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Audit of Intellectual Capital at an Industrial Enterprise: Open Data Analysis Digital-Model

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Abstract. Intellectual capital determines the strategic competitiveness of enterprises in any industry, but there are still no universal approaches to managing intellectual development in the corporate environment. The functioning of the industrial complex is associated with the active use of intellectual resources. This article discusses the assessment of the intellectual capabilities of enterprises based on audit and digital transformation. The article aims to create a model for auditing the intellectual capital at the industrial enterprise focusing on digital analysis of data from open sources. The object of the article is the intellectual capital of industrial enterprises. Within the framework of the study, a mechanism for evaluating individual components of intellectual capital was developed, taking into account their significance for industrial enterprises. Audit activities will make it possible to identify problem areas and improve the efficiency of managing specific knowledge and resources. The study is based on the digital analysis of corporate enterprise reporting for auditing. The authors believe those audit activities will facilitate the formation of new approaches to identifying bottlenecks in the field of industrial intellectualization. The research resulted in the determination of a number of coefficients, on which it is proposed to build an integral assessment of the intellectual capital of an enterprise and develop recommendations for resolving problems to ensure the intellectual growth of an enterprise.

Keywords: Audit activities; Industrial production; Innovative development; Intellectual capital; Intellectualization

1. Introduction

Intellectual capital management (hereinafter referred to as IC) is imperative for the effective development of economic entities. Intellectualization embraces the dynamic relationship of organizational learning, innovation, skills, competencies, experience and knowledge (Sarlija & Stani, 2017). The functioning of a modern enterprise is impossible without IC. The evolution of business in the information space has led to an increase in the importance of the intellectual component, while the financial and industrial aspect is left in the background (Xia, 2010). Such approaches lead to an expansion of ways to maintain competitiveness based on the practical use of intellectual resources (Klein, 2009). Intangible values have acquired a basic role in the functioning of business structures,

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determining the relevance of research in the field of studying the issues of intellectual efficiency (Roy, 2013). The relevance of studying the processes of creating intellectual efficiency in the business environment is growing. Over the past decades, the emphasis on creating an effective organizational structure has shifted towards human resource management and the continuous reproduction of knowledge.

At the same time, the assessment of the knowledge structure is a complicated process since there are some implicit factors that are difficult to take into account in the innovation policy of enterprises (Edler & Fagerberg, 2017). Objective trends in various segments of the national economy raise the question of the need to develop methods for assessing IC. Despite the importance of intellectual resources, there are still no universal approaches to managing intellectual development (de Pablos, 2020). Thus, the scientific problem lies in the lack of methods for assessing IC.

The object of the study is the IC of industrial enterprises. It is advisable to focus on industrial enterprises, as they act as drivers of economic growth. In this context, the justification of the efficiency of industrial production is of interest, which is largely due to the use of intellectual resources that contribute to increasing the intensity of production.

It is proposed to use a methodological apparatus to determine the indicators for calculating IC based on a digital analysis of corporate reporting available in the public domain. These methods include auditing. The study also uses the method of intellectual capital assessment and the method of coefficients. The authors of this study propose to expand the apparatus for managing the intellectual capabilities of the company using the technologies of auditing. The purpose of the study is to consider the possibilities of conducting an IC audit, focusing on the features of industrial production. To achieve this purpose, a system for evaluating individual elements of IC, with an emphasis on their importance for industrial enterprises, was devised.

Conflicts in the business environment have a negative impact on its development. The contradictions between owners and managers affect the enterprise management system, pushing the vector of its development away from intellectual trajectories (Shadova et al., 2016). Unfortunately, this practice is common in business, and certain efforts are required to identify negative trends. In particular, the IC audit technology using digital tools makes it possible to identify many problem areas.

Audit services today are becoming increasingly popular, which affects many industries. A smart audit can provide information on assessing the potential benefits of acquiring intellectual property rights (Nikzad, 2015). Based on the assessment of intellectual resources, economic entities are able to develop effective strategies to increase the level of innovation with an acceptable complication of their intellectual development system.

The analysis of reporting documents reveals the relationship between intellectual property and the competitive advantages of a business. The strongest correlation is observed in high-tech industries, for example, in the field of IT (Roy, 2013). At the same time, in high-tech companies, it is much easier to analyze explicit and implicit knowledge and develop recommendations for enhancing the most significant factors in creating intellectual efficiency (Zheng et al., 2009).

