 0%. This may lead to incorrect conclusions. An example can be a situation where most of the products are new, but the number of items in the assortment is less than in the previous period. To solve this problem, it is necessary to use such an indicator as the rate of new product introduction.

The new product introduction rate not only solves the above problem, but also is an indirect indicator of the new product profitability. If the new items in the assortment are less profitable compared to the earlier ones (implying limited production capabilities, transportation, etc.), the old items will not be replaced and the new ones will not go into production. Although the previous indicator is related to the number of items in the assortment, it can distort the obtained data when certain types of products are excluded from the assortment. The corrective index is calculated as:

$$\boldsymbol{NP^R} = \frac{\boldsymbol{NPT_t^n}}{\boldsymbol{TPT_t^n}} \tag{8}$$

where $\mathrm{NPT_t^n}$ the number of new items introduced in the assortment; $\mathrm{TPT_t^n}$ is the number of items in the assortment at time t; $\mathrm{NP^R}$ is the rate of innovative product introduction.

The key point of the proposed methodology is to measure the effect of innovation against the previous assessment. The presence of interrelated factors to identify the desired result is normal. In case there is no innovation, the proposed methodology will bring zero percent result. If there is an innovation at the enterprise, a new product is expected to be introduced, which involves a direct change in the product assortment. It is vital, because innovations are supposed to be profitable. Sometimes a new product may be introduced, but it does not produce the expected value. With two interrelated factors, the model ensures that the new product is innovative and its profitability is higher than that of previous products. The ratio of new products can be calculated by dividing the number of innovative product types by the total number of product types.

Despite the fact that the first two factors are promising indicators for assessing the potential of the intellectual infrastructure in technological development as part of the organizational and management component, changes in the product assortment cannot reveal the potential of the intellectual infrastructure in technological development completely. It is notable that the production of different types of products does not always create value if they are not sold on the market. Development of high-tech products is nothing but waste if the customer refuses to buy them, unless it is aimed at reducing costs at the enterprise. In this case, however, these innovative solutions fall into other components of the intellectual infrastructure potential in technological development. Consequently, it is necessary to analyze the volume of sales of new products against total sales. This ratio is calculated as:

$$\mathbf{NP^{SAR}} = \frac{\mathbf{NP_t^{SA}}}{\mathbf{TP_t^{SA}}} \tag{9}$$

Where: NP_t^{SA} the number of new products sold over time t; TP_t^{SA} is the total number of goods sold over time t; NP^{SAR} is the coefficient of sales of new products (in natural units).

To assess the organizational and managerial component in terms of the selected approach also requires specifying the amount of revenue from the sales of innovative products, as well as the share of this revenue in its total volume. This indicator is necessary since the natural expression of the share of innovative products may be unrepresentative in terms of financial performance of the organization. These indicators are used to form representation of management effectiveness. For this purpose, the new products sales ratio was calculated [15]:

$$\mathbf{NP^{SRR}} = \frac{\mathbf{NP_t^{SR}}}{\mathbf{TP_t^{SR}}} \tag{10}$$

Where: NP_t^{SR} revenue from the sale of new products over the time t; TP_t^{SR} is total sales revenue for the time t; NP^{SRR} is the sales coefficient of new products (monetary units).

The last indicator defining the organizational and managerial component of the intellectual infrastructure potential in technological development will be the profitability of sold innovative products.

$$\mathbf{NP^{p}} = \frac{\mathbf{NP_t^{SP}}}{\mathbf{NP_t^{SC}}} \tag{11}$$

where: NP_t^{SP} is revenue from the sale of new products over the time t; TP_t^{SR} is the cost of sales of new products for the time t; NP^{SRR} is the profitability of new products (monetary units).

The intellectual component is the next element in the potential of the intellectual infrastructure in technological development. This component is divided into scientific and technical, and human resources components.

