The present research substantiates the theoretical and methodological foundations of quantitative assessment of the prerequisites for the implementation of strategic directions of innovative development of industrial enterprises under conditions of changing technological arrangement and the fourth industrial revolution. External and internal prerequisites for catching-up, leading and outstripping innovative development were determined and systematized. The two-step approach to assessing the sufficiency of prerequisites for the implementation of these directions was developed. It was proposed to assess external prerequisites according to the relative values of the indicators of the Global Innovation Index of the analyzed country, which take into account the highest and the lowest estimates of all countries Unlike existing approaches, the point-based score, rather than rating estimates of the indicators of countries are taken into account, which increases the assessment objectivity. The compliance of quantitative estimates with the levels of sufficiency of external prerequisites was determined using the Harrington Verbal-Numerical scale. It was proposed to assess internal prerequisites according to the author's method of expert evaluations, which unlike existing ones, allows assessing the level of sufficiency of subsystems of the potential of innovative development of an enterprise. The two-step approach allows quantitative and comprehensive assessment of sufficiency of the prerequisites for the implementation of strategic directions of innovative development of industrial enterprises. It is possible to identify problems of prerequisites' sufficiency, which allows their reasonable correction. The sufficiency of prerequisites for alternative directions of innovative development of machine-building enterprises was evaluated using the new approach and the best directions were chosen. The analysis time was reduced by 25–33 %, the accuracy of choice of directions and the effectiveness of their implementation strategies are increasing. The new approach improves strategic management of innovative development of industrial enterprises in the context of technological transformations

Keywords: innovative development, directions of innovative development, prerequisites for innovative development, industrial enterprises, strategic management

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APPROACH TO ASSESSMENT OF PREREQUISITES FOR IMPLEMENTATION OF STRATEGIC DIRECTIONS OF INNOVATIVE DEVELOPMENT OF INDUSTRIAL ENTERPRISES

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1. Introduction

Modern economy is characterized by a sharp acceleration of transformation processes, which were initiated by the completion of the 5th and the birth of the 6th technological arrangement, as well as the deployment of the 4th industrial revolution. These processes are dualistic in nature.

On the one hand, transformation processes generate a number of problems for business entities of different levels (state, industry, separate enterprise), which cannot be solved with the help of traditional technique, technology, management methods, etc.

On the other hand, they provide a chance for outstripping innovative growth by creating and commercializing innovations that effectively solve existing and predictable problems. Innovations allow forming, strengthening, and implementing relative competitive advantages, taking strong positions in the national and international markets. World experience convincingly shows that new relevant knowledge is at the heart of the development strategies of most inno-

vative companies. Knowledge is embodied in new products, new technologies of their manufacture and use (consumption), new management methods at all stages of production and promotion of products in the market, etc.

In the context of the above, the problem of determining the necessary and sufficient prerequisites for the formation and implementation of strategies of knowledge-oriented outstripping innovative development of business entities of different levels and industries is becoming more relevant. For many countries that do not belong to the leaders of innovative growth, this problem is especially topical for the industry, the enterprises of which are based mainly on the production of former technological processes. Maintaining the existing state threatens the systemic separation of their economy from the countries – innovative leaders, since it is the development of industry that determines the pace of scientific and technological progress (STP) of most industries. The solution of this problem will make it possible to determine reasonably the promising strategic directions of knowledge-oriented outstripping innovative development of industrial enterprises of these countries. In addition, it will allow purposeful management of the formation and implementation of relevant strategies, ensuring the conditions for sustainable economic growth and improvement of the quality of life of their peoples.

The existing approaches to determining the strategic directions of innovative development in their considerable part are based on matrix methods of qualitative analysis and do not give quantitative estimates, which makes it difficult to compare alternative variants. In assessing the external prerequisites for innovative development, reputable international ratings are also traditionally used. However, the ratings characterize the prospects for economic growth of national economies on a rather wide scale. These ratings are usually used by strategic investors, politicians, government circles, community organizations, etc. However, from the positions of specific enterprises, ratings are not in demand enough. As for the existing methods of quantitative analysis of external and internal prerequisites for determining strategic directions of innovative development, they are used to analyze only certain factors of influence of the external and internal environment. In most cases, factors are chosen without proper justification, which prevents comprehensive assessment of the prerequisites for the innovative development of industrial enterprises and leads to errors in determining their trajectories of innovative growth.

Thus, the problem area of research related to the development of approaches to quantitative comprehensive evaluation of external and internal prerequisites for the implementation of strategic directions of innovative development of industrial enterprises is updated. This will allow enhancing the efficiency of management of innovative development of industrial enterprises, in terms of substantiated choice of its strategic directions, under conditions of technological transformations caused by a change in technological arrangements and the fourth industrial revolution.

2. Literature review and problem statement

Conceptual principles of economic development under conditions of the fourth industrial revolution, the essence of strategies of outstripping innovative growth, based on information and communication technologies 4.0, the consequences of their implementation were highlighted in paper [1]. It was shown that these strategies are based on new relevant knowledge about the possibility of combining human intelligence, computer information technologies and automated production in self-regulated systems. However, the prerequisites for using 4.0 technologies are indicated only indirectly, the approaches to choosing the strategies for their implementation are not considered.

Modern approaches to the development of the theoretical principles of innovative development of large enterprises based on the cooperation with small innovative firms in the direction of the concept of open innovations were studied in research [2, 3]. The authors conclude that the issue of evaluating the effectiveness of such cooperation as a driver of innovative growth requires further research. Approaches to the management of open innovations in small and medium-sized enterprises from the standpoint of ensuring their innovative growth were studied in paper [4]. The peculiarities of open innovation management at small and medium-sized enterprises, which were almost not considered by other researchers, were outlined. In general, open innovations form innovative connections, make it possible to use intellectual property, reduce time consumption, provide synergistic effect, etc. However, it should be noted that open innovations are only one of the external prerequisites for success focused on knowledge of innovative development. It is necessary to analyze and take into account other prerequisites as well.

Paper [5] considers the topical issues of screening of potential partners in joint networks in order to choose them for cooperation and knowledge exchange. In study [6], the important role of knowledge-oriented scientifically intensive business services in commercialization of technologies and the development of new products of production firms was substantiated. These works highlight the relevant directions for ensuring the success of innovation activities under conditions of the formation of knowledge economy. However, in these studies, like in papers [2–4], only some prerequisites for innovative development are analyzed, while the others are not, which does not allow their comprehensive evaluation.

Paper [7] highlighted the essence of the strategy for commercialization of breakthrough technologies, based on new scientific knowledge, revealed the features of its implementation. However, there is no approach to choosing such strategies, which requires further research.

The problem of knowledge management from the positions of generation of strategies of innovative development of organizations based on it was explored in paper [8]. Particular attention was paid to motivation of project team members to obtain and use knowledge. The effectiveness of the use of knowledge obtained from different sources was analyzed. The research is based on the survey of 341 project team members. Practical recommendations on improving the effectiveness of processes of knowledge gaining and using were offered. However, the study considers mainly internal prerequisites for innovative development, while external prerequisites are explored to a lesser extent. In order to make reasonable decisions on the choice of promising directions of innovative development, it is also advisable to take into account external prerequisites.

A system of indicators to determine the stages of implementation of technologies of the fourth industrial revolution was formed in research [9]. This allows enhancing

the accuracy and effectiveness of the actions on strategic management of implementation. However, the study is more devoted to the level of the industry as a whole and requires more research that would consider the level of a particular enterprise.

Based on analysis of 172 subsidiaries of multinational companies located in France, research [10] focuses on the role of open innovation (incoming and outcoming) and knowledge management as drivers of leading innovation development. Recommendations on the practical use of the proposed approaches to ensuring knowledge-oriented innovation leadership in international business were developed, directions of further research were outlined. Study [11] analyzes the impact of knowledge management on the creation and implementation of innovations, as well as the productivity and efficiency of companies. An appropriate model was constructed to quantify this impact, the model was tested at 120 companies that are members of the Iranian Energy Syndicate. It was proved that the production and application of knowledge is a driver of innovative growth and improvement of companies' efficiency. Paper [12] deals with the organizational aspects of providing knowledge-oriented innovation activities in an organization. The positive impact of knowledge management on the effectiveness of innovations implementation was emphasized. However, it should be noted that in papers [10–12], only part of internal prerequisites for innovative development was studied, while others, such as technical and technological, financial, marketing, etc., were not considered. Accordingly, a comprehensive consideration of internal prerequisites, which is important for enterprises that have a limited resource base, is required. In addition, the presented approaches are quite complex from the positions of management of innovative activities.

