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Scenario forecasting information transparency of subjects' under uncertainty and development of the knowledge economy

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Abstract. Topicality of modeling information transparency is determined by the influence it has on the effectiveness of management decisions made by an economic entity in the context of uncertainty and information asymmetry. It has been found that information transparency is a poorly structured category which acts as a qualitative characteristic of information and at certain levels forms an additional spectrum of properties of the information that has been adequately perceived or processed. As a result of structuring knowledge about the factor environment, a fuzzy cognitive model of information transparency was constructed in the form of a weighted digraph. Structural analysis and scenario forecasting of optimal alternatives of the fuzzy cognitive model made it possible to evaluate the classes of factors, identify their limited relations, establish the centrality of the roles of information transparency and information and communication security in the system built and evaluate their importance when modeling the situation self-development. Information visibility, reliability and availability have been found to have the strongest impact on the system. Taking into account different initial weights of the key factors — information transparency and information and communication security — the study substantiates the strategic ways for economic entities to achieve their goals in the context of uncertainty and information asymmetry, which allows us to use this approach as a tool for strategic management in the information environment.

Keywords: information transparency, forecasting, fuzzy cognitive modeling, digraph, factors, relations, strategic management.

1 Introduction

Information transparency is a possibility for any economic stakeholders to track the chain of actions and stages of forming the information content [29] which is important enough to make effective management decisions. On the one hand, information

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transparency in required scope ensures that its provider can be held accountable for the content and consequences of its disclosure, while on the other it builds trust and reliance on a company and reduces alienation between interaction parties [15]. That is, systemic information transparency determines positive expectations regarding company development, builds up confidence and improves business climate, which is always relevant in the context of competition, economic downturn, changes in socio-political and socio-economic vectors of development.

From the point of view of content understanding, information transparency is interpreted by authors [6] as a requirement, norm, standard or as a goal which, being set, defines the specifics of achieving it. Thus, transparency as one of the 8 major characteristics of the Good governance concept [26] means that decisions taken and their implementation follow rules and regulations. It also means that information is freely available and directly accessible to those who are affected by the decisions and their enforcement. According to the concept, main attributes of information are the scope of information provided and that it is provided in easily understandable forms and media. Another approach can be found in the article [25] whose authors define transparency as perceived quality of the information intentionally shared by its sender. We believe that information transparency is a poorly structured category which nevertheless is a qualitative characteristic of information and at certain levels forms an additional spectrum of properties of the information which has been adequately perceived or processed. Ambiguity of information transparency complicates drawing its overall portrait for comprehensive research and identifying its optimal level for different economic entities and their various purposes.

Furthermore, in economics poorly structured categories are generally studied by means of soft modeling including dynamic cognitive modeling and cognitive mapping. In our case, information transparency is the object of the research, while cognitive modeling of how transparency and its constructs influence each other is its subject. Scientific search is aimed at structuring the information transparency factor environment, identification of strategic changes in its level and the levels of its factors which result in accelerated and decelerated development of the system, extracted from a specific eco-socio-economic environment during t period. Information types, degree of completeness of information, the type of the company's operations, its size, organizational and legal form are decisive factors for characterizing its information transparency.

The openness of the organization's activities and management decisions, disclosure of information in a complete, timely, reliable and understandable form creates space for the formation of transparency in business for the main groups of stakeholders: employees, investors, consumers, suppliers, creditors, government and local authorities, etc. [5; 12; 17; 19; 20].

Own approach to the definition of information transparency of business entities is proposed in the research [34]. The authors of the study understand information transparency as providing free access for all stakeholders to information about various areas of the enterprise's activities, management status, ownership structure, and other data that will be useful for making decisions on interaction with this entity. The authors of the article consider information transparency in two aspects: external and internal.

The external aspect contributes to the formation of a positive image and increases the competitiveness of the enterprise. The internal aspect forms trust within the organization. The authors argue that information transparency is an important tool in the process of preventing and combating economic crime.

Transparency is an integral part of public administration, which is considered in the article [30]. Transparency is determined by the degree of citizens' awareness of important manifestations of the material and procedural aspects of the activities of state authorities and local self-government. The author of [9] notes a close relationship between information transparency of companies and the corporate governance model. A high level of information transparency contributes to the formation of a high-quality model of corporate governance, increasing investment attractiveness. According to the [11] information transparency is a conceptual basis for solving investment risk problems. In the [15] it is noted that the availability of information and transparency helps to strengthen the reliability of the company and reduce misunderstandings between the organization and stakeholders.

Transparency as an openness that allows stakeholders to receive the necessary information for making informed decisions considers in [32]. Availability, timeliness, relevance, and quality are considered characteristics of transparency. At the same time, the lack of transparency is the basis for the development of corruption, it negatively affects economic growth in any industry. Increasing information transparency helps to improve management transparency.

The author of [24] considers transparency as a function that has three variables. This function consists of the owner of the information, the information, and the persons who have access to the information. Transparency is seen as a way of regulation, democracy, and efficiency. Possession of information facilitates control over the entity. At the same time, transparency is not a category that must maximize. The optimal level of transparency is between “highly desirable” and “necessary”.

