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# DEVELOPMENT OF A SYSTEMOLOGICAL METHOD FOR MEASURING INTELLECTUAL CAPITAL OF IT COMPANIES USING THE FIBONACCI SEQUENCE

The object of research is the intellectual capital (IC) of IT companies. From the perspective of systemology, IC is conceptualized as a system formed from sub-systems and embedded within a meta-system. The ability of a system to adapt to the functional need of the meta-system, within the framework of systemology, is described by the key characteristic of the degree of systemization ( $\mu_s$ ), which reflects the degree of correspondence between the system's current properties and the functional need of the meta-system. That is, it serves as a criterion for the adaptability of the object (the IT company) to the functional need of the meta-object (the IT market). Thus, it is not simply the IC as a set of elements that is being studied, but rather their capacity for functional adaptation, which enables IT companies to meet current market demands.

The problem addressed lies in the absence of an objective and systemically coherent method for measuring IC of IT companies. The key methodological contradiction within extant approaches manifests as a discrepancy between component and holistic methods.

In the course of this research, a systemological Fibonacci-oriented method for measuring IC was developed and substantiated. A non-linear weighting function, constructed upon the harmonic ratios of the Fibonacci sequence. The final measurement is based on determining the measure of degree of systemization ( $\mu_s$ ), which constitutes a one-dimensional projection of the multidimensional state-space of IC onto a scale within the range [0; 1] ( $\mu_s \in [0; 1]$ ). This provides for the objective classification of any unique IC profile of IT companies.

The primary practical value of the method lies in its applicability for constructing an adaptive rating system for IT companies, featuring full automation and integration into expert-analytical software complexes.

**Keywords:** intellectual capital measurement, degree of systemization, systemological assessment method, IT companies, Fibonacci sequence.

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## 1. Introduction

In the context of digital transformations, when the main part of the value of IT companies is formed at the expense of intangible resources, which is studied in detail in the work [1], there is a need to create methods capable of accurately assessing this type of assets. This is especially relevant for the IT sphere, because it is characterized by an extremely high rate of technological change. The short life cycle of products and constant updating of knowledge create an environment that requires IT companies not only to accumulate intellectual capital (IC), but also to be able to effectively manage it in dynamic conditions. The presence of such management competencies is a key factor determining the level of adaptability of IT companies to the current conditions of the IT market. The global dynamics of growth in investments in intangible assets is analyzed in a joint report [2] of the World Intellectual Property Organization and the Italian business school LUISS Business School. According to their data, investments in intangible assets in 27 high- and middle-income countries increased by approximately 3% in real terms, reaching 7.6 trillion USD in 2024 (compared to 7.4 trillion in 2023). Such investment activity is economically justified, because, as studied in the work [3], high intensity of use of intangible assets has a positive effect on the efficiency of companies.

In the IT sector, this trend takes on the most pronounced forms, as evidenced by the reporting data of the IC assessment agency At-tainix Consulting [4]. In particular, according to the agency, as of September 30, 2025, the share of intellectual capital in the market value structure of leading IT companies is characterized by consistently high values, Table 1.

In Table 1 indicators illustrate fundamental changes in the paradigm of value creation, where intellectual assets, unlike physical ones, are the main driver of the generation of superprofits of technological giants.

**Table 1**

Cost and share of intellectual capital of leading IT companies in the world (as of September 30, 2025)

Company	Country of origin	IC value (million USD)	IC share (%)
Alphabet Inc (Google)	USA	2,032,513.25	67%
Microsoft	USA	1,951,675.88	50%
NVIDIA Corp	USA	1,843,539.13	37%
Apple Inc	USA	985,688.81	25%

**Note:** compiled by the authors based on data from [4]

At the same time, as researchers note in [5], human capital accounts for more than 50% of the value of intellectual capital, which makes it the most important component of the assets of modern IT companies. In turn, in [6] it was studied that the introduction of artificial intelligence contributes to the growth of total factor productivity of companies due to the optimization of the structure of human capital. The authors also note that the effect of the application of artificial intelligence technologies is heterogeneous and significantly depends on the characteristics of companies, primarily on the level of human capital development and organizational maturity. This additionally highlights the need to develop and use adaptive methods for assessing intellectual capital that can take into account structural differences and individual development profiles of IT companies.

Thus, the relevance of developing new effective methods for assessing the intellectual capital of IT companies is due to the objective need of the modern IT market for flexible, scalable and high-precision tools for analyzing intangible assets.

As part of a scientific study [7], during which a systematic literature review (SLR) and bibliometric analysis of leading scientific databases (Web of Science, Scopus and EBSCO Business Source Ultimate) were conducted, as of February 2023, 2709 publications were identified on the issues of measuring and assessing intellectual capital. However, despite such a significant volume of publications, the analysis did not reveal a single, generally accepted approach to assessing IC. The authors also note that different methods give contradictory results depending on the industry, size and location of companies. Such conclusions indicate the complexity of this problem and methodological uncertainty among scientists regarding its solution, as well as its importance for modern scientific and practical research. As a response to these challenges, the authors proposed their own Integrated Intellectual Capital Measurement (IICM) model, which is positioned as a comprehensive and adaptive system. However, a critical analysis of the IICM structure shows that this model is mainly conceptual in nature. In essence, it only outlines groups of qualitative and quantitative elements of intellectual capital that are subject to measurement and declares the principles of their integration. At the same time, the proposed model does not offer a formalized mathematical apparatus for calculating an integral indicator that would allow an unambiguous assessment of the state of intellectual capital.

Of particular interest is the approach outlined in [8], where the authors propose to carry out a quantitative assessment of knowledge generation processes for high-tech enterprises. The developed methodology is based on the indicator of the intellectual share in the development of human capital, which is calculated as the ratio of the increase in intellectual capital to the increase in human capital. However, a critical analysis of this approach reveals its limitations in the context of the IT industry. The authors hypothesize that the basis of the IC development is exclusively human capital (qualifications, skills, scientific activity of employees), considering other components (software products, information technologies) only as derived elements. Such an approach cannot be considered systemic for the IT sphere, since it ignores the independent value of other important elements of IC and the network nature of their interaction, reducing all IC management only to personnel management.

An attempt to assess intellectual capital at the level of entire industries is presented in [9]. The authors proposed the calculation of the sectoral intellectual capital index (SICI) based on the modified value-added intellectual coefficient (MVAIC) model. However, a critical analysis of this approach reveals its significant methodological limitations. The assessment is based on a single economic method that reduces the complex nature of intellectual assets exclusively to financial indicators of accounting (personnel costs, marketing, etc.). This approach led to paradoxical conclusions, according to which the technology industry took one of the last places in terms of the efficiency of using IC. The study concludes with a set of general recommendations for industries (for example, to invest in IC or to improve the profes-

sionalism of employees), which are declarative in nature. The work is actually limited to stating the financial correlation between assets and profitability (return on assets (ROA) and return on equity (ROE)), leaving out of consideration the peculiarities of functioning and the complex structure of the IC.

