DOI: 10.17323/2587-814X.2023.3.53.69

Formation of the causal field of indicators for an organization's intellectual capital development: A concept and a fuzzy economic and mathematical model

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Abstract

The development of intellectual capital theory through the introduction of the concept of implicitness involves considering intellectual capital as an implicit factor, so that the process of its formation is largely determined by the impact of specific hidden factors whose impact is expressed implicitly and is difficult to formalize. Currently, the process of selecting explicit and implicit factors affecting intellectual capital is not formalized in domestic and foreign studies, and therein is the relevance of this work. The purpose of this study was to develop a scheme for selecting explicit and implicit factors in the development of the organization's intellectual capital in conjunction with its strategy based on a modified Balanced Scorecard, taking into account the distribution of indicators by types of cognitive activity. The implementation of this scheme was carried out by developing a fuzzy economic and mathematical model suitable for practical use. The main feature of the model is the possibility of fuzzy setting of "cut-off boundaries" for explicit and implicit factors. We present the results of testing the model on the example of a large regional university. Sets of explicit and implicit factors of the university's intellectual capital are given for various "cut-off boundaries" using various defuzzification methods.

Keywords: cognitive activity, fuzzy model, implicit factor, intellectual capital, strategic management

Citation: Zavalin G.S., Nedoluzhko O.V., Solodukhin K.S. (2023) Formation of the causal field of indicators for an organization's intellectual capital development: A concept and a fuzzy economic and mathematical model. *Business Informatics*, vol. 17, no. 3, pp. 52–69. DOI: 10.17323/2587-814X.2023.3.53.69

Introduction

In the context of the formation of the knowledge-based economy, the main sources of competitive advantages for organizations are intangible factors of production, including the organization's intellectual capital (hereinafter referred to as IC). IC is the instrumental core of the knowledge-based economy. The nature of IC development is largely determined by the impact of specific hidden factors whose impact on the development process is implicit and difficult to formalize. This circumstance necessitates the identification of such factors [1–3].

The development of the IC theory through the introduction of the concept of implicitnes made it possible to provide an explanation and interpretation of the business processes of economic systems at a fundamentally new level of generalization. Within the framework of the theory, the IC itself is an implicit factor, the process of formation of which is largely determined by the impact of a number of implicit factors affecting it [4]. The concept of implicitness was originally formulated in cognitive psychology [5] developed in linguistics [6, 7], and at the present stage it has found practical application in economic sciences [8, 9].

Implicit factors are non-obvious factors that have a significant impact on the business processes of an economic entity which are based on hidden information [10]. In the context of the knowledge-based economy, when the impact of information as the most important resource becomes most significant, the impact of implicit factors in the management system of an organization increases [11, 12]. Accordingly, it seems appropriate to single out, in addition to factors that clearly affect the IC development (explicit), factors of hidden, indirect impact (implicit). Taken together, the selected groups of key indicators of IC development, explicit, or obvious factors that have a direct impact on the IC development, as well as implicit factors, make up the causal field of indicators of the IC development in an organization [13].

The IC development as a source of competitive advantages is carried out within the framework of strategic management of an organization. The most important tool for structuring and implementing the strategy is the Balanced Scorecard (BSC). This system management method proposed by Kaplan and Norton allows us to translate formulated strategic goals and objectives of the organization, considering all aspects of its further development, into specific actions [14–16]. Over its thirty-year history, the BSC concept has undergone significant evolution, not only retaining but also strengthening its popularity. It is used by almost all well-known consulting companies, while all major developers of enterprise information systems offer BSC tool support [17–19].

The possibility of using the BSC in relation to the assessment of organizations' IC is due, firstly, to the emphasis on intangible indicators, and secondly, the relationship between the traditionally distinguished main structural IC components (human capital, organizational capital, relational capital) and the prospects of the BSC [15, 20–23].

Despite its recognized advantages, the BSC is not devoid of shortcomings and has been criticized throughout its evolution [13, 24–27]. Let us single out two shortcomings that are critical from the point of view of the objectives of this work.

Firstly, the traditional BSC model does not consider the indirect impact of implicit factors on the organizations' key performance indicators. Cause-and-effect relationships in strategic maps reflect factors of direct impact (obvious dependencies).

Secondly, in the classical version of the BSC, the inequality of the organization's stakeholders from the point of view of taking into account their interests was initially laid down. However, the most important structural component of the IC is relational capital, which is determined by the nature of the organization's relationships with external entities [28–32].