The COVID-19 pandemic contributed to the transformation of economic and social processes, ensuring the ongoing promotion of digitalization in all areas of business and the acceleration of intellectual growth in the business environment. Enterprises generate information resources, contributing to the development of new tools for auditing intellectual elements (Rodionov et al., 2021). The acquisition of knowledge can be considered like an asset and a potential component of the efficiency of an enterprise and its competitive advantages. In production and economic activities, a strategic potential is

formed on the basis of the intellectual factor, the effective management of which has already become a generally recognized factor in improving the financial performance of business entities (Santos-Rodrigues et al., 2012).

Industrial enterprises are developing their innovative activity and determining the coefficients to assess the effectiveness of development, taking into account their technological support. The availability of adequate economic and mathematical methods makes it possible to identify areas of development and growth in the innovation environment, and IC plays a significant role in achieving strategic innovation objectives. This practice is typical for many important industries, such as engineering and metallurgy (Savchenkov et al., 2020). For some industries, knowledge resource is an important element in modernizing production capabilities and in finding ways to optimize value-creation processes. The studies confirm that modernization is constrained not only by innovative factors but also by investment factors. For example, agriculture is forced to find ways of technical modernization, but it does not have sufficient potential to build an intellectual development strategy (Kiritsa et al., 2021; Chahal et al., 2020). The result of these problems is the intellectual inefficiency of this industrial sector.

The sector intellectual inefficiency is determined by the authors of the study as a set of problems related to intellectual development that is characteristic of a particular sector of the national economy. These problems are most obvious in the industry, represented by many sectors and manufacturing enterprises, which makes it possible to prepare a sufficient array of data to study problem areas and build high-quality digital models.

Sector intellectual inefficiency can seriously distort data when calculating quantitative and qualitative indicators in IC assessment; however, when comparing enterprises in one sector, it becomes possible to identify average sector values (it is recommended to take the median value) and develop relative models to identify problematic characteristics. IC audit in this context makes it possible to calculate all the necessary coefficients to compare enterprises, ignoring sector-specific information gaps that prevent obtaining an objective picture. Digital models based on the proposed algorithms allow for accelerated calculations of the values that were selected in the indicators according to the developed methodological framework (Zaytsev et al., 2020b; Burova et al., 2018).

Achieving the success of an industrial complex in a competitive business environment is impossible without IC. This statement is supported by many studies. The article of Sarlija & Stani (2017) examined the relationship between IC and enterprise's sustainable growth. A positive dependence of enterprise growth on human and organizational capital was revealed. The article of Bril et al. (2018) highlighted the complication of the mechanisms for the formation of financial and economic indicators through the use of intellectual factors.

These conditions determine the improvement of the methodology of financial and economic assessments, focusing on the new structures of innovation risk. Researchers confirm that for the sustainable development of an industrial enterprise, it is necessary to take into account not only financial and production aspects but also to form a basis for managing human resources, including their intellectual derivatives, which are the basic element for increasing labor productivity.

A variety of approaches to determining the essential structure of IC creates a solid ground for the development of a set of measures aimed at facilitating the intellectualization of labor and diversification of mental activities (Kuzmina et al., 2020; Nadtochiy & Budovich, 2018). The role of IC in the innovation-digital economy gives rise to the need for an in-depth study of the processes of the development and application of IC in key sectors of the national economy. In industrial production, the intellectual property of the company and the potential of R&D results play a special role. However, the measurement of

intellectual property does not fully reflect the problems of IC. Therefore, for an extended assessment, it is advisable to conduct timely monitoring and auditing, which cannot be done without digital tools (Teng, 2007).

Audit activities allow us to assess the strengths and weaknesses of the enterprise, as well as to provide information on the potential opportunities and problems of innovative development based on digital analysis (Vlasova et al., 2021; Yoon et al., 2015; Zhixiong & Yuanjian, 2010). IC audit is focused on providing operational assessments by independent experts through digital analysis of corporate reporting. As a result, bottlenecks in the IC management system are identified, and recommendations are developed for their correction.

