

Development of technology for assessing the effectiveness of technological integration

Miller A.E.

Omsk State University after Dostoevsky F.M.
Omsk, Russia
aem55@yandex.ru

Miller M.A.

Omsk State University after Dostoevsky F.M.
Omsk, Russia
millerma@yandex.ru

Abstract — The article is devoted to the development of methodological tools for assessing the effectiveness of technological integration in the manufacturing sector. The background for accelerating the development of technological integration in the digital economy is summarized. A technology has been developed for assessing the effectiveness of technological integration, which consists of 5 stages and includes production and technological efficiency, organizational effectiveness and economic efficiency of integration processes.

The developed technology involves the use of 2 methods: expert analytical and calculation. As part of using the expert analytical method, it is proposed to apply an "0-1-2" rating scale, by which 10 performance indicators are assessed. The heterogeneity of indicators, the degree of significance of each of them is taken into account with the help of weights coefficients. For each indicator, examples of grounds for grading on the "0-1-2" system have been developed.

The final performance of technological integration determined by the calculation method shows the degree of approaching the level of technological integration of production entities in accordance with the tasks set.

Keywords — *technological integration, effectiveness, assessment technology, indicators, manufacturing industry.*

I. INTRODUCTION

In modern conditions of the digital economy formation, the creation of organizational, financial and legislative mechanisms ensuring the harmonization of scientific, scientific-technical, innovative, industrial, economic and social policies is being actualized. At industrial enterprises of the manufacturing sector, the importance of conducting a complex of organizational, technical and economic research aimed at identifying the problematic aspects of technological integration and moving to a new technological level, increases.

The need to promote the technological resources of industrial enterprises of the manufacturing industry has predetermined the relevance of research into the process of technological integration, since this sector of the economy remains key for national economic growth and badly needs a technological breakthrough. A fundamental change of the situation in the manufacturing industries entails the need to modernize the facilities for the production of high-tech products. Right now there is an urgent need for intrasectoral and intersectoral technological integration.

When solving the problems of transition to deep resource-saving technologies in manufacturing, it becomes obvious that there is a need to develop and implement special organizational mechanisms and assessment tools. In accordance with the trend of technologization, this occurs within the framework of the formation in the world economic

system of the sixth technological order, characterized by the development of intelligent technologies such as "smart factory", digital design of business processes.

The preconditions that "accelerate" the development of technological integration at the present stage of the digital economy formation are as follows.

In the global manufacturing sector, competition based on the so-called "technology struggle" is becoming increasingly acute.

Manufacturing technologies are becoming a resource for increased productivity and lower costs. In this regard, since a separate production entity often does not have all the necessary capabilities (production, economic) to build the entire production process chain based on advanced technology, the technological integration of economic industrial entities becomes a way to solve this problem.

The emergence of digital, mediated forms of interaction between organizations due to changes in the content of the production process and the development of information and telecommunication technologies.

Due to the active implementation of modern technical and technological solutions of Industry 4.0 level (including digital modeling, additive technologies, etc.), the structuring of the industrial sector is being transformed, various forms of cooperation and network interaction, including remote one, are developing. As a rule, such cooperation ties are mainly based on technological interaction of a greater or lesser level of integration.

Reduction of the period of technological changes in modern production.

The technological cycle in the production process is accelerating, which not only contributes to the intensification of integration processes in industry, but also requires the technological integration of production units to be able to quickly synchronize several production and technological bases and processes. The active development of digital design and modeling of new product models contributes to the formation of technological integration models on a software-digital basis. Technological integration of the future is an intelligent system for the formation of the products manufacturing chain.

Thus, technological integration, as the direction of system technologization, includes a set of mechanisms, tools and methods for practical implementation at industrial enterprises.

Accordingly, the importance of the development and implementation of special methodological tools for monitoring the technological modernization of production is being updated.

In this regard, the purpose of the article is to develop a technology for assessing the effectiveness of technological integration.

Studies of the integration processes of business entities in the economic literature are aimed at theoretical substantiation and practical decisions regarding the tools and mechanisms for optimizing the business processes in business structures in line with modern trends to the high-tech-oriented production processes.