In the article [33] considers two conceptual approaches to transparency. The first approach looks at information transparency, which involves increasing the quantity and quality of information available to stakeholders. The second approach looks at accountability, which manifests itself in the strengthening constraints on employees to hold them accountable for their actions. So, on the one hand, transparency is a means of transmitting information and on the other, it is a tool that restrains the actions of officials. The article substantiates that due to different types of transparency and their economic effects, it is impossible to introduce a single quantitative indicator to measure the level of transparency.

Thus, for economic entities information can be transparent, partially transparent or nontransparent. The main parameters of information transparency management are time, tactical, strategic and technological constrains on the flow of information for a limited or unlimited number of stakeholders. Information flow in the research [6] is characterized by the following parameter tuple:

$$\langle I, IP, IR, IM, IE \rangle, \quad (1)$$

information (I), information provider (IP), information receiver (IR), information medium (IM), and information entity (IE).

It seems reasonable to add information constraints (such as on the scope of information usage) to this set of defined parameters. It is also appropriate to take into account the period with its inherent social and economic trends, which can ensure more accurate and adequate interpretation of results. The authors [6] place emphasis on the importance of subject affiliation when studying the risks of achieving information transparency, which explains different quality of certain level of information transparency for different stakeholders. Information receivers and media also differ in terms of their goals, capabilities and time allocated to the operation, which should also be taken into consideration when assessing the feasibility of increasing or reducing information transparency in order to improve rather than aggravate the situation.

Transparency depends on information type (financial, non-financial, business, public, private etc.) so basic transparency attributes will be further explained through specific characteristics that determine the specialization of a particular type of information. By way of example we can mention corporate information: corporate transparency is defined as widespread availability of relevant, reliable information about periodic performance, financial position, investment opportunities, governance, value, and risk of publicly traded firms [3]. Also, taking into account subjective nature of information (for example, information for external stakeholders) a company's external information transparency determines the degree of completeness of information regarding its own business activities, provided by each company to the market [31].

2 Materials

One of the main attributes of information transparency is *visibility* of information content which in its turn is determined by general availability of information, accessibility of information to third parties and degree of approval to disseminate information [29]. Information visibility is also differentiated according to its degree as visible, partially visible and invisible. In the article [29] the authors argue that high information visibility may result in attention span, produce a flood of information, overwhelming our cognitive and interpretive capabilities, thus rendering the information meaningless or confusing. Moreover, maximum visibility can mask formality of actions or results of the decisions taken, which are presented in the information [29]. On the other hand, insufficient disclosure of information may result in an attempt to compensate for it with some other, forecasted, predicted, guessed, insider information, trustworthiness and reliability of which may not be sufficient to make an effective management decision. The authors of the article [15] point out that transparency arises under the condition of certain balance between the degree of information disclosure and the degree of its perception and understanding by users. Hence, we can make a conclusion that only limited (up to a certain level) visibility ensures high level of transparency, provided that it is the key and quality information that is disclosed, not its noises. In general, the degree of information transparency determines the *associated risk of its disclosure or concealment*. According to the [15], information visibility is determined by *how responsible* its providers are, that is, how consciously they assess the advantages, necessity and need to disclose certain amount and type f information. The attitude and policy of an economic entity in terms of establishing the boundaries of information transparency determine *the degree of confidence* it enjoys as an information provider and medium. *Information availability* depends on how well information reflects actions and decision-making stages in easily recognizable data forms through a reliable storage of those data. In the article [29] it is interpreted as a degree of complexity associated with the extraction and interpretation of information. It is determined by such attributes as possibility for an unlimited number of people to be informed, insignificant amount of time, finances and efforts necessary to find the relevant information, veracious perception of information content. Information availability is ensured by its relevant classifiers, systematizes etc. *Ongoing development of information and communication technologies* has been improving the conditions, forms and methods of storing and transmitting information as accurately as possible, which allows us to expand the possibilities of managing information transparency and its constructs. In order to assess the level of information and communication technologies development, different indices are used, including ICT Development Index, Networked Readiness Index (surveys at the state, business and community levels). Growing complexity of information and communication technologies requires continuous improvement of existing skills on the part of economic entities and drives the need for life-long learning. At the same time, technological advances mean higher associated risks, which urge stakeholders to provide the required *level of information and communication security*.

Adequate and realistic perception of information content by receivers, which is crucial for effective decision making, is determined by *cognitive limitations* of economic entities. Information overload may result in deliberate distancing from all information sources. In addition, dubious quality of information, its shortage or poor relevance cause wrong decisions. We cannot ignore the human factor, i.e. the difference in perception of the same facts by different economic entities, which also contributes to information asymmetry. In general, the above determines *how effectively an economic entity uses the information visible to it*. Information society has been creating new information services and changing approaches to delivering old ones by means of increasing use of modern technologies. Therefore, in order to understand the state of implementing information and communication technologies in society and evaluate the effectiveness of new technologies introduction, there is an urgent need to develop approaches to evaluate knowledge and skills of the service receivers, their social communication skills and skills large-scale data processing [18]. When discussing information transparency, it is absolutely necessary to take into account the role of transparency as an economic entity's accountability. It is not the information itself that is considered, but rather the potential disclosure of that information, which forces stakeholders to “do the right thing”, so information transparency is often quite closely linked to the problem of *corruption*. Hence, we think of information transparency as a vital tool that helps reduce corruption [33]. We find the list of information transparency factors, suggested by the experts, substantial, but offer to add information transparency levels, degrees, and constraints that occur in a real-life environment when it transfers from one state to another. This will help to substantiate the feasibility of achieving a change in specific degrees or levels of factors, informational transparency, in order for stakeholders to achieve their goals. As a result of structuring knowledge on factor loading of information transparency we have identified the following main factors that accelerate and decelerate the development of an economic entity system: the degree of confidence in the medium and source of information, the degree of the economic entity responsibility, the scope of information visibility, the degree of information availability, the degree of information accessibility to third parties, approval to disseminate information, the degree of information reliability, the level of information and communication technologies development, cognitive limitations of the user, the level of information use efficiency, the level of information and communication security, the level of corruption reduction, risks of information disclosure or concealment.