Based on the analysis of theoretical materials, the following conclusions can be drawn: *Audit activities need to be improved due to the increasing importance of information and knowledge as factors of production and the inclusion of auditing in the company's intellectual growth system; Audit activities can identify the problems of enterprise development and specify the areas of contact between industrial production and the specialized information sector of the economy; Audit activities are aimed at rationalizing the use of labor with the involvement of intellectual resources since they increase the importance of IC elements to achieve the efficiency of the enterprise.*

The unresolved problems associated with the assessment of IC in the industry open up opportunities for adapting new approaches to their study, and audit activities based on the use of corporate reporting allow us to identify bottlenecks and potential opportunities for improving the efficiency of managing knowledge and resources of the subject. The key goal of the study is to consider the methodological possibility of conducting an IC audit based on the calculation of the selected coefficients that fully reflect the intellectual development of industrial enterprises.

It should be noted that in the process of auditing IC, a basis is formed for the digital analysis of its components. Information from this database can be further used to develop and implement strategic proposals. IC audit may include the following elements: assessment of the IC value of an enterprise by the methods tailored to the requirements of external and/or internal users that are in line with business goals; development of proposals and business ideas for rational HR management, focused on increasing the return on available human capital; development and implementation of effective motivational models in the economic activities of the business; reducing the cost of staff incentives while maintaining the current performance standards; increasing the level of labor productivity.

2. Research Methodology

The significance of the IC audit is increasing due to the need to develop and implement strategies for achieving high rates of innovative development, which allows us to consider various algorithms for conducting audit activities. As a result, it is possible to develop recommendations for improving productivity, optimizing costs, motivating employees, as well as identifying corporate opportunities for IC development. Since the IC audit is targeted at the analytical identification of the necessary resources for carrying out intellectual changes, it is necessary to conduct a comprehensive assessment of IC, which will provide data on problem areas in the functioning of the enterprise and managing personnel and labor knowledge and resources. For example, in scientific practice, there are the following dominant methods for assessing IC: direct assessment methods; market capitalization methods; yield-based methods; assessment methods based on a system of indicators, including non-financial indicators. However, the limited and incomplete

information prevents the above IC estimation methods from being used effectively (Chahal et al., 2020; Mupepi, 2017).

The universal methodology for assessing IC has not been developed yet. When considering IC, the emphasis is often placed on its innovative component. The intensification of innovative activity in the industry is a condition for the creation of IC, aimed at eliminating threats and instability of the economic environment through developing innovative technologies, releasing innovative products and introducing innovative processes. For example, the article of Asaturova and Kochman (2020) analyzes the factors affecting the innovative activity of an enterprise and determines the conditions for the development and reproduction of its innovative potential. Also, the researchers highlight the role of human capital in creating intellectual business opportunities.

Thus, the article (Azarenko et al., 2020) discusses the structure of human capital and evaluates the effectiveness of tools for its development. The emphasis is made on available financial information, which is suitable for independent auditing. In the work of Suleimankadieva et al. (2020) approaches and methods for assessing IC business are systematized, paying attention to improving the structural approach based on the study of such factors as: the art of management, the ability to make effective management and investment decisions that can affect the intellectual position of economic entities.

The articles (Zaytsev et al., 2020c; Nikolaichuk et al., 2019) propose an algorithm for assessing the effectiveness of IC management and innovative development based on structural and cost aspects. The authors point out that the assessment methods should take into account the factors of IC cost formation and the sector specifics of the audited organization. Effective knowledge management is a serious competitive advantage in today's industry. The highest growth rates are observed in small and medium-sized enterprises. The study of Syahchari and Sahban (2019) uses quantitative and multiple regression methods to analyze data and substantiate the significant relationship between IC and knowledge management in the context of building corporate competitiveness. The article (Kryzhko et al., 2020) proposes an assessment of innovative components based on DEA (Data Envelopment Analysis) modeling technology, which allows for taking into account differentiating parameters. At the same time, models can be enhanced with digital tools, which will greatly speed up obtaining final data.

In practice, specific IC audit tools are not used. When conducting an IC audit, it is necessary to take into account the formal and real capital of the enterprise. The following tasks are to be fulfilled: to determine the structure of intellectual resources and the state of each individual component of IC; to identify the results of intellectual activity that require legal protection; to develop strategic goals for managing intellectual development; to highlight the probabilistic impact of intellectual elements on the market capitalization of the enterprise. The most acceptable method within the framework of the audit is the construction of integrated IC assessments, which, with the help of expert points of view, can provide quality material for the further development of an intellectual growth strategy.