The solution to the first problem is offered by Nazarov [13], who has developed a model for the reflexive selection of implicit factors for an organization's management activities and its application to the development of a modified BSC. In turn, in works [33, 34], a modification of the BSC is proposed for the so-called stakeholder-company. Within its framework, among other things, they propose a method of constructing a strategic objectives map which eliminates the initial inequality of stakeholders' interests inherent in the classical BSC. According to the objectives of this work, it seems promising to combine the described modifications of the BSC – namely, to apply the model of implicit factors reflexive selection within the framework of the "stakeholder" modification of the BSC.

It is important to note that the formation of an organization's IC is carried out by identifying its basic characteristic – cognitive activity. The cognitive activity reflects the main condition for the emergence of various IC types and is carried out through various mental processes and states [35–37]. The identification of the possible types of cognitive activity in an organization (education, involvement, production rationalization, self-improvement, customer-oriented rationalization, innovation) enables us to implement specific managerial interventions for them at various levels. The types of cognitive activity can be correlated with the structural components of the IC as follows: education and self-improvement contribute to development of human capital; involvement and production rationalization develop organizational capital; customer-oriented rationalization and innovation provide an increase in relational capital.

The hiddenness of implicit factors and the mediation of their impact on IC development (which, in turn, is an implicit factor) leads to the need to use fuzzy tools in their identification. A significant advantage of using fuzzy models and methods is the possibility of formalizing various kinds of uncertainties (primarily linguistic uncertainty). The use of fuzzy tools in relation to a wide variety of objects and areas of knowledge has proven itself well in conditions of incomplete information and various uncertainties. Unfortunately, in the scientific literature, we were unable to find fuzzy models for identifying implicit factors of the IC. At the same time, there are works that offer fuzzy tools in relation to a wide variety of implicit factors of socio-economic systems [38–41].

The work [4] proposes a fuzzy model for identifying implicit factors in an organization's BSC. Identification of indirect impacts within the framework of the model is based on the technology for evaluating fuzzy binary relations on a certain set. At the same time, the elements of the matrices of fuzzy binary relations are single-point fuzzy sets, which to a certain extent narrows the possibilities of using the model. It seems promising to develop this model in relation to the IC within the framework of a new modification of the BSC in relation to the main structural components of

IC, considering the distribution of indicators by types of cognitive activity with a change in the technology for assessing fuzzy binary relations.

Thus, the purpose of this study is to develop a method for selecting explicit and implicit factors in the development of an organization's IC in conjunction with its strategy based on the modified BSC, which considers the distribution of indicators by types of cognitive activity in a fuzzy setting.

1. The method of forming the causal field of IC development indicators

The formation of the causal field of an organization's IC development indicators involves the allocation of three groups of indicators:

1. the key IC development indicators;
2. he explicit IC factors (having an obvious direct impact on IC development);
3. the implicit IC factors (having an indirect impact on the IC development).

The formation of the causal field of an organization's IC development indicators is proposed to be carried out within the framework of the modified BSC. It is proposed to group the organization's strategic objectives that are significantly related to the development of its IC into three groups corresponding to the main structural components of IC. At the same time, integral indicators corresponding to the main structural components of the IC can be considered as the IC key indicators.

Since, as noted above, each structural component of the IC can be correlated with two types of cognitive activity, in fact, there is a grouping of strategic objectives into six groups.

The preliminary selection of indicators applying for inclusion in the groups "explicit IC factors" and "implicit IC factors" takes place among the indicators of strategic objectives from six groups. The BSC concept assumes that each strategic objective corresponds to a set of the lagging indicators, the values of which make it possible to judge the degree of the objective's achievement. Strategic objectives that contribute, to some extent, to the development of the organization's IC, may be directed towards the development of other key aspects of the organization's activities. Therefore, not all the lagging indicators of these objectives will be indicators of IC development.

The formed set of indicators should be divided into three subgroups: explicit IC factors; implicit IC factors; indicators whose impact on the development of the IC can be neglected (for a specific organization within its strategy at this stage of its development).

To do this, at the first stage, it is necessary to assess the impact of all selected indicators on the key IC indicators. Under the indicator's impact on the IC, we will understand the integral degree of impact of this indicator on the key IC indicators. All indicators, the degree of impact of which on the IC exceeds a certain boundary, will be referred to as explicit factors of the IC.

At the second stage, it is necessary to evaluate the impact of all the remaining indicators on the already selected explicit IC factors. Here, following Nazarov [2], we accept the hypothesis that implicit factors affect the key performance indicators of an organization indirectly. Moreover, explicit factors act as indirect indicators. Accordingly, the impact of the remaining indicators on the IC development can be assessed as a superposition of the impact of these indicators on the explicit IC factors and the explicit IC factors on key IC indicators. All indicators, the degree of the final (indirect) impact of which on the IC exceeds a certain boundary, will be referred to as implicit factors of the IC. Note that in the general case, the "cut-off boundaries" in the selection of explicit and implicit factors may not coincide. We will assume that the impact on the IC of indicators remaining after the selection of explicit and implicit factors can be neglected.