The tools and organizational mechanisms that ensure the development of innovative potential of companies were determined in research [13]. The development of innovative potential was shown to take place due to behavior and skills, procedures, processes, mechanisms of learning and knowledge. But like in previous research [10–12], attention is paid only to separate components of the internal prerequisites for innovative development, which does not allow their comprehensive assessment.

Article [14] proposes a business model for the development of an industrial company operating in science-intensive industries. The model is based on the data from 102 biological and pharmaceutical companies. This model allows taking into account the influence of the main factors of influence of the external innovation environment, which increases the efficiency of the company's innovation activities. However, along with external ones, it is necessary to analyze the internal factors that the proposed model does not take into account. The proposed model is more focused on the stable conditions of countries with a developed innovation system.

The problem of ensuring the prerequisites for outstripping innovative growth at the macro level is revealed in the studies of Ukrainian scientists. In studies [15, 16], knowledge is considered as a component of intellectual capital and potential of innovative development of the state. Paper [15] proposes some qualitative indicators of prerequisites of outstripping innovative development at the state level, in particular: outstripping development of public administration, human potential, civil society, etc. Article [16] contains analysis of the trends in the development of national innovative systems of developed countries of the world according to the integrated indicator of the Global Innovation Index (without detailing its components). The possibilities of applying existing experience in countries that are not leaders of innovative growth were outlined. However, in these works, the external prerequisites for innovative development are considered in a generalizing way, which is sufficient for the level of the state, but insufficient for a reasonable choice of promising directions for innovative development of a particular enterprise. It is necessary to take into account the whole range of factors that influence the success of strategies of innovative development, extend the list of evaluation indicators and formalize the evaluation procedures. It should also be noted that the Global Innovation Index [17] is often used to evaluate the innovative capabilities of countries of the world both by their resource base and by their ability to implement it. The ratings of countries as a whole are normally analyzed according to the specified index and its separate components, based on which the conclusions about the innovative capability of these countries are made. Indices (indicators) of the Global Innovation Index can be used for large-scale assessment of external prerequisites for innovative development. When it comes to the possibility of their application for detailed quantitative assessment of external prerequisites, additional research is required.

Research [18] deals with the specific features of transition of the Ukrainian economy to outstripping innovative development in comparison with other countries that have stepped on this path. Separate factors that form the prerequisites for innovative outstripping development in different countries were analyzed. The results of analysis of experience of outstripping innovative development of different countries were presented. However, the consideration of a limited number of factors of influence does not allow obtaining objective assessment of the external prerequisites for innovative development. Accordingly, it is necessary to detail external factors of fluence and methodological principles of their assessment.

Paper [19] shows that enhancement of accuracy and efficiency of choosing directions of innovative development of an enterprise is one of the key factors in improving the management system of its innovative development under unstable conditions of modern economy. However, the approach to improving the selection procedure was not explicitly proposed. This kind of improvement requires assessment of external and internal prerequisites for the implementation of strategic directions of innovative development.

The problems of improving approaches to knowledge-oriented innovative development of enterprises were explored in papers [20–22] and others. The main approaches to ensuring the strategic competitive advantages of an enterprise in knowledge and innovations, created on their basis, were analyzed in research [21]. Paper [20] explored the specific features of knowledge management of international companies from the position of ensuring their high competitiveness in the global innovation environment, the main components of this environment were outlined. Knowledge is considered as the foundation for creating innovations that are the basis of economic growth under modern conditions.

Paper [22] outlined the role of the organizational culture of innovative type (innovative culture) as one of the internal prerequisites for effective management of the company's knowledge in the context of ensuring its innovative development. Innovative culture of an enterprise as an important component of the formation of an innovative and favorable

environment is considered in paper [23]. However, only one of the factors of influence is analyzed, specifically, innovative culture, which does not allow comprehensive assessment of external and internal prerequisites for innovative development.

Paper [24] studies the impact of innovations on economic growth of enterprises, reveals the trends in changing directions of their innovation activity, in particular, the growth of a share of technological innovations. It is shown that a prerequisite for the success of innovative growth of enterprises is the orientation of innovation activities to solving global socio-economic problems. This emphasizes the importance of analysis and evaluation of sufficiency of external and internal prerequisites for innovative development.

Paper [25] outlined an approach to identifying priority areas of innovative development in the context of global changes and integration of post-socialist enterprises into the world economic space, taking into account the influence of external and internal factors. However, the emphasis is placed on the internal prerequisites for innovative development, in particular, innovative resources of an enterprise. However, practice shows the need for comprehensive assessment of the external and internal prerequisites for innovative development, which proves the necessity to develop an appropriate approach.

Papers [26–28] examined the specific features of direct commercialization of knowledge of enterprises embodied in products of intellectual property: patents, licenses, etc. The approaches to monitoring and evaluating the commercial potential of intelligent technologies as prerequisites for ensuring the innovative development of machine-building enterprises, as well as methodological tools for the effective commercialization of these technologies were developed in paper [26]. The issues of economic evaluation of innovation technologies are considered in research [27] as the basis for innovative development of the enterprise that commercializes them. Research [28] outlines the essence of the developed internal contract system for the transfer of developed innovative technologies at machine-building enterprises. The main prerequisites for ensuring the success of the process of such transfer were determined. Practical approbation of the proposed approach was carried out. However, quantitative assessment of the prerequisites for the success of commercialization of products of intellectual property as one of the directions of innovative development has its own specific features. The proposed approaches are difficult to apply to assess the prerequisites for innovative development, for example, based on product innovations. It is necessary to develop a universal approach that would be suitable for all types of innovations.

Analysis of literary sources concerning determining, analysis and systematization of prerequisites, as well as the choice of strategic directions of knowledge-oriented innovative development of industrial enterprises based on it, revealed the following unresolved problems:

– there is no generalizing systematization of external and internal prerequisites for innovative development of industrial enterprises in the context of ensuring the possibility of implementation of its main strategic directions;

– the criterion base and the system of indicators for quantitative comprehensive assessment of sufficiency of external and internal prerequisites for the implementation of strategic directions of innovative development of industrial enterprises has not been formed;

– available methodological recommendations for the choice of promising strategic directions of innovative development of industrial enterprises require significant improvement in terms of taking into account the necessary and sufficient prerequisites for their implementation.

Thus, existing developments mainly solve only certain aspects of these problems. Some complex developments based on the experience of developed countries do not take into account the specifics of the formation of prerequisites for the transition of industrial enterprises of countries, which are not innovative leaders, to knowledge-oriented innovative development. Their direct use, without appropriate adaptation, discredits the idea of strategies of innovative outstripping development based on the knowledge of patterns of influence of external factors, the state of potential of innovative development of enterprises, and effective ways of its strengthening and implementation.

3. The aim and objectives of the study

The aim of the research is to develop a new approach to assessing the sufficiency of external and internal prerequisites for choosing promising strategic directions of innovative development of industrial enterprises based on its results.

To achieve the set goal, the following tasks were set:

– to determine and systematize external and internal prerequisites for the innovative development of industrial enterprises in terms of its main strategic directions;

– to develop methodological principles, including the criterion base and the system of indicators to assess the sufficiency of external and internal prerequisites for the innovative development of industrial enterprises;

– to develop methodological principles for the substantiation of the choice of strategic directions and the types of innovative development of industrial enterprises, depending on the existing external and internal prerequisites; to perform their approbation at domestic machine-building enterprises.

