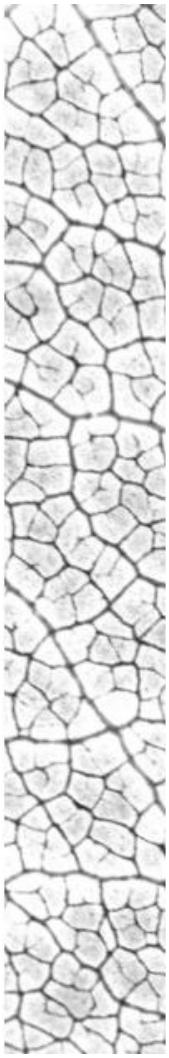

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Cooperation as an effective form of transition of industrial enterprises to the concept of "Industry 4.0"

Alsu A. Lubnina [1*], Lyudmila N. Abutalipova [1], Marina V. Shinkevich [1], Indira G. Salimyanova [2], Oksana N. Kiseleva [3]

[1] Kazan National Research Technological University, Kazan, RUSSIA
[2] St. Petersburg State University of Economics, St. Petersburg, RUSSIA
[3] Saratov State Technical University named after Y.A. Gagarin, Saratov, RUSSIA
*Corresponding author: alsu1982@yandex.ru

Abstract
One of the most promising forms of industrial enterprises effective transition to the concept of "Industry 4.0" is cooperation. The paper proposes a methodology for assessing the development level of industrial enterprises, thus allowing to calculate the integral indicator "Industry 4.0", consisting of three components: indicators of levels of digitalization, eco-efficiency, and resource efficiency. This monitoring method of the production level organization on the basis of new management principles allows to identify and track problem areas in the Industry 4.0 triad of an industrial enterprise sphere. Also, the article provides an overview of modern forms in industrial enterprises cooperation, their effectiveness assessment in types of activities and reveals a close relationship between the enterprise industrial development level and cooperation in the creation of SEZs and industrial parks.

Keywords: cooperation, "Industry 4.0", eco-efficiency, resource efficiency, digitalization, industrial enterprises

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INTRODUCTION

To ensure industrial enterprises effective transformation to the concept of "Industry 4.0", management decisions development based on assessment monitoring of its level becomes relevant. In this regard, there is a need to develop new management principles for production level of organization to allow identifying and tracking problem areas in industrial enterprise Industry 4.0 triad such as assessing the level of digitalization, eco-efficiency and resource efficiency.

At the same time, due to limited resources the transition to the concept of "Industry 4.0" within the framework of one enterprise activities could be ineffective or even impossible. Organizational structures and production processes of enterprises cooperation with ventures of related industries, educational, research organizations, allows solving the problem of non-optimal use of the potential of these organizations.

The task of public administration in these conditions is to search for mechanisms and tools to stimulate uncoordinated resources system consolidation into a single production complex to make sure the flexibility and adaptability of production systems in the context of changing market and political conditions. In this regard, the tasks of cooperation are becoming development driver, providing a quick transition to new economic conditions. By combining various factors and competencies of uncoordinated elements system, cooperative mechanisms allow optimizing the costs of resources for all participants, ensuring maximum results (Levina et al., 2019). The task designation determines not only the search for integration mechanisms, but also the determination of methods that are adequate to the current parameters of the infrastructure environment, the formation of which has a systemic nature. In this context, human resource becomes the weak point, that demonstrates a persistent shortage of qualified staff that meets modern level production system requirements, demanding not only high qualification level in the tough competencies of the professional field, but also the development of "soft" complex competencies, the formation of which is impossible on the basis of institutes of vocational education in isolation from practice in solving production problems. In this regard, the basis for production system sustainable development is the triad: the state, industry and universities, which, through close integration, form a unified system.

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In this context, an appropriate scientific task is to research and modernize cooperation mechanisms to ensure interaction of all elements at a high efficiency level for the purpose of moving to the Industry 4.0 path, based on relevant theoretical and practical concepts systematization. This topic, characterized by technical and technological processes complexity, integrated product supply chains and the presence of network interactions between the participants in the technological chain, is of particular value for production.