In general, the basic scheme for forming the causal field of IC development indicators is presented in *Fig. 1*.

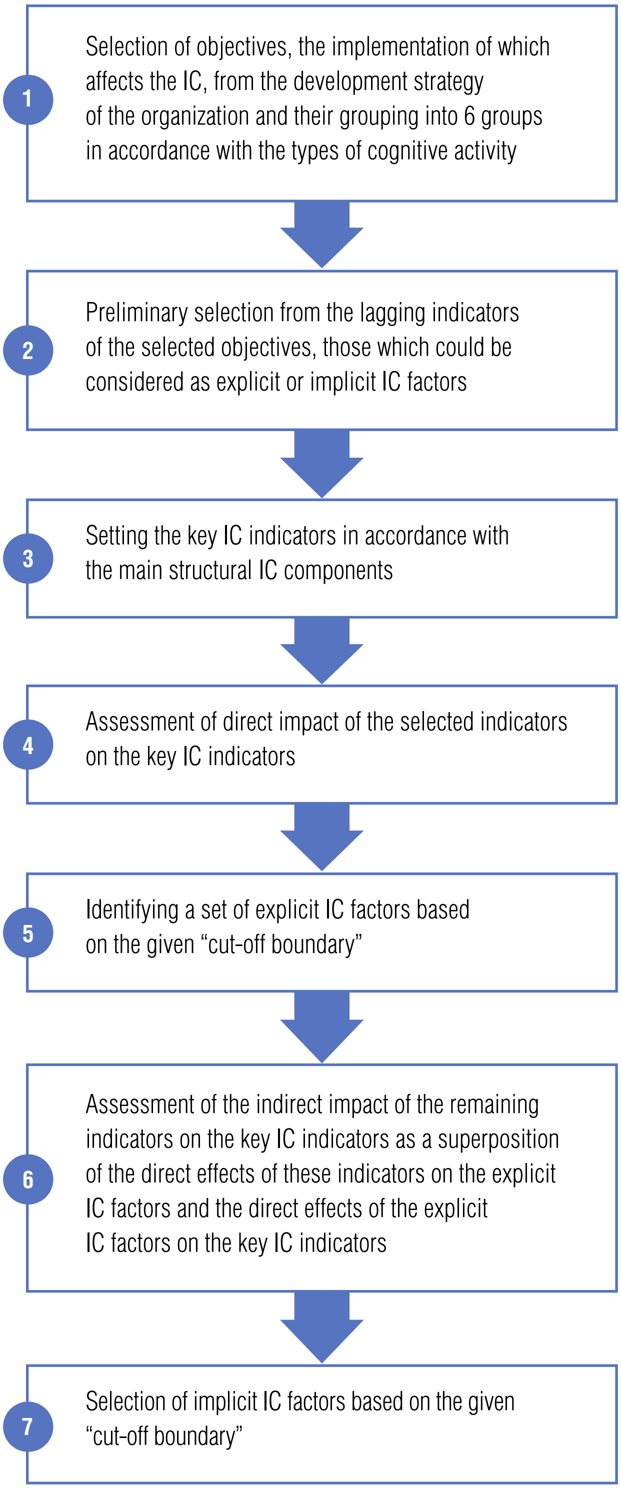

Fig. 1. The basic scheme for forming the causal field of IC development indicators.

2. Fuzzy model

Let $C = \{c_1, c_2, ..., c_k\}$ be the set of key indicators of the IC development;

$E = \{e_1, e_2, ..., e_t\}$ – the set of strategic objectives indicators that affect the IC development;

$B = \{b_1, b_2, ..., b_m\}$ – the set of explicit IC factors;

$A = \{a_1, a_2, ..., a_n\}$ – the set of implicit IC factors;

$D = \{d_1, d_2, ..., d_s\}$ – the set of factors whose impact on the IC development can be neglected.

Thus, $E = B \cup A \cup D$, and $B \cap A \cap D = \varnothing$, that is $t = m + n + s$.

The degree of impact of the set E indicators on the set C indicators are determined by experts in a given linguistic scale. *Table 1* shows a possible linguistic scale and the membership functions of fuzzy sets corresponding to linguistic variables.

Table 1.

Term set of the linguistic variable "the impact of the indicator e_i on the indicator c_j"

Value of the linguistic variable	Trapezoidal membership function
Very weak	<0; 0; 0.5; 1.5>
Weak	<0.25; 1.0; 1.5; 2.75>
Average	<1.0; 2.0; 3.0; 4.0>
Strong	<2.25; 3.5; 4.0; 4.75>
Very strong	<3.5; 4.5; 5.0; 5.0>

The experts' responses should be verified for consistency and averaged. Each expert may be assigned with a crisp or fuzzy weighting coefficient reflecting their level of competence.