4. Materials and methods of research

Based on critical analysis of printed and electronic scientific and analytical sources, external and internal prerequisites for the implementation of strategic directions of innovative development of industrial enterprises were determined. In particular, publications related to determining conditions and drivers of innovative growth at macro- and micro levels, as well as at the levels of a separate enterprise, were analyzed. Using the method of logical generalization of results of analysis, taking into account the essence of catching-up, leading and outstripping development, we systematized external and internal prerequisites for the implementation of strategic directions of innovative development of industrial enterprises. According to the results of systemic analysis of the Global Innovation Index indicators, which characterize the components of the innovative capabilities of countries (resource base and ability to implement it), a system of indicators for quantitative assessment of external prerequisites for innovative development was formed.

Systemic and structural analysis of subsystems and elements of the potential of innovative development of an

industrial enterprise made it possible to determine a set of indicators for quantitative assessment of its internal prerequisites for innovative development. The most important of them were chosen using the method of expert surveys of managers and leading specialists of industrial enterprises. The method of analysis was used in the study of a complex of indexes and sub-indices of the Global Innovation Index, which characterize the components of the system of innovative capabilities of a country and their elements.

The methods of comparative analysis and synthesis were used in substantiation of methodological principles of calculation of normalized relative quantitative estimates of indicators of separate elements of these components, integrated estimates of components and of the country as a whole. The method of comparative analysis was used in the formation of a criterial base for assessing the sufficiency of external prerequisites for the implementation of promising strategic directions of innovative development of an industrial enterprise. The method of expert evaluation was used when substantiating the methodological principles of estimation of internal prerequisites for innovative development, in particular, in pairwise comparison and determining the weight of evaluation indicators of internal prerequisites. The method of expert evaluations was also used in situational analysis and assessment of sufficiency of internal prerequisites for choosing priorities from a number of alternatives to strategic directions of innovative development.

Approbation of the developed approach to assessing the sufficiency of external and internal prerequisites for selection of promising strategic directions of innovative development, based on its results, was carried out at machine-building enterprises that produce machines and equipment.

5. Results of the research into the development of an approach to assessing the prerequisites for innovative development of industrial enterprises

5. 1. Determining and systematization of external and internal prerequisites for innovative development of industrial enterprises

Permanent changes in the conditions of the external macro- and micro- environment of the modern economy require bringing the potential of innovative development of enterprises in line with these changes. This involves monitoring and assessing the state and trends of changes in parameters of the external and internal environment.

According to world experience, one of the most effective ways to bring in line internal opportunities with external ones is to create and implement innovations and move on their basis to innovative growth. This method is especially relevant during the periods of transformation of technological processes.

This enables enterprises not only to adapt to the transformation of industries or markets under the influence of the STP, but also (ideally) to program these changes. Programming changes is possible in the case of implementation of radical innovations that can initiate the creation of new productions, industries or complexes of interconnected industries. It is possible to take as examples the following: additive production, in particular 3D printing; renewable power industry; industrial Internet of Things: software, sensor and communication systems, computer equipment, cybernetic actuary mechanisms, etc.

The decision on determining the strategic directions of bringing internal capabilities of innovative development in line with the external ones requires the solution of three interrelated tasks:

– identification of problems of enterprises (manufacturers of products or service providers) caused by transformation processes;

– identification of problems of consumers of products of the industry of analyzed enterprises (related industries) caused by transformation processes;

– analysis/forecasting of tendencies in the development of the STP, in particular, scientific and technological developments), which can be used to create innovations that solve identified problems of consumers and enterprises that are manufacturers of goods or service providers.

The scheme of mutual coordination of the processes of solving these problems is shown in Fig. 1. At the same time, a set of knowledge is formed, regarding: strategic directions of innovation activity; specific innovations that will be their basis; the degree of consideration of the interests of consumers and producers (ideally – all subjects of the innovation process).

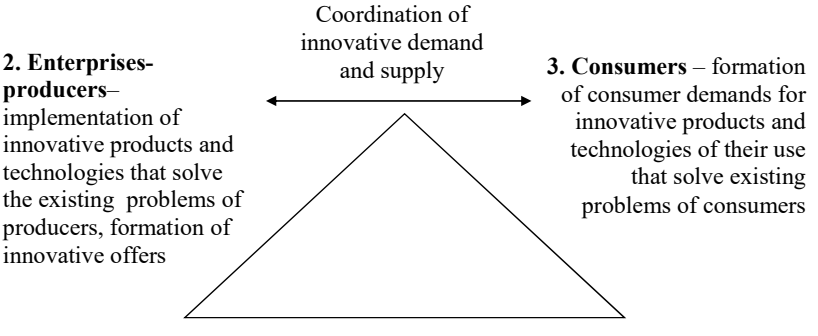

Fig. 1. Scheme of mutual coordination of solving problems on determining strategic directions of innovative development

However, success of innovation activities is possible only in the presence of certain external and internal prerequisites. In the first approximation, existence of external prerequisites for innovative development can be determined by the indicators of the Global Innovation Index (GII). In general, with the help of the GII, innovative opportunities (opportunities for innovative growth) of the countries of the world are evaluated. The assessment is carried out according to groups of indicators that characterize both the resource base and the effectiveness of its implementation. The choice of GII indicators is also justified by the fact that, as shown by one of the authors of this article [23], there is a dense stochastic relationship between the GII of a country and a share of GDP per capita of its population. Since the main purpose of innovation activity is to form and strengthen competitive advantages as a base of economic growth, the GII adequately reflects the possibilities of its provision.

It is proposed to evaluate the internal prerequisites for the innovative development of a particular enterprise using the indicators of the level of its potential for innovative development (PID) both as a whole and on by its separate potential subsystems (market, innovative, production and sales [29]). They assess market potential as the existence of solvent demand or the ability to form it – for radical innovations that have no analogues. Further, innovative potential is assessed as an opportunity to implement the achievements of STP in innovative products and technologies that can meet the needs of consumers. Then, as production and sales potential as technical and economic capacity, as well as economic appropriateness to create, manufacture and promote innovations to the market.

Each of the possible directions of innovative development and relevant strategies for their implementation need their own set of prerequisites. In general, in paper [30], the following strategic directions of innovative development are separated: catching- up, leading, outstripping. The analysis reveals that these strategic directions of innovative development are inherent, respectively, in the following types of economy: factor-oriented economy; efficiency-oriented economy; innovation-oriented economy.

The following types of innovative development strategies correspond to these strategic directions:

– protective, which involve the improvement of existing products, technologies, and management methods in order to protect satisfactory market positions or maintain them in the market;

– moderately offensive (leader), involving imitation of market leaders and competition with them;

– aggressively offensive (outstripping), involving the creation of "breakthrough"/radical innovations that will allow taking leading positions in radically transformed or new markets (industries).

The main prerequisites for their innovative development were separated and systematized. The variant of systematization, which includes prerequisites of different types of innovative development mentioned above, is shown in Table 1.

External prerequisites for innovative development can be adequately described using GII indices (indicators). Table 1 shows that in order to assess the prerequisites of catching-up innovative development, first of all, it is proposed to analyze the GII indices, which characterize: institutional support, infrastructure, human capital and the research base. Other indices in this context play a supporting role. For leading innovative development, indicators that characterize the development of markets are added to the specified indices of catching-up development. For outstripping innovation development, the whole range of GII indicators is used, as well as an indicator of the level of innovative culture of economic counterparties and contact audiences in target markets (actual or potential). On this basis, decisions on the availability of external prerequisites for a specific direction (directions) of innovative development are made. The stage of development of the industry, in which the analyzed enterprise work, is taken into account during evaluation.

During periods of technological transformations and industrial revolutions, which are closely related to outstripping development and "creative destruction" of industries and markets [31], the requirement for macroeconomic stability is not mandatory. According to world experience, during periods of technological transformations, it was instability that "pushed" business structures to innovative outstripping development, which gave the chances to discoverers of new industries, industries, markets, etc.

It was proposed to describe the internal prerequisites for innovative development with the help of indicators that characterize the state of the components of potentials- subsystems of its potential for innovative development. The corresponding potentials-subsystems and their components are shown in Table 1 (in brackets in column 3).

