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# Development of the technology for diagnostic assessment of scientific, technical and financial risks of technology integration with production systems

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**Abstract.** The paper deals with the definition and measurement of scientific, technical and financial risks of technology integration in business processes. The aim of the paper is to develop the methodological tools for the diagnostic assessment of risks as a result of technology integration with production systems. Two groups of scientific methods were used in the study. The first group (the method of logic and the method of theory construction) was used to develop the technology of diagnostic risk assessment. The second group of methods is a part of the proposed technology (document analysis, expert survey, grouping and description methods, expert analytical and calculation methods, as well as the method of expected value). These methods as an objective and subjective basis of the research are aimed at providing the qualitative and quantitative assessment of the potential events that pose the scientific, technical and financial threats for technology integration in business processes. The main results of the study are the technologically related diagnostic and evaluation steps helping to determine the risks of technology integration in the industrial sector. The paper proposes the necessary tools (methods) and discusses the expected result of their use in the written form for each stage (and sub-stage) of the technology for diagnostic risk assessment.

## 1 Introduction

The transformation of the world economic system in terms of industrial high-tech production currently sees the collaborative efforts of production entities. The result of the interaction of industrial enterprises with each other, as well as with other partners (scientific and educational organizations, service, engineering firms, etc.) is the development and implementation of a new or improved technology, (technological) solution, product. All these make it possible to increase productivity and gain competitive advantages in the market.

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Industrial enterprises are constantly searching for industry partners including foreign companies that can offer complementary resources and increase overall competitiveness.

A favorable environment for the technology integration is a result of much stricter requirements for technological solutions in modern production processes, the specific character of each component of the proposed technology and an acute shortage of professional staff to deal with each specific component. Normally, industrial enterprises do not have enough additional funds, qualified specialists, time and other resources to implement new technological solutions. Therefore, the global practice of industrial enterprises operating in the conditions of scientific and technological acceleration allows us to make a conclusion about the increasing predominance of the cooperative over the competitive interaction, the emergence of new opportunities for industrial enterprises. In general, technology integration contributes to a stabilization potential in the face of crucial technological changes and transformations in industrial sector.

It is increasingly difficult to find an enterprise that has all the necessary resources (technological reserves, subject matter experts with up-to-date competencies, financial resources, etc.) for competitive technological development of an Industry 4.0 level. Modern technological solutions are complex in terms of technical elaboration, require long-term technological resources and high initial and subsequent costs, as well as qualified human resources including those with comprehensive competencies. In addition, in the face of current competition, the speed of the development and implementation of new technologies is of great importance. In this regard, any technologically and economically limited enterprise is unable to be competitive all by itself. That makes enterprises combine efforts and resources with the partners to jointly solve urgent tasks through various forms, including technology integration.

Technology integration is viewed as systemic technologization, which includes a set of mechanisms, tools and methods to be implemented at production facilities [1].

Technological integration by itself, as in any other form of interaction, cannot be considered as success only. This is due to the various risks, primarily scientific, technical and financial arising herein. This paper deals with probable events that may affect the implementation of the technology integration project.

The issues of technological development in material production were studied in the works of John R. Hicks, E. Reinert, S. Bodrunov. Thus, John R. Hicks' model of technical progress considers technological progress as capital-efficient (increasing labor productivity), labor-saving (labor substitution) and neutral (ensuring a reduction in the amount of capital and labor based on the production of a commodity unit) [2]. On the other hand, E. Reinert views production as a driver of technological progress and national economic well-being [3]. S. Bodrunov substantiates the concept of a new industrial society of the second generation, where high-tech material production predominates in modern economies [4].

J. Nash's Game Theory and R. Coase's Transaction Costs laid the scientific background for the studies on the collaborative interaction of economic entities. Game theory considers the situations when none of the economic entities alone can improve their performance. This becomes possible only through joint efforts [5]. The theory of transaction costs confirms the long-term possibility of reducing the costs through collaborative interaction in organizing the production [6].

Klaus Schwab, the founder of the World Economic Forum, believes that as a part of the Fourth Industrial Revolution, new partnerships will inevitably emerge as the companies become aware of the importance of new forms of cooperation" [7].

Morten Hansen, a professor at University of California, who studies collaborative interaction, comes to a conclusion that interaction projects tend to "quickly come to a standstill". This is due to the unwillingness of the companies to cooperate [8]. Huston L. and Sakkab N. share a similar view. These scholars argue that most companies still adhere to the so called invention model. The companies focus on the R&D infrastructure and the idea that their development should be mainly locked within the four walls [9].