3 Methods

The methodology of information transparency evaluation includes a wide scope of modern methods, from social research to modeling; results of many surveys and observations are studied using econometric tools. The results of critical analysis presented in the article [15] show that there are different approaches to transparency evaluation (market-based, analyst perception-based and accounting-based measures) and researchers invoke different techniques including web content analysis, verbal protocol study, principal component analysis etc. However, it is index approach that has gained popularity in this area of research. In addition, information transparency is defined as a component of a more general indicator, or examined in the context of information type (financial, fiscal, political, economic information). The index method was used in the study [33] to measure Information Transparency Index and the Accountability Transparency Index constructed using a methodology similar to the one used in Transparency International's Corruption Perceptions Index. In the first stage, the researchers selected indicators that determine the index for the maximum period, and normalized them. The resulting index was calculated as a mean of the components of its normalized indicators. The large-scale study [2] provides a transparency index for 194 countries. The indices comprise an aggregate transparency index with two sub-components: economic/institutional transparency and political transparency. By means of correlation and regression analysis using substantiated indicators, the authors showed that information transparency is associated with better human and economic development indicators, higher competition and lower corruption. Political transparency has also been studied separately; the main indicator used over the years has been the Freedom House *Freedom of the Press* index. Its advantage is extensive coverage across countries combined with significant temporal coverage (going back to 1979) [33]. Economic transparency index was presented in the article [10] where it was developed using regression estimation (based on the World Bank and IMF data). The index measures the frequency with which governments update economic data that they make available to the public as a condition of existence (or absence) of laws on freedom of information. The authors took into account the quantity of data released by governments, rather than their timeliness. As a result, they proved that information transparency is directly proportional to effective governance. It is also worth mentioning the Open Budget Index, prepared by the International Budget Partnership, which is aimed at studying fiscal transparency [33]. In addition to these indicators, transparency is studied as a component within larger frameworks. In particular, the World Bank's CPIA indicators have a component on "transparency in the public sector". Information transparency for businesses in terms of obtaining information about government policies and regulations affecting business activities is considered in the Global Competitiveness Report, while freedom of the press as a condition for information transparency is represented in the *CIRI Human Rights* database [33].

One of the priority indicators of the state of information transparency in Ukraine is the Transparency Index of Ukrainian companies' websites; the dynamics of this indicator is shown in figure 1.

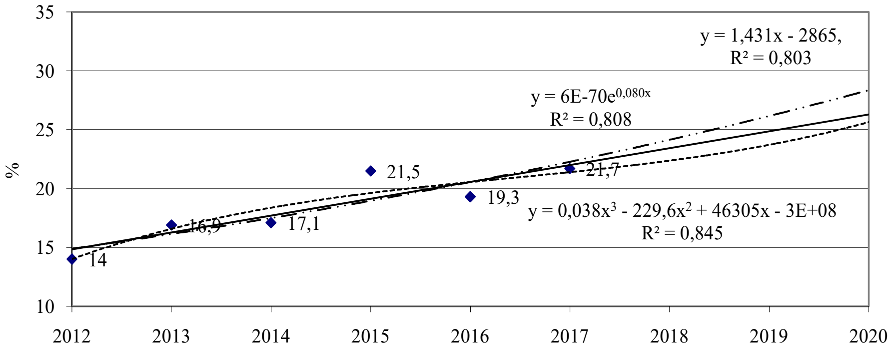

Fig. 1. Dynamics of the Transparency Index of Ukrainian companies' sites.

The results of the analysis of the dynamics and structure of the Transparency Index of Ukrainian companies' websites show that the level of indicators is low however it grows every year, in particular: in 2012 the level of the studied indicator is 14%, in 2013 – 16.9%, in 2014 – 17.1%, in 2015 – 21.5%, in 2016 – 19.3%, in 2017 – 21.7% [35]. The study involved sites of companies that are large taxpayers and leaders of information transparency of the previous period. Transparency companies are in the energy sector, the agricultural sector, communications and transport, metallurgy, and alcohol production. Companies belonging to the mining industry have the worst values. DTEK, SCM, and ArcelorMittal Kryvyi Rih are stable leaders in information transparency.