Table 1

Prerequisites for implementation of directions of innovative development

Direction of innovative development	External prerequisites	Internal prerequisites (components of PID)
Catching-up	Macroeconomic stability; developed infrastructure; resource base (natural resources, personnel, etc.); industry of an enterprise is at maturity stage	Strong marketing and production divisions (market and sales potentials)
Leading	Macroeconomic stability; developed infrastructure; resource base; developed markets: financial, labor resources, commodity market, etc.; industry of an enterprise is the growth/ maturity stage; innovative culture of society	Ability to take advantage of new technologies; human capital: quality of labor force, with both basic and higher education (innovative potential, its intellectual, informational, interface, and research components; market potential; production and sales potential, its financial, personnel, technological, marketing, organizational and management components)
Outstripping	Institutional support: political, regulatory-legislative, business environment; human and research capital; developed infrastructure; market development and business development; innovative culture of society (innovative readiness of market entities); production, influence and dissemination of knowledge; the role of creativity in innovation; radical transformation of the industry of an enterprise, up to winding down the existing one and forming a new one	Innovative culture of personnel: intellectual capability and psychological readiness; complexity of innovation activity: combination of technological, product, management, marketing innovations; costs for scientific, technical and innovation activities (innovative potential, including innovative culture of an enterprise, market, production and sales potentials)

5. 2. Formation of criterion base and system of indicators of evaluation of prerequisites for innovative development

5. 2. 1. Methodological principles of estimation of external prerequisites

The point-based system is used to assess specific countries according to the commonly known GII indicators (a detailed description of the indicators is given in [17]). The positions of these countries in their entire set, for which the GII are calculated, are determined. A fragment of such assessment is shown in Table 2.

Table 2

Dynamics of the global innovation index of Ukraine, position and point-based score (constructed according to data [17])

Year	Global Innovation Index, $(I_{rs}+I_{rz})/2$	Innovation resources, I_{rs}	Innovation results, I_{rz}	Innovation effectiveness, I_{rz}/I_{rs}
2020	45 (36.3)	71 (40.1)	37 (32.5)	5 (0.81)
2019	47 (37.4)	82 (40.7)	36 (34.1)	5 (0.84)
2018	43 (38.5)	75 (40.5)	35 (36.6)	5 (0.9)

However, such assessment does not give an objective idea of the innovation capabilities of countries. In particular, the indicators of innovation efficiency of Ukraine and the USA according to the GII are equal for both countries and approximately amount to 0.8. At the same time, the point-based score of the resource base is 68.8, and that of the result of innovation activity is 52.3. This indicates much greater innovative opportunities of the United States at the equal with Ukraine indicator of innovative efficiency. Positions of countries according to the GII can also vary significantly at almost equal values of their point score.

Obviously, it is necessary to choose another way to evaluate countries by GII indices and sub-indices. Taking into account the above, it was proposed to calculate the country's indicators from the formula

$$I_n = \frac{\left(I_a - I_{\min}\right)}{\left(I_{\max} - I_{\min}\right)}, \quad (1)$$

where I_n is the normalized value of the indicator of Ukraine; I_a is the actual value of the indicator of Ukraine; $I_{\min}$ is the minimal value of the indicator among all countries included in the rating; $I_{\max}$ is the maximal value of the indicator among all countries included in the rating.

Thus, calculated normalized values of indicators of innovative capabilities of Ukraine will be in the range of 0...1.

It is proposed to determine the score of sufficiency of the level of a specific indicator I_n (single or integrated) using the Harrington verbal-numerical scale [32]:

– $0<I_n\leq 0.2$ – very low level;
– $0.2<I_n\leq 0.37$ – low level;
– $0.37<I_n\leq 0.63$ – medium level;
– $0.63<I_n\leq 0.8$ – high level;
– $0.8<I_n\leq 1.0$ – very high level.

The separated levels of sufficiency correspond to the risk level, respectively: catastrophic; critical; elevated; minimum; conditionally absent. That is, the minimum condition for the feasibility of implementing a certain direction is the medium level of the I_n indicator, this corresponds to elevated risk, which is characteristic of innovation activity. Indeed, the essence of innovation is changes (and changes are always associated with risk) that are seen as a source of income growth.

Table 3 shows the results of estimation of indices (indicators) of components of GII.

Table 3

Dynamics of indicators (sub-indices) of the GII of Ukraine (calculated according to the data of [17])

Year	Ukraine, fact			Maximum, position and scored points	Maximum, position and scored points
	Position, points	Normalized score	Level		
Innovation resources					
2020	71 (40.1)	0.40	medium	1 (70.2) Singapore	131 (19.9) Yemen
2019	82 (40.7)	0.37	low	1 (72.2) Singapore	129 (22.5) Yemen
2018	75 (40.5)	0.35	low	1 (74.2) Singapore	126 (22.2) Yemen
1. Institutions					
2020	93 (55.6)	0.42	medium	1 (94.8) Singapore	131 (27.7) Yemen
2019	96 (53.9)	0.39	medium	1 (94.9) Singapore	129 (27.5) Yemen
2018	107 (49.1)	0.31	medium	1 (94.7) Singapore	126 (28.7) Yemen
2. Human capital and research					
2020	39 (40.5)	0.58	medium	1 South Korea (65.2)	131 (6.1) Guinea
2019	51 (35.6)	0.52	medium	1 South Korea (66.5)	131 (1.4) Zambia
2018	43 (37.9)	0.51	medium	1 Singapore (73.3)	131 (1.4) Zambia
3. Infrastructure					
2020	94 (33.1)	0.35	low	1 Norway (64.6)	131 (16.4) Zimbabwe
2019	97 (36.0)	0.39	medium	1 Norway (69.9)	129 (14.0) Burundi
2018	89 (38.1)	0.37	low	1 Hongkong (68.9)	126 (20.3) Zimbabwe
4. Market development					
2020	99 (42.1)	0.34	low	1 Hongkong (86.5)	131 (19.6) Ethiopia
2019	90 (43.3)	0.28	low	1 USA (87.0)	129 (26.1) Burundi
2018	89 (42.7)	0.27	low	1 USA (85.1)	126 (26.9) Niger
5. Business development					
2020	54 (29.5)	0.33	low	1 Sweden (68.0)	131 (10.4) Myanmar

Continuation of Table 5

2019	47 (34.8)	0.35	low	1 Sweden (68.8)	129 (16.3) Yemen
2018	46 (34.5)	0.38	medium	1 Netherlands (65.1)	126 (15.7) Yemen
Innovation results					
2020	37 (32.5)	0.41	medium	1 (62.8) Switzerland	130 (7.3) Yemen
2019	36 (34.1)	0.49	medium	1 (63.5) Switzerland	129 (6.4) Yemen
2018	35 (36.6)	0.49	medium	1 (67.1) Switzerland	126 (7.9) Yemen
6. Knowledge and technologies					
2020	25 (35.1)	0.51	medium	1 (65.5) Switzerland	131 (4.0) Guinea
2019	28 (34.6)	0.47	medium	1 (70.3) Switzerland	129 (2.9) Guinea
2018	27 (36.7)	0.45	medium	1 (74.9) Switzerland	126 (5.6) Yemen
7. Role of creativity in innovations					
2020	44 (29.9)	0.47	medium	1 (61.6) Hongkong	131 (2.4) Niger
2019	42 (33.5)	0.59	medium	1 (56.6) Switzerland	129 (0.4) Niger
2018	45 (36.5)	0.61	medium	1 (59.4) Switzerland	126 (0.6) Burkina-Faso

Analysis of Table 3 reveals the minimum sufficient level of external prerequisites for innovative development (2020) in both the resource, and effective components of the GII. However, separate indicators (indices), in particular, 3, 4, 5, indicate shortcomings that will obviously complicate the transition to the path of innovative development and indicate an increased risk of the transition process.

The level of innovative culture of society can be assessed according to the indicators and methodology outlined in [23]. The stage of development of the industry can be estimated by the indicators of its growth/decline.