The shared idea of the abovementioned and other scholarly papers is the benefit of promoting technology integration interaction with production systems in the present context.

Boschma R., Hartog M. [10], Milner B. [11], Davidenko L., Shelomentseva V. [12] regard technology integration as a process of combining technologies. It is a part of a general integration strategy and a control instrument of a company's business processes. All these lead to the need to promote technology integration and technological resources for economic entities. The authors of this article share the point of view of the given researchers on the concept of technology integration.

Scholars sporadically analyze the issues of diagnostics risk assessment with regard to technology integration in production process in their studies. However, the works of Moskowitz S.L. [13], Knight F. [14], Yurieva L.V., Dolzhenkova E.V. [15] address certain issues that serve as a background for the intellectual development of the subject under discussion. Emerging risks are of paramount importance for the sustainable technology integration [16, 17, 18, 19].

At the same time, despite the proper theory elaboration, identification of development trends and feasibility studies, there remains a need for guidance papers on technology integration. This includes methodological tools for the diagnostics and assessment of scientific, technical and financial risks arising due to the technology integration in production processes.

## 2 Materials and methods

The purpose of this study is to develop a technology for diagnostics and assessment of scientific, technical and financial risks of technology integration in manufacturing sector. We seek to answer the following questions: what research risks of technology integration are important at this particular stage; what tools (technology) can be used for consistent diagnostic risk assessment; what methods can be applied herein.

The study employs two types of tools for monitoring technology integration in business processes.

The first tool involves the use of information and analytical systems based on the materials and data in the open sources, modern information technologies and software products.

To collect the material, we have investigated modern trends in the world economy (including intellectual specialization [20, 21, 22], technologies [23, 24, 25, 26], climate, environmental policy [27, 28, 29]). Those are the trends particular for various countries and regions with their own characteristics [30, 31, 32, 33, 34, 35, 36]. The approaches to monitoring global technological trends have been considered [37, 38, 39, 40, 41]. We have explored the global priorities of operation and technology transition in the production and economic activities of industrial enterprises [3, 4, 7, 42].

We have applied the second type of the tools for monitoring technology integration in business processes. Thus, we were able to obtain the data from the primary sources of information, i.e. the managers and specialists of industrial enterprises, as well as the data gained on the production facilities as a result of the observation. The material obtained through monitoring, expert visits, excursions to the industrial enterprises, open meetings, research and development activities in which the enterprises took part, etc. has also been analyzed. The material was restricted in use due to the requirements of industrial enterprises for confidentiality.

As the goal of the paper is developing the technology for diagnostic assessment of science and technology, financial risks of technology integration, this results in two groups of research methods. They are the methods for developing the technology and the methods as a part of the technology.

Research methods for developing the technology:
1) A method of logic implying a conceptual scheme for diagnostic risk assessment of technology integration;
2) the method of science theory construction suggesting the identification and substantiation of the stages and tools of diagnostic risk assessment of technology integration.
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Research methods as a part of the technology:
1) the method of data analysis is the study of documents and analytical expert information gained from the specialists (experts), the financial issues of technology integration in business processes in order to identify the areas of potential scientific, technical and financial risks;
2) an expert survey as a collection of subjective assessments of risks associated with highly qualified specialists required for implementing the technology integration in business processes;
3) a grouping method as the classification of identified risks and their division into the main groups (subgroups);
4) a description method implying the formulation and substantiation of the main risks of technology integration;
5) an expert analytical method as an expert assessment based on the analysis of the quantitative empirical data on the business activities related to technology integration;
6) a calculation method as sequential calculations to determine the assessment of risk probability;
7) a method of expected value as the calculation of weighted average for probable damage assessment in case of a risk event.

At the initial stage of the research, we identified the object, subject and entities of the technology of diagnostic risk assessment.

The object of the technology is the scientific, technical and financial risks of technology integration of industrial enterprises. Scientific and technical risks of technology integration are associated with a certain degree of ambiguity of research and development and feasibility results related to the entities. Moreover, financial risks might hinder budgeting the project (activities) for technology integration due to the violation of the original plan.

The aim of the technology is the diagnostic assessment of scientific, technical and financial risks of technology integration (hereinafter referred to as STF risks) of industrial enterprises. The subjects of the technology are an expert group conducting the diagnostic assessment of scientific, technical and financial risks of technology integration of industrial enterprises. The expert group may include the management members, specialists of industrial enterprises as well as external experts.

