INTELLIGENT ENTERPRISE CAPITAL CONTROL BASED ON MARKOV CHAIN

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Abstract
This scientific work is devoted to the processes of creating technologies, as well as the use of their mathematical representation in the form of models in the context of the formation and development of the intellectual capital of an enterprise. To select a goal, a vision was formed to prove or refute any possibility of using Markov's theory in practice, namely the creation of a stochastic model of the intellectual capital of an enterprise in monetary terms, which manifests itself in investments in intangible assets.
As an initial model hypothesis, the statement is accepted that investments in the enterprise's intangible assets are a factor in the transformation of intellectual capital into the company's value. Based on the results of applying the stochastic Markov chain model, the potential profit of the company's intangible assets was estimated, the main elements of which were intellectual capital assets during the study. A matrix of transition probabilities has been formed and modeling of the limiting probabilities of the system states has been implemented. The necessary conditions and boundaries of the scope of the mathematical model are also determined. The mathematical method of modeling the company's intellectual capital proposed in the article allows determining the contribution of each of the structural components to the formation of the value of the enterprises intellectual capital, thereby making it possible to establish a current balance between all its elements, which contributes to a comprehensive study of the company's intellectual assets.

Keywords
markov chain; intelligent control; stochastic modeling; investments.

Introduction

In the modern economic practice of studying the company's IC, expert methods for determining the value of its individual components predominate. The similarity to tools is also seen in the VAIC (Value Added Intellectual Coefficient) model, which considers the assets of an enterprise, can be both tangible and intangible. Namely: value added of physical capital (CEE), value added of structural capital (SCE) and value added of human capital (HCE). The value of the intellectual value-added coefficient (VAIC) is the sum of these indicators, which reflects the efficiency of the company's use of intellectual assets, which is the ability to create added value [1]. Another example widely used in the financial analysis of an enterprise's intangible assets is the calculation of the Market Value Added (MVA) indicator. This approach implies that the difference obtained between the market and book value of the company's assets is the value of the company's IC [2].

The existing financial and non-financial methods for assessing the IC of an enterprise are usually divided into the following groups [3]:

- Methods of direct measurement of IC (Direct Intellectual Capital methods - DIC) - methods in which the value of IC, expressed in monetary terms, is determined as the sum of the values of intangible assets owned by the enterprise.
- Methods of market capitalization (Market Capitalization Methods - MCM) - methods in which the value of the IC of an enterprise is determined by the difference between the market and book value of the company's assets.
- Return on Asserts methods (ROA) - methods in which the value of the enterprise's IC is determined by discounting cash flows from the use of intangible assets.

Scorecard Method (SC) is a non-financial method for evaluating an enterprise's IC using indicators and indices that reflect the value of its various components by scoring. The limited application of these methods is associated with a significant dependence of the results on the chosen methodology of expert evaluation and on the sample size of panel data, and also as a consequence of the fact that the probabilistic behavior of the market does not lend itself to the assumptions of the law of normal distribution - the impossibility of obtaining plausible results of estimating IC when predicting its value under conditions macroeconomic fluctuations.

In contrast to similar approaches, the methodology proposed by the authors for studying the enterprise's IC is based on stochastic modeling using the theory of Markov chains and the relationship between the company's investments in the enterprise's intangible assets and the value created by the company's IC.

It should also be noted that the existing studies (Table 1) of the relationship between the elements of intellectual capital and company efficiency showed a strong and/or confident positive relationship between these elements.

Table 1. The impact of the development of intellectual capital on the efficiency of the company. *Source: analyzed by the authors.*

No.	Author	Statement (approach)
1	Kujansivu et al. [4]	Based on a statistical analysis of financial statements, indicates a strong relationship between the amount of intellectual capital and the performance of Finnish companies, not only in high-tech industries and in the service sector of the economy, but also in the gas industry, in electric power companies.
2	Peng et al. [5]	The author explores the nature of the relationship between the elements of intellectual capital in the process of transforming business models in the healthcare sector, showing that intellectual capital indirectly affects the efficiency of companies.
3	Cabrita et al. [6]	The study is based on a three-component "navigator" of intellectual capital, reveals a strong relationship between structural capital and the performance of companies in the Portuguese banking sector based on the analysis of structural equations.
4	Andreeva et al. [7]	Use structural models to study intellectual capital in industry based on an analysis of the experience of 240 companies, noting that structural and human capital have a positive impact on performance, while there are no stable significant links between performance and relational capital.
5	Santos-Rodrigues et al. [8]	They show that human capital is important for maintaining process and product innovations in companies, which in turn determine competitiveness at a strategic level.
6	Chen et al. [9]	They note that the external and internal elements of intellectual capital have a positive impact on the technological competencies of the company, which are directly related to its financial performance.