The important indicators for the scientific and technical component are those reflecting the level of innovation activity in the region and at the enterprise. These indicators are the most representative in terms of the impact on the intellectual infrastructure potential in technological development [17]. These indicators include the share of patented scientific products (in the sample of interest), the level of practical use of scientific development (in the sample of interest), and the share of employees with scientific degrees among employees involved in the development. Among these indicators are also the share of employees engaged in scientific development in the average number of employees of the enterprise, the share of costs for research and development in total expenditure, and the cost-effectiveness ratio for the development of scientific projects.

To build a model for assessing the human resources component, it is essential to analyze and use indicators that characterize the state, availability, development and outflow of labor force in the region and at the enterprise. These indicators provide a direct reflection of the state of human resources in production, as well as determine the possibility of recruiting new labor force. This block will require such indicators as the coefficient of employees' qualification (labor experience), the coefficient of advanced professional training for

employees, and the coefficient of compliance of workplaces with standard requirements. This block also includes the coefficient of employee loyalty (inverse coefficient of turnover), the ratio of personnel availability, the share of wage costs, the coefficient of costs for vocational training, and the ratio of the growth rate of labor productivity to the wage growth rate.

The most valuable indicators for the production component are those characterizing the provision of production plant operation with modern equipment, the level of injuries at production sites, and defect ratios, that is, these are indicators reflecting the extent to which production meets modern requirements [18]. This list includes such indicators as the level of production mechanization, the share of the active part of fixed assets, the share of innovative products, and the share of innovative technologies. This list continues with the ratio of the use of available equipment, the capital productivity ratio, the rate of injuries, the share of materials of improper quality, the ratio of the planned provision of resources, the actual provision of resources, and the management effectiveness ratio.

The raw materials component is characterized in terms of the internal intellectual and technological environment. Indicators reflecting the sufficiency and turnover rate of resources within the enterprise, and the availability of inventories can measure this component [19]. Thus, the list of indicators is as follows: the coefficient of downtime due to delays in delivery, inventory turnover ratio, the rate of waste after processing, the duration of the production cycle, and the provision of own current assets.

The financial component should include indicators measuring the amount of investment in innovation, as well as the possibility of drawing additional, borrowed sources of finance. The current amount of loan capital and financial stability of the enterprise determine the possibility of borrowing additional capital [20]. Thus, the most important indicators will be the share of borrowed finance in the capital of the enterprise, the financial leverage ratio, and the equity share of investment in R&D, the investment ratio in R&D, the autonomy ratio, the investment coverage ratio, and the ratio of short-term debt.

Currently there are trends to increase the level of environmentally friendly production, criticize publicly environmental contamination and improve environmental regulations. Thus, the environmental component of the intellectual infrastructure potential in technological development must be taken into account. Indicators of the environmental component should primarily reflect the effect of current operations at the enterprise in terms of contamination as far as each innovation must contribute to the reduction of emissions or its implementation will be extremely difficult. Calculation in the considered methodology is based on statistical indicators in calculating innovation potential coefficients and indicators.

Similar to the indicators of the internal environment of the enterprise it is advisable to divide the intellectual component into scientific, technical, and human resources components. The indicators that are representative for the human resources section are as follows. They are the ratio of employees with a university degree to the total number of those employed in the economy, the share of vocational education students in the total number of those employed in the economy. They also include the ratio of personnel involved in R&D to the total number of the employed in the economy, and the ratio of researchers with advanced degrees and postgraduate students to the total number of the employed in the economy.

To evaluate the scientific and technical component, it is advisable to use such indicators as the share of scientific works in the total GRP, the share of organizations engaged in innovative activities in the total number of organizations, and the ratio of new patents of the current period to the number of new patents in the previous period. Then this component includes the ratio of issued patents to used patents, and the ratio of the number of employed best practices to the same indicator of the previous period.