## 3 Results

Structurally, the technology consists of the two main stages (Fig. 1).

At the first stage, we deliver risk diagnostics – a comprehensive and in-depth analysis of the risks of technological integration including their identification, classification and interpretation.

Within the risk identification we specify the scientific, technical and financial risks characteristic of business processes and those likely to affect technology integration. It is noteworthy that risk identification is not a one-time process but consistent and purposeful work to monitor changes in risk impact on technology integration with production systems. The methods used to identify risks may include a method of analyzing materials and an expert survey.

Next, it is recommended to classify risks, i.e. group them by their origin (scientific, technical and financial) and further sort them out by additional criteria, if necessary. In this case, the application of a grouping method seems justified due to the fact that the method enables us to summarize the identified risks and divide them into the main groups (subgroups).

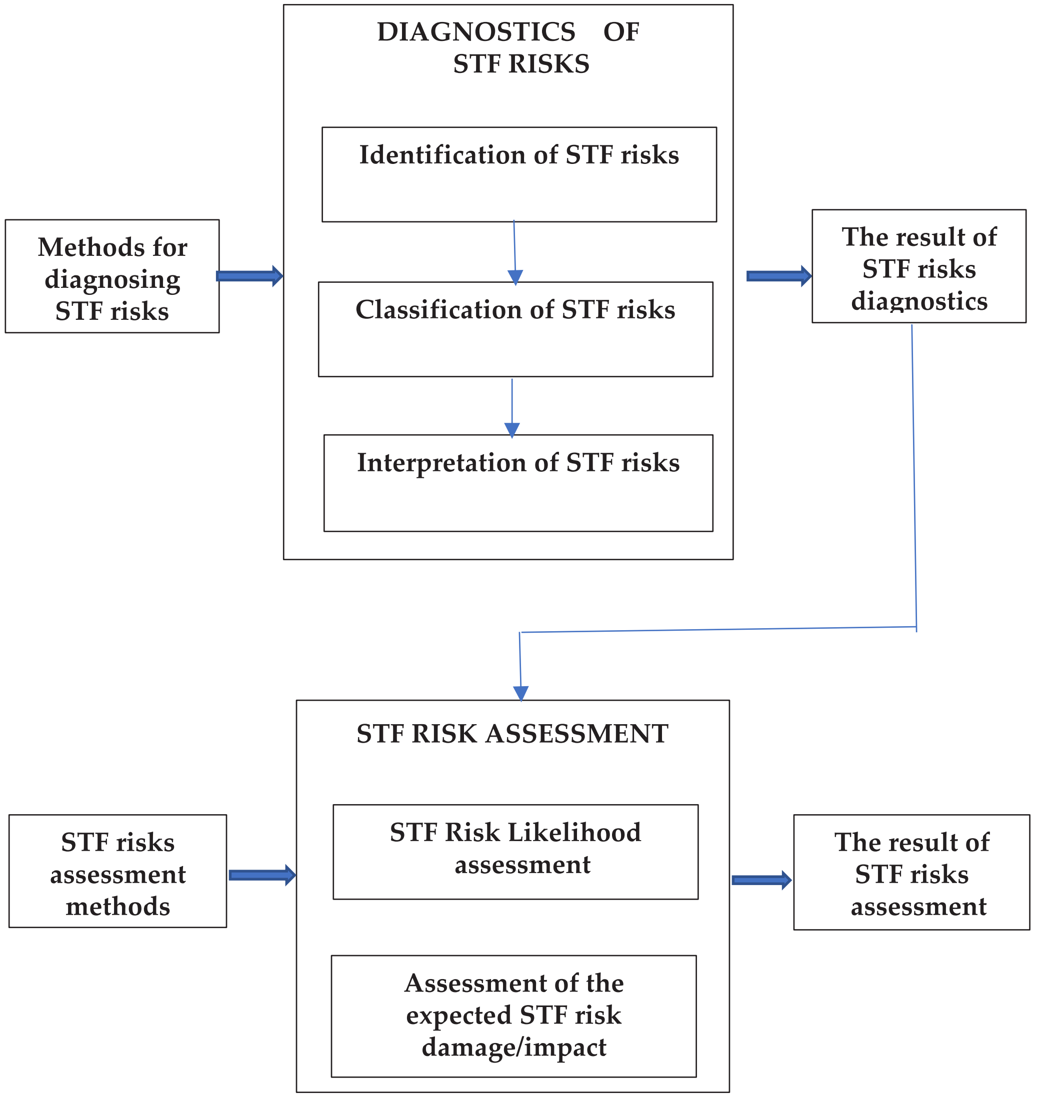


**Fig. 1.** Technology of diagnostics and assessment of scientific, technological and financial (STF) risks of technological integration of industrial enterprises (developed by the authors).