As a result, we have a matrix M_{EC} of dimension $t \times k$, the elements of which are fuzzy numbers. Note that the elements of this matrix and subsequent fuzzy matrices can be fuzzy numbers of an arbitrary type (not necessarily singleton fuzzy numbers).

Let us associate a column vector M^*_{EC} of length t with the matrix M_{EC} as follows:

$$(M^*_{EC})_i = \sum\nolimits_{j=1}^{k} w_j (M_{EC})_{ij}, \qquad (1)$$

where w_j are weight coefficients of key indicators of IC development. Note that in the general case the coefficients w_j can be fuzzy (in this particular case, we can consider $w_1 = w_2 = w_3 = 1/3$). The elements of the column vector M^*_{EC} determine the impact of the set E indicators on the IC.

Then we will consider the explicit factors of the IC to be the indicators e_i, for which $(M^*_{EC})_i$ exceed the exogenously set “cut-off boundary”. The “cut-off boundary” of explicit factors in general case can be defined fuzzily. In this case, it is necessary to use one of existing methods for comparing fuzzy sets [42]. If the “cut-off boundary” is a crisp number, then the fuzzy elements of the column vector M^*_{EC} can be defuzzified; after that the resulting crisp numbers can be compared with a crisp “cut-off boundary.”

Note that traditionally the “cut-off boundary” for explicit factors is set verbally. For example, explicit factors in a key performance indicator of an organization are usually understood as indicators whose impact is “strong” or “very strong”. Sometimes (rarely) indicators with an “average” impact are also added to them. In this case, a fuzzy “cut-off boundary” should be understood as a fuzzy set with a membership function corresponding to a given verbal assessment.

Let $F = \{f_1, f_2, ..., f_{n+s}\}$ be the set of strategic objective indicators that are not explicit factors. That is, $F = E \backslash B = A \cup D$.

Let us determine expertly in a given linguistic scale the degree of impact of the set F indicators on the set B indicators. As a result, we have a matrix M_{FB} of dimension $(t - m) \times m$, the elements of which are fuzzy numbers.

Consider a matrix M_{BC} of dimension $m \times k$, obtained from the M_{EC} matrix by deleting rows corresponding to the indicators of the set F. The elements of the M_{BC} matrix reflect the degree of impact of explicit factors on the key indicators of the IC development.

Let the M'_{FC} matrix obtained as a result of the product of the matrices M_{FB} and M_{BC}:

$$(M'_{FC})_{ij} = \sum\nolimits_k (M_{FB})_{ik} \cdot (M_{BC})_{kj}. \qquad (2)$$

The product and addition of matrix elements in this case is carried out according to the given rules for the product and addition of fuzzy numbers.

There are two main approaches to the implementation of fuzzy arithmetic operations: the α-cut approach using interval arithmetic, and the extension principle approach using different t-norms. For trapezoidal fuzzy numbers, within the framework of the first approach, one can use the well-known addition and product formulas [43].

There are more sophisticated ways to implement fuzzy arithmetic using computational methods that eliminate the shortcomings of the two main approaches (overestimation of the uncertainty in the resulting fuzzy numbers in the first approach and high sensitivity to changes in the input fuzzy numbers in the second approach). However, in some cases, the complexity of performing computational operations within the framework of these methods can be unacceptably high. In this regard, there are simplifications of the procedure for arithmetic operations on fuzzy numbers of certain types, including trapezoidal ones [44]. The paper [45] proposes a unified system of rules for performing arithmetic operations on (L-R)-type fuzzy numbers.

Note that when using basic formulas for addition and multiplication of trapezoidal fuzzy numbers, the weighted expert assessments will also be trapezoidal fuzzy numbers. However, when applying the mentioned arithmetic operations system to ((L-R)-type fuzzy numbers, the weighted expert assessments may have exponential (Gaussian) membership functions (more precisely, the membership functions of the obtained fuzzy sets are well approximated by Gaussians).

If necessary, we normalize the elements of the matrix M'_{FC} in such a way that the universal set of the resulting fuzzy numbers coincides with the original universal set (in our case [0; 5]). The resulting matrix will be denoted by M_{FC}.

The elements of the matrix M_{FC} reflect the degree of impact of the set F indicators on the key indicators of the IC development.

Let us associate a column vector M^*_{FC} of length t with the matrix M_{FC} as follows:

$$(M^*_{FC})_i = \sum_{j=1}^{k} w_j (M_{FC})_{ij}. \tag{3}$$

The elements of the column vector M^*_{FC} determine the impact of the set F indicators on the IC.