The approach outlined in [10] deserves special attention, where the authors attempted to formalize intellectual capital through the development of a detailed measurement scale. Using a two-stage methodology that included a Delphi panel and statistical validation, the researchers actually created a prototype of a knowledge base for an expert system, independently synthesizing a set of 47 evaluation criteria. Despite the high quality of the empirical research and a large sample (1798 respondents), this method has significant contextual limitations: it was developed exclusively for the academic environment and scientific teams. The specificity of the selected indicators (focus on publications, scientific grants, academic culture) complicates their direct adaptation to the business models of IT companies. A critical shortcoming of the work from the standpoint of systems analysis is the lack of mathematical apparatus for collapsing indicators. The authors focused on psychometric testing of the reliability of the scales (using exploratory and confirmatory factor analysis, Cronbach's alpha), but did not propose a methodology for calculating the integral index.

An important contribution to the rethinking of approaches to assessing IC is the work [11], where the authors demonstrate a deep understanding of the complex nature of knowledge assets. Researchers rightly criticize existing approaches for their low practical applicability. Scientists also aptly note that the problem is not the lack of metrics (of which there are a significant number), but that they do not help managers to actually manage value creation processes. At the same time, the solution to the problem proposed by the authors is mainly conceptual in nature. Instead of developing a specific method or mathematical mechanism for evaluation, the work is limited to formulating a set of theoretical challenges and criteria that are necessary to improve measurement. That is, the study actually forms methodological requirements for future tools, but does not provide a ready-made algorithmic solution suitable for software implementation and operational use in the management of IT companies.

A study on the assessment of technologies as a tool for stimulating innovative activity was conducted by scientists in [12]. However, despite the attempt to build a comprehensive evaluation system, the model has significant conceptual limitations. In particular, the authors narrow the concept of technology only to patented technologies (patent-protected technology), which is a critically narrow view of the IC of modern IT companies that does not take into account the specifics of the IT industry. This is a significant limitation, as a significant part of IC (team expertise, established processes) is not patented, but is essential for the formation of innovative potential and long-term efficiency of IT companies. This confirms the need to develop more flexible, adaptive methods.

In turn, in [13] the authors note that all existing methods for assessing the IC of companies can be divided into four groups: direct measurement, market capitalization, return on assets and scoring. By their nature, these methods are mainly linear and consider IC as a product (through cost calculation) or as capital (through assessment of profitability from its use). These methods for assessing IC are often limited in practical application, since they are mainly based on economic approaches (such as accounting, cost, income or value). In particular, in [14] it is noted that the indicators used in the assessment depend on the context and must be adapted for each company and each goal, which can significantly complicate their use. In addition, such approaches have difficulties in application in the presence of a large amount of heterogeneous data that are difficult to aggregate. In [15], the researchers separately highlight integral methods that are based on a complex combination of several groups of indicators into a single system. However, it is noted that these methods take into account quantitative

indicators, but do not take into account qualitative indicators. Taking into account that IC is intangible by nature, it is obvious that qualitative indicators not only play a key role, but will also constitute the vast majority in such indicators. This is due to the fact that most IC elements (such as knowledge, competencies, process quality, innovativeness) cannot be measured by direct quantitative methods, and therefore, they can be adequately described only by ordinal (qualitative) scales. In turn, such a specific nature of individual IC components complicates the construction of a single universal method for its quantitative assessment.

In [16], researchers distinguish two groups of IC assessment methods: monetary and non-monetary. However, they argue that despite the advantages that each group has, existing methods remain unable to correctly reflect the key properties of IC. In particular, these methods do not solve the problems of comparability of results between different companies, determination of reasonable weighting factors for the IC elements, and also do not take into account the mechanisms of interaction and synergistic effects between its components. It can also be added that in the case of monetary valuation, obtaining reliable financial information about individual elements is often simply impossible. This leads to incompleteness of the assessment due to the fact that only those indicators that are subject to quantitative measurement are included in the calculation, while other, more qualitative characteristics are left out of consideration.

In work [17], researchers divide methods for assessing intellectual capital into two other large groups: component (analytical) and holistic (holistic). The idea of component methods is based on the IC decomposition into individual components, the subsequent measurement of each of them and the aggregation of the results obtained into a general assessment. In contrast, holistic methods consider the IC as a single system, assessing it through the market value of the company that it forms or strengthens. However, as the researchers note, component methods are criticized for ignoring the effect of synergy between the IC elements, which cannot be adequately reflected when measuring each IC element in isolation. This significantly limits the accuracy and transparency of these methods. Holistic methods, in turn, are also not without criticism, since they unreasonably identify the entire off-balance sheet value of the company with intellectual capital. This approach simplifies the IC nature, not taking into account the influence of other types of capital that jointly create the market value and value of the company. As a result, there is a risk of overestimating the IC role and losing analytical accuracy in strategic planning. For the sake of completeness, it is also possible to mention comparative approaches that offer a more comprehensive vision. However, they require the search for analogues for comparison, which is practically impossible in the IT sphere, where the intellectual product has a unique, unrepeatable character.

Taking into account the above, it can be stated that the most systematic methods of assessing intellectual capital are described when they are divided into component and holistic. This division causes a methodological contradiction between two different ways of understanding and assessing intellectual capital, each of which has its own advantages and significant limitations. In this regard, it is relevant to search for approaches capable of integrating the analytical detail of component methods with the systemic synergy of holistic methods, thus eliminating the existing methodological contradiction between them. In addition, it is important to fully include in the assessment both quantitative and qualitative indicators of various nature, which is currently not fully implemented by any of the existing methods. Thus, an urgent scientific and practical task is to develop an approach that will provide the possibility of objectively assessing the IC of IT companies. Moreover, this approach to assessing IC should easily adapt to changes in market conditions and allow for rapid modification of assessment parameters. This is especially critical for IT companies, which activities are based on knowledge, innovation and rapid adaptation to changes in the external environment. It is also important that it remains intuitive for users and does not require special training. In addition, the method

must be compatible with existing ontological (classification) models of IC and suitable for software implementation.

The development of such a method for assessing IC is a complex practical task that requires deep fundamental study and justification. The successful development of such a method will create the necessary conditions for ensuring effective management of intellectual capital, and will also provide an opportunity to increase the accuracy of forecasting in conditions of high dynamism of the digital economy and market uncertainty. An important condition is also the suitability of the method for real implementation in the IT sphere.

Thus, *the object of research* is the intellectual capital of IT companies, and the subject of research is the systemological method for assessing the IC of IT companies, based on the use of the degree of systemization ( $\mu_s$ ) and the mathematical apparatus of the Fibonacci series.

Taking into account the above, *the aim of research* is to develop a systemological method for assessing the IC of IT companies using the Fibonacci sequence, which overcomes the methodological limitations of component and holistic approaches to assessment.

To achieve this aim, it is necessary to:

- justify the use of the systemological approach, the degree of systemization ( $\mu_s$ ) and the Fibonacci series to build a nonlinear assessment model;
- develop a mathematical apparatus (algorithm) of a nonlinear model for assessing and classifying multi-criteria alternatives;
- assess the possibilities of software implementation of the method and the prospects for its integration into analytical and expert systems.

## 2. Materials and Methods

The theoretical and methodological basis of research is the system-analytical and classification approaches, which are based on the fundamental principles of systemology [18]. According to these principles, the intellectual capital of IT companies is considered as a holistic, dynamic system of interconnected elements, which allows the application of structural analysis and synthesis methods.

A systemological characteristic was chosen as a theoretical tool – a degree of systemization ( $\mu_s$ ). Within the framework of research, this indicator is used to quantitatively assess the degree of coherence, stability, integrity and adaptation of the system to the functional request of the meta-system.