According to the method of construction, the index is an integrated value of indicators and such categories as content, reporting, navigation, accessibility. The degree of disclosure of the indicator "content" of companies is gradually growing. So it was 6.7% in 2013, 6.3% in 2014, 9% in 2015, 10.3% in 2016, 12.8% in 2017 [35]. In the category of "reporting" companies were assigned 9% in 2012, 13% in 2013, 14% in 2014, 17% in 2015, 12% in 2016, and 16% in 2017. In the reporting category, companies were assigned 9% in 2012, 13% in 2013, 14% in 2014, 17% in 2015, 12% in 2016, and 16% in 2017. Companies scored 3.5 out of 8 possible points in terms of navigation and 6 out of 17 possible points in terms of accessibility. The analysis of indicators also confirmed the importance of the impact of the financial condition of both companies and sectors on the level of information transparency of companies. The experts made the following conclusions about the state of information transparency of companies: it is necessary to ensure systematic updating of information, use modern data visualization technologies, increase accessibility, accelerate disclosure of information on compliance with sustainable development and non-financial reporting, to research information needs of society and the market. Thus, to increase the level of information transparency of Ukrainian companies, the target benchmarks are high availability, visibility of relevant information. Information is presented in an understandable form that fully reveals the principles of sustainable development and the level of corporate social responsibility. Gives information about correlation between the industry indicators and the Information Transparency Index (table 1).

Table 1. The correlation coefficient between the industry indicators and the Information Transparency Index.

Indicator	Industry	Agriculture	Financial and insurance activities	Trade	Transportation and storage	Real estate activiti es
Current liquidity, %	-	0,69	-0,98		0,74	-
Absolute liquidity, %	0,83	0,7	-0,64	0,81	0,99	-
Financial autonomy ratio, %	-0,61	0,59	-0,96	-	-0,68	-0,72
Return on assets, %	0,87	0,78	-	0,7	0,63	-
Return on current assets ,%	0,84	0,78	-	0,7	0,63	0,6
Net margin, %	0,83	0,77	0,51	0,84	0,63	0,53
Return on total assets, %	-	0,77	-0,65	-	0,54	0,55
Total asset turnover	0,91	-	-0,58	-	0,77	0,58
Working capital turnover	-	-	-0,58	-	0,78	-
Receivables turnover ratio	0,8	-	-0,55	-	0,75	-

According to table 1, there is a direct close relationship between the level of information transparency and indicators of the financial condition of industrial and agricultural complexes. There is also a direct but average density relationship between the studied index and the transport and storage sector. Also, the feedback of the average density is shown between the indexes of information transparency and indexes of the financial condition of the financial and insurance sector. The trade sector has a direct close relationship with the indicators of information transparency, however, not for the entire studied financial index, only for absolute liquidity, return on assets and working capital, net margin. Medium-density direct connection with information transparency is the return on assets and return on current assets, net margin, total asset turnover, there is inverse relationship with financial autonomy ratio of the real estate sector. Thus, there is both a qualitative and quantitative link between information transparency and sectoral indicators of the national economy, which determines the feasibility of further research in this area.

The research [13] offers to use a modified Delphi technique in order to study information transparency. This technique implies having rapid reviews from stakeholders, namely researchers, policy makers, industry and health care providers. However, the results of this approach are rather subjective as respondents often change their opinion under the influence of different factors.

The paper [8] proposes four reference models which form a baseline for transparency requirements in information systems. The models cover actors involved in the process of ensuring transparency and information circulation among them, transparency meaningfulness, transparency usefulness for a specific audience, and information quality in transparency. The reference models are further used to create TranspLan, a modeling language for capturing and analyzing information transparency requirements among stakeholders [7]. Thus, a broad range of methodological tools gives researchers quantitative measures of information transparency, the impact it makes and gets. However, each approach or method has inherent risks when used in practice due to assumptions, limitations that are not achievable in real life. In addition, there is no general system of forming information transparency as an economic category since it is impossible to formalize this poorly structured category without considerable impact of subjectivity and assumptions. Considering the importance of the cognitive method when studying poorly structured categories, we propose to analyze information transparency using the methodology of cognitive modeling and impulse processing [17; 23]. The proposed approach is based on structuring knowledge about the object of study, building a cognitive model of object development in the form of a digraph, scenario modeling of the dynamics in the state of the system when it is stable and changing, justification of the option that can help to achieve the goals of the research.

However, the results of previous studies have proved [14] that the level of the values of influencing factors plays a crucial role in substantiating an adequate and high-quality forecast scenario for achieving the required level of information transparency. To solve this problem, we propose to apply the methodology of fuzzy cognitive modeling.

The process of fuzzy cognitive modeling is presented as a sequence of steps. At the first stage, the purpose of modeling and target indicators are determined. In the second stage, there is a substantiation of a fuzzy cognitive map (causal graph) by forming a set of factors of the subject area of research. Factors are divided into four categories: target, which form the purpose of modeling, controlled – these are those that can be directly influenced, intermediate – to describe the subject area, observed – externalities. Factors are selected according to the level of significance and set for each level scale [1; 28]:

$$\tilde{G} =< C, \tilde{R} >, \tag{2}$$

where $C = \{c_1, c_2, \ldots, c_n\}$ – set of factors, $\widetilde{R}$ – fuzzy causal relations on the set C, $\tilde{R} = \{(\mu_R(c_i, c_j)/(c_i, c_j))\}$ – fuzzy set of edges, $c_i, c_j \in C^2$; $\mu_R\{(c_i, c_j)\}$ – the degree of belonging of the edge $\{(c_i, c_j)\}$ to fuzzy set of oriented edges $\widetilde{R}$ [1; 28].