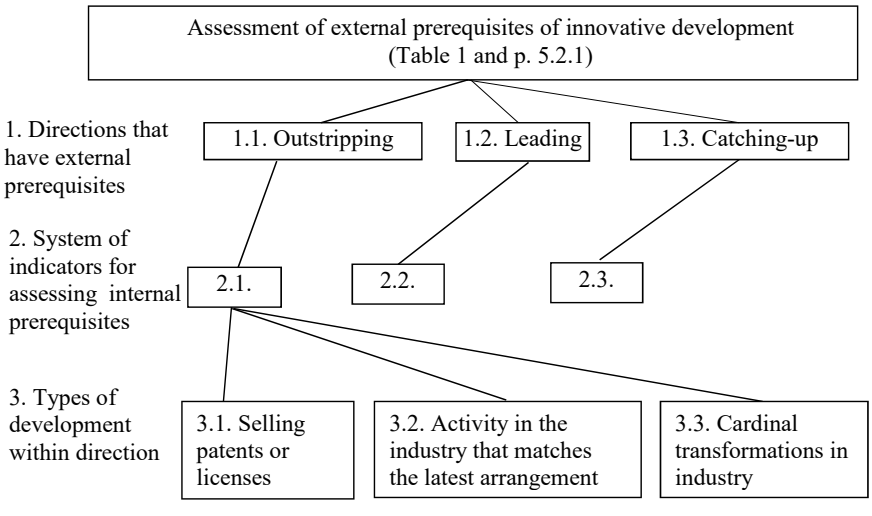

Fig. 2. Scheme of choosing priority directions of innovative development of an enterprise

5. 2. 2. Methodological principles of evaluation of internal prerequisites

Based on the results of analysis of the activities of companies that are world leaders in innovative growth [33], the directions of innovative development were detailed. It was shown that innovative development at the level of a leader (moderate-offensive strategies) includes the following types of it:

– copying and adaptation of the most successful innovations in the market;

– acquisition of external start-ups to ensure leading positions in the market;

– emphasis on organizational and marketing innovations.

The outstripping innovative development includes, respectively:

– sale of patents for innovative technical and/or technological developments created at an enterprise;

– creation and/or implementation of innovative developments in the field of enterprise activity, which lies in the course of the latest technological arrangement;

– creation and/or implementation of innovations that cause a radical transformation of the traditional industry of an enterprise or formation of a new one.

To assess the internal prerequisites and to choose the priority direction and type of innovative development, an approach, the scheme of which is shown in Fig. 2, was proposed.

At the first stage, according to the results of assessment of external prerequisites for innovative development, the possibility of implementing its specified directions is determined: catching-up, leading or outstripping. Promising directions of development are assessed and chosen according to the methodology and indicators shown in Table 3. Thus, possible strategic directions of innovative development, which are predefined based on knowledge about the problems of consumers, problems of a commodity producer, trends of the STP, are analyzed (Fig. 1). In this case, the whole set of indicators of external prerequisites is evaluated (Table 3). Specific indicators of sufficiency of prerequisites for each of the main directions of innovative development are shown in Table 3. In some cases, for an in-depth study, it may be necessary to analyze the whole set of the GII indicators (82 indicators) [17].

According to the results of assessment, it may turn out that external prerequisites for the implementation of several different or similar directions of innovative development have a sufficient level. In this case, each of them is analyzed in the sequence specified in the previous paragraph.

At the second level, a system of indicators is formed/specified to analyze the internal prerequisites for innovative development of a particular enterprise. The formed system includes:

– I_1 – marketing potential (possibility to form and stimulate demand for innovations);

– I_2 – management potential (adaptive management system, management decentralization);

– I_3 – technical and technological potential (capability to apply new technologies, using their advantages);

– I_4 – intellectual potential of personnel (qualification, knowledge, experience of personnel);

– I_5 – innovative culture (creativity, intellectual capability and psychological readiness to create, use and implement innovations);

– I_6 – complexity of innovative activity (combination of various types of innovation activity and innovations);

– I_7 – financial potential (costs of scientific and innovation activity).

The presented system of evaluation indicators was formed by the expert method taking into account the data of Table 1. Specialists of machine-building enterprises were involved as experts: LLC SPE "Techno"; LLC "Technologist"; LLC SPE "Variant-Hermotechnika"; PE "Promenergomash"; LLC "Technochim"; PF "Spetsobladnannia"; LLC "Sumy Machine-Building Plant".

The importance of indicators characterizing internal prerequisites for the innovative development of an enterprise was assessed by a scale of 1...10, according to the experts' survey. A fragment of calculations of scores of indicators is shown in Table 4.

Table 4

Calculation of indicators of internal prerequisites for innovative development of an industrial enterprise

Experts	Indicators						
	I_1	I_2	I_3	I_4	I_5	I_6	I_7
1	9	9	9	10	10	8	9
2	10	10	10	10	10	8	10
3	9	10	10	10	10	8	10
4	10	10	9	10	10	7	10
5	9	9	10	10	9	8	9
6	10	10	10	10	10	9	10
7	10	9	9	10	9	8	9
8	9	10	10	10	10	8	10
9	10	10	10	10	10	9	10
10	9	10	9	10	10	8	10
11	9	9	9	10	10	7	10
12	10	10	10	10	10	8	10
Total score	114	116	115	120	118	96	117
Average points for indicators	9.5	9.67	9.58	10	9.83	8	9.75
Deviation of average point from mean total score (d_i)	0.0243	0.1943	0.1043	0.5243	0.3543	–1.4757	0.2743
d_i^2	0.0006	0.0378	0.0109	0.2749	0.1255	2.1777	0.0752

The calculation of concordation factor, which characterizes the consistency of experts' opinions, confirms (K_y=0.67) that the results of the survey can be trusted.

To determine the significance of indicators, they are compared pairwise by the scale that is shown in Table 5.

Table 5

Scale of pairwise comparisons of indicators by significance

Relative significance in points	Estimation by serial scale
1	Indicators are equally significant
2	One indicator is more significant than the other
3	Essential outweighing of one of the indicators
4	Essential outweighing of one of the indicators
5	Absolute outweighing of one of the indicators

Table 6 shows a variant of pairwise comparison of evaluation indicators of internal prerequisites for innovative development. Comparisons are made by lines: first, second, etc. to the seventh inclusively).

Table 6

Pairwise comparison of indicators for decision-making at level 2, Fig. 2.

Indicators	Indicators						
	1	2	3	4	5	6	7
1. Marketing potential		0.5	0.33	0.2	0.2	0.25	0.33
2. Technical and technological potential	2		0.33	0.33	0.33	0.33	0.33
3. Management potential	3	3		0.33	0.25	0.33	1
4. Intellectual potential	5	3	3		1	1	1
5. Innovation culture	5	3	4	1		2	2
6. Complexity of innovation activity	4	3	3	1	0.5		1
7. Financial potential	3	3	1	1	0.5	1	

During comparison, the indicator in a line is compared with the indicators in columns (in Table 6, they are marked with numbers corresponding to the numbers in the lines). At the same time, while comparing the N-th indicator with the N+1 indicator, expert score is 3 (significant outweighing of the N-the), comparing N+1 with N, the inverse score is taken, that is, 1/3.

Weights of evaluation indicators are calculated as follows:

1. Calculate the sums of elements in the columns of Table 6 (original matrix):

S_{col}=22; 15,5; 11,66; 3,86; 2,78; 4,91; 5,66.

2. Calculate the elements of normalized matrix by dividing the original matrix (Table 6) by vector S_{col}. Construct a normalized matrix in Table 7.

3. Calculate sums of elements of a normalized matrix (Table 7) in lines:

S_{lin}=0,339; 0,514; 0,836; 1,678; 2,143; 1,453; 1,236.

4. Reduce vector S_{lin} to the standard form. To do this, each element is divided by the sum of elements (8,199):

$S_{lin.st}$=0,041; 0,063; 0,102; 0,205; 0,261; 0,177; 0,151.