IC audit, in practice, is intended to ensure effective management of labor knowledge and intellectual resources. To do this, a number of coefficients considered in the formulas below (K1 - K10) can be used (table 1). These coefficients are compiled on the basis of the needs of an industrial enterprise in intellectual constituencies that determine innovative development. The selected coefficients are available for comparison and can be included in regression models, which increases their significance.

First of all, the assessment of the intellectual potential is necessary for industrial enterprises to compare their capabilities with the market needs, strengthen their positions and survive in a highly competitive environment. Thus, the dynamics of these coefficients

can be compared with the output or the efficiency of the individual structural production units, which will allow us to identify qualitative dependencies and build economic and mathematical models. The coefficients can be calculated by digital tools, which will simplify the process of obtaining calculated data and their dynamics and make it possible to conduct a comparative analysis.

Table 1 Intellectual capital audit coefficients

K1 is the share of employees involved in R&D	$K1 = \frac{W_{R\&D}}{W}$, (1)	$W_{R\&D}$ is the number of employees involved in R&D W is the total number of employees of the enterprise
K2 is the share of employees with scientific degrees in the total number of employees involved in R&D	$K2 = \frac{W_{PhD(R\&D)}}{W_{R\&D}}$, (2)	$W_{PhD(R\&D)}$ is the number of employees with academic degrees involved in R&D $W_{D(E)}$ is the number of managers and specialists with a master's degree and higher degrees
K3 is the share of managers and specialists with a master's degree and higher degrees in the total number of managers of the enterprise	$K3 = \frac{W_{D(E)}}{W_D}$, (3)	W_D is the total number of managers of the enterprise $W_{S(E)}$ is the number of specialists who completed training or advanced their qualifications in the reporting period
K4 is the share of specialists who received training or improved their qualifications in the reporting period	$K4 = \frac{W_{S(E)}}{W_S}$, (4)	W_S is the total number of specialists $W_{S(Y)}$ is the number of young professionals (under 35) A_{IP} is the cost of intellectual property
K5 is the share of young professionals (under 35 years old)	$K5 = \frac{W_{S(Y)}}{W_S}$, (5)	A_n is the cost of fixed assets I_{hc} are the investments in education and training of personnel in the reporting period I_{id} is the general investment in innovative development
K6 is the share of the value of intellectual property in fixed assets	$K6 = \frac{A_{IP}}{A_{nc}}$, (6)	Inn_{im} is the number of innovations implemented over the past three years
K7 is the share of investments in education and training of personnel	$K7 = \frac{I_{hc}}{I_{id}}$, (7)	Inn_{dev} is the number of innovations developed over the past three years $I_{R\&D}$ are the investments in R&D in the reporting period
K8 is the share of implemented innovations	$K8 = \frac{Inn_{im}}{Inn_{dev}}$, (8)	I_t. is the total investment of the enterprise in the reporting period.
K9 is the share of investment in R&D	$K9 = \frac{I_{R\&D}}{I_t}$, (9)	
K10 is the expert coefficient of human capital satisfaction in production (*set in the range from 0 to 100 points*).	Research centers, consulting agencies, auditors and other invited experts with significant experience in the industry under study can act as experts. It is also possible to calculate this coefficient on the basis of algorithms embedded in a special digital platform capable of conducting in-depth factor analysis.	

It is possible to analyze these coefficients by deriving a general indicator based on the introduction of normative weight values, for example, based on the digital normalization of weight values using machine learning and processing the values to determine the significance of each of the proposed coefficients for the industry under study. However, it is advisable to consider each of the proposed indicators separately, taking into account sector average parameters. Schematically, the algorithm for auditing the IC of an industrial enterprise based on the listed coefficients is shown in Figure 1. It reflects the need to carry out calculations for a set of enterprises (*1, 2, ..., i*, where *i* is a set of enterprises) of a specific industrial sector (*Xn*, where *n* is the industry designation number) to identify the sector average values of each coefficient ($Km \in \Delta E$, where *m* is the coefficient number). It is recommended to use the median value since it is closest to the true mean and will reduce the error. To obtain data for the audit, it is necessary to conduct a digital analysis of the corporate reporting of each enterprise (*E1, E2, ... Ei*).