The mathematical basis for modeling weight coefficients is the Fibonacci sequence. The choice of this tool is due to its ability to formalize nonlinear proportions between criteria and harmonize evaluation models of multi-criteria alternatives. The apparatus of set theory was used to formalize the subject area and structure unique profiles of intellectual capital.

The research procedure includes the stages of forming a set of alternatives, calculating their parameters according to the developed algorithm and interpreting integral estimates. The source of input data for testing the method's performance was model datasets (test datasets), formed on the basis of ranges of values typical for the activities of IT companies. The results were verified by logical control and numerical analysis of the sensitivity of integral estimates to changes in input parameters. Computational experiments were performed using the Python programming language (with the use of data processing libraries), which ensures the accuracy of calculations, reproducibility of results and the possibility of further software implementation of the method.

## 3. Results and Discussion

### 3.1. Justification of the use of a systems approach and the Fibonacci series

The task of assessing the intellectual capital of an IT company is a complex, multifactorial task that requires the use of a formalized

methodological apparatus and classification tools. Due to the intangible nature of intellectual capital and its dynamic nature, it is proposed to build the assessment process on a system of criteria, each of which has a corresponding scale (quantitative, qualitative, ordinal, etc.). This approach will allow aggregating heterogeneous information about the elements and types of IC (human, structural, relationship capital, etc.), as well as the nature of their interaction at the system level.

The final stage of the assessment involves the IC classification of IT companies, during which the integrated IC indicator is associated with one of the defined final classes. In the developed method, the interpretation of these classes directly depends on the indicator of the degree of systemization ( $\mu_s$ ), which in systemology is the main characteristic of any object as a system and acts as a criterion for the adaptability of the object to the request of the meta-system. This value corresponds to the degree of proximity of the results of the formation or adaptation of the object to some optimum, which depends on the place and role of the object in the superobject, that is, on the degree of its perfection.

The key result of the research is the developed comprehensive method for assessing the intellectual capital of IT companies. This classification method is based on an additive model, which allows aggregating the contribution of various criteria. The conceptual basis of this method is to determine the level of consistency (adaptation) of the IT company's intellectual capital with the functional request of the IT market and the strategic priorities of the development of the IT sphere as a whole. Thanks to this approach, it is possible to carry out a well-founded construction of the rating of the intellectual capital of IT companies both on the domestic and international IT markets. In turn, such a rating can be used as an objective analytical comparison tool to support the adoption of managerial, strategic and investment decisions by the management of IT companies and other stakeholders.

The proposed approach is based on the integration of the fundamental principles of systemology and the mathematical apparatus of the Fibonacci series for the classification of multi-criteria alternatives in the IT sphere. As already noted, the developed complex method is based on an important systemological indicator – the degree of systemization ( $\mu_s$ ). This indicator, which is used to quantitatively reflect the internal and external integrity of the system, allows formalizing the assessment of intellectual capital from the standpoint of its structural unity and functional efficiency.

Such an assessment model is universal due to its systemic nature. In addition, it demonstrates high potential for application not only in the IT sphere, but also in a wide range of different sectors of the economy, including financial, educational and scientific, insurance, medical, industrial and others. According to the classical definition [8], the degree of systemization is defined as the ratio of the field of possible functional states of the system to the field of its required functional states

$$\mu_s = \frac{\text{field of possible states}}{\text{field of required states}} \quad (1)$$

In the context of assessing intellectual capital, this indicator actually becomes an adaptability criterion. It allows to consider the properties of the system (intellectual capital) as a manifestation of its activity in establishing exchange relations in the external and internal environment.

From a practical point of view, the degree of systemization ( $\mu_s$ ) quantitatively reflects the degree of compliance of the functional and structural properties of the IT company's IC with the requirements of the meta-system (IT market). And the higher this compliance, that is, the better the functional and structural properties of the IT company's IC meet the target market demand for the available vacant node that the IT company seeks to occupy, the closer the degree of systemization approaches unity ( $\mu_s \rightarrow 1$ ). Conversely, inconsistency or degradation of the relations between the IT company's IC and the requirements of the meta-system leads to the approximation of the degree of systemization

to zero ( $\mu_s \rightarrow 0$ ), which indicates low adaptability and inefficiency of the IT company's IC.

This interpretation allows to use the concept of the degree of systemization in the future as an adaptability criterion that takes into account a set of criteria of different nature to determine more correct system-object models of organizational systems, including IT companies. Thus, the degree of systemization ( $\mu_s$ ) provides an objective quantitative assessment of the quality of the system integration of IT into the market environment.

The next step is to determine the relationship between the degree of systemization ( $\mu_s$ ) and the Fibonacci sequence (1, 1, 2, 3, 5, 8, etc., i. e. where each subsequent value is the sum of the two previous ones), which was also used in the developed method.

First of all, it is worth noting that the use of the Fibonacci series as a mathematical apparatus is not accidental. In the IT sphere, especially in agile software development methodologies, the Fibonacci series has long been used in the everyday work of IT companies around the world. It is used in IT projects for nonlinear assessment of the complexity of tasks expressed in story points [19]. Based on this principle of harmonious nonlinear correlations of the Fibonacci series, an innovative nonlinear additive method for assessing the intellectual capital of IT companies was developed in the course of research. The proposed approach provides an objective and methodologically consistent quantitative assessment of the adaptability of the intellectual capital of IT companies, which is expressed by the integral indicator of the degree of systemization ( $\mu_s$ ).

So, as already noted, the degree of systemization ( $\mu_s$ ) reflects the degree of consistency of the functional and structural properties of the IT company's intellectual capital with an external determinant (the demand of the meta-system, i. e. the market). And the better this consistency, the closer the degree of systemization ( $\mu_s$ ) approaches 1 ( $\mu_s \rightarrow 1$ ) and vice versa, the degree of systemization ( $\mu_s$ ) approaches 0 ( $\mu_s \rightarrow 0$ ) with increasing inconsistency. This means that when classifying the intellectual capital of IT companies, that is, when assigning it to certain classes, these same classes should be expressed through an objective indicator of the degree of systemization ( $\mu_s$ ). That is, if the degree of systemization has a value in the interval  $[0; 1]$  ( $\mu_s \in [0; 1]$ ), then the classes ( $k$ ) on this scale (regardless of their number) should have discrete weight values ( $W_k$ ), which are distributed in the same interval ( $W_k \in [0; 1]$ ). In addition, they should strictly correlate with the increase and decrease in the level of adaptability of the system to the request of the meta-system. That is why, in order to ensure such a correlation and avoid subjectivity (primarily of experts), it is proposed to calculate the weights of classes ( $W_k$ ) and criteria ( $W_{gr}$ ) based on the inverse Fibonacci series, the values of which are located to the left of 1 in the range  $[0; 1]$ . In this range, the inverse values of the Fibonacci series (for example,  $1/2, 1/3, 1/5, \dots$ ) nonlinearly asymptotically tend to zero ( $1/F_n \rightarrow 0$ ). That is, to the right of 1 is the Fibonacci series itself, and to the left is its symmetrical inverse series, which can be expressed as follows ( $0 \leftarrow 1 \rightarrow \infty$ )

$$0, \dots, \frac{1}{13}, \frac{1}{8}, \frac{1}{5}, \frac{1}{3}, \frac{1}{2}, 1, 1, 2, 3, 5, 8, 13 \dots \infty \quad (2)$$

However, one should also take into account the mathematical peculiarity of the inverse Fibonacci series: although it asymptotically tends to zero, it is impossible to reach the value 0 using this series in a finite number of measurements. However, in real practice, situations are possible when the intellectual capital of an IT company is actually absent (for example, for a newly registered IT company that exists only de jure). In the language of systemology, this means that the system is not yet a substance of the meta-system and is not yet included in it. This creates a situation where the external determinant of the system (the request of the meta-system) already exists, but the functioning system with the corresponding internal determinant (a set of functional and

moreover, supporting relationships) does not yet exist. In other words, the necessary system, as a manifestation of this entity, does not yet exist, but it is conditioned by the already existing external determinant. In such a case, it is said that "the system exists before it exists" (Die Sache ist, ehe sie existiert) [20].