Table 7

Normalized matrix

Indicators	1	2	3	4	5	6	7
1. Marketing potential	0.046	0.032	0.028	0.052	0.072	0.051	0.058
2. Technical and technological potential	0.091	0.065	0.028	0.086	0.119	0.067	0.058
3. Management potential	0.136	0.194	0.086	0.086	0.090	0.067	0.177
4. Intellectual potential	0.227	0.194	0.257	0.259	0.360	0.204	0.177
5. Innovation culture	0.227	0.194	0.343	0.259	0.360	0.407	0.353
6. Complexity of innovation activity	0.182	0.194	0.257	0.259	0.180	0.204	0.177
7. Financial potential	0.136	0.194	0.086	0.259	0.180	0.204	0.177

These are the weight characteristics of the evaluation indicators of internal prerequisites for choosing directions of innovative development of an industrial enterprise. To assess the sufficiency of their level similarly to the indicators of external prerequisites, it was proposed to use the Harrington Verbal-Numerical scale (p. 5. 2. 2).

At the third level, the alternative types of development within the specified directions are assessed by the formed set of indicators according to the procedure, which is a modification of known approaches [34]. The essence of the proposed procedure is outlined below. According to this procedure, the relative estimate of the evaluation indicators of internal prerequisites for the directions of innovative development takes values within 0...1.

5. 3. Methodical principles of choosing strategic directions of innovative development of industrial enterprises and their approbation

The large-scale block-diagram of the algorithm of substantiation of the choice of strategic directions of innovative development of industrial enterprises was developed (Fig. 3).

The developed approach was tested at the machine-building enterprise, which, among other things, produces pumping equipment for chemical production. This is mainly single and small-series production under the order of specific enterprises. The problem for the manufacturer is to find ways to reduce the production cycle and reduce the cost, which are important competitive advantages because competition in this area is very acute. The industry is at the maturity stage. Customers are interested in products that have better price/quality ratio (quality of the products themselves, their pre-sale and after-sales service, etc.).

To solve existing problems, the possibility of introducing additive production technology (industry technologies 4.0), in particular, 3D printing of working pump wheels, is considered. This allows reducing the cost of time and financial resources by replacing the traditional technology, which involves manufacturing the model and casting the workpiece, its thermal treatment, mechanical treatment, and balancing. 3D printing technology lies in the line with technologies of the 6th technological arrangement and technologies 4.0 [1], that is, the elements of the strategy of transition to outstripping innovative development are supposed to be introduced.

Alternatively, other options are considered: 3D printing of cast models, which reduces the cost of resources similarly to the first option (4.0 technology, outstripping innovative development); improvement of the pump design in order to increase its manufacturability and reduce the cost in order to occupy leading positions in the market (leadership by costs), that is, innovative development at the leader level.

Table 3 gives the idea of the external prerequisites of innovative development. However, despite the general minimum sufficient level of them, the GII indicators (indices) 3, 4, 5 GII reveal the existence of certain problems. To determine their impact, we will perform detailed analysis of individual components (sub-indices). Table 8 shows the results of detailed analysis of these indicators as of the end of 2020.

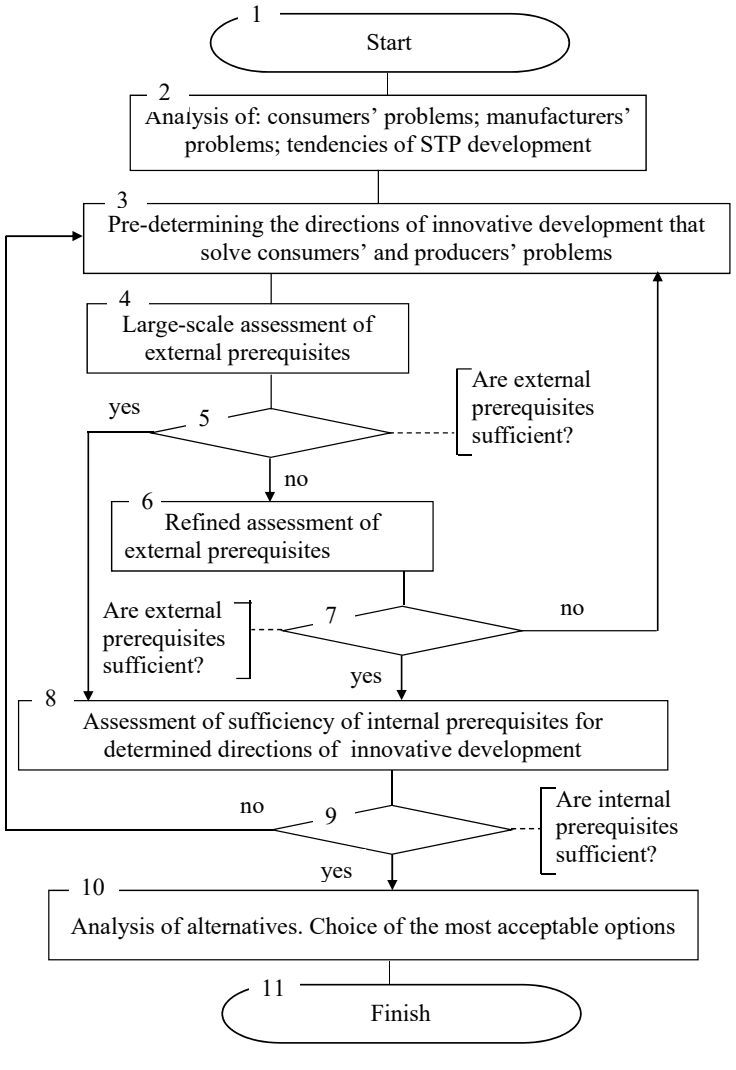

Fig. 3. Block-diagram of the algorithm for choosing strategic directions of innovative development of an industrial enterprise

Table 8.

In-depth analysis of problematic GII indicators (calculations made according to [17])

Ukraine, fact			Maximum, position and scored points	Minimum, position and scored points
Position, scored points	Normalized estimate	Level		
...	...	...	...	...
3. Infrastructure				
94 (33.1)	0.35	Low	1 Norway (64.6)	131 (16.4) Zimbabwe
3.1. Information computer technologies (ICT)				
82 (58.8)	0.56	medium	1 Great Britain (93.6)	131 (14.6) Yemen
3. 2. General infrastructure				
95 (20.2)	0.28	low	1 Mozambique (67.3)	131 (2.0) Zimbabwe
3. 3. Ecological sustainability				
99 (20.2)	0.15	very low	1 Estonia (60.9)	131 (12.8) Benin
4. Market development				
99 (42.1)	0.34	low	1 Hongkong (86.5)	131 (19.6) Ethiopia
4. 1. Credits				
86 (35.3)	0.39	medium	1 USA (89.7)	131 (0.2) Yemen
4. 2. Investments				
121 (23.8)	0.21	low	1 Hongkong (93.6)	131 (5.1) Ethiopia
4. 3. Trade. competition. market scale				
45 (67.2)	0.66	high	1 USA (90.7)	131 (21.3) Togo
5. Business development				
54 (29.5)	0.33	low	1 Sweden (68.0)	131 (10.4) Myanmar
5. 1. Knowledgeable employees				
47 (39.0)	0.48	medium	1 PRC (77.9)	131 (3.3) Myanmar
5. 2. Innovation relations				
81 (18.8)	0.22	Low	1 Israel (81.6)	131 (1.5) Niger
5. 3. Use of knowledge				
59 (30.6)	0.31	Low	1 Netherlands (68.3)	131 (14.0) Guinea

Analysis of Table 8 shows that the indicator of one of the important components of infrastructure support (ICT state) testifies to a minimum sufficient level. And this is important under conditions of the fourth industrial revolution, which is based on ICT (technology 4.0). It can be argued that there are prerequisites for innovation activity based on 4.0 technologies, even taking into account the low level of indicators of the general state of infrastructure and environmental sustainability.

Indicators of the components of the market development indicator show a high level of market potential and medium level of credit potential, which is positive from the perspectives of innovation activity. However, the low investment rate indicates an insufficient interest of investors in innovative developments.

Indicators of the components of the business development indicator shows a certain potential from the knowledge intensity of business, which is positive from the position of knowledge-oriented innovative development. However, other indicators indicate an insufficient level of demand for knowledge.