The mechanisms of the influence of intellectual capital on performance are also covered in the literature. Among the key drivers of competitiveness and value of companies, researchers note innovations that are born as a result of using elements of intellectual capital to support business, as well as additive effects that appear due to the combination of intellectual resources in everyday activities.

Methods

In the used mathematical model for studying the intangible assets of an enterprise, it is assumed that the investment process in the elements of the company's IC is stochastic in nature and is one of the factors affecting its transformation into value. Therefore, we believe that the costs of forming an IC company are equivalent to investments for the purpose of further capitalization [10]. In accordance with the above, a general paradigm of the IC structure was formed. So, it was determined that at the first level (stage) it is necessary to compare and / or analyze the company's capital investments in its structural elements. These can be called potential or possible scenarios of the analysis system, which will later be evaluated at their cost. At the second level (stage), a chain of Markov is created, the states of which are the components of the IC, reflecting their created value, and a matrix of the conditional probabilities of the transition of the system is formed, characterizing the stochastic nature of the investment process into the elements of the Markov chain. At the third level (stage), the dynamics of the changes in the enterprises IC are simulated, a motionless stochastic vector is determined, the components of which characterize the limiting probabilities of the states of the studied system. The model allows you to obtain probabilistic distribution of IC elements in its common structure in accordance with the quantitative equivalent of the created value. The structure of the IC enterprise is defined by the authors of this article using the example of Edvisson's approach. In accordance with the concept proposed by Edvisson, IC are divided into two categories: intellectual capital and accumulated (structural) capital [11].

The scheme of transformation of IC into value as a result of the company's investments in intangible assets (Figure 1).

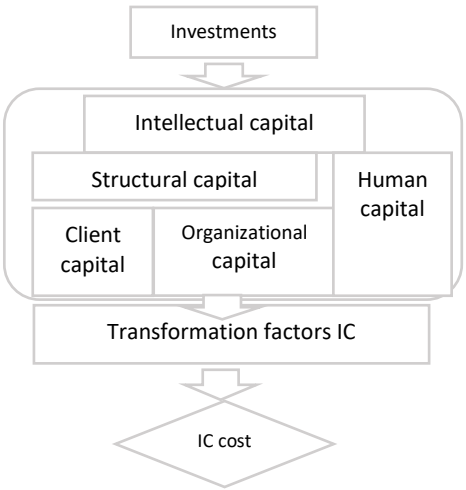

Figure 1. The scheme of transformation of investments into elements of the IC enterprise. *Source: own development.*

Following the proposed scheme (Figure 1), investments in IC are distributed between structural and human capital, where the following are accepted as objects of investment activity in the company's intangible assets: human capital, enterprise capital, client capital. At the next stage, due to the influence of transformation factors, investments in IC components are converted into the value of IC as one of the enterprises assets. Investment activity in the enterprises IC components is presented (Table 2).

For this study, it was customary for the authors to use the financial relationship between investments and their future cost changes in the value of the company's IC as a mathematical relationship.

Table 2. The activity of the enterprise in investments, considering the components of IC. *Source: own development.*

Element IC	**Type of enterprise investment**	**Articles of investment activity of the enterprise**
Human capital	Payroll costs	Payroll
	Investments in human capital	Investments in social policy. Costs for training and retraining
Organizational capital	Management costs	Management expenses
	Production organization costs	Investment in refurbishment. Investment in innovation
	Waste on the organization of labor	Payment of advances to suppliers and subsidiaries and affiliates for raw materials and services
Client capital	Customer Acquisition and Retention Costs	Selling expenses
		Payment to customers for raw materials and services

To assess client capital (Client Value - CLV), we used the method proposed by Berger and Nasr - the BN approach [12]. This method uses the following assumptions:

- the cost of customer retention is assumed to be annual, and the retention rate remains constant over time,
- sales of goods and services are annual,
- and the profit received from the customer remains the same over the entire period of cooperation with the company.