Thus, a situation may arise when a certain IT company, having received zero values for all criteria, will have a final indicator of the degree of systemization equal to 0 ( $\mu_s \rightarrow 0$ ). In this case, its intellectual capital will be attributed to the lowest (worst) class. However, from a mathematical point of view, each class ( $k$ ) on a one-dimensional scale of the degree of systemization ( $\mu_s \in [0; 1]$ ) is formally mapped to an interval (a subset of the segment). Each such interval, which can be open, closed or semi-open/semi-closed, has certain boundaries, which are also boundaries for classes (for example, ( $k_3 \in [0; 0.2]$ )). This creates a methodological problem, since IT companies that have a minimum but non-zero indicator of the degree of systemization greater than 0 ( $\mu_s > 0$ ), even if it is 0.001, will also fall into this worst class. In other words, this creates an unjustified "positive bonus" for IT companies that actually do not have formed intellectual capital. In addition, among the criteria for assessing the intellectual capital of IT companies there may also be those that have only binary (dichotomous) values ("yes"/"no" or 1/0). To take this feature into account, as well as to ensure methodological integrity and consistency, it is proposed to allocate an additional subclass "Explicit Zero" (EZ) within the lowest class with a weight of 0 ( $\mu_s \in [0; 0] \Leftrightarrow \mu_s \in \{0\}$ ). This subclass (or criterion value) will be used in cases of complete absence or impossibility of assessing the intellectual capital of an IT company or its individual elements.

In turn, in the best class, it is advisable to highlight the subclass "Explicit One" (EU) with a weight of 1 ( $\mu_s \in [1; 1] \Leftrightarrow \mu_s \in \{1\}$ ). The purpose of such highlighting is to emphasize the exceptional results of IT companies that have achieved maximum values for all criteria and have a general indicator of the degree of systemization of 1 ( $\mu_s = 1$ ). However, it should be noted that these are very exceptional cases from the point of view of systemology.

Thus, the scale of the degree of systemization ( $\mu_s$ ), which is initially set on a closed segment ( $\mu_s \in [0; 1]$ ), is transformed into an open interval (0; 1) with explicitly allocated boundary points 0 and 1, i. e.

$$\mu_s \in (0; 1) \cup \{0; 1\}. \tag{3}$$

Separate allocation of a marginal, discrete subclass ("Explicit Zero") with a fixed weight of 0 ( $\mu_s = 0$ ) guarantees that newly created and unadapted IT companies will receive a clearly separated zero score. This prevents methodologically incorrect mixing with the results of IT companies, which, although they fall into the lowest class, have at least a minimal non-zero value of the degree of systemization ( $\mu_s > 0$ ). At the same time, IT companies with an absolute indicator of the degree of systemization equal to 1 ( $\mu_s = 1$ ) will receive an additional allocation of their exceptional status.

This approach provides both mathematical and methodological completeness of the scale of the degree of systemization ( $\mu_s$ ), on the basis of which the IC class of the IT company is determined.

Thus, the use of the inverse Fibonacci series in the range [0; 1] harmoniously agrees with the nature of the concept of the degree of systemization, which is determined in the same range ( $\mu_s \in [0; 1]$ ), which makes the connection between them logically consistent, methodologically complete and mathematically rigorous.

### 3.2. Mathematical apparatus of the assessment model

#### 3.2.1. Algorithm for forming classes

The following presents an algorithm for forming classes, which includes calculating their weights and setting the boundary boundaries. Formally, on the scale of the degree of systemization ( $\mu_s \in [0; 1]$ ), the weights of the classes are distributed on different segments (closed, as

partial cases for explicit subclasses, semi-open/semi-closed or open), that is, they take the following forms

$$[W_x; W_y], (W_x; W_y), [W_x; W_y). \tag{4}$$

Accordingly, each class has its own boundaries, which are determined by discrete values of the weights (for example,  $k_n \in [W_x; W_y]$ ), as shown in Fig. 1.

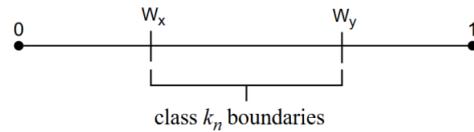


Fig. 1. Scale of systemization and class boundaries  $k_n$

For a simplified example, the condition is assumed under which the classification of intellectual capital of IT companies is carried out according to three main classes ( $k = 3$ , then there are classes 1, 2, 3). In addition to the numerical expression, the classes may also have qualitative names (for example, 1 – Leaders, 2 – Professionals, 3 – Beginners). Additionally, in the lowest 3rd class, it is possible to allocate a subclass "Explicit Zero" with a weight of 0, and in the best 1st class, a subclass "Explicit One" with a weight of 1. According to the developed method, to determine the weights ( $W_k$ ) on the boundaries of these classes, it is necessary to take  $n = k$  (according to the number of classes) of the first consecutive inverse numbers from the Fibonacci series to the left of 1. That is, at  $k = 3$ , the required values are 1/2, 1/3, 1/5, which will then act as weight reduction coefficients ( $P_{red}$ ) for the classes and will accumulate from higher classes to lower ones. In a geometric sense, such accumulation determines the lengths of segments ( $l_n = |W_x - W_y|$ ) on the scale of the degree of systemization ( $\mu_s$ ), which correspond to the ranges of the classes. In practical terms, the accumulation of weight reduction coefficients reflects the nonlinearly increasing criticality of the IT company's intellectual capital's distance from ideal market adaptability. In other words, moving to the next better class requires not only confirmation of compliance with the requirements of the current class, but also demonstration of additional qualitative improvements characteristic of a higher level of adaptability. To narrow the range of boundaries of higher (better) classes, it is possible to take a sequence with a shift of 1, 2 or more values. Then, when shifted by one value, the required inverse values of the Fibonacci series will be 1/3, 1/5, 1/8, and when shifted by two values, respectively, 1/5, 1/8, 1/13. However, the greater this shift, the narrower the higher (better) classes will be and the wider the lower (worse), especially the last classes. In some cases, such a shift may have a certain practical logic and need for application.

In the next step, to ensure a gradual non-linear decrease in weights from higher to lower classes, the inverse values from the Fibonacci series are reversed in order of decreasing denominator (i. e. 1/5, 1/3, 1/2). The corresponding calculations for the 3 classes are given in Table 2.