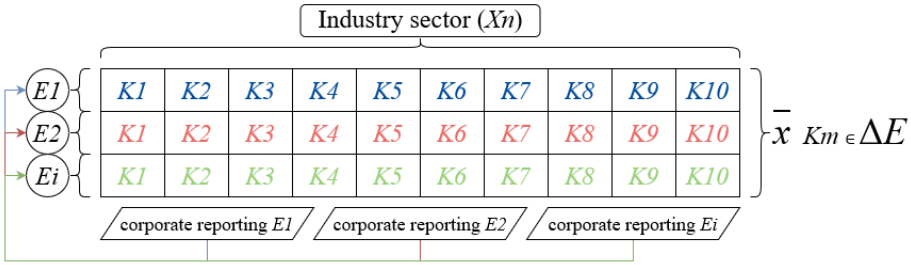

Figure 1 IC audit based on coefficients (K1 – K10)

Processing a large amount of information about the enterprise's industry sector is required in order to undertake a qualitative analysis. This condition is seriously complicated by the need to use computational computer technologies and digital tools. After obtaining the industrial sector average values, it is necessary to reduce them to comparable values by dividing each calculated coefficient by its industrial sector average level. The resulting value will be called the *comparable coefficient*. As a result of the audit, the value of IC comparable coefficients is obtained, which is presented in Table 2. Based on the obtained values, it becomes possible to identify bottlenecks in the field of intellectualization of an industrial enterprise. Note: Ei is a set of analyzed enterprises.

Table 2 Comparable IC audit coefficients of industrial enterprises

Industry sector (Xn)	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
E1	$K_{1c(E1)}$	$K_{2c(E1)}$	$K_{3c(E1)}$	$K_{4c(E1)}$	$K_{5c(E1)}$	$K_{6c(E1)}$	$K_{7c(E1)}$	$K_{8c(E1)}$	$K_{9c(E1)}$	$K_{10c(E1)}$
E2	$K_{1c(E2)}$	$K_{2c(E2)}$	$K_{3c(E2)}$	$K_{4c(E2)}$	$K_{5c(E2)}$	$K_{6c(E2)}$	$K_{7c(E2)}$	$K_{8c(E2)}$	$K_{9c(E2)}$	$K_{10c(E2)}$
Ei	$K_{1c(Ei)}$	$K_{2c(Ei)}$	$K_{3c(Ei)}$	$K_{4c(Ei)}$	$K_{5c(Ei)}$	$K_{6c(Ei)}$	$K_{7c(Ei)}$	$K_{8c(Ei)}$	$K_{9c(Ei)}$	$K_{10c(Ei)}$

3. Results and Discussion

Based on the proposed methodology, it becomes possible to build a rating table of enterprises in the industry sector and identify the critical position of specific indicators, then these indicators should be thoroughly analyzed in the process of auditing. An example is given in Table 3, which presents data on 5 enterprises from the analyzed set of subjects (total – 13). Note: the analysis was carried out at the enterprises of the machine-building industry operating in the same region; E1-E5 are specific enterprises in the sector; with a value of 1, the indicator of the enterprise is equal to the industry average value; if the value is less than 1, then the indicator of the enterprise is below the industry average; if the value is greater than 1, then the indicator of the enterprise exceeds the industry average.

Table 3 Comparable IC audit coefficients of industrial enterprises (testing – 2021)

Enterprise	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
E1	0.96	1.04	0.99	1.05	1.12	1.05	1.16	0.98	0.97	1.06
E2	0.81	0.79	1.05	0.82	0.93	0.78	0.71	0.89	0.93	0.99
E3	1.17	1.23	1.12	1.15	1.09	1.11	1.04	1.05	1.08	1.02
E4	0.71	0.76	0.94	0.79	0.81	0.94	0.83	0.63	0.97	0.68
E5	1.24	1.35	1.08	1.14	1.19	1.26	1.12	1.15	1.07	1.02

Testing of the proposed model makes it possible to draw reasonable conclusions about the functioning of enterprises in the industry sector. The highest average rank is found at the enterprises E5 (1.432) and E3 (1.127), leaders in the sector. Enterprise E1 (1.042) is in line with the industry sector average. Enterprise E5 (0.855) is seriously behind the industry average. Enterprise E4 (0.800) is in a critical position in terms of intellectual growth and is an underdog in the industry sector.