LITERATURE REVIEW

The following works are devoted to the considered research topic: E.S. Andreeva et al. (2015) «Enhancement of Performance of Infrastructural Assets Built through a Public and Private Partnership», A.N. Dyrdonova (2016) «Methodological approach to evaluation of clustering potential and efficiency improvement management for development of the regional industry clusters», A.N. Dyrdonova and T.S. Lin'kova (2019) «Principles of petrochemical cluster' sustainability assessment based on its members' energy efficiency performance», N.U. Fomin et al. (2017) «Cluster-based model of socioeconomic and innovative development of regions», A.A. Lubnina and M.V. Smolyagina (2016), «Concerning the environmental marketing of waste management in the context of sustainable development», A.A. Lubnina et al. (2018) «Innovative strategy for improving the efficiency of industrial enterprises management» A.I. Shinkevich et al. (2016) «Formation of network model of value added chain based on integration of competitive enterprises in innovation-oriented cross-sectorial clusters», A.I. Shinkevich et al. (2019) «Reserves for improving the efficiency of petrochemical production on the basis of «Industry 4.0».

METHODOLOGICAL FRAMEWORK

Statistical Base of the Study Description

The paper proposes a methodology for assessing development level of industrial enterprises, allowing calculating the integral indicator "Industry 4.0" and consists of three components: indicators of digitalization level, indicators of eco-efficiency level, and indicators of resource efficiency level.

Assessment of digitalization level (Id) includes the following indicators:

- innovative enterprise activity, %;
- share of innovative products in the total volume of products,%;
- innovative products introduced over the past three years, million rubles;
- the number of fundamentally new technologies, units;
- the number of fundamentally new technologies used, units;
- the number of acquired new technologies, software, units;
- expenses for technological innovation of organizations, million rubles.

The assessment of eco-efficiency level (Ie) includes the following indicators:

- emissions of air pollutants, thousand tons;
- capture and pollutants neutralization, thousand tons;
- discharge of contaminated wastewater, mln. meters;
- waste, million tons;
- use and disposal of waste, million tons;
- investments aimed at nature conservation, million rubles;
- current expenses for nature protection, million rubles.

The assessment of the level of resource efficiency (Ir) includes the following indicators:

- coefficient of renewal, disposal, depreciation of fixed assets,%;
- investments in fixed assets, billion rubles;
- production indices, in% to the previous year;
- production volume, million rubles;
- profitability,%.

Let's consider the algorithm for calculating the integral indicator Industry 4.0 (I4.0), which consists of three components: indicators of digitalization level(Id), indicators of eco-efficiency level(Ie), indicators of resource efficiency level (Ir). Aggregated indicators Id, Ie, Ir are calculated as the sum of the listed indicators. Due to the fact that these indicators have different dimensions, when calculating the Industry 4.0 indicator, they are normalized.

Therefore, I4.0 is defined as the sum of the indicators with the corresponding weights:

$$I4.0 = \sum_{i=1}^{n} (I_i * N_i), \quad (1)$$

where I4.0 is the Industry 4.0 indicator; Ii - aggregated indicator (Id, Ie, Ir); Ni is the relative weighting factor; Id - indicator of digitalization level; Ie - indicator of eco-efficiency level; Ir is an indicator of resource efficiency level.