Then the implicit factors of the IC will be considered the indicators f_i, for which $(M^*_{FC})_i$ exceed the exogenously set "cut-off boundary". The "cut-off boundary" for implicit factors can also be defined fuzzily and, in the general case, does not coincide with the "cut-off boundary" for explicit factors.

3. Approbation of the model

The model was tested on the example of a large regional university (Vladivostok State University, VVSU). VVSU has developed a strategy for the university's development formalized as strategic maps in accordance with the "stakeholder" modification of the BSC. Strategic objectives that are significantly related to the development of the university's IC have been grouped into six categories according to types of cognitive activity (*Table 2*).

Table 2.

University strategic objectives in the field of the IC development (fragment)

Stakeholder group	BSC perspective	Objective	Indicator	Cognitive activity	Structural component of the IC
Employees	Resource	Implementation of procedures and criteria for evaluating the quality and effectiveness of e-learning courses used	Use of e-learning (E_1)	Education	Human capital
Employees	Resource	Implementation of procedures and criteria for evaluating the quality and effectiveness of e-learning courses used	Effectiveness of using distance education technologies (E_2)	Education	Human capital
Employees	Resource	Establishment of a university-business interaction center	Internship activity (E_3)	Education	Human capital
…					
Employees	Resource	Modernization of the university's material and technical infrastructure	Infrastructure provision (E_7)	Involvement	Organizational capital
Employees	Stakeholder	Formation of a unique corporate environment promoting the development and maintenance of corporate culture	Socio-psychological satisfaction (E_8)	Involvement	Organizational capital
Business community	Process	Forming a portfolio of projects and research topics, demanded by the business	Level of scientific and scientific-production cooperation with partners (E_9)	Production rationalization	Organizational capital
…					

Stakeholder group	BSC perspective	Objective	Indicator	Cognitive activity	Structural component of the IC
Clients	Process	Creation of a system for evaluating the effectiveness of the use of e-learning courses in the educational process	Digitalization of the educational process (E_{11})	Production rationalization	Organizational capital
…					
Clients	Process	Inclusion of Russian and foreign internships into higher education and secondary vocational education programs	Efficiency of networking with partners (E_{14})	Production rationalization	Organizational capital
…					
State; Society	Stakeholder	Formation of scientific schools	Publication activity (E_{21})	Self-improvement	Human capital
…					
Employees	Stakeholder	Creation of a system of staff motivation to achieve high performance and career growth	Personal growth of teaching staff (E_{27})	Self-improvement	Human capital
…					
Clients	Stakeholder	University brand development	Student satisfaction with the quality of education (E_{30})	Customer-oriented rationalization	Relational capital
Clients; Business community; Society	Stakeholder	University brand development	Brand management effectiveness (E_{31})	Customer-oriented rationalization	Relational capital
Business community; Society; State	Stakeholder	Creation of a comfortable envi-ronment and modern developed infrastructure necessary for hosting major significant events	Efficiency of public and business initiatives (E_{32})	Customer-oriented rationalization	Relational capital
…					
Employees; Clients; Business community; State	Stakeholder	Development of interdisciplinary scientific research projects	Interdisciplinary scientific projects (E_{40})	Innovation	Relational capital
Business community; State	Stakeholder	Creation of an R&D system potentially demanded by the real sector of the economy	R&D income (E_{41})	Innovation	Relational capital
…					
Business community; State; Society	Stakeholder	Ability to execute scientific projects and, in particular, to lead student teams in carrying out scientific projects, fostering STEMskills	Patent activity (E_{44})	Innovation	Relational capital

Among the lagging indicators of the selected objectives, indicators were selected whose values make it possible to judge the degrees of achieving the objectives in the aspect of developing the IC:

1. Use of e-learning (E_1).
2. Effectiveness of using distance education technologies (E_2).
3. Internship activity (E_3).
4. Efficiency of internship activity (E_4).
5. Degree of staff's qualifications matching the tasks being solved (E_5).
6. Staff retention (E_6).
7. Infrastructure provision (E_7).
8. Socio-psychological satisfaction (E_8).
9. Level of scientific and scientific-production cooperation with partners (E_9).
10. Degree of correspondence of the staff's motivation system to the tasks being solved (E_{10}).
11. Digitalization of the educational process (E_{11}).
12. Infrastructure efficiency (E_{12}).
13. Degree of individualization of educational trajectories (E_{13}).
14. Efficiency of networking with partners (E_{14}).
15. Level of advanced technologies adaptation (E_{15}).
16. Level of automation of management processes (E_{16}).
17. Level of accessibility of digital educational resources (E_{17}).
18. Level of use of open educational platforms (E_{18}).
19. Level of expert support according to WorldSkills standards (E_{19}).
20. Mastery level of WorldSkills standards (E_{20}).
21. Publication activity (E_{21}).
22. Grant activity (E_{22}).
23. Dissertation defenses (E_{23}).
24. Organizational culture formation (E_{24}).
25. International science degree (E_{25}).
26. International academic mobility (E_{26}).
27. Personal growth of teaching staff (E_{27}).
28. Innovative and entrepreneurial activity of teaching staff (E_{28}).
29. Student employment (E_{29}).
30. Student satisfaction with the quality of education (E_{30}).
31. Brand management effectiveness (E_{31}).
32. Efficiency of public and business initiatives (E_{32}).
33. Level of support for student entrepreneurship activity (E_{33}).
34. Uniqueness of a university's educational program portfolio (E_{34}).
35. Level of digital marketing use in interacting with applicants (E_{35}).
36. Internal demand for additional educational university programs (E_{36}).
37. External demand for additional educational university programs (E_{37}).
38. International educational activity (E_{38}).
39. Implemented scientific projects (E_{39}).
40. Interdisciplinary scientific projects (E_{40}).
41. R&D income (E_{41}).
42. Qualification of staff in the field of R&D (E_{42}).
43. Efficiency of the innovation business incubator's activities (E_{43}).
44. Patent activity (E_{44}).

At the next stage, an expert survey was conducted which included representatives of the academic and administrative staff of the university, as well as specially invited external experts. The experts, within the given linguistic scale, assessed the degree of impact of the selected indicators on the key indicators of the IC development corresponding to the main structural components of the IC. Experts' answers were checked for consistency and averaged considering exogenously given expert competence levels. Note that each individual expert assessed the impact of not all 44 indicators on key IC indicators, but only those in respect of which he had the appropriate expert knowledge (competencies). The results of this stage of the expert survey are weighted average expert assessments represented as Gaussian-type fuzzy numbers. *Table 3* shows the parameters of the corresponding approximating Gaussians.

Since the "cut-off boundaries" of explicit and implicit factors were not known in advance, experts also needed to assess the mutual impact of all 44 indicators on each other. In this case, each expert also answered only questions related to their area of expertise. Thus, each expert needed to answer a reasonable number of questions within an acceptable time frame. This approach allows the decision maker to have a wide range of options for varying the "cut-off boundaries" without requiring additional expert questions. The results of the second stage of the expert survey (in the form of parameters of the Gaussians, approximating the weighted average fuzzy expert assessments) are partially shown in *Table 4.*

To conduct an expert survey, process expert answers and perform the necessary calculations based on the fuzzy model, a software package was developed. Among other things, it allows us to form sets of explicit and implicit IC factors for given "cut-off boundaries" and selected defuzzification methods (if "cut-off boundaries" are defined as crisp numbers).

Table 5 shows the sets of explicit and implicit factors of the university's IC for various "cut-off boundaries" obtained using three defuzzification methods (Center of Gravity / Maximum of Maximums / Median).

The decision-maker is able to set the first ("explicit") "cut-off boundary" based on the requirements for the strength of the direct impact of the selected factors on the lagging IC indicators. As a result, a set of explicit IC factors will be formed. Then, based on the requirements for the strength of the indirect impact of the selected factors on the lagging indicators, the second ("implicit") "cut-off boundary" is selected. Thus, a set of implicit IC factors is formed.

Table 3.

Fuzzy assessments of the impact of the set E indicators on the IC development key indicators (fragment)

Indicator	Human capital (C_1)		Organizational capital (C_2)		Relational capital (C_3)		Intellectual capital	
	μ	σ	μ	σ	μ	σ	μ	σ
E_1	2.4472	0.2675	1.2536	0.1401	3.7685	0.2108	2.4999	0.3247
E_2	3.8603	0.3763	1.2991	0.2477	0.1345	0.2980	1.8461	0.2185
E_3	2.3443	0.3999	2.4939	0.3249	3.6572	0.1670	2.8657	0.2251
…								
E_{42}	2.4143	0.3371	2.3756	0.4054	4.8342	0.2865	3.1524	0.1353
E_{43}	3.9457	0.1746	3.8787	0.3795	4.7375	0.1445	3.8849	0.1578
E_{44}	3.5705	0.1556	3.7692	0.1379	3.6417	0.2386	3.5971	0.3190

Table 4.

Fuzzy assessments of the impact of the set E indicators on the IC development key indicators (fragment)

Indicator	E_1		E_2		E_3		…	E_{42}		E_{43}		E_{44}	
	μ	б	μ	б	μ	б		μ	б	μ	б	μ	б
E_1	*		0.26	0.14	4.72	0.14		4.93	0.14	4.85	0.28	3.55	0.34
E_2	1.26	0.27	*		1.07	0.35		2.55	0.29	1.23	0.26	2.31	0.33
E_3	3.83	0.33	4.57	0.20	*			4.64	0.20	3.74	0.35	3.83	0.14
…													
E_{42}	3.61	0.17	3.56	0.19	4.81	0.13		*		0.42	0.26	4.73	0.21
E_{43}	4.66	0.39	4.66	0.18	2.46	0.24		2.62	0.25	*		0.35	0.23
E_{44}	4.89	0.18	4.73	0.39	3.63	0.28		1.28	0.38	0.19	0.33	*	

Table 5.