Table 2

Calculations for the 3 classes

Classes, $k$	Class Name	Fibonacci numbers, $F_n$	Inverse Fibonacci numbers, $F_{inv}$	Reverse Fibonacci numbers, $F_{rev}$
1	Leaders ("Explicit One")	1 ( $F_2$ )	1	0
1	Leaders	2 ( $F_3$ )	1/2	1/5
2	Professionals	3 ( $F_4$ )	1/3	1/3
3	Beginners	5 ( $F_5$ )	1/5	1/2
3	Beginners ("Explicit Zero")	0 ( $F_n$ )	0	1

Further, the obtained inverse and expanded values from the Fibonacci series ( $F_{rev}$ ) will be directly used to determine the limit weights at the class boundaries ( $W_k$ ) according to the following formula

$$W_k = 1 - P_{red}, \tag{5}$$

where the cumulative weight reduction coefficient ( $P_{red}$ ) for the  $k$ -th class is calculated as the sum of the current and previous inverse Fibonacci numbers ( $F_{inv}$ ) before it

$$P_{red}^k = \sum_{F_i}^{k-1} \left( \frac{1}{F_i} \right). \tag{6}$$

Since the calculation is carried out from higher classes to lower ones, calculations regarding the limit weights cannot be performed for the last class. This is due to the fact that the upper limit for it will be the lower limit of the previous class, and the lower limit will be the limit of the "Explicit Zero" class with weights 0. From this it is possible to see that the limit weight values of the last (lowest) class, and therefore its boundaries, are formed automatically. This is also deduced using simple geometric logic, according to which to divide a linear object into  $n$  separate parts,  $n - 1$  internal cut points (divisions) are required. Thus, the calculation of additional internal division points for the last (lowest) class is redundant and not required. From this it is possible to conclude that the corresponding calculations for the reduction factor, and therefore for determining the limiting weight values of the last (lowest) class with the value  $\frac{1}{2}$  from the inverse Fibonacci series, are not required. For the subclasses "Explicit zero" and "Explicit One", the weight reduction factor ( $P_{red}$ ) is equal to 0 and 1, respectively. The corresponding calculations of the cumulative reduction factor ( $P_{red}$ ) according to formula (6) and the determined weight factors at the class boundaries ( $W_k$ ) according to formula (5) are given in Table 3.

Calculation of the cumulative reduction factor, limit weights for classes and their ranges

Class, $k$	Class Name	Reverse Fibonacci numbers, $F_{rev}$	Reduction factor, $P_{red}$	Weights at the beginning of the class boundary, $W_k$	Class boundary range
1	Leaders ("Explicit One")	0	0	$1 - 0 = 1$	[1; 1]
1	Leaders	$\frac{1}{5}$	$\frac{1}{5} + 0 = \frac{1}{5} = 0.2$	$1 - 0.2 = 0.8$	[0.8; 1]
2	Professionals	$\frac{1}{3}$	$\frac{1}{3} + \frac{1}{5} + 0 = \frac{8}{15} = 0.53(3)$	$1 - 0.53 = 0.47$	[0.47; 0.8]
3	Beginners	$\frac{1}{2}$	automatically determined	automatically determined	(0; 0.47)
3	Beginners ("Explicit Zero")	1	1	$1 - 1 = 0$	[0; 0]

Thus, the distribution of weight values for 3 classes on the scale of the degree of systemization ( $\mu_s$ ) can be presented in the following form

$$W_k \in \{0\} \cup (0; 0.47) \cup [0.47; 0.8) \cup [0.8; 1) \cup \{1\}. \tag{7}$$

The graphically obtained distribution of weight values for a simplified example with 3 classes and their boundaries on the scale of the degree of systemization ( $\mu_s$ ) can be presented as follows (Fig. 2).

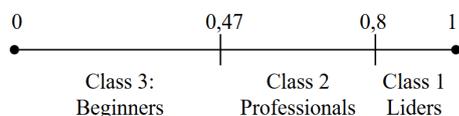


Fig. 2. Distribution of classes and their boundaries

### 3.2.2. Formation of criteria, determination of their weights and boundaries

After determining the number of classes by which the IC of IT companies will be classified, the names of these classes and their weight boundaries, work with criteria begins. The criteria will be used to determine the level of consistency (compliance) of the functional and structural properties of the IC of IT companies with the requirements of the meta-system (external determinant, i. e. the IT market).

The number, type and content of these criteria, as well as the length of their scales within the framework of the proposed method are not limited. This makes it universal and provides ample opportunities for its flexible adaptation in arbitrary conditions, areas of activity and purposes. This allows the developed method to be used in assessing not only the intellectual capital of IT companies, but also other arbitrary categories in any industry. In particular, to determine the investment attractiveness of projects, startups, the condition of movable and immovable property, health status, quality of knowledge, etc.

The criteria that should be developed by profile experts and/or the relevant profile community are formalized indicators and/or questions that reflect the quality of the functional and structural properties of the elements of intellectual capital of IT companies. In this case, each criterion should have its own scale or answer options with two or more values, which can be expressed by different types of data:

- binary scales (dichotomous, i. e. with the values "yes"/"no" or 1/0), where the answer directly correlates with the presence or absence of a certain functional state/manifestation of the intellectual capital element. An example of a criterion could be the question of whether an IT company has an ISO/IEC 27001 quality certificate, which sets requirements for an information security management system. The answer to this question can be two options: "yes" or "no" (i. e.,

Table 3

the certificate is either there or it is not).

Since the criterion scale is a segment, and therefore has two endpoints, that is why, as already noted, the values of "Explicit One" and "Explicit Zero" are used for such cases, as shown in Fig. 3;

- qualitative scales (ordinal) that reflect the degree of manifestation of a property (such as "always", "partially", "never"). A feature of qualitative criteria is that 2 values on the scale (as in the case of binary scales) always correspond to "Explicit One" and "Explicit Zero" as the endpoints of the segment, and other weight values are calculated using formula (5). A graphical example of a qualitative scale is presented in Fig. 4.

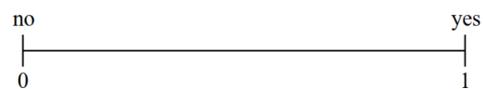


Fig. 3. Example of a binary criterion scale

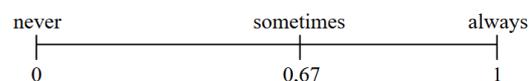


Fig. 4. Example of a qualitative criterion scale

An example of a criterion can be the question of how mandatory code review is for an IT company in the development process, which can be expressed in qualitative values as follows, Table 4: Quantitative

scales that can be expressed in absolute values or percentages. Moreover, for indicators where the critical value is not just the maximum or minimum value, but a certain optimal balanced range, the scales can be flexibly adjusted to identify this optimum. For example, the indicator of the share of technical specialists in the total number of employees of an IT company on a scale from 0% to 100%, where both the approximation of the value to 0% and the approximation to 100% are equally undesirable. To identify the optimal range, it is possible to form a scale, as shown in Table 5.