Based on these assumptions, the following relationship is used to calculate CLV:

(1) $$CLV = GC * \sum_{I=0}^{n} \frac{r_i}{(1+d_i)} - M * \sum_{I=1}^{n} \frac{r^{i-1}}{(1+d)^{i-0,5}}$$

where n - is the number of years;
d - is the annual discount rate;
GC – is the annual profit received from the buyer;
M – is the annual investment in customer retention;
r - is the customer retention rate.

To assess human capital (Human Value - HV), the calculation method was applied taking into account the goodwill factor [13,14]:

(2) $$HV = K * Gd + I * t$$

where K - is the wages paid to the staff;
Gd - is the goodwill of the personal potential of the personnel;
I – is the investment in human capital;
t - is the period under consideration.

At the same time, wages in this case are treated not as company costs, but as investments in personnel in order to create additional value.
Thus, it is possible to determine the business reputation of the company [15]:

(3) $$Gd = I_{pr} + I_{cs} + K_p$$

where I_{pr} - is the profitability index;
I_{CS} – is the cost index;
K_p– is the coefficient of personal prospects.

Organizational capital (Organizational Value - ORV) is defined by the authors as the sum of the value of innovation capital (Innovation Capital - INC) formed by the enterprise and the company's total investment in process capital (Process Capital - PRC):

(4) $$ORV = INC + PRC$$

where INC - is the cost of innovative capital;
PRC – is the investment in process capital.

In this case, the total amount of innovation capital can be defined as the sum of the costs and developments of research activities, which in turn also entails the cost of intangible assets of the enterprise. The joint-stock company "Military-Industrial Corporation" Scientific and Production Association of Mechanical Engineering" (hereinafter referred to as "S&P Mechanical Engineering ") was chosen as the object of study. Data on investment activity and assessment of the elements of the intellectual capital of the company under study: client (CV), human (HV) and organizational (ORV) capital are presented in Tables 3-5, respectively, and in Figure 2.

Table 3. Estimation of the value of the client capital of the company "S&P Mechanical Engineering ". *Source: calculated by the authors*

Client capital, CV					
Year	Discount rate (d), %	Sales profit (GC), UAH	Customer retention costs, (m), UAH	Customer retention rate (r), %	Price (CV), UAH
2021	4.17	1 704.857	5271.871	90	27359.80
2020	4.32	914.782	5216.714	90	13213.90
2019	4.79	1 888.76	4741.083	90	27388.65
2018	3.85	1 709.626	5143.398	90	29389.52
2017	5.40	1 444.716	3581.835	90	18900.47
2016	5.56	1 961.977	4937.228	90	24989.70
2015	5.01	833.330	3365.941	90	11106.16

Table 4. Estimating the value of a company's human capital "S&P Mechanical Engineering ". *Source: calculated by the authors.*

Human capital, hV				
Year	Payroll costs (K), UAH	Goodwill (Gd), units	Investments in hV, (InVhV), UAH	Price (hV), UAH
2021	2 649.23	6.80	115.30	18118.73
2020	2 416.65	6.07	88.30	14764.03
2019	1 968.85	6.19	86.00	12270.95
2018	1 636.50	6.04	83.90	9975.22
2017	1 431.26	6.39	79.20	9223.23
2016	1 226.66	5.53	69.30	6856.62
2015	1 004.61	5.53	66.10	1 004.61

Table 5. Estimation of the cost of the company's organizational capital "S&P Mechanical Engineering ". *Source: calculated by the authors.*

Human capital, orV					
Year	Investment capital (InC)	Process capital, prC			Price, UAH
	Cost of intangible assets, UAH	Organization of production, UAH	Management organization, UAH	Labour Organization, UAH	
2021	1 050.172	1 493.600	1518.928	9 004.297	13 066.00
2020	1 178.027	1 349.800	1095.971	14 895.630	18 519.43
2019	732.224	1 693.900	0	18 773.163	21 199.29
2018	571.571	1 827.400	0	10 833.129	13 232.10
2017	469.598	1 266.100	0	6 480.280	8 215.98
2016	672.120	817.800	0	4 937.228	6 427.15
2015	698.012	813.600	0	3 365.941	4 877.55