Sets of explicit and implicit IC factors

First cut-off boundary	Numbers of IC indicators taken as explicit	Second cut-off boundary	Numbers of IC indicators taken as implicit
2	1, 2, 4, 5, 6, 9, 11, 14, 21, 22, 23, 24, 31, 39, 40, 41, 42 / 1, 2, 4, 5, 6, 9, 11, 14, 21, 22, 23, 24, 31, 39, 40, 41, 42 / 1, 2, 4, 5, 6, 9, 11, 14, 21, 22, 23, 24, 31, 39, 40, 41, 42	1.5	3, 7, 8, 10, 12, 15, 26, 27, 28, 32, 33 / 3, 7, 8, 10, 12, 15, 26, 27, 28, 32, 33, 43, 44 / 3, 7, 8, 10, 12, 15, 26, 27, 28, 32, 33, 43, 44
		1.75	3, 7, 8, 12, 27, 33 / 3, 7, 8, 12, 27, 33, 43 / 3, 7, 8, 12, 27, 33, 43
		2	7, 8, 12 / 7, 8, 12 / 7, 8, 12
		2.25	None / None / None
2.5	1, 4, 6, 9, 11, 14, 21, 22, 23, 24, 31, 39, 40, 41, 42 / 1, 4, 6, 9, 11, 14, 21, 22, 23, 24, 31, 39, 40, 41, 42 / 1, 4, 6, 9, 11, 14, 21, 22, 23, 24, 31, 39, 40, 41, 42	1.5	2, 3, 5, 7, 8, 10, 12, 15, 26, 27, 28, 32, 33, 43, 44 / 2, 3, 5, 7, 8, 10, 12, 15, 26, 27, 28, 32, 33, 43, 44 / 2, 3, 5, 7, 8, 10, 12, 15, 26, 27, 28, 32, 33, 43, 44
		1.75	2, 3, 7, 8, 12, 27, 28, 33, 43 / 2, 3, 7, 8, 12, 27, 28, 33, 43 / 2, 3, 7, 8, 12, 27, 28, 33, 43
		2	2, 7, 8, 12 / 2, 7, 8, 12 / 2, 7, 8, 12
		2.25	2 / 2 / 2

First cut-off boundary	Numbers of IC indicators taken as explicit	Second cut-off boundary	Numbers of IC indicators taken as implicit
3	1, 6, 9, 11, 14, 21, 22, 23, 39, 40, 41, 42 / 1, 6, 9, 11, 14, 21, 22, 23, 39, 40, 41, 42 / 1, 6, 9, 11, 14, 21, 22, 23, 39, 40, 41, 42	1.5	2, 3, 4, 5, 7, 8, 10, 12, 15, 24, 26, 27, 28, 32, 33, 43, 44 / 2, 3, 4, 5, 7, 8, 10, 12, 15, 24, 26, 27, 28, 32, 33, 43, 44 / 2, 3, 4, 5, 7, 8, 10, 12, 15, 24, 26, 27, 28, 32, 33, 43, 44
		1.75	2, 3, 4, 7, 8, 12, 24, 27, 28, 32, 33, 44 / 2, 3, 4, 7, 8, 12, 24, 27, 28, 32, 33, 44 / 2, 3, 4, 7, 8, 12, 24, 27, 28, 32, 33, 44
		2	2, 3, 4, 7, 8, 12, 24, 28 / 2, 3, 4, 7, 8, 12, 24 / 2, 3, 4, 7, 8, 12, 24, 28
		2.25	2, 4, 7, 12, 24 / 2, 4, 7, 12, 24 / 2, 4, 7, 12, 24
3.5	1, 6, 9, 11, 14, 22, 41, 42 / 1, 6, 9, 11, 14, 22, 41, 42 / 1, 6, 9, 11, 14, 22, 41, 42	1.5	2, 3, 4, 5, 7, 8, 10, 12, 13, 15, 17, 21, 23, 24, 28, 31, 32, 33, 39, 40, 43, 44 / 2, 3, 4, 5, 7, 8, 10, 12, 13, 15, 17, 21, 23, 24, 28, 31, 32, 33, 39, 40, 43, 44 / 2, 3, 4, 5, 7, 8, 10, 12, 13, 15, 17, 21, 23, 24, 28, 31, 32, 33, 39, 40, 43, 44
		1.75	2, 3, 4, 5, 7, 8, 12, 21, 23, 24, 28, 32, 33, 39, 40, 43, 44 / 2, 3, 4, 5, 7, 8, 12, 21, 23, 24, 28, 32, 33, 39, 40, 43, 44, / 2, 3, 4, 5, 7, 8, 12, 21, 23, 24, 28, 32, 33, 39, 40, 43, 44,
		2	2, 3, 4, 7, 8, 12, 24, 32, 33, 39, 40 / 2, 3, 4, 7, 8, 12, 24, 32, 33, 39, 40 / 2, 3, 4, 7, 8, 12, 24, 32, 33, 39, 40
		2.25	2, 4, 7, 12, 24, 39, 40 / 2, 4, 7, 12, 24, 39, 40 / 2, 4, 7, 12, 24, 39, 40