The applied research methods and materials allowed us to identify and classify the scientific, technological and financial risks of technological integration of manufacturing enterprises (see Table 1).

Finally, at the end of the first stage, it is necessary to interpret the risks – filing a detailed description of the identified scientific, technical and financial risks of technology integration of industrial enterprises. The method of description, which provides for the identification and substantiation of the type of risks of technology integration, is perfectly suitable for this task.

The result of the first stage of the technology is filing the list of the identified risks classified according to their similar characteristics and based on the nature and effects. The final list of risks is compiled, classified and described on the basis of the diagnostics of scientific, technical and financial risks of particular enterprises involved in technology integration. The following can be recommended as an option to be used as a part of the given technology.

**Table 1.** Classification of scientific, technological and financial risks of technological integration (developed by the authors).

| **Scientific and technical risks of technical integration** | |
|---|---|
| **Research and development risks** | **Technical risks** |
| - the wrong choice of a promising research area;<br>- the discrepancy between the personnel's competence and the level and scale of the assigned research task;<br>- the negative results of research;<br>- non-feasibility of positive theoretical results of research | - failure to achieve the planned technical parameters;<br>- the difficulties in ensuring compliance of the developed technology with the technical characteristics of the production facility;<br>- the extension of the terms of technology integration due to the great dependence on the resources provided by the partners (raw materials, components, etc.);<br>- the immaturity of the technology with regard to the emerging alternative technologies with competitive characteristics |
| **Financial risks of technological integration** | |
| **External financial risks** | **Internal financial risks** |
| - the increase in tax rates, insurance rates;<br>- the increase in financing costs due to the inflation and instability in the financial market;<br>- increase in the loan cost;<br>- reduced profitability of the technological integration project due to the currency fluctuations | - lack of working capital for financing;<br>- availability of credit resources;<br>- increase in the amount of overdue debts to the creditors;<br>- late budgeting;<br>- inefficient system of settlements with the counterparts;<br>- unforeseen costs due to the financial and economic condition of the enterprise and its partners;<br>- losses resulting from the financial instability of the technological integration project due to the delayed internal problems |

Scientific and technical risks can be classified into research risks, i.e. a part of technology integration at the stage of formulation, theoretical and methodological substantiation of science and innovation challenge; and the technical risks probable at the stage of practical synchronization of technologies and production facilities of the integration partners. The wrong choice of a promising research area or the non-feasibility of positive theoretical research results is an example of research risks. The difficulties in ensuring compliance of the developed technology with the technical characteristics of the production facility, or the extension of the time of the technology integration due to the high technological dependence on the resources provided by the partners (raw materials, materials, components, etc.) can be considered technological risks.

As a result of diagnostics, we propose to classify the financial risks of technology integration into external and internal ones. External risks are related to the global or national financial environment; internal risks are due to the financial and economic activities of the entities involved in integration. Basically, external risks are an increase in tax rates, insurance rates, an increase in loan cost, etc. Internal risks are a lack of working capital for financing, the unforeseen costs associated with the financial and economic condition of the enterprise and its partners, etc.

The second stage of the technology is aimed at risk assessment and includes determining qualitative and quantitative risk measurements in order to provide analytical support for further decision-making on risk leveling.

We recommend conducting expert and analytical work to assess the degree of risk probability as the initial steps of this stage. This work also involves risk prioritization, i.e. determining important and relevant risks at the moment.

The methods proposed for assessing the risk probability are:

- an expert analytical method suggesting expert assessments on the basis of the analysis of the quantitative empirical data on the activities of the enterprises involved in technology integration;
- a calculation method providing for the sequential calculations to assess the risk probability.

Next comes the assessment of the expected impact of the risk event. Such an assessment is the calculation of the expected losses of industrial enterprises involved in technology integration in case of risk event. Accordingly, we recommend applying the calculation method to address this issue.

The result of the second stage of the technology should be a final analytical document including a list of risks ranged accordingly to both their probability and the mitigation of the risk event damage. It is advisable to use a method of expected value to obtain an integral quantitative assessment of the significance and relevance of negative consequences (with risk probability and the expected impact).