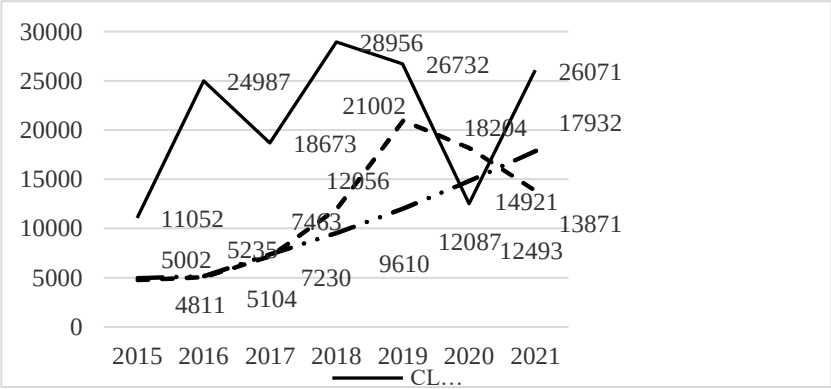

Figure 2. The scheme of transformation of investments into elements of the IC Enterprise. *Source: calculated by the authors.*

An analysis of the IC components of an enterprise in the period from 2015 to 2021 showed that the only steadily growing investments were made in human capital. That is, the enterprise, based on existing scientific developments, considers the fact that personnel is essential for its development. As for the other two components - organizational and client, they do not have a constant stable upward trend, which indicates the changeable nature of investments in these areas. Correspondingly, these intangible assets, which are difficult to calculate in monetary terms, do not cause the enterprise to initiate transformational development processes. When forming goals, missions and ways to implement them, enterprises practically do not consider the assessment of intellectual capital. Nevertheless, a fairly complete review of the methods for measuring intellectual capital was presented by Sveiby in 2010 [16]. He identifies 25 measurement methods grouped into 4 categories:

a) methods of direct measurement of intellectual capital. This category includes all methods based on the identification and valuation in monetary terms of individual assets or individual components of intellectual capital. Thus, an integral assessment of the company's intellectual capital is derived. In the modern world, the assessment of intellectual capital by its elements (human, structural and consumer capital) in monetary terms does not provide for a formed system of their accounting.

b) methods of market capitalization. In this case, the cost of intellectual capital is considered as the difference between the market capitalization of the enterprise and its own capital. When using methods in this category, note the following:

- the formation of the value of shares in the stock market cannot affect the management of an enterprise with intellectual capital, since government policies, and vice versa, the stock market practically does not depend on the “mood” of economic agents;
- capital has a special attitude to accounting for the intellectual capital of high-tech and knowledge-intensive companies. For example, the bankruptcy, liquidation or sale of such companies at a price below the level of their market value does not indicate the absence of intellectual capital at all;

- unfortunately, industrial enterprises skillfully manipulate valuation indicators, such as accounting for the value of assets and market capitalization. Depending on the purpose of their use, the value of indicators is overestimated or underestimated. For example, their artificial increase can have a positive impact on attracting investment;
- from the point of view of managing the intellectual capital of an enterprise, managers no longer pay attention to its total cost, but to its elements, which are considered in the dynamics of the analyzed period. Including companies consider the performance of their competitors.
  One example of valuing investments using market capitalization methods is the Tobin ratio. With its help, you can determine the degree of efficiency of the enterprise. A company can have tangible assets of similar value, but at the same time have a greater economic benefit, which will certainly be reflected in an increase in its market price. The Tobin coefficient indirectly considers the value of investments in human capital, as well as in research and development;

c) methods of return on assets. These methods adhere to the following theory that it is the value of intangible assets that is the price that distinguishes an enterprise from its competitor.