In this part, Machula I., Khusainov B., Ilyin M., Shelomentsev A., Razmanova S., Gerasina Yu., Tsvetkov V. consider technological integration of production units, including the combination and compatibility of technological solutions, as a manifestation of national industrial policy. In this regard, the effectiveness of technological integration in many respects depends on the measures of state support of industry that are available and used by economic structures.

In turn, Valitov Sh., Proskuryakova L., Batkhin V., Klepikov Yu., Vishnevsky K. believe that technological integration creates a synergistic effect when combining business entities and integrating their resources. In addition to the expected reduction in administrative costs, synchronization of technologies is an important advantage of integration, which reduces production costs and increases productivity.

Boschma R., Dahmen A., Milner B., Hartog M., Gomtsyan S., Ivanov Yu., Arutyunova D., Davidenko L., Shelomentseva V. represent technological integration as a process of combining technologies that is a part of general integration strategy and regulator of enterprises' production activity. All this causes a periodic need to enhance the integration of technological processes and the promotion of technological resources at the level of economic entities. The point of view of the authors of this article regarding the understanding of technological integration is similar to the positions of these researchers.

In general, in the above and similar works of economists a lot of material is devoted to the study of the theoretical and methodological background of technological integration and to modern trends of its development. However, to date,

researchers have poorly developed tools that help assess the effectiveness of technological integration, which would make it possible to carry out periodic analytical monitoring of integration processes at the level of technological integration of business entities.

II. RESEARCH METHODOLOGY

The goal set in the article related to the development of technology for assessing the effectiveness of technological integration, predetermines the use of 2 groups of research methods: methods for developing technology, and methods that are proposed to be used in technology.

Research methods for technology development:

1) description method - identification of indicators characterizing the assessment of the effectiveness of technological integration;

2) grouping method - systematization of selected indicators and their division into key groups assessing the level of integration effectiveness.

Research methods for use in technology:

1) expert analytical method - experts set ratings based on the quantitative empirical analysis focused on characterizing the activities of the enterprise;

2) calculation method - the implementation of successive calculations of indicators of the effectiveness of technological integration.

The proposed technology for assessing the effectiveness of technological integration consists of several stages.

Stage 1. Allocation of indicators for assessing technological integration.

The evaluation technology under consideration offers the following groups of indicators:

- 1) production and technological performance;
- 2) organizational performance;
- 3) economic performance

Approximate versions of indicators of evaluation by groups are given in Table 1.

Stage 2. Selection of a method for evaluating indicators of technological integration effectiveness.

Evaluation of indicators is proposed to carry out on a 3-point scale, where 0 corresponds to the non-fulfillment of the indicator, 1 - partial implementation, 2 - full implementation. Since the value of each indicator of assessment is heterogeneous, it is proposed to establish weights for groups of indicators (in the sum equal to 1), then weights of each indicator within the group (see Table 1).

TABLE 1. SUMMARY TABLE OF METHODOLOGICAL MATERIAL FOR THE APPLICATION OF TECHNOLOGY ASSESSING THE TECHNOLOGICAL INTEGRATION EFFECTIVENESS

Indicators	Reasons for assessing the indicator	Weighting factor (W)	Indicator assessment (A)	A*W
Group of indicators "Production and technological performance" (T_{1,2})				
T₁ - The degree of the technological compatibility of the production equipment of integrated enterprises	(0) - the number of technological inconsistencies is significant and leads to frequent stops of the production process (1) - the number of technological inconsistencies is minimal (2) - there are no technological inconsistencies	W _{T1}	A _{T1}	W _{T1} * A _{T1}
T₂ - Degree of compliance of technological processes with the tasks of technological integration	(0) - technological processes are focused exclusively on a separate enterprise outside the tasks of technological integration (1) - technological processes are partially carried out in accordance with the tasks of technological integration (2) - technological processes are built and implemented in full compliance with the tasks of technological integration	W _{T2}	A _{T2}	W _{T2} * A _{T2}
Σ_T		0.4	ΣA_{Ti}	$\Sigma W_{Ti} * A_{Ti}$