The financial component should characterize the measure of access to financial resources for enterprises and availability and use of these resources in the region where these organizations are located [21]. Equally, important indicators will be those defining the

amount of financial resources allocated to the development of intellectual infrastructure. Thus, the relevant indicators will be the following: the share of expenditures on technological innovation in the gross regional product, the share of expenses on research and development in the gross regional product, and the gross regional product per capita. This list includes the net profit of industrial sector organizations in relation to the previous year, the index of investment in fixed capital per capita, the index of investment in fixed capital, the index of foreign investment, and the share of own assets of industrial sector organizations in the total amount of investment in the fixed capital.

The elements of the organizational and managerial component will be indicators of innovation performance, which is the parameter of management efficiency. Thus, this category includes such indicators as the share of innovative products, works, services in the total volume of goods sold, the ratio of sold innovative products, works, services to the gross regional product, and the ratio of organizations using information and communication technologies to the total number of organizations in the region. The list contains the ratio of organizations using global information networks to the total number of organizations in the region, the share of organizations using special software, the share of organizations engaged in innovative activities in the total number of organizations, and the share of organizations using advanced production technologies.

The indicators reflecting the volume of innovations used at the enterprises, as well as the equipment of the production process characterize the production component of the intellectual infrastructure potential in technological development. This component incorporates such indicators as the renewal coefficient of fixed assets, the ratio of expenditures on technological innovations as a percentage of the internal expenditures on R&D. There are also the share of organizations engaged in technological innovations in the total volume of organizations, the degree of depreciation of fixed assets, and the ratio of fixed assets of enterprises to the total number of employees in the region in this group of indicators.

At the meso level, it is difficult to determine macroeconomic indicators for the raw material component. The infrastructure elements showing the mobility of resources in the region and on the inter-regional markets have the main influence on the raw material component [22]. Accordingly, it is necessary to identify the presence or absence of the main logistics hubs in the region with the assignment of appropriate coefficients. A separate parameter is the availability of necessary resources for the industrial sector, such as electricity, the access to water bodies and water systems, the presence or absence of extractive industries of the main types of raw materials in the region [23]. Thus, it is possible to assign values of zero or one to each of the parameters, as well as to take into account the weighting coefficients depending on the characteristics of a particular parameter based on the characteristics of the region. Similarly, weighting factors should be applied to the assessment of the availability of logistics hubs. For example, air service and inland navigation clearly gives less advantage in terms of cargo turnover compared to the railroads and seaports. Thus, the list of indicators is as follows: the availability of major railway hubs in the region with links to other regions, the availability of airports in the region, and navigable rivers with links to other regions. This group of indicators incorporates the availability of seaports in the region, the availability of water bodies suitable for water intake for technological needs, the availability of large infrastructure facilities for power supply in the region, and the availability of broadband Internet connection in the region.

5 Conclusions

It can be concluded that the division of the methodology for assessing the stability of the intellectual infrastructure potential in technological development into two separate blocks based on the affiliation of influencing factors to the internal or external intellectual and

technological environment is justified. The reason is a higher degree of universality of macro-environment indicators in relation to intra-company indicators [15-20]. Further development of the methodology assumes the preservation of an identical approach for these two blocks. It consists in analyzing the structure of the intellectual infrastructure potential in technological development, which is based on the resource component of intellectual and technological processes. Hence, there is a need for further division of factors into blocks due to the levels of resources aggregation according to the classification. This makes it possible to detail the analysis of deviations and changes in the intellectual infrastructure potential in technological development, as well as to identify other problem points during the analytical evaluation procedure. Each of the resource blocks, in turn, is divided into a number of indicators characterizing it. Thus, the methodology for assessing the stability of the intellectual infrastructure potential in technological development involves the calculation of a number of integral indicators. They are eventually collected into a cumulative multifactorial indicator characterizing the intellectual infrastructure potential in technological development in the region and at the enterprise.

This approach allows talking about the flexibility of the evaluation procedure, to add and exclude indicators inside categories, as well as assign various subjective weighting coefficients to existing ones. Moreover, the statement that this methodology is universal for industrial enterprises is right. The lists of indicators are advisory in nature and can change for the internal intellectual and technological environment. In addition, the external environment has a relatively similar impact for all enterprises in the region.

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