Elements $r_{ij} \in \widetilde{R}$ $(i, j = 1, \ldots, n)$ characterize the direction and degree of intensity (weight) of the impact between the factors c_i and c_j [1; 28]:

$$r_{ij} = r\,(c_i, c_j), \tag{3}$$

where r – indicator of intensity of influence (characteristic function of the relation $\widetilde{R}$), which may have any value in the interval [–1, 1] with considering:

- $r_{ij} = 0$, if the value c_i does not depend on c_j (no influence) [1; 28];
- $0 < r_{ij} < 1$ if the influence c_i to c_j is positive (increasing the value of the factor-cause c_i leads to an increase in the value of the factor-consequence c_j) [1; 28];
- $-1 < r_{ij} < 1$ if the influence c_i to c_j is negative (increasing the value of c_i leads to an decrease in the value of c_j) [1; 28].

The next step is to determine the initial state of the factors and the influence of external factors [1; 28].

In the fourth stage, an adjacency matrix is formed $M = \left\|m_{ij}\right\|_{n\times n}$ based on reasonable characteristics of the type of relationship between factors [1; 28].

Suppose a signed digraph with adjacency matrix A determines information transparency and its factor environment. The vertices of the digraph are represented by the set $u_1, u_2, \ldots, u_n$. Every vertex u_i has the value of $v_i(t)$ at discrete moments of time $t = 0, 1, 2, \ldots$. The value of $v_i(t+1)$ is determined by the value of $v_i(t)$ and information on whether other vertices u_j, adjacent with u_i, have increased or decreased their values at moment t. The change of $p_j(t)$, set by the difference of $v_j(t) - v_j(t-1)$, is called a pulse if $t > 0$. The initial condition should be specified when $t = 0$. We introduce the following notation:

$$sgn(u_j, u_i) = \begin{cases} 1,\text{if edge is positive,} \\ -1,\text{if edge is negaive,} \\ 0,\text{if edge is missing.} \end{cases}, \tag{4}$$

Analysis of the statistical characteristics of the model, determination of the balance of the system, consonance and dissonance of influence are carried out at the next stage [1; 28]. Detect the indirect interactions of factors on each other in the system, for this purpose convert the initial matrix of the intensity of interactions C into a transitively closed matrix Z, the elements of which are pairs $(z_{ij}, \overline{z_{ij}},)$, where z_{ij} characterizes the power of positive influence, $\overline{z_{ij}}$ – the strength of the negative influence of the i-th factor on the j-th [1; 28].

Based on the Z matrix system characteristics of the fuzzy cognitive map can be calculated (see table 2).

The consonance indicator expresses the degree of confidence in the sign and the strength of the impact (the higher the consonance, the more convincing the expert's opinion) [1; 28]):

p_{ij} – the number of positive influences of the i-th factor on the j-th factor;
n_{ij} – the number of negative influences of the i-th factor on the j-th factor;
k_{ij} – consonance of the influence of one factor on another;

d_{ij} – dissonance of the influence of one factor on another.

Table 2. System characteristics of fuzzy cognitive map [27].

Characteristics	Dissonance of influence	Consonance of influence
Influence of the *i*-th factor on the *j*-th	$d_{ij} = 1 - k_{ij}$	$k_{ij} = \frac{\lvert p_{ij} - n_{ij} \rvert}{p_{ij} + n_{ij}}$
Influence of the *i*-th factor on the system	$D_i = \frac{1}{n}\sum_{j=1}^{n} d_{ij}$	$K_i = \frac{1}{n}\sum_{j=1}^{n} k_{ij}$
Influence of the system on the *j*-th factor	$D_j = \frac{1}{n}\sum_{i=1}^{n} d_{ij}$	$K_j = \frac{1}{n}\sum_{i=1}^{n} k_{ij}$

At this stage, dynamic modeling is performed based on the use of a pulse process according to the following formula [1; 28]:

$$v_i(t+1) = S(v_i(t) + q_i(t+1) + o_i(t+1) + \textstyle\sum_{j=1}^{K} T\,(w_{ij}, p_j(t))), \qquad (5)$$

where $v_i(t)$ – the value of factor c_i at moment t; $v_i(t+1)$ – the value of factor c_i at moment $(t + 1)$; $q_i(t + 1)$ – external influence on c_i at moment $(t + 1)$; $o_i(t + 1)$ – controlling influence on c_i at moment $(t + 1)$; $r_{ij} = r(c_i, c_j)$ – intensity of influence between factors e_i and e_j; $p_j\,(t)$ – change the value of c_j at moment t; T – operation T-norms (the product is used); S – operation S-norms (Lukasevich's S-norm is used).

At the final stage, form a basic set of alternative strategies for system development and justification of priority strategies for achieving targets.

Modern information technologies provide researchers with a possibility to simplify cognition procedure. In particular, to achieve the goal of this research we can use some software products, such as Decision Explorer Application, aimed at providing the user with illustrative cognitive maps which can be further analyzed to better understand the issue under study, links between its factors. Another specialized software product is FCMapper which helps to analyze, model fuzzy cognitive maps, explore behavior of the system and interaction between its factors. FCMapper calculates structural characteristics of the system based on the created digraph, and provides a variety of scenarios. The logistic squashing function is used for standard scenario calculation. It can be written as $f(x)=1/(1+e^{-x})$ [4]. The results obtained for each scenario are compared with the initial one, where the output weights for each vertex are set at the same level, that is, the situation self-development is modeled. The final development of the system in the form of a cognitive model in the absence of external influences can be reduced to a fixed-point attractor, a boundary cycle of repeating binary vectors, or to chaotic or aperiodic attractors [21].