The calculation of the aggregate indicator "Industry 4.0" helps to identify the most advanced types of activities, including: production of other vehicles and equipment (I4.0 = 0.55), production of finished metal products, except for machinery and equipment (I4.0 = 0, 54), production of machinery and equipment (I4.0 = 0.53). The lowest indices of the aggregate Industry 4.0 indicator are demonstrated by the following activities: production of other non-metallic mineral products (I4.0 = 0.33), wood processing and wood products production

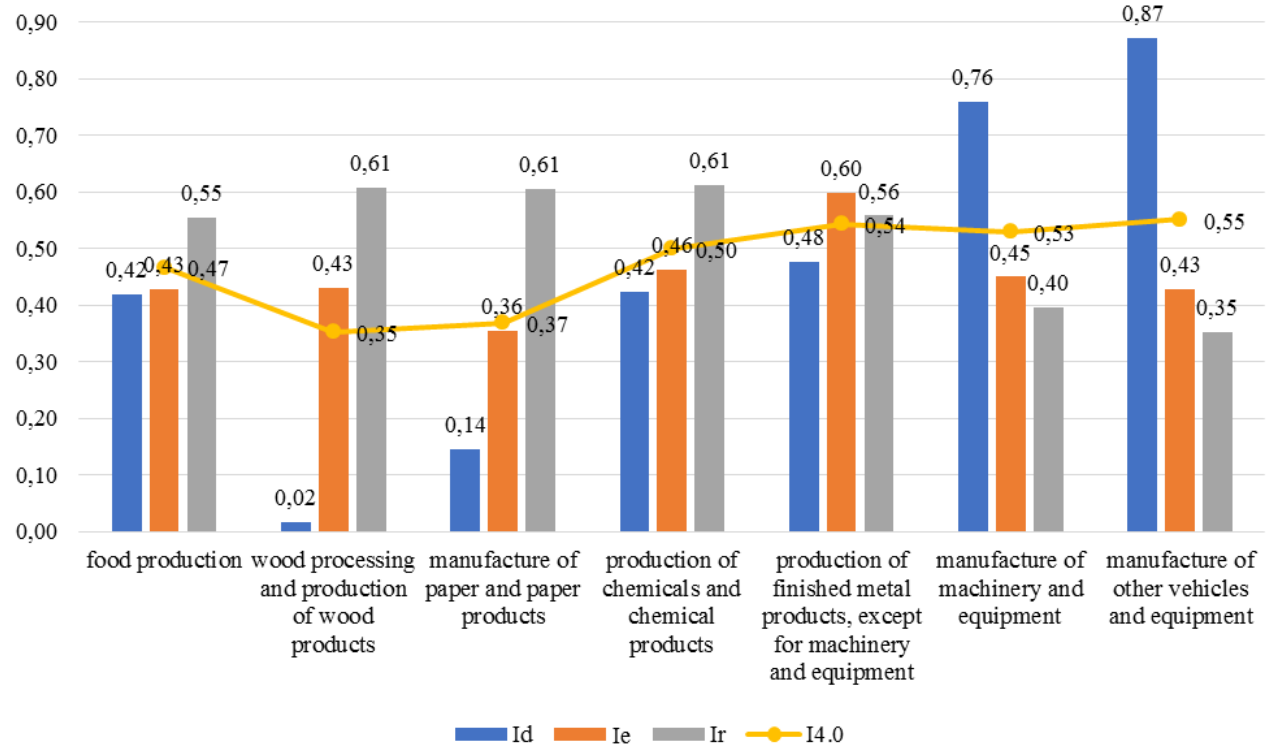

Fig. 1. Aggregated Industry 4.0 indicator by type of activity in 2018

(I4.0 = 0.35), paper and paper products (I4.0 = 0.37). Low values are primarily due to low rates of enterprises digitalization in these types of activities. The development of management decisions based on the use of various forms of cooperation is becoming especially relevant for the process of industrial enterprises effective transition to the concept of "Industry 4.0".

Research Methods

The article uses descriptive statistics method in investment attractiveness assessment of industrial parks and SEZs in the context of activities.

The paper proposes a methodology for assessing development level of industrial enterprises, allowing calculating the integral indicator "Industry 4.0", which consists of the three components: indicators of the level of digitalization, indicators of the level of eco-efficiency, indicators of the level of resource efficiency.

Comparative analysis helps to determine the relationship between the aggregate indicator "Industry 4.0" and the share of investments in SEZs by type of activity.