The disadvantage of calculating these parameters in the audit process is its stretching in time. It is necessary to consider indicators for a specific time interval to solve this problem. For example, it is advisable to obtain an average score over 5 or 10 years, which can facilitate the digital modelling process and focus specialists' attention on specific problems of the intellectual functioning of the enterprise. However, these factors should always be considered before drawing up a plan-fact for IC audit when setting its objectives. As a result, the use of these coefficients in the process of IC auditing will ensure the flow of information about the enterprise, the value of which is determined by the following conditions: assessment of the intellectual potential of the company, taking into account its strategic development guidelines; development of algorithms for leveling bottlenecks in economic growth through development and research; preparation of information for the projects and comprehensive reorganization programs development; change in the cost characteristics of the enterprise.

The proposed method can complement existing audit activities in the field of IC and innovation, as considered in the studies (Curtis et al., 2016; Roy, 2013). It allows us to identify problematic situations and bottlenecks of an industrial enterprise in the field of intellectualization and evaluate the level of innovations. Knowledge management in this context can be either effective or ineffective, which provides an opportunity to develop recommendations to strengthen the links between intelligence strategies and competitive advantages. The need for such recommendations is also considered in the study (Gargate, 2018), which highlights the importance of knowledge in creating competitive advantages of enterprises and the need to develop knowledge-intensive strategies aimed at identifying the hidden potential of an enterprise and its capabilities through the open data audit based on the digital analysis of corporate reporting. Similar views are discussed in the study (Zheng et al., 2009) however, the emphasis is on the KPI system, which is more adapted to determine the effectiveness of technological innovations at the enterprise level. In modern conditions, an in-depth digital performance audit will allow us to further develop a range of effective measures to identify the problems of a particular enterprise relative to other players in the industry.

An IC audit makes it possible to obtain an independent factorial assessment of the value of an industrial enterprise. The resulting range of factors indicates the presence or absence of the intellectual value of the business, which allows us to develop a digital model that takes into account the availability of opportunities for optimizing options for managing human resources and innovative development. For this model, economic indicators can be used to provide information on IC's effectiveness and offer recommendations for transforming innovation policy (Vlasenko et al., 2020; Edler & Fagerberg, 2017).

It is proposed to further adapt IC digital audit algorithms for building lean manufacturing tools (Zaytsev et al., 2020a; 2021) and intelligent leverage (Dmitriev et al., 2020). The synergetic use of the proposed conceptual approaches will make it possible to use the economic and mathematical apparatus to improve the efficiency of entrepreneurial activity in industries. It is assumed that a number of relevant studies will allow us to develop an instrumental apparatus for managing intellectual resources, taking into account the need for auditing, attracting investments and reducing production costs based on the digital analysis of large amounts of data on enterprises.

The importance of IC in production industries is obvious. For effective industrial production, it is vital to develop the intellectual activity of a business, which eliminates barriers to corporate growth. The study shows that it is possible to conduct an IC audit based on the use of corporate reporting available for analysis in the public domain. The lack of universal approaches determines the need to use various methods, including digital

auditing as an alternative method, the practical use of which makes it possible to draw a conclusion about its viability. The study shows that on the basis of audit activities, it is possible to improve the efficiency of knowledge and resource management of an economic entity, focusing on the use of corporate enterprise reporting. For the audit, coefficients were selected, on the basis of which it is possible to build an integral assessment of the IC of the enterprise and develop practical recommendations for resolving the problem areas to ensure intellectual growth.

The reasonableness of this model assumes the use of indicators in the coefficients that have the greatest weight for the analyzed industry. In the context of the conducted research, an example of an industrial industry is given, and indicators are selected, which are planned to be expanded in the future to strengthen and detail the model. In turn, this leads to the following limitation: for each industry, it is planned to replace and rearrange the indicators that will have the greatest weight for the functioning of the analyzed sector.

4. Conclusions

Testing the developed method at machine-building enterprises made it possible to identify the objective patterns and dependencies between enterprises in key areas of IC use. The obtained values can be used in practice to build economic and mathematical models of increased complexity in identifying correlations with other indicators and developing strategies for sustainable growth, focusing on industry leaders. The proposed list of coefficients can be further expanded. In the future, it is planned to develop research in this area to obtain extended coefficients for specific industries and determine integral values for a specific industry and territory. It is also planned to expand the technology of digital audit to identify problem areas of the intellectual development of an enterprise over time, which will make it possible to identify problematic values not only for a specific year, but also to focus on retrospective indicators and build long-term trends.

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