On the whole, based on the results of analysis of the results shown in Tables 3, 8, it can be argued that there are external prerequisites for innovative development, which gives chances for the success of the implementation of relevant strategies.

However, final conclusions can be drawn only after analyzing the sufficiency of internal prerequisites for innovative development of a particular enterprise (Fig. 3).

A fragment of such analysis, performed in accordance with the proposed approach by the scheme shown in Fig. 2 (two types of outstripping and one type of leading development) is shown below. To analyze alternatives, the set of indicators proposed in Table 5 was used. Relative estimates of alternatives for each of the indicators presented in Table 5 were calculated. The scale presented in Table 4 was used for the assessment. The results of comparison (similarly to the one performed in Table 6) are shown in Table 9.

Table 9

Calculation of relative scores of alternative options for innovative development

Alternative options	3D-print of a working wheel	3D-print of cast models	Improved design of the pump
1. Marketing potential			
3D-print of a working wheel	–	2	2
3D-print of cast models	0.5	–	1
Improvement of pump design	0.5	1	–
2. Technical and technological potential			
3D-print of working wheel	–	3	0.5
3D-print of cast models	0.33	–	0.25
Improvement of pump design	2	4	–
3. Management potential			
3D-print of a working wheel	–	1	1
3D-print of cast models	1	–	1
Improvement of pump design	1	1	–
4. Intellectual potential			
3D-print of a working wheel	–	1	1
3D-print of cast models	1	–	1
Improvement of pump design	1	1	–
5. Innovative culture			
3D-print of a working wheel	–	0.5	3
3D-print of cast models	2	–	4
Improvement of pump design	0.33	0.25	–
6. Complexity of innovative activity			
3D-print of a working wheel	–	0.5	2
3D-print of cast models	2	–	3
Improvement of pump design	0.5	0.33	–
7. Financial potential			
3D-print of a working wheel	–	2	0.33
3D-print of cast models	0.5	–	0.33
Improvement of pump design	3	3	–

The relative estimate of the option of innovative development (one of the three alternatives) for each of the indicators was calculated as a share of dividing the sum of scored points in a row of Table 9 of pairwise comparisons by the sum of scored points of all lines of the same Table 9 related to the corresponding indicator.

1. Marketing potential:
– 3D-print of a working wheel:

(2+2)/(2+2+0.5+1+0.5+1)=0.572;

– 3D-print of cast models:

(0.5+1)/(2+2+0.5+1+0.5+1)=0.214;

– improvement of pump design:

(0.5+1)/(2+2+0.5+1+0.5+1)=0.214.

2. Technical and technological potential:
– 3D-print of a working wheel:

(3+0.5)/(3+0.5+0.33+0.25+2+4)=0.347;

– 3D-print of cast models:

(0.33+0.25)/(3+0.5+0.33+0.25+2+4)=0.058;

– improvement of pump design:

(2+4)/(3+0.5+0.33+0.25+2+4=0.595.

3. Management potential:
– 3D-print of a working wheel:

(1+1)/(1+1+1+1+1+1)=0.334;

– 3D-print of cast models:

(1+1)/(1+1+1+1+1+1)=0.333;

– improvement of pump design:

(1+1)/(1+1+1+1+1+1)=0.333.

4. Intellectual potential:
– 3D-print of a working wheel:

(1+1)/(1+1+1+1+1+1)=0.334;

– 3D-print of cast models:

(1+1)/(1+1+1+1+1+1)=0.333;

– improvement of pump design:

(1+1)/(1+1+1+1+1+1)=0.333.

5. Innovative culture:
– 3D-print of a working wheel:

(0.5+3)/(0.5+3+2+4+0.33+0.25)=0.347;

– 3D-print of cast models:

(2+4)/(0.5+3+2+4+0.33+0.25)=0.595;

– improvement of pump design:
(0.33+0.25)/(0.5+3+2+4+0.33+0.25)=0.058.

6. Complexity of innovative activity:
– 3D-print of a working wheel:

(0.5+2)/(0.5+2+2+3+0.5+0.33)=0.300;

– 3D-print of cast models:

(2+3)/(0.5+2+2+3+0.5+0.33)=0.600;

– improvement of pump design:

(0.5+0.33)/(0.5+2+2+3+0.5+0.33)=0.100.

7. Financial potential:
– 3D-print of a working wheel:

(2+0.33)/(2+0.33+0.5+0.33+3+3)=0.254;

– 3D-print of cast models:

(0.5+0.33)/(2+0.33+0.5+0.33+3+3)=0.091;

– improvement of pump design:

(3+3)/(2+0.33+0.5+0.33+3+3)=0.655.

Then compile the decision-making table (Table 10).

According to calculation results shown in Table 10, the best option is the option with a higher value of the generalizing indicator (0.663). The value of the indicator of over 0.63 by the Harrington verbal-numerical scale shows a high level of sufficiency of internal prerequisites for innovative development. That is, the direction of outstripping innovative development, which involves 3D printing of pump working wheels, is the best. Further, in order of decreasing priority: 3D printing of cast models for casting of working wheels (medium level of sufficiency); improvement of pump design (low level of sufficiency).

Final decisions are made by comparing the best options according to the criterion of the minimum value of risk/economic result.

Table 10

Table of decisions on selection of the best alternatives of innovative development

Alternative variants	Evaluation indicators and their weights							Generalizing indicator
	Marketing potential (0,041)	Technical and technological potential (0.063)	Management potential (0.102)	Intellectual potential (0,205)	Innovative culture (0,261)	Complexity of innovative activity (0,177)	Financial potential (0,151)	
3D-print of a working wheel	0.572	0.347	0.334	0.334	0.347	0.300	0.254	0.663
3D-print of cast models	0.214	0.058	0.333	0.333	0.595	0.600	0.091	0.390
Improved pump design	0.214	0.595	0.333	0.333	0.058	0.100	0.655	0.2803

6. Discussion of the developed approach to assessment of prerequisites and choice of directions of innovative development of enterprises

The performed systematization of external and internal prerequisites for innovative development (Table 1), in contrast to the existing ones [15, 18], considers the peculiarities of the implementation of catching-up, leading and outstripping strategic directions under conditions of technological changes. This allows describing in more detail the existing prerequisites, enhancing the ground for determining promising strategic directions for innovative development of specific industrial enterprises. The results of systematization form the theoretical basis for comprehensive assessment of external and internal prerequisites for innovative development of industrial enterprises in the context of the transformation of technological processes and the fourth industrial revolution.

The proposed new methodological approach allows quantitative comprehensive assessment of sufficiency of external and internal prerequisites for the implementation of strategic directions of innovative development of industrial enterprises according to formalized procedures. These directions are catching-up, leading, outstripping, including their separate types. Unlike the existing ones, in particular [25], the new approach makes it possible to compare alternative options for innovative development according to quantitative estimates of sufficiency of their external and internal prerequisites and to choose the best reasonably.

The evaluation of external prerequisites is based on generally recognized indicators (indices, sub-indices, and their elements) of the Global Innovation Index (Tables 3, 8), which characterize the possibilities of innovative growth of the countries of the world. At the same time, external prerequisites can be assessed both on a large scale (similarly to the estimated shown in Table 3) and (if necessary) in detail. Detailed evaluation is carried out similarly to the one shown in Table 8 (by sub-indices), or with even greater degree of detailing – by the elements of sub-indices shown in Table 8.

Taking into account the capabilities of a country to produce and use relevant knowledge, as well as abilities and degree of knowledge implementation in innovative developments, can be considered as a positive side of using the indicators of the Global Innovation Index. That is, taking into consideration the possibilities of knowledge-oriented innovative development both from the position of availability of a relevant resource base, and from the standpoint of its effective implementation. It should be noted that Ukraine still has a sufficiently powerful system for producing new relevant knowledge, but their implementation does not correspond to the existing potential [35].

The proposed normalization of evaluation indicators (1) allows assessment by the unified scale, which increases the objectivity of analysis. Aligning threshold levels (ranges of assessments that characterize certain levels) of the prerequisites for innovative development and the levels of risk corresponding to them allows making comprehensive assessment considering the risk of implementing the selected options. This, in turn, increases the degree of substantiation of strategic decisions made based on the results of assessment of strategic decisions on the choice of directions of innovative development of an industrial enterprise.