RESULTS AND DISCUSSION

Modern Forms of Cooperation of Industrial Enterprises

The concept of "Industry 4.0" has a significant impact on the nature of industry functioning, determining the need to take into account digitalization, technological and economic indicators in the production process. In the current conditions, cooperation development between participants of production process in the context of the three noted elements determines the competitiveness of industries and their viability.

Cooperation allows not only to improve production systems efficiency, but also significantly affects the overall sectorial level of development through the intensification of inter-sectorial interaction and limited investment and intellectual resources optimization of the distribution which makes it possible to increase the production level of investment-limited facilities. **Fig. 2** provides an overview of the main modern cooperation forms between industrial enterprises, science and education, as well as their definitions.

The transition to the path of "Industry 4.0" requires a reorganization of not only infrastructural factors, but also efficiency priorities revision and criteria for their assessment. The existing mechanisms and tools for assessing enterprises development are unable to form a set of necessary information for making high-quality management decisions on production systems development at the level of individual, regional and sectorial enterprises production clusters and complexes in these conditions. Having considered the modern forms of cooperation between enterprises, we will examine their effectiveness in the context of types of economic activity.

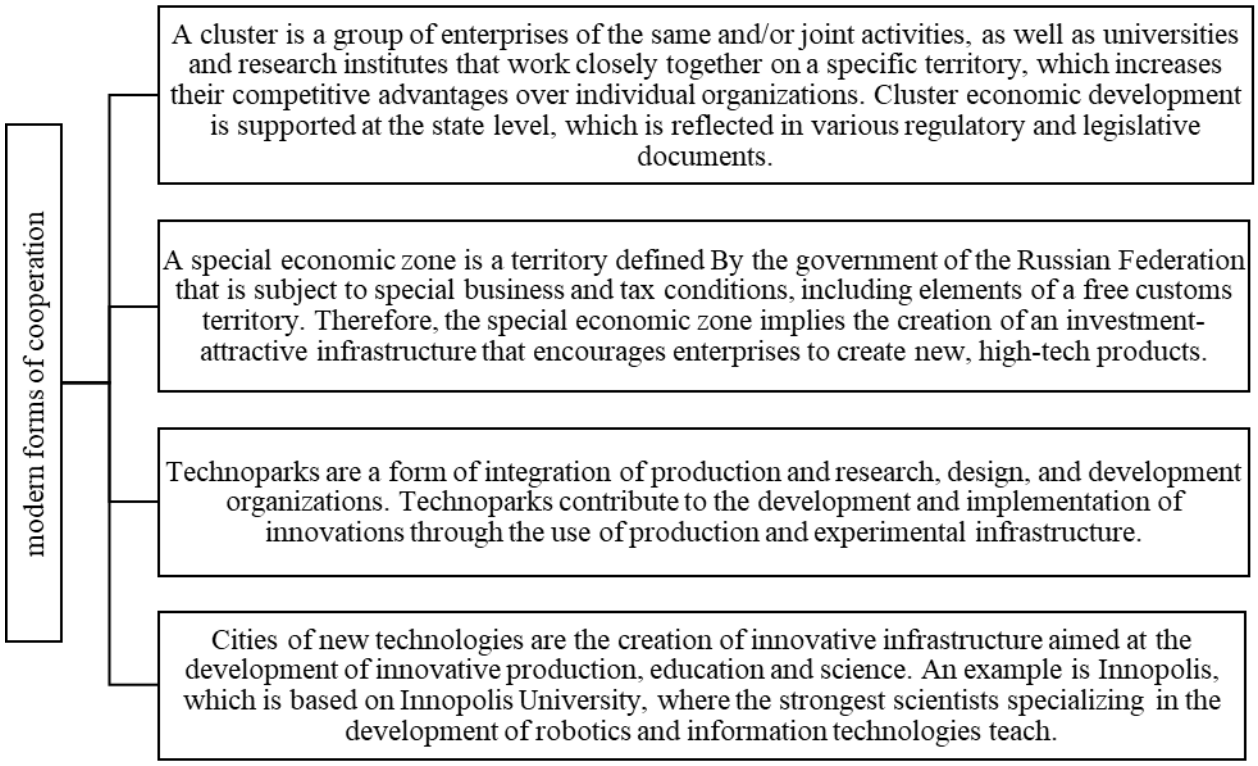

Fig. 2. Modern forms of cooperation

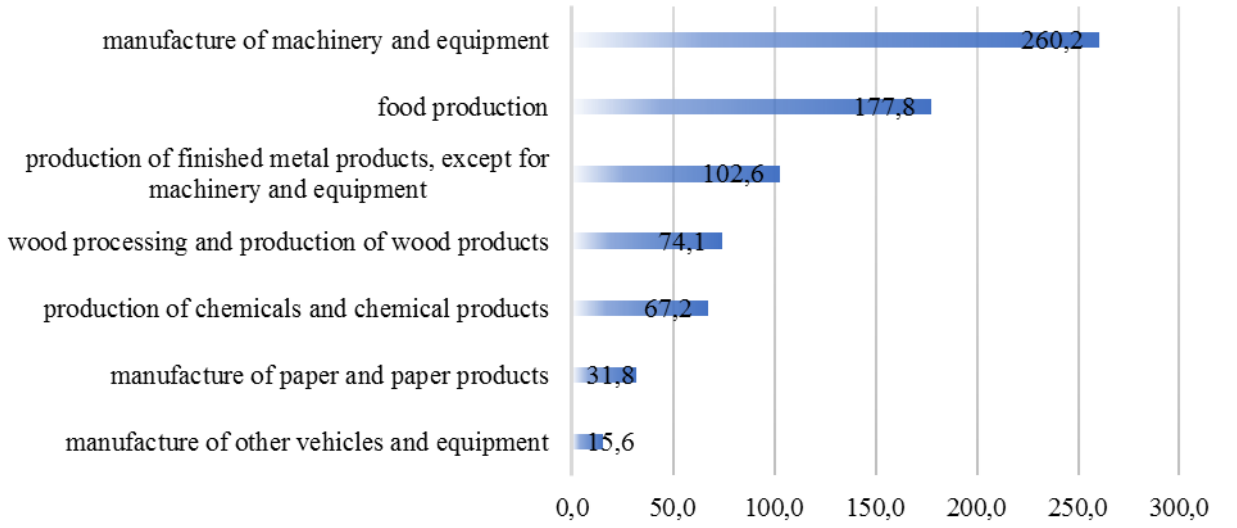

Fig. 3. Investments in industrial parks and SEZs by type of economic activity, billion rubles (data from Rosstat, 2020)

Analysis of the Effectiveness of Modern Forms of Cooperation in Russia

Considering the efficiency of industrial parks in the SEZ of Russia, there was an increase in the number of new residents, namely 2,882 enterprises became part of industrial parks, which attracted 1.2 trillion. rubles of direct investments in 2018. The occupancy rate in 2018 approached 60%. Between 1998 to 2018 more than 1217 billion rubles were invested in the creation of 227 industrial parks and special economic zones of industrial and production significance. 498 billion rubles out of this number are accounted for by domestic enterprises, and the participation of Germany, the USA, Japan and Turkey is also significant (Association of Industrial Parks, 2019).