From this approach, it follows that the difference in the intellectual assets of the enterprise, which it may not have, corresponds to its lost value. In confirmation of this assumption, the task is to determine the price that a competitor pays for his miscalculations - neglect or inability to manage intellectual assets. Based on this, the accounting of intellectual capital occurs in the following sequence:

- for a specified period, the gross profit of the enterprise is calculated, the balance sheet is used as a data source;
- for a specified period, the average cost of fixed production assets is calculated, the balance sheet is used as a data source;
- then the overall profitability of the enterprise is calculated by dividing the first action by the second: funds - gross profit by the value of fixed assets;
- the overall profitability of the industry is established using statistical data;
- it remains to calculate the profit delta, the value of the excess of the enterprise's profit over the profit of an average company in the industry. To determine it, from the gross profit of the company, it is necessary to subtract the product of the total profitability for the industry and the average value of the company's fixed assets;
- the average amount of the tax is calculated for the established period;
- further, the company's premium is calculated for the effective use of its intellectual capital (the average tax is deducted from the profit delta);
- the cost of capital for the enterprise is set within 10% - 20%;
- then the enterprise premium is divided by the established cost of capital, this value is considered the net present value of intellectual capital.

Thus, the heads of the enterprise can determine the value of intellectual capital, which was not previously reflected in its balance sheet. With its help, it will not be difficult to determine the competitiveness of the company, due to intellectual resources, among competitors limited to one industry. It also allows for intra-enterprise analysis, such as between business units or across entire companies within a corporation. But unlike obtaining data on the enterprise, which is usually easy, with reliable data on competitors, difficulties most often arise. This method has a significant drawback: the resulting delta will not necessarily be the result of the effective and profitable use of intellectual capital, it may be determined by business conditions, the state of fixed assets, the availability of tax incentives in the region, and more.

d) scoring methods. Various components of intangible assets or intellectual capital are identified, indicators and indices are generated and reported in the form of scoring or as graphs. This category does not involve the evaluation of intellectual capital in monetary terms. It is similar to the diagnostic information system methods.

Results and discussion

Considering the fact that the intangible assets of the company's IC are very difficult to calculate financially, we presented an assumption, what kind of investments and/or financial investments in the structure of the company's IC under any possible situations and risks have a positive effect on the transformational processes of

the enterprise's development. That is, the higher is the activity of the company's investments in its ICs, the higher is their development in particular and in general. In the course of our study, we believe that the structure of the company's IC is and investments in it are constant and continuous, which allows us to draw more reliable analysis conclusions in a given time period. We believe that the process of investing in the company's IC components directly depends only on its current state, and not on the factors of past possible investments and their latest, as well as all possible future ones. All considered events of the system are incompatible. Therefore, we believe that an increase in the company's investment in the corresponding element of the IC does not cause a simultaneous increase in investment in another element. So, it is possible to observe the system at discrete moments of time $t_0<t_1<t_2$… and let be $p_k = [p_1(t_k), …, p_n(t_k)]$ - a probability vector, where $p_j(t_k)$ - the absolute probability of the system S_j in a state of time t_k for j=1, 2,…, n; k = 0,1,2,…
Interpreting the above in terms of the described model, we believe that the probability vector p_K describes the probability of transformation of the corresponding capital S_j (Figure 3).

	CLV	ORV	HV
CLV	p_{11}	p_{12}	p_{13}
ORV	p_{21}	p_{22}	p_{23}
HV	p_{31}	p_{32}	p_{33}

Figure 3. Enterprise IC transition matrix. *Source: own development.*

Conditional probabilities p_{ij}, forming a transition matrix P of the system S, are defined as the probability of the influence of the component Sj on the creation of the value of the IC at the moment of time t_kt_k if at the moment of time t_{k-1} the main influence was exerted by the Si component of the IC. Definition of conditional probabilities $p_{ij}p_{ij}$ and creating a transition matrix P system S is as follows: The time period is selected, during which the maximum cost of this element Si IC is observed i=1,2,…, n.