According to the results of the assessment of external prerequisites (Table 3), the ones formed by methods and tools of state regulation of innovation activity were separated as most problematic. That is, the greatest risk of transition of Ukrainian industrial enterprises to innovative development (as well as the country's economy as a whole) is caused by state institutions. In this context, the projected weakening of vertical relations and strengthening of horizontal relations [1] in the course of the fourth industrial revolution, which leads to a decrease in the effectiveness of state regulation and stimulation methods, should be perceived as an inevitable undesirable reaction to the event. At the same time, the influence of international corporations on the state policy, which is already observed in many countries, including Ukraine, will actually increase. And these corporations are unlikely to be interested in strengthening their potential competitors. From these positions, it is necessary to positively evaluate the possibilities of analysis detailing according to the proposed approach of external prerequisites for innovative development. This will make it possible to outline the range of factors that contribute (may contribute) to the formation of competitive advantages. Thus, the proposed approach provides a fundamental opportunity not only to assess the existing state of things, that is, sufficiency/insufficiency of external prerequisites for innovative development. Its application allows outlining the range of prerequisites, the formation/strengthening of which should be paid attention to in the first place.

The assessment of internal prerequisites is based on expert assessment of the components of the potential of innovative development of a particular industrial enterprise (Tables 5–7) according to the proposed scheme (Fig. 2). The proposed method for evaluating internal prerequisites is adaptive and can be adjusted in accordance with the conditions of application and the specifics of the activities of a particular enterprise. In particular, in terms of clarification by experts (managers and leading specialists of an enterprise, as well as involved persons) of the composition of evaluation indicators (Table 4) and their weight. This makes it possible to use it to assess the internal prerequisites for the innovative development of enterprises in various industries, different scales of activity, oriented to different types of markets: internal or external.

The proposed methodological approach to quantitative complex evaluation of the prerequisites for the implementation of strategic directions of innovative development of industrial enterprises solves the problem of substantiation of comparing alternatives for the choice of the most promising ones.

The developed methodological principles of substantiation of the choice of strategic directions of innovative development of industrial enterprises are based on the classification of their external and internal prerequisites, as well as a methodological approach to their quantitative complex evaluation. The proposed sequence and content of procedures (Fig. 3) involves two stages of assessing the adequacy of prerequisites for the implementation of innovative development directions: external (Tables 3, 8), and then internal (Table 9). That is, the preliminary selection of directions, for which there are no external prerequisites and the choice of promising directions from those that passed the first stage (Table 10). This makes it possible to reduce time and improves the quality of selection. The proposed approach can be used for strategic management of innovative development of specific industrial enterprises, in particular, in terms of well-grounded choice/adjustment of promising directions of their innovative development. It can also be

used at the level of an enterprise to assess the adequacy of the level of components of the existing potential of innovative development in order to make appropriate adjustments. It can be used at the industry level to identify problems (in order to find ways to solve them) of sufficiency of external prerequisites for the implementation of certain areas of innovative development of enterprises of specific industries. The use of a simple mathematical apparatus, the formalized procedure for conducting the assessment, the availability of the information base facilitate the application of the proposed approach in the practical activities of industrial enterprises, mainly small and medium-sized enterprises. However, practical application of the proposed approach requires appropriate organizational support, which, obviously, will differ in these types of enterprises, which may outline the range of further areas of research.

Further research should be aimed at forming the principles of organizational and economic mechanism of management of the choice of strategic directions of innovative development of industrial enterprises, as well as the development and implementation of relevant strategies for their implementation.

7. Conclusions

1. We determined the composition and made generalizing systematization of external and internal prerequisites for the implementation of catching-up, leading and outstripping strategic directions of innovative development of industrial enterprises under conditions of changes in technological arrangements and the fourth industrial revolution. External prerequisites include components of innovative opportunities of countries, that are taken into account in the Global Innovation Index, innovative culture of entities of innovation activity in target markets, trends in the development of the industry of analyzed enterprises. For each of the directions of innovative development, the corresponding complexes of external prerequisites were determined: the minimum – for catching-up direction of development, the maximum – for the outstripping direction. The system of internal prerequisites includes components of the subsystems of the potential of innovative development of an industrial enterprise, including its innovative culture. Each of the directions of innovative development is put in line with a certain set of internal prerequisites. The performed systematization allows describing favorable/unfavorable environment and the potential of an enterprise for the implementation of the specified directions of innovative development more precisely than in existing approaches. This, in turn, provides an opportunity to increase the efficiency of strategic management of innovative development of industrial enterprises in the context of technological transformations.

2. The methodical approach to quantitative comprehensive two-step sequential assessment of sufficiency of, first of all, external and then internal prerequisites for the implementation of strategic directions of innovative development of industrial enterprises was developed. Its specific feature is the combination of the assessment of external prerequisites according to the normalized score values of the Global Innovation Index indicators with an expert assessment of internal prerequisites according to the indicators of the state of components of the potential of innovative development of the analyzed enterprise. The indicators of the Global Innovation Index sufficiently characterize the role of knowledge in ensuring the possibilities of innovative growth of a country, which makes it possible to evaluate the external prerequisites for knowledge-oriented directions of development. The use of normalized point-based assessments of indicators of the Global Innovation Index, rather than ratings, like in existing approaches, allows ensuring high reliability and objectivity of quantitative assessment of sufficiency of external prerequisites. Determining, with the use of the Harrington verbal-numerical scale, the ranges of values of quantitative estimates that correspond to the levels of sufficiency of external prerequisites and their corresponding risk levels makes it possible to assess reasonably the possibilities of implementing specific directions of innovation development. Determining the fundamental scheme and development of methodological principles of expert evaluation of internal prerequisites, including the formation of a set of evaluation indicators, provide an opportunity to evaluate their sufficiency for the implementation of strategic directions of innovative development of a particular industrial enterprise. This ensures the adaptability of the methodology for assessing internal prerequisites to the specific conditions for its use at particular enterprises.

The developed new methodological approach solves the problem of quantitative comprehensive assessment of the adequacy of external and internal prerequisites for the implementation of strategic directions of innovative development of industrial enterprises under conditions of transformations of technological arrangements.

3. The methodical approach to substantiation of a choice of strategic directions was developed and based on them – the types of innovative development of industrial enterprises. Unlike existing ones, the new approach takes into account the results of a comprehensive quantitative two-step assessment of the level of sufficiency of external and internal prerequisites. This provides an opportunity to exclude from consideration unacceptable options for development at the first stage, taking into account the external prerequisites, and concentrate the efforts only on promising ones. The peculiarity of the new approach is high reliability and validity of the choice, which is ensured by the formalized nature of the relevant procedures according to the proposed algorithm, which reflects the sequence of their implementation, as well as the criteria for making managerial decisions. This makes it possible to evaluate and select the strategic directions of innovative development of top priority from the previously determined ones, based on analysis of three complexes of knowledge of: consumers' problems, producers' problems, and tendencies of the STP. Their implementation will bring internal possibilities of innovative development of the analyzed industrial enterprise in line with external ones, which are changing under the influence of the transformation of technological processes and the deployment of the fourth industrial revolution. Accordingly, the conditions for the successful innovative growth of an industrial enterprise in the context of selected strategic directions are ensured.

The proposed new approach also allows identification of the existing problems of sufficiency of external and/or internal prerequisites, which enables us to form reasonably the complexes of measures aimed at solving identified problems.

Practical approbation of the developed approach was performed at medium-sized machine-building enterprises with small-scale and single production type that operate in

the national and/or foreign markets. The presented fragment of approbation characterizes the adequacy of application of this approach to solve the problems of choosing strategic directions of knowledge-based outstripping innovative development of an industrial enterprise that manufactures machines and equipment.

The obtained scientific and applied results deepen and develop theoretical and methodical principles of innovative management. In particular, in terms of improving theoretical and methodical approaches to assessing sufficiency of external and internal prerequisites for choosing promising strategic directions of innovative development of small and medium-sized industrial enterprises, based on its results.

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