4 Results

As a result of structuring knowledge on factor environment of information transparency we have identified a set of vertices and their cause-effect relations; together they determine the corresponding cognitive model in the form of a weighted digraph (see fig. 2).

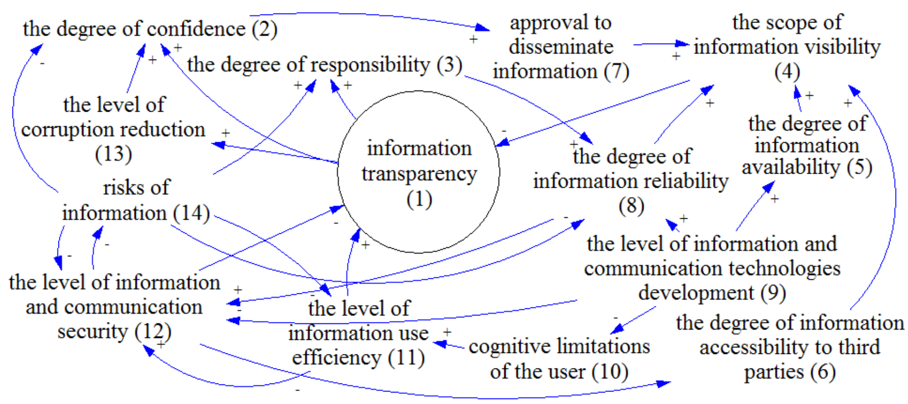

Fig. 2. Cognitive model of information transparency [14].

For the constructed digraph, based on the situation simulation, the following vertices have been found to have the greatest influence on target vertex 1: 8, 9, 11, 12, 14. However, not all of these vertices can be affected in terms of goals and opportunities of economic entities. The following figure shows the results of studying a simulation of the vertex parameter dynamics in the context of system interaction without external influence for $t = 12$, where t is the study period, and the initial values of the vertex parameters $v_i = 0$ (see fig. 3).

The diagram shows the dynamics of the influence those vertices 4, 9, 11, 12 have on the target vertex (1). The diagram shows variable values of vertex 1, but we can see that factors 12 and 4 tend to have a negative influence; factor 11 has a positive influence, while factor 9 does not have a clearly defined tendency during the period under study. Let us now examine the effect of changes in transparency level on vertices 2, 3, 7 and 13 (see fig. 4).

We can see a positive dynamics of the influence that target vertex 1 had on vertices 2, 3, 7 and 13 throughout the period under study. Having analyzed structural characteristics of the cognitive map using FCMapper, we arrived at the following results. One vertex functions as a Transmitter, it is vertex 9, the level of technology development. Other vertices are Ordinary, there are no Receiver vertices in the model. Classification of the cognitive model vertices by these classes helps us better understand the structure of the graph. Having analyzed the cognitive model using the Decision Explorer Application, we identified two key elements of the cause-effect relationship system (based on the calculation of vertices centrality which reflects the strength of relationships between the vertices). The index that shows the proportion of existing connections of potentially possible (density) is calculated to be 0.14. It gets values within [0; 1]. The higher its value is, the more active interaction between the vertices takes place. They are the information and communication security (12) and information transparency (1). Using FCMapper software you can set the initial weights of vertices and investigate their influence on other system indicators. To quantify the system development dynamics, the influence of one vertex on the other is represented by the following set of values: very strong (0.8; 1]; strong (0.6; 0.8]; medium (0.4; 0.6]; weak (0.2; 0.4]; and very weak (0; 0.2]. During the situation self-development modeling (the total number of iterations is 60) the constructed model came to a stable state, which was achieved due to feedbacks, with the maximum number of iterations (51) for the degree of information accessibility to third parties (6) and risks (14), the fewest iterations (25) were required for the availability (5) and technology development (9) vertices. The calculations obtained indicate that the factor with the greatest impact on the system is the scope of information visibility (4). Information reliability (8) and approval to disseminate information (7) are found to be of high influence. The degrees of confidence (2), responsibility (3) and information availability (5) also showed significant influence. Then we analyzed the situation development scenarios under the change of the key elements of the cause-effect relationship system, namely the level of information and communication security (12) and information transparency (1). For the first scenario the initial vertex value was set at a low level (0.1), for the second scenario at a medium level (0.5) and for the third one at a high level (0.9). When the value of vertex 12 is of low and medium level, the most positive changes are observed for the following vertices: information transparency (1), the degree of responsibility (3), the degree of information accessibility to third parties (6), the level of corruption reduction (13) and risks (14). The high value of vertex 12 has the most positive influence on the level of information use efficiency (11). When the value of vertex 12 is of low and medium level, the most negative changes are observed for such vertices as the degree of information reliability (8) and the level of information use efficiency (11) The high value of vertex 12 has the most negative effect on the vertices of information transparency (1), the degree of responsibility (3), the degree of information accessibility to third parties (6), and risks (14). Now, we can have a close look at the influence of information transparency (1) on the cognitive model factors. In general, the level of information transparency does not affect the system significantly, it is 0.32 in the context of the system self-development scenario. At the same time, a decrease in the level of vertex 1 reduces the influence of such factors as the degree of responsibility (3) and the degree of confidence (2) on the system. An increase in the level of vertex 1 results in the growing influence of the corruption reduction factor (13), while low level of vertex 1 causes an increase in the level of corruption (13). A low level of vertex 1 slightly increases such factors as risks (14) and information accessibility to third parties (6), the value of the approval to disseminate information (7) increases when the level of vertex 1 is higher.