The method of expected value in probability theory and mathematical statistics is the calculation of the average weighted through the probability of the value of a random variable. In relation to the tasks of this study, the expected value is the average weighted of risk impact assessment in the risk event.

The expected value formula has the form:

$$M(X) = \sum_{i=1}^{n} x_i \cdot p_i, \quad (1)$$

where: $x_i$ – value (monetary assessment) of damage in the i-th situation; $p_i$ – risk probability of in the i-th situation; n is the total number of probable situations.

Taking into account the available initial data, we get n = 2, that is, there is $p_{risk}$ - the risk probability, and $p_0$ - risk failure; $p_{risk} + p_0 = 1$.

Therefore, the model for assessing the degree of damage will have the form:

$$M(X) = x_{risk} \cdot p_{risk} + x_0 \cdot p_0 = x_{risk} \cdot p_{risk} + 0 \cdot p_0 = x_{risk} \cdot p_{risk} \quad (2)$$

Thus, in order to obtain an integral assessment of the significance and relevance of probable damage, it is necessary to calculate the product of the risk probability and the monetary assessment of probable damage (see Table 2).

**Table 2.** The calculation of the integral assessment of risk probability and monetary assessment of probable damage (see the example).

| **Risk** | **Risk probability ($p_{risk}$)** | **Monetary assessment of probable damage ($x_{risk}$), monetary units** | **Expected value ($x_{risk} * p_{risk}$), monetary units** | **Risks ranged by integral assessment** |
|---|---|---|---|---|
| A-risk | 0.3 | 2 490 000 | 747,000 | 2 |
| B-risk | 0.42 | 789,000 | 331,380 | 5 |
| C-risk | 0.85 | 1 000 000 | 850,000 | 1 |
| D-risk | 0.99 | 640,000 | 633,600 | 3 |
| E-risk | 0.6 | 810,000 | 486 | 4 |

On the basis of the above data, one can deduce that the least significant damage is expected for B-risk, and the most significant expected damage is predicted for C-risk.

## 4 Discussion

On the one hand, the material presented in this paper is a logical outcome of the previous work of the authors on various aspects of technology integration [1, 43, 44, 45, 46, 47, 48, 49, 50].

On the other hand, the studies on the technology integration in business processes and the risks in the production and economic activities of the economic entities as well as the risks arising from technical progress served as the background for developing the proposed technology. The technology is a methodological tool for diagnostic assessment of scientific, technical and financial risks of technology integration.

The study develops the theories and methodologies given in the scientific literature related to technology integration in business processes. However, the scientific novelty of the study is a methodological approach to the definition and measurement of risks arising from technology integration (scientific, technical and financial). This methodology is the given technology itself. The conducted research and the results obtained make it possible to provide the economic studies with an approach consisting in identifying the risk probability and assessing the damage in case of risk event. This will result in a more comprehensive understanding and forecasting of the most challenging scientific, technical and financial issues of the technology integration of the entities.

The results obtained lay the foundations for new directions in the studies of technology integration. These may deal with the emerging risks for the enterprise, as well as elaborating the methods for calculating such risks thus contributing to the technology integration in business processes.

## 5 Conclusions

The technology integration in business processes leads to the search for new comprehensive forms of assessing the efficiency of production activities with due consideration of probable risk factors.

To achieve the set goal, we have developed a technology for diagnostic assessment of scientific, technical and financial risks of technology integration in production processes. Identifying and classifying scientific, technical and financial risks of technology integration with

production systems makes it possible to increase the predictability of technical and technological interaction of the entities and reduce the amount of unexpected restrictions and obstacles.
However, the identified scientific, technical and financial risks of technology integration in business processes are not universal and the only possible ones. They can and should be managed though considering the economic and technological changes which the subjects of the integration may face in the future.
Any enterprises of industrial sector can apply the given technology. At the same time, it is necessary to adapt the developed technology to a particular industry (mechanical engineering, chemical industry, etc.) and to specific industrial enterprises with their own characteristics.
Another important issue is a careful selection of the experts for the particular stages of the technology. Undoubtedly, the group of these experts should include external consultants, whose opinion can be very valuable for decision making.
The technology is easy to use and does not require significant resources. The given technology may be of interest to industrial enterprises involved or planning technology integration. The technology is valid when it is necessary to apply a particular approach to achieve sustainable technology integration in risk events.

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