III.RESULTS OF THE RESEARCH

Group of indicators "Organizational performance" (O_{1,2,3,4})				
O₁ – Completeness and demand for technological integration events	(0) - frequent adjustment/replacement/addition of measures for solving the problems of technological integration (1) - adjustment/replacement/addition of technological integration measures is fragmentary (2) - a high level of completeness and demand for measures, the adjustment is of a single and objective nature and does not significantly affect the solution of technological integration problems	W _{O1}	A _{O1}	W _{O1} * A _{O1}
O₂ –Meeting deadlines for the implementation of technological integration measures	(0) - deadlines for implementing measures are periodically broken down (1) - violation of the deadlines for the implementation of measures is of a single character (2) - full compliance with the deadlines for the implementation of measures	W _{O2}	A _{O2}	W _{O2} * A _{O2}
O₃ – The level of professional qualification of the measures executing staff.	(0) - selection of the measures executors did not fully meet the objectives of technological integration, as a result, in the process of implementing the measures, there is a need to complete the required competencies and/or partial replacement of the executors. (1) - professional qualification of the measures executing staff requires a fragmentary correction in terms of competences and personnel (2) - professional qualification of the executing staff is on a high level	W _{O3}	A _{O3}	W _{O3} * A _{O3}
O₄ – Provision of process integration with economic resources	(0) - the process of technological integration is experiencing a shortage of economic resources (1) - the process of technological integration is experiencing periodic failures in the provision of economic resources (2) - the process of technological integration is fully provided with economic resources	W _{O4}	W _{O4} * A _{O4}	W _{O4} * A _{O4}
Σ_o		0.3	ΣA_{oi}	$\Sigma W_{oi} * A_{oi}$
Group of indicators "Economic performance" (E_{1,2})				
E₁ – The level of use of the budget of technological integration measures	(0) - budget in fact exceeds the planned value significantly (1) - budget in fact is slightly exceeded, mainly for internal organizational causes (2) - the budget is used in accordance with the planned values or is slightly exceeded, mainly for external objective causes	W _{E4}	A _{E4}	W _{E4} * A _{E4}
E₂ – The scale of production losses after the implementation of technological integration measures	(0) - the scale of production losses remained virtually unchanged (1) - the scale of production losses has decreased (2) - production losses are close to zero	W _{E4}	A _{E4}	W _{E4} * A _{E4}
Σ_E		0.3	ΣA_{Ei}	$\Sigma W_{Ei} * A_{Ei}$
$\Sigma_{T,O,E}$		1	$\Sigma A_{T,O,E}$	N

Stage 3. Determination of the grounds for the decision to evaluate each indicator.

Table 1 recommends wording of the grounds for estimating the proposed indicators using the “0-1-2” system.

Stage 4. Selection of experts who score on indicators.

Stage 5. Evaluation of indicators, first by groups, then by the overall effectiveness of technological integration in accordance with the formulas specified in Table1.

In accordance with the developed technology, the final performance of technological integration (N), defined as the total summary value of the groups of indicators T, O and E, is also estimated by the system "0-1-2". Thus, values close to 0

indicate a low degree of performance, values that do not significantly differ from 1 - average performance, equal to 2 or close to this value - high performance of the development of technological integration.

IV.DISCUSSION OF RESULTS

The template version of the proposed technology allows business entities to adapt it to their production specifics and assessment tasks. Thus, the choice of an expert who assesses the effectiveness of technological integration can be formalized only after comparing all the characteristics of the enterprise (enterprise group), including the credibility of the

individual, reputation for objectivity of such assessments, the absence of a possible conflict of interest, etc. The same applies to the number of experts: if a decision is made to involve several experts, their assessments can be compared, the average value is derived from them, etc.

The determination of weight factors for groups of indicators also depends on the specifics of integrating production entities, the technological integration model used and the priorities set in it. Depending on the goals of technological integration, a greater weighting factor among the recommended groups of indicators may be characteristic of indicators of production and technological, and/or economic performance.

V.CONCLUSION

Thus, in the article, based on the actualization of the need to introduce the use of additional tools for analyzing the results of technological integration, a technology has been developed and described for assessing the effectiveness of technological integration. The use of the technology allows discrete monitoring of the problem areas of technological integration of economic entities, including its production, technological, organizational and economic components, and develop mechanisms for synchronizing the technological chain, whose production processes reduce costs and contribute to increasing productivity in the industrial sector of the economy.

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