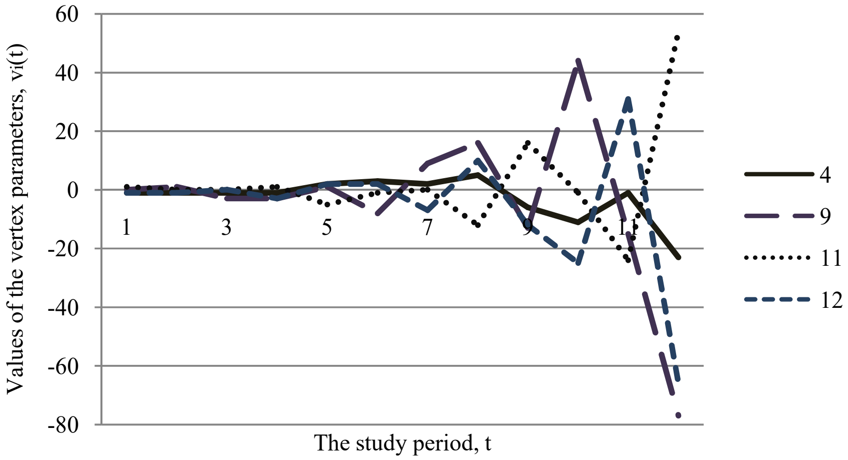

Fig. 3. The dynamics of the value of target vertex 1 under the influence of vertices 4, 9, 11, 12.

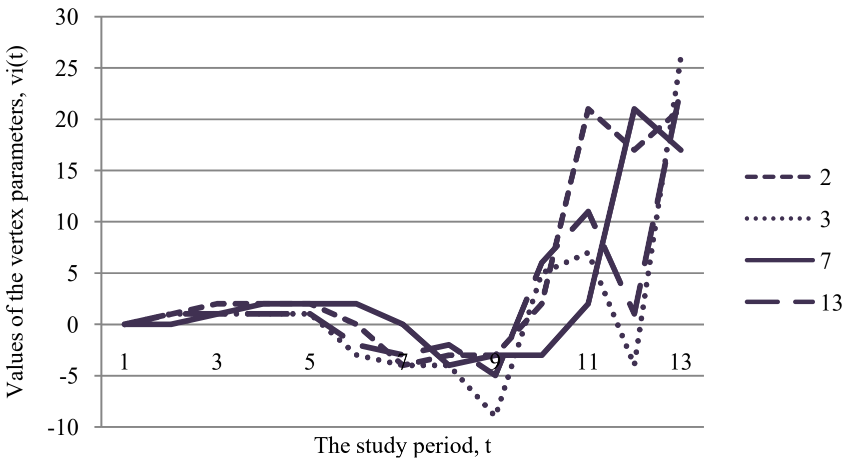

Fig. 4. The dynamics of the influence of target vertex 1 on vertices 2, 3, 7, 13.

Considering that the determining factors are characterized by different initial levels, we will investigate the created cognitive model, taking into account fuzzy logical conclusions regarding their influence on information transparency.

For research, we represent the cognitive model as a fuzzy map. For this, in the digraph, the vertices will be designated as linguistic variables [16]. The set of linguistic variables is characterized by the following parameter tuple:

$$<B_i, T, X, G, M>, \tag{6}$$

where: B_i – linguistic variables, $i = \overline{1,14}$, B_1 – "information transparency", B_2 – "the degree of confidence", B_3 – "the degree of responsibility", B_4 – "the scope of information visibility", B_5 – "the degree of information availability", B_6 – "the degree of information accessibility to third parties", B_7 – "approval to disseminate information", B_8 – "the degree of information reliability", B_9 – "the level of information and communication technologies development", B_{10} – "cognitive limitations of the user", B_{11} – "the level of information use efficiency", B_{12} – "the level of information and communication security", B_{13} – "the level of corruption reduction", B_{14} – "risk of information". T = {"low", "below average", "average", "above average", "high"}; X={information space}; G – procedure for the formation of new terms using logical connective "and", "or"; M – semantic procedure for the formation of fuzzy variables X, and the corresponding fuzzy set for the terms G(T) according to the translation rules fuzzy connective "and", "or".

In this case, T is the terms of these input and output variables of the fuzzy model, which are represented as fuzzy sets $T = \{(\alpha,\ \mu(\alpha)) : \alpha \in X,\ \mu(\alpha) \in [0;1]\}$ $T = \{(\alpha, \mu(\alpha)) : \alpha \epsilon X, \mu(\alpha) \epsilon [0;1]\}$, where α – elements of the set X, $\mu(\alpha)$ – the membership function of a fuzzy set [16]:

$$\mu(\alpha) = \begin{cases} \text{low} & \in [0;\ 0,2) \\ \text{below average} & \in [0,2;\ 0,37) \\ \text{average} & \in [0,37;\ 0,63) \\ \text{above average} & \in [0,63;\ 0,8) \\ \text{high} & \in [0,8;\ 1] \end{cases} \tag{7}$$

We present a linguistic description of the values of the factors and their measured values using the Harrington's desirability functions. The scale value is confined to the closed range of [0, 1]. Zero value corresponds to the worst measured factor state, and one corresponds to the best measured factor value. For a static analysis of the situation, we will calculate the consonance and dissonance of the cognitive map based on the research in [27]. Consonance determines how consistent the presence of factors in the system is. Dissonance determines how well-reasoned the influence of the system on each of the factors. The following table 3 gives system indicators of cognitive model.