Conditional probabilities are determined p_{ij} for each of the component of the IC on a given time interval and normalization of their transition probabilities is performed

(5) $$\sum_{j=1}^{n} p_{ij} = 1.$$

The transition matrix of the system is written, where the elements along the diagonal show the probability of creating the value of the IC component at its maximum created value, the elements in the columns show the probability of creating the value of the element when moving from one IC component to the given one, the elements along the rows show the probability of creating value by the element, when moving from this IC component to another. When creating the IC transition matrix, to determine the transition probabilities, the authors used a sample for a three-year time period during which the maximum values of the IC element cost were observed. System transition matrix $P=(p_{ij})$ size nxn , which contains all the transition probabilities of this system for the company under study:

(6) $$P = \begin{bmatrix} 0.489171 & 0.276151 & 0.234678 \\ 0.4337579 & 0.331040 & 0.231381 \\ 0.409654 & 0.318175 & 0.272171 \end{bmatrix}$$

For the model under study, matrix P describes the conditional probabilities of transformation p_{ij} of IC components into value.
The matrix P is stochastic and is denoted $P = (p_{ij})$,

(7) $$P_{ij} \geq 0 \sum_{j=1}^{n} p_{ij} = 1 \text{ for i=1, 2,…, n}$$

Then the unconditional transition probability $p_i(t_k)$ systems into a state S_i at the time t_k on the k-m move.

(8) $$p_i(t_k) = \sum_{j=1}^{n} p_{ij} p_j(t_k - 1),\ i = 1 \ldots . n, k = 0,1,2 \ldots ..$$

Let's represent the above in matrix form: $p_k=P_{pk-1}$
And, if we assume the existence of the initial state of the system S, then let p_0 - vector column of initial states. Then the vector p_k will be written in the form:

(9) $$p_k = p_{p_0}^k,\ k=0,1,2, \ldots$$

The above process is a homogeneous Markov chain with transition matrix P [17,18]. Figure 4 shows the considered Markov chain in the form of a directed graph of system states.

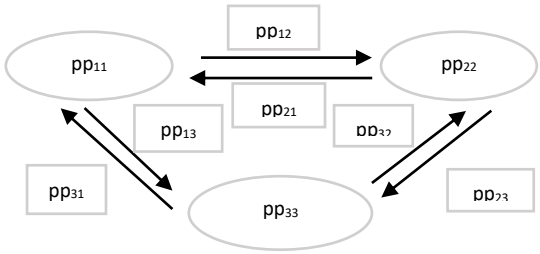

Figure 4. Enterprise IC transition matrix.*Source: own development.*

That is, under the condition of the formed probability vector at the initial state p_0 and having complete information pij, it is quite possible to simulate the possible dynamics of the change in the vector pk at each k-m step, which can qualitatively form the structure of the object's IC.
If we proceed from the assumption that, within the framework of the described model, the process under consideration is fixed and quasi-stationary, then there is a limiting behavior of the probabilities $p_i(t_k)$ at $t_k \to \infty$ and limit probabilities of states $y_i = lim_{t_k \to \infty} p_i(t_k)$, independent of the state the system S was in at the initial moment of time t_0.

Then $Y = lim_{k \to \infty} P^k$ - the limit matrix of probabilities of states - the structural components of the IC enterprise and $lim_{k \to \infty} P^k$ p_0 = y where y - is the fixed stochastic vector of the system [19]
.
Based on this conclusion, according to the initial data, the fixed vector y of the system S under study is calculated for the described mathematical model of the company's IC structure:

(10) $$\left(p_{CLV}, p_{ORV}, p_{HV}\right) * \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ p_{31} & p_{32} & p_{33} \end{bmatrix} = \left(p_{CLV}, p_{ORV}, p_{HV}\right)$$

at $p_{CLV} + p_{ORV} + p_{HV}$ = 1 where p_{CLV}, p_{ORV}, p_{HV} the marginal probabilities of the states of the client, organizational and human capitals of the enterprise, respectively.

Finding the limiting probabilities of the system is reduced to solving the system of equations:

(11) $$\begin{cases} p_{CLV}p_{11} + p_{ORV}p_{21} + p_{HV}p_{31} = p_{CLV} \\ p_{CLV}p_{12} + p_{ORV}p_{22} + p_{HV}p_{31} = p_{ORV} \\ p_{CLV}p_{13} + p_{ORV}p_{23} + p_{HV}p_{33} = p_{HV} \\ p_{CLV} + p_{ORV} + p_{HV} = 1 \end{cases}$$

where we get $y = (p_{CLV}, p_{ORV}, p_{HV}) = (0.46; 0.30; 0.24)$.