4. Discussion

The analysis of the obtained results shows the following.

A change in the first ("explicit") "cut-off boundary" leads to a change in the sets of the IC factors taken as explicit. At the same time, the larger the "cut-off boundary" (which means stricter requirements for the strength of the direct impact of the selected factors on the lagging indicators), the smaller the number of explicit factors, and vice versa. Interestingly, with different defuzzification methods, the sets of explicit factors do not change for a fixed "cut-off boundary". This is due to the fact that the crisp estimates of the strength of the direct impact of factors obtained using different defuzzification methods differ insufficiently to change the composition of explicit factors. This, in turn, is most likely due to the trapezoidal type of the chosen membership functions.

2. A change in the second ("implicit") "cut-off boundary" also leads to a change in the sets of the IC factors taken as implicit. Moreover, the higher the "cut-off boundary", the fewer implicit factors are included. When choosing implicit factors, the choice of the defuzzification method begins to play a role, but only for small values of both "cut-off boundaries."

3. Changes in the sets of implicit factors when changing the second "cut-off boundary" largely depend on the selected first "cut-off boundary", regardless of the defuzzification method.

4. Some factors can be defined as explicit (for some "cut-off boundaries") and implicit (for other "cut-off boundaries"). This is related, firstly, to the requirements for the strength of the direct or indirect impact of the factor on the lagging indicators to assign it to a particular group, and secondly, to the linguistic uncertainty in formulating such requirements and expert evaluation of the strength of the impact. That is why it became necessary to develop a fuzzy model.

5. The proposed method of forming the causal field of IC indicators is generic in the sense that it is applicable to various types of organizations of different industry affiliations. The key IC indicators corresponding to its main structural components (human capital, organizational capital, relational capital), types of cognitive activity (education, involvement, production rationalization, self-improvement, customer-oriented rationalization, innovation), and the correspondence between types of cognitive activity and IC structural components are universal. All stages of the basic method scheme are universal as well.

6. At the same time, the sets of explicit and implicit IC factors for different organizations may differ significantly for the following reasons. Firstly, the set and composition of stakeholders in organizations and their requests to organizations can vary considerably. Consequently, the strategic maps of an organization's objectives will differ significantly, including the objectives related to IC development and their lagging indicators (i.e., the initial set of IC development indicators from which explicit and implicit factors are selected). Even if the initial sets of indicators are relatively similar in composition, the degrees of impact of these indicators on key IC indicators and on each other can vary significantly. Finally, decision-makers may choose different "cut-off boundaries" and defuzzification methods.

Conclusion

A conceptual scheme for the formation of the causal field of the IC indicators in conjunction with the organization's strategy and types of cognitive activity is proposed. The implementation of this scheme was carried out by developing a fuzzy economic-mathematical model that makes it possible to identify explicit and implicit factors of IC. The proposed scheme and model have the following distinctive features. The set of the IC indicators is formed based on the lagging indicators of strategic objectives selected from the objective map of the modified BSC grouped by six types of cognitive activity. The key IC indicators are the main structural components of the IC (human capital, organizational capital, relational capital). The explicit IC factors are selected based on the results of assessing the direct impact on the key IC indicators by setting a "cut-off boundary". The implicit IC factors are selected based on the results of assessing the indirect impact on the key IC indicators through explicit factors by setting another "cut-off boundary". Estimates of direct impact are carried out expertly in a given linguistic scale with the corresponding membership functions of fuzzy sets. Estimates of indirect impact are calculated based on operations with matrices whose elements are fuzzy numbers. The results of testing the model on the example of a university are presented. It is shown that the sets of explicit and implicit factors of the university's IC vary depending on the given "cut-off boundaries" and the chosen defuzzification method. ■

Acknowledgments

The study was sponsored by the Russian Science Foundation (RSF) as part of research project No. 23-28-01091 (https://rscf.ru/project/23-28-01091/).

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