Description of the "Code review practice" criterion

Qualitative value of the criterion	Explanation	Interpretation of the criterion value	Weights ( $W_k$ ) according to formula (5)
Always	Code review is fully integrated into the CI/CD process and is a mandatory step when making any changes	Ideal	1
Partially	Code review is formally required, but is regularly skipped, especially under tight deadlines	Normal	0.67
Never	Code review is not required and is only done occasionally at the initiative of individual developers	Unacceptable	0

Table 4

Description of the quantitative (percentage) scale of the criterion "Share of technical specialists"

Percentage criterion value	Range	Interpretation of the criterion value	Weights ( $W_k$ ) according to formula (5)
85–87%	[85; 87]	ideal	1
80–84, 88–90%	[80; 84] ∪ [88; 90]	optimal	0.875
50–79%	[50; 79]	acceptable	0.675
1–49%, 91–99%	[1; 49] ∪ [91; 99]	bad	0.342
0%, 100%	{0; 100}	unacceptable	0

Table 5

As can be seen from the examples (Fig. 3, 4 and Tables 4, 5), weight coefficients according to formula (5) can be immediately added to the values on the criteria scale (regardless of their type and logic). These coefficients are calculated using an algorithm identical to the calculation of the weight values of class boundaries ( $W_k$ ) on the scale of the degree of systemization ( $\mu_s$ ). That is, the corresponding weight coefficients for the criteria values are calculated based on their number identically to the calculations of class weights, where they are calculated depending on the number of classes. At the same time, the number and logic of the criteria can be arbitrary, they can be flexibly changed (adjusted, removed) if necessary, without affecting the complexity and time of calculations required for the new classification of the IC of IT companies.

This means that the developed method provides a direct transition from any qualitative and quantitative values of the criteria to values on the scale of the degree of systemization ( $\mu_s \in [0; 1]$ ). This allows for a methodologically consistent objective assessment of each individual element (parameter) of the IC, groups of elements (types of IC: human, organizational, relationship capital, etc.) and, ultimately, the total intellectual capital of IT companies. Moreover, the development of criteria in accordance with ontological (classification) IC models is methodologically justified. Such an approach to the development of criteria will ensure systemic consistency of the assessment according to the principle of structural decomposition, increase its logical consistency and reliability at the level of the structural model of intellectual capital. Thus, the proposed approach combines analytical detailing of structural elements with the possibility of their assessment, if necessary, both separately and in aggregate, and also provides a holistic IC assessment. This is achieved through a flexible mechanism of criteria that can reflect not only the state of individual elements or their groups, but also their synergy, coherence and results of interaction at the systemic (emergent) level. The obtained

values are further integrated into a single indicator of the degree of systematization ( $\mu_s$ ). In this way, the developed method overcomes the contradictions inherent in the component (analytical) and holistic (holistic) approaches, ensuring their methodological combination within the framework of a comprehensive systemic assessment.

**3.2.3. Formation of the space of possible states**

The formalization of criteria and their values is a key stage in the developed method, since thanks to them, a set of multi-criteria alternatives is formed during the assessment,

which reflect different states or levels of formation of the intellectual capital of IT companies. Each IT company, assessed according to a certain set of criteria, actually forms a unique profile of its functional and structural properties of the IC. This profile is a multi-criteria alternative, i. e. a vector of states (for example,  $C = \{c_1, c_2, \dots, c_n\}$ ), where each element  $c_i$  corresponds to a certain value of the criterion. Thus, the developed model operates with a set of multidimensional alternatives, which significantly increases the analytical depth and provides the possibility of a clear assessment of the unique state of the IT company's intellectual capital relative to all possible states.

The set of all possible states of intellectual capital (the so-called state space of the system) is calculated as the Cartesian product of the number of all discrete values for each scale of criteria.

If  $N_i$  is the number of values (variants) of the  $i$ -th criterion, then the total number of possible states ( $M$ ) is determined by the formula

$$M = N_1 \times N_2 \times \dots \times N_n = \prod_{i=1}^n N_i. \tag{8}$$

That is, for 3 criteria, where one criterion is binary with 2 values ( $N_1 = 2$ ), one qualitative criterion with 3 values ( $N_2 = 3$ ) and one quantitative with 5 values (ranges) ( $N_3 = 5$ ), the total number of possible multi-criteria alternatives according to formula (8) will be  $M = 2 \times 3 \times 5 = 30$ .

**3.2.4. Criteria weighting factors**

A comprehensive system assessment of the intellectual capital of an IT company may require a large number of criteria that differ in their impact and significance. To ensure the mechanism for their differentiation, the developed method provides for the possibility of additional (optional) assignment of an importance coefficient ( $K_{imp}$ ) to the criteria with the possibility of its update and complete cancellation if necessary.

The criterion differentiation mechanism is used in response to the evolutionary nature and nature of the functional request of the meta-system (IT market). This approach allows to take into account changes in current market conditions, when certain criteria may acquire increased priority and critical importance for maintaining the functional properties of the meta-system. Nowadays, these may be criteria related to code security, software architecture quality, use of artificial intelligence, etc. In turn, certain criteria may, on the contrary, lose their significance over time.

In classical assessment models based on the principle of "zero-sum game", increasing the weight of one criterion requires a forced reduction in the weights of others, which makes them inflexible and complex with

a large number of criteria. In the developed weight model, it is proposed to use importance coefficients  $\geq 1$  ( $K_{imp} \geq 1$ ), which is a fundamentally different approach to forming an assessment model, unlike traditional criterion weights. This approach avoids the complexity of traditional normalization, where the sum of all weights is equal to 1 ( $\sum W_{cr} = 1$ ).

The proposed multiplier coefficients ( $K_{imp} \geq 1$ , where 1 is the base value) use a scale derived from the Fibonacci series. This allows for a harmonious and nonlinear differentiation of the values of important functional and structural properties of the IT company's IC in the final indicator of the degree of systematization ( $\mu_s$ ), without limiting the significance of other elements of the intellectual capital of IT companies. Using the Fibonacci series to determine the importance coefficients ( $K_{imp}$ ) avoids the subjectivity of experts and arbitrary or unfounded values (for example, 1.01 or 1.15). This approach is methodologically consistent with the widespread practice in the IT sphere of assessing the complexity of tasks in story points and eliminates the need for constant rebalancing of the entire model.

Thus, the developed approach ensures not only the systematic consistency of the criteria with the Fibonacci series and the degree of systemization scale ( $\mu_s$ ), but also provides experts with a reasonable, understandable and universal toolkit for differentiation.

The formula for calculating the importance coefficient ( $K_{imp}$ ) has the following form

$$K_{imp} = 1 + \frac{F_n}{10}, \tag{9}$$

where  $F_n$  – the corresponding number from the Fibonacci series (1, 2, 3, 5, 8, 13, ...).

The use of coefficients derived from the Fibonacci series helps to highlight important criteria and, accordingly, provide a methodologically sound assessment of priority areas and significant parameters of the IC of IT companies. Calculation of coefficients for determining the importance of criteria according to formula (9) are given in Table 6.