Let us consider the investment attractiveness of creating industrial parks and SEZs for enterprises of various types of activities that are shown in **Fig. 3**. Thus,

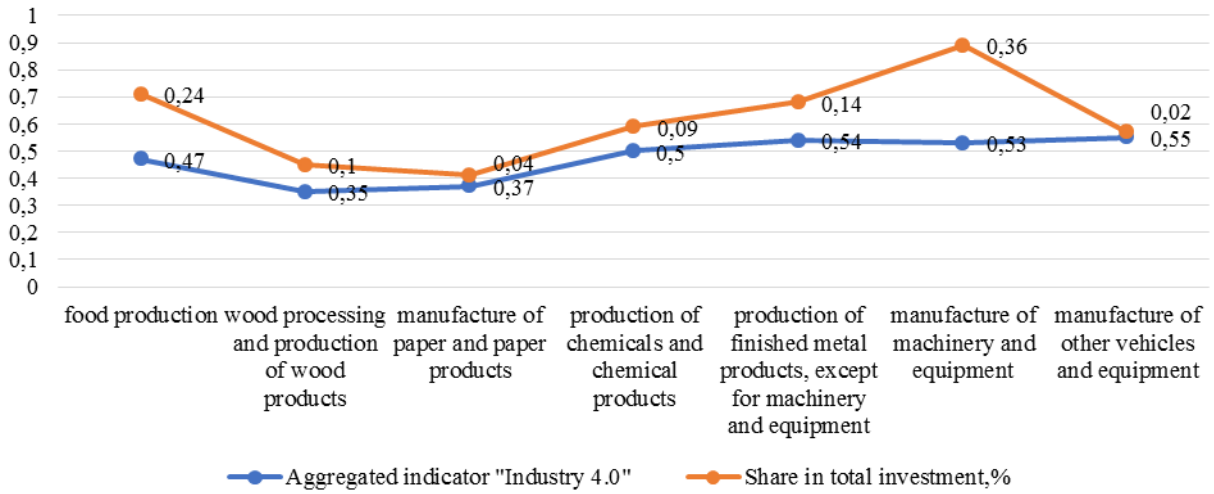

Fig. 4. Aggregated indicator “Industry 4.0” and the share of investments in SEZs by type of economic activity

in the types of activities taken into consideration, the largest volume of investments falls on the production of machinery and equipment - 260.2 billion rubles, on the production of food products - 177, 8 billion rubles, for the production of finished metal products, except for machinery and equipment - 102.6 billion rubles, for wood processing and the production of wood products - 74.1 billion rubles, for the production of chemicals and chemical products - 67.2 billion rubles. The least interest among investors is caused by enterprises producing other vehicles and equipment - 15.6 billion rubles and the production of paper and paper products - 31.8 billion rubles.

Analysis of **Fig. 4** helps to identify the relationship between investments in the creation of SEZs and industrial parks and the development level of enterprises within the framework of the Industry 4.0 concept. Consequently, for an increase of digitalization, eco- and resource efficiency levels of industrial enterprises, it is more productive to cooperate between enterprises in the field of creating industrial parks and SEZs.

CONCLUSION

The current development level of production systems determines the high degree of importance of active interaction between participants in the production chain. High degree of industries specialization requires significant efficiency of such interaction, which is especially important in the context of increasing competition from imported industries. At the same time, high complexity of production technologies requires significant number of enterprises participation in the implementation of the production process. This task is even more complicated in the context of innovative design and implementation, where the degree of cooperation determines not only the success, but also the viability of the innovation process.

The article proposes a methodology for assessing the aggregated indicator “Industry 4.0”, consisting of three components: digitalization, eco-efficiency, and resource efficiency levels, and also provides calculations between the economic activity types. The calculation of the aggregated indicator “Industry 4.0” helps to identify the most advanced types of economic activities, including: production of other vehicles and equipment, production of finished metal products, except for machinery and equipment, as well as activities with the lowest indicators: production of other non-metallic mineral products , wood processing and production of wood products.

The study demonstrates the importance of industrial enterprises cooperation and considers its modern forms, analyzing the effectiveness of their activities, and allowing us to come up to the following conclusions. Industrial parks and SEZs in the production of machinery, equipment and food production demonstrate high indicators of investment attractiveness, low indicators in enterprises producing other vehicles and equipment and the production of paper and paper products.

Related industries enterprises cooperation, educational, and research organizations help to stimulate transition to the concept of “Industry 4.0”, and contributes to synergistic effect emergence that is impossible with an independent production organization.

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