Based on the presented model of all possible conditions and restrictions, as well as on the condition of the obtained statistical data, it is fashionable to form the transition matrix P = (pij) of the system S - enterprise IC. The resulting structure of the marginal distribution of the enterprise IC components is shown in Figure 5.

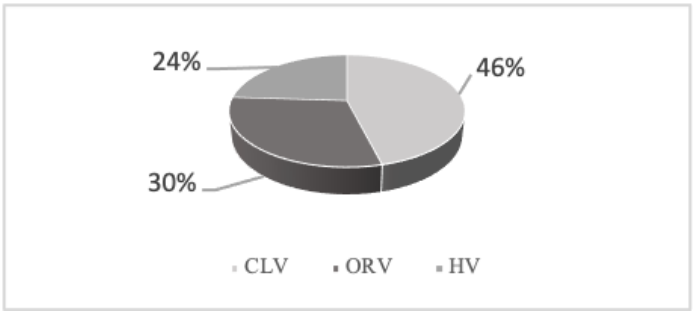

Figure 5. Distribution of shares of IC components from the total cost on the example of the enterprise "S&P Mechanical Engineering". *Source: own development.*

The result obtained can be interpreted as follows: regardless of the state of the considered system S at the initial moment of time, the following results of the components can be formed: CLV - 46% of the total value of the enterprise's IC, ORV - 30%, HV - 24%, respectively.

Key theoretical position that allows the application of circuit theory Markov for the study of stochastic processes is the Markov property of the independence of the conditional probability of each of the states of the process in the future t>t0, from the past t<t0 for any fixed moment of time t0 in the present [20]. Another theoretical position of the described model is the assumption that the structure of the IC enterprise is assumed to be quasi-stationary, which means, when averaged over long-time intervals, the functional dependences of the transformation of investments into the cost of IC are constant and unambiguously characterize the dynamics of changes in the IC cost of the object under study in time [21,22]. We also want to emphasize that in the course of the study a certain selection of financial data was formed, which, under any other circumstances and possible increased risks in the company and the macro environment, can negatively affect the modeling results, but to a lesser extent than the deviation is not more than 3-5%. For a more detailed presentation by the IC component in the structure of the enterprise, the data is laid out in Table 6.

Table 6. Descriptive statistics of the shares of IC elements in the overall structure for the enterprise "S&P Mechanical Engineering ". *Source: calculated by the authors.*

Observed values	**CLV**	**ORV**	**HV**
Expected value M (s), %	49.25	26.30	24.45
Standard deviation σ (s), %	10.50	7.47	5.21
Confidence interval at a = 0,05	± 7.78%	± 5.54%	± 3.86%
Simulation results	45.42%	30,30%	24.28%

Figure 6 shows the characteristics of the dynamics of fluctuations in the observed values of the shares of IC elements in its overall structure with the results of their values obtained by modeling intellectual capital, where the indices are real, the model means the observed value and the value is obtained as a result of modeling, respectively.

According to the analysis of the values of the shares of IC elements, presented in Table 6 and Figure 6, it follows that the results of modeling the behavior of IC components using the Markov chain adequately describe the distribution of shares of elements from the total cost of IC, considering the key advantages that affect their deviations from average values and causing their uneven distribution in the overall balance.In order to obtain more reliable data, namely, to test static approaches and sample the model proposed by the authors, it is necessary, in our opinion, to process and apply for a larger number of companies in the technological and high-tech fields of activity.