**Table 6**

Calculation of criteria importance coefficients

Importance level	Values from the Fibonacci series, ( $F_n$ )	Calculation of the importance coefficient ( $K_{imp}$ ) according to formula (9)
Low	1 ( $F_2$ )	$1 + \frac{1}{10} = 1.1$
Moderate	2 ( $F_3$ )	$1 + \frac{2}{10} = 1.2$
Medium	3 ( $F_4$ )	$1 + \frac{3}{10} = 1.3$
High	5 ( $F_5$ )	$1 + \frac{5}{10} = 1.5$
Very high	8 ( $F_6$ )	$1 + \frac{8}{10} = 1.8$
Critical	13 ( $F_7$ )	$1 + \frac{13}{10} = 2.3$

The developed scale of importance of criteria and the principle of its expansion (narrowing) based on the Fibonacci series provide experts with the opportunity to clearly differentiate criteria based on a limited set of nonlinear values. This approach greatly facilitates the choice of coefficient and provides the opportunity to compare the importance of criteria identically to the complexity of tasks in story points. As in the case of assessing the complexity of tasks, the nonlinearity of these coefficients reflects the increasing importance and influence of critical parameters on the overall degree of systemization ( $\mu_s$ ) of the IC in the final class. The use of Fibonacci-oriented importance coefficients in the process of expert development of criteria ensures

methodological consistency and reduces the empirical error associated with the subjectivity of expert decisions, enhancing the final reliability of the indicator of the degree of systemization ( $\mu_s$ ) when classifying the IC of IT companies. Taking into account the above, the definition of the class of the IC of IT company in general terms within the framework of the developed method looks as follows. The obtained values for the criteria are multiplied by the importance coefficient (if any) and then the obtained values are added

$$S = \sum_{i=1}^n (K_{imp,i} \times W_{cr,i}), \tag{10}$$

where  $K_{imp}$  – the importance coefficient of the criterion,  $W_{cr}$  – the obtained weight for the criterion

To obtain a distribution in the standard range [0; 1] or [0%; 100%] after aggregating all the obtained values ( $S$ ) when assessing the IC of a particular IT company, final normalization is applied. This ensures the comparability of the IC of IT companies regardless of the number of criteria used

$$R = \frac{S}{\sum W_{cr,i}}. \tag{11}$$

That is, if an IT company, for example, received a value of 3 out of 5 possible, then according to formula (11) it is possible to obtain a value  $R = 3/5 = 0.6$  corresponding to one of the classes of the general classification, for example, class 3.

Thus, the degree of systemization ( $\mu_s$ ) is a one-dimensional projection of a multidimensional distribution of alternatives onto an open interval (0; 1) with explicitly allocated boundary points 0 and 1 ("Explicit Zero" and "Explicit One", respectively). It is this model that makes it possible to unambiguously classify any unique profile of the intellectual capital of IT companies, regardless of its complexity and structural configuration.

That is, if the alternative vector is described as  $C = \{c_1, c_2, \dots, c_n\}$ , then the degree of systemization is some aggregation function of this vector

$$\mu_s = f(C), \tag{12}$$

where  $0 \leq \mu_s \leq 1$ .

This function plays the role of a projection, that is, it reflects the collapse of a set of multidimensional states into a single integral indicator of the degree of systemization ( $\mu_s$ ).

### 3.2.5. Full example and analysis of alternatives

After a detailed consideration of all the main elements and steps of the developed method, a full example of its practical application is given below and an analysis of alternatives is carried out.

To simplify the calculations, a set of two criteria with three values each was used. In this case, the first criterion is assigned the importance coefficient  $K_{imp1} = 1.1$ , and the second  $K_{imp2} = 1$ . Next, the IC classification was carried out according to 3 classes ( $k = 3$ ) using the subclasses "Explicit Zero" and "Explicit One". Given the uniformity of the calculations of weight values ( $W_k$ ) for classes and criteria, the corresponding data were obtained directly from Table 3 and Fig. 4.

Thus, for the example under consideration, where the first criterion has 3 values ( $N_1 = 3$ ) and the second also has 3 values ( $N_2 = 3$ ), the total number of possible multi-criteria alternatives according to formula (8) will be  $M = 3 \times 3 = 9$ . According to Fig. 4, for a criterion with 3 values, the weights will be 1, 0.8 and 0. Finally, the distribution of possible alternatives will be as follows, see Table 7.

In the given simple example (with two criteria of 3 values), 3 alternatives ( $C_1, C_2, C_4$ ) fell into the first class, 3 into the second ( $C_3, C_5, C_7$ ), and 3 into the third ( $C_6, C_8, C_9$ ).

Table 7

The set of probable states (alternatives) and their distribution by classes on the scale of the degree of systemization

Parameters	$C_1$	$C_2$	$C_3$	$C_4$	$C_5$	$C_6$	$C_7$	$C_8$	$C_9$
Criteria 1 with $K_{imp1} = 1.1$	1	1	1	2	2	2	3	3	3
Criteria 2 with $K_{imp2} = 1$	1	2	3	1	2	3	1	2	3
State vector	(1; 1)	(1; 2)	(1; 3)	(2; 1)	(2; 2)	(2; 3)	(3; 1)	(3; 2)	(3; 3)
Total value for state, ( $S$ )	2.1	1.77	1.1	1.737	1.407	0.737	1	0.67	0
Degree of systemization, ( $\mu_s$ )	1	0.842	0.523	0.827	0.67	0.35	0.476	0.319	0
IC class	1 (EO)	1	2	1	2	3	2	3	3 (EZ)

It should be noted that in real conditions, in practical application, there are no restrictions on the number, type of criteria and their values, which can potentially increase the number of alternatives to  $10^{100}$  or more. In this case, it is not necessary to perform full calculations of the distribution by class, since the actual number of alternatives that require calculation is equal to the number of IT companies that have decided to evaluate their intellectual capital.

### 3.3. Assessment of the possibilities of software implementation and integration of the method into analytical and expert systems

In the context of practical application of the proposed method, first of all, it should be noted that the calculation of the integral assessment is carried out for each alternative separately and does not require the implementation of complex combinatorial procedures. Unlike classical brute force or pairwise comparison methods (for example, the hierarchy analysis method), which have quadratic or exponential complexity, the proposed approach is characterized by linear computational complexity  $O(n)$ , where  $n$  is the number of evaluation criteria. This means that the calculation time increases directly proportionally to the number of criteria, because the calculations are performed separately for each specific IT company. In this case, the calculation is reduced to simple mathematical operations: the obtained values for the criteria are multiplied by the importance coefficient (if any), then these values are added, and the final result is normalized by division. Such an algorithmic structure of the proposed method is optimal from the point of view of software implementation and does not require significant computing resources. This means that the deterministic complexity allows the client part of the system to be implemented even on performance-limited computing devices, including personal computers, tablets or smartphones with minimal system requirements. This makes the method highly effective, accessible for wide practical application and suitable for software implementation. In particular, a possible software implementation option is a web application in the format of Single Page Application (SPA) or Progressive Web App (PWA) with a server part in the form of scalable services or microservice architecture.

In this context, the prospects for integrating the method into analytical and expert information systems are determined by its architectural and technological features, among which the following can be distinguished:

1. *API-orientation.* The method can be easily encapsulated in the form of a RESTful API, which creates the possibility of automated collection of input data directly from corporate information systems of IT companies (HRM, ERP, project management systems, etc.). This will reduce the subjectivity of manual data entry and increase the reproducibility of assessment results.

2. *Semantic adaptability and graph modeling.* In order to adequately reproduce the complex topology of intellectual capital, it is advisable to use graph databases, which will allow transforming static tabular data into a live semantic network. In combination with the proposed assessment method, this opens up new analytical possibilities. In particular, based on the obtained quantitative indicators, it becomes possible to model the states of the system "if-then" (what-if

analysis), which turns the IC assessment from a statement of fact into a proactive management tool.

3. *Possibilities of predictive analytics.* The accumulation of historical data of the assessment results creates a basis for the further application of machine learning methods in order to predict the dynamics of the development of IT companies and assess their potential success based on the current level of intellectual capital.