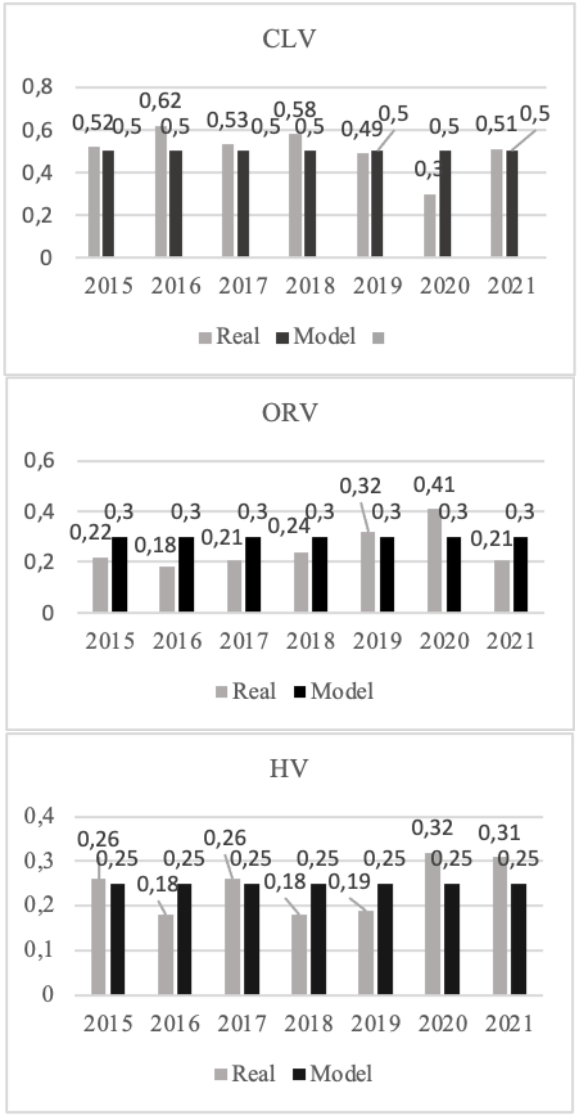

Figure 6. Dynamics of the distribution of shares of IC elements from the total cost for the "S&P Mechanical Engineering" in the period 2015–2021. *Source: calculated by the authors.*

Impact

According to the above, the advantage of the proposed method for studying IC is the possibility of modeling the IC of a company as a system operating with the presence of random variables [23], in contrast to the method of expert assessments based on the deterministic behavior of the system. With this method, the change in the value of IC and its components is reflected in the change in the value of the company, so only the improvement of the results of creative work will have a positive effect on the growth of the company's value. These methods include the creation of new lines of business, the conclusion of market transactions, the distribution of limited resources, etc. Modeling IC seems to us the most important stage in managing the value of a company, its management will allow any economic entity to identify the most promising areas for using IC, considering the properties of its components, which will allow or increase the value of the IC itself, or create added value as a result of its use, or find such conditions for its use that will positively affect the financial results of the company. The practical significance of the study lies in the ability to use the proposed model and the results obtained to search for drivers of the company's investment attractiveness and substantiate the strategy for investing in individual elements of intellectual capital. The application of the methodology for a specific company will allow us to trace the relationship between the perception of intellectual capital elements and the stakeholders' assessment of the return on the business as a whole and use the data to position intangible assets in non-financial reporting, increasing the sensitivity of investors to intellectual capital as an indicator of the company's performance. In turn, the development of intellectual capital can lead to an increase in the value of the company. After all, intellectual abilities and innovative

products in the conditions of private property and competition can create economic value, sometimes exceeding the value of all material resources. For modern industrial enterprises, patents, licenses, copyrights, culture, know-how, management approaches, corporate client databases, brands and other intellectual capital become valuable assets that define their core competencies and ensure their success in the market. Rapid qualitative technical changes, the spread of information technologies, the complication and integration of the financial market require a more detailed study and a more complete use of intangible assets.

Conclusions

As a result of the study, applying the theory of Markov chains and stochastic modeling, it was found that the proposed approach of the enterprise IC components allows determining the contribution of each and forming a system. The research methodology and the main stages of stochastic modeling of the company's IC as a set of structural components are described, based on the assumption that investments in the company's intangible assets are a factor in the transformation of IC into value. A scheme is given for converting an enterprises investment into IC elements, which differs in that the formation of the value of IC is influenced by random changes in both the external environment and internal changes in the system - transformation factors. The IC model is formalized, and a homogeneous Markov chain is written out, the states of which are the elements of the IC of the company, a method for finding the fixed vector of the system, the components of which characterize the limiting probabilities of the system being in its states-elements of the IC, is described. Analyzing the relationship between IC and its elements, it can be argued that intellectual capital is formed through the interaction of structural components that have a synergistic effect. Accordingly, for the purpose of the strategic development of the company, it is necessary to maintain a balance between all components of the IC system.

Conflict of interest

There are no conflicts to declare.

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