### 3.4. Discussion

Taking into account the above, it can be concluded that the developed method for assessing the IC of IT companies, which is based on the fundamental principles of systemology, proves its broad methodological orientation. Systemology, as a scientific concept, allows to effectively study and investigate complex objects of arbitrary nature, determine their essential properties, as well as the reasons for their occurrence, the dynamics of adaptation and development. That is why it allows for more effective management of any complex objects to ensure their stability and security, predict development and study fundamental problems. Interpreted in terms of a specific science, systemology can perform unlimited methodological functions in this science.

The key element of the developed method for assessing the IC of IT companies is a nonlinear and methodologically sound weight model based on the Fibonacci series, which allows:

- to objectively classify ICs through the use of the inverse Fibonacci series, due to which moderate nonlinearity of the distribution of weight coefficients is achieved and the natural harmony of system relationships is preserved;
- to effectively differentiate criteria, due to which, in the process of classifying multi-criteria alternatives, qualitative performance is clearly separated from its absence, and the weight coefficients of importance ( $K_{imp}$ ) determine the exact contribution of each criterion to the integral value of the degree of systemization ( $\mu_s$ ).

The developed method is a reliable, systemically consistent tool, which, due to the simplicity and universality of its application, provides effective and uncomplicated work with multi-criteria alternatives of arbitrary complexity. This is achieved by collapsing the complex multidimensional state space into a single integral indicator of the degree of systemization ( $\mu_s$ ) and provides a highly accurate assessment of the quality of systemic integration of ICs into the market environment.

The conducted research confirms that IT companies function as stochastic systems, and the properties of their IC cannot be reduced to a simple sum of its components. The effectiveness of the proposed evaluation method is explained by the fact that the mathematical apparatus of the Fibonacci sequence used isomorphically reflects the natural processes of growth and self-organization inherent in complex socio-economic systems. The high differentiating ability of the degree of systemization ( $\mu_s$ ) is interpreted as a consequence of taking into account the emergence effect: the method captures not just the availability of a resource (for example, personnel), but the harmony of its adaptation to the request of the meta-system (IT market). The introduction of the concepts of "Explicit Zero" and "Explicit One" allowed to interpret the limit states of the system not as abstract mathematical points, but as

qualitative levels of complete disorganization or ideal systemic coherence, respectively.

A distinctive feature of the developed method is overcoming the methodological opposition characteristic of existing component and holistic methods of IC assessment. In particular, the proposed method, thanks to the nonlinear distribution of weights based on the Fibonacci sequence, allows for a systematic assessment of the unique state (profile) of the IC of an IT company, taking into account both the state of its individual elements and emergent properties as a whole. This allows for objective identification of hidden risks of loss of stability of an IT company even before they appear in financial statements. The uniqueness of the method lies in the combination of the mathematical rigor of quantitative assessments with the flexibility of qualitative systemic analysis. This allows for the formation of adaptive ratings of IT companies based on systemic IC metrics without a complex procedure for retraining the model when market conditions change and the corresponding change in the set of evaluation criteria. The practical value of the proposed method goes beyond a simple tool for calculating the integral indicator of the degree of systematization. The main value of the method lies in the possibility of its use for building an adaptive rating of IT companies with full automation and integration into expert-analytical software complexes. This opens the way to operational monitoring of the dynamics of intellectual capital development, multi-criteria comparison of IT companies, as well as forecasting the development trajectories of both individual IT companies and the IT sphere as a whole. Due to the versatility of the proposed mathematical approach, the method is not limited to the IT industry and can be effectively adapted to assess the degree of systemization and rating of objects in any other field of activity.

The key limitation of the proposed method is its dependence on the quality of the input data. The objectivity and validity of the final indicator of the degree of systemization ( $\mu_s$ ) directly depend on the completeness, correctness and adequacy of the set of criteria that experts formulate when determining the functional request of the meta-system (IT market). An incorrect or incomplete set of criteria will lead to a biased and/or unsystematic assessment. This research focused on the theoretical and methodological substantiation of the weight model. However, for full implementation, further empirical verification on real data of IT companies and comparative analysis of the obtained results with existing economic indicators (e. g., ROI, EBITDA, market capitalization, etc.) is necessary.

The directions of further research are based on the current limitations and tasks of practical implementation of the developed method. First, the priority direction is the empirical testing of the method through its software implementation in the form of a full-fledged expert-analytical complex and its testing on a sample of real IT companies. Second, to reduce subjectivity, the current direction is the development of methodologically justified criteria according to ontological (classification) models of intellectual capital for different types of IT companies (for example, product, outsourcing, R&D, etc.). Third, the study of the dynamics of the degree of systemization ( $\mu_s$ ) over time and the application of artificial intelligence for automatic identification and formalization of criteria based on the analysis of current market conditions (meta-system query) is of scientific interest.

#### 4. Conclusions

1. The systemological approach to assessing the intellectual capital of IT companies is substantiated, the feature of which is the use of the degree of systemization ( $\mu_s$ ). It is proven that the use of a degree of systemization ensures systematic consistency of the assessment of heterogeneous criteria (qualitative, quantitative), which increases the accuracy of the assessment. The result of the assessment is to obtain an objective integral value in the interval [0; 1], suitable for ranking alternatives and comparative analysis. The practical value of the developed

method lies in the creation of a universal toolkit that overcomes the limitations of holistic and component assessment methods.

2. A mathematical apparatus and algorithm for a nonlinear model of assessment and classification of multi-criteria alternatives have been developed, the feature of which is the combination of a systems approach and the Fibonacci sequence. The resulting algorithm allows to form unique profiles of the state of intellectual capital of IT companies and classify them by the level of systemic consistency (adaptation) with the functional request of the meta-system (IT market). The practical value of the method lies in its scalability and versatility: the developed toolkit is suitable for both a holistic IC assessment as a whole and for the analytical assessment of individual sub-systems (in particular, human capital). The method can also be adapted to solve multi-criteria assessment problems in other subject areas without restrictions on the number of criteria and their types (qualitative, quantitative). The developed method allows for a clear differentiation of alternatives even with close values of partial indicators, which increases the sensitivity of the developed weight model and its analytical value.

3. The possibilities of software implementation of the developed method are assessed and the prospects for its integration into expert and analytical decision support systems are substantiated. It is established that the algorithm of the method is computationally efficient and can be implemented in the form of a software module for analytical platforms of IT companies. In particular, the developed method is characterized by linear computational complexity  $O(n)$ , where  $n$  is the number of evaluation criteria. The practical use of the results allows to increase the validity of management decisions regarding the development of intellectual capital, optimization of its structure and comparisons (benchmarking) of IT companies in dynamics. Also, based on the system metrics of intellectual capital, it is possible to form a rating of IT companies. It is also important that the practical use of the developed method does not require special training of users, which is critical in conditions of limited time and resources of the dynamic IT market.

#### Conflict of interest

The author declares that he has no conflict of interest in relation to this research, including financial, personal, authorship or other, which could affect the research and its results presented in this article.

#### Financing

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#### Data availability

The manuscript has no associated data.

#### Use of artificial intelligence

The author confirms that he did not use artificial intelligence technologies in the creation of the presented work.

#### Authors' contributions

**Oleksandr Andreichikov:** Conceptualization, Methodology, Formal analysis, Writing – original draft preparation, Writing – review and editing.

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