The highest values of the consonance of the influence of a factor on the system are such indicators as the degree of confidence, the degree of information availability, the degree of information accessibility to third parties, approval to disseminate information, the level of corruption reduction. The digraph of the interaction of factors is shown below in fig. 5.

The highest values of the consonance of the influence of system on the factor are such indicators as the degree of information availability, the level of information and communication technologies development, cognitive limitations of the user. The digraph of the interaction of factors is shown below in fig. 6.

The highest values of the dissonance of the influence of system on the factor are such indicators as the degree of confidence and approval to disseminate information. Analysis of the dissonance of the influence of the system on the factor revealed the need to increase the degree of confidence in the medium and source of information, and the need to expand the boundaries of permission to disseminate information. All these actions, in general, lead to a decrease in dissonance. The highest values of the dissonance of the influence of factor on the system are such indicators as the level of information and communication technologies development and risk of information.

Table 3. The main system indicators of the cognitive model of information transparency.

Linguistic variables	Consonance of the influence of factor on the system	Consonance of the influence of system on the factor	Dissonance of the influence of factor on the system	Dissonance of the influence of system on the factor	Influencing of the factor on the system	Influencing of the system on the factor
B_1	0,867	0,621	0,133	0,379	0,150	-0,098
B_2	0,908	0,532	0,092	0,468	0,029	0,013
B_3	0,701	0,684	0,299	0,316	0,040	0,025
B_4	0,887	0,625	0,113	0,375	-0,113	0,161
B_5	0,908	1	0,092	0	-0,018	0,036
B_6	0,908	0,823	0,092	0,177	-0,018	-0,052
B_7	0,908	0,532	0,092	0,468	-0,018	0,045
B_8	0,662	0,666	0,338	0,334	0,018	0,068
B_9	0,486	1	0,514	0	0,071	0
B_{10}	0,640	1	0,360	0	0,085	-0,036
B_{11}	0,633	0,870	0,367	0,131	0,107	0,021
B_{12}	0,622	0,803	0,378	0,197	-0,107	0,050
B_{13}	0,908	0,641	0,092	0,359	0,052	-0,011
B_{14}	0,582	0,823	0,418	0,177	-0,107	-0,052

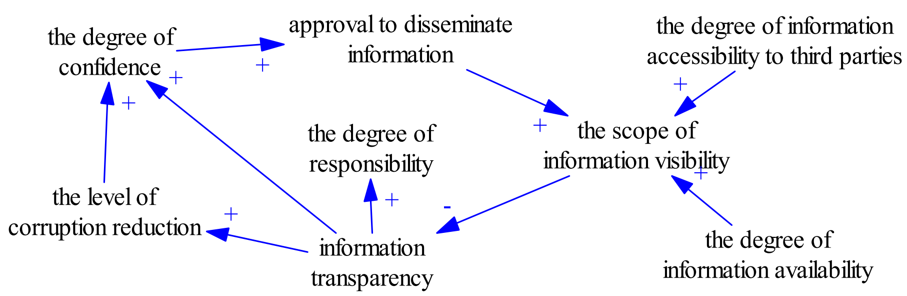

Fig. 5. Digraph of consonance of the influence of factor on the system (slice level 0,7).

Let us give a characteristic to each factor of the system:

B_1 – "information transparency" most strongly influences on the system among other factors (0.15), which is confirmed by the high value of the consonance of the influence of the factor on the system (0.867), but the system as a whole reduces the transparency of information;

B_2 – “the degree of confidence” influences on the system relatively weakly (0.029), the system, in turn, does not influence on a factor considerably (0.013). The dissonance of the system's influence on the factor is sufficiently high (0.468);

B_3 – “the degree of responsibility” - for this indicator, the consonances of the influence of the factor and the system are sufficiently high and have approximately equal values. This factor provides the strengthening of the system. This is an indicator of the prospect of strengthening the system due to the awareness of the need to disclose a certain amount and type of information;

B_4 – “the scope of information visibility” has significant negative influence on the system. But the system reinforces this factor. The value of the consonances of the influence of the factor on the system is quite high (0.887).

B_5 – “the degree of information availability” has a high value of the indicators of the consonances of the factor and the system, their values are approximately equal. It indicates that this factor strengthens the system. The prospect of strengthening is possible by expanding access to information. But the factor has a significant negative impact on the system;

B_6 – “the degree of information accessibility to third parties” weakens the system generally, and so does it. The values of the consonance of the influence of the factor and system are high;

B_7 – “approval to disseminate information” influences negatively on the system. The system does not influence significantly on a factor. The value of the consonance of influence of the factor is high. The value of the dissonance of the system's influence on the factor has a sufficiently high value in comparison with other vertices;

B_8 – “the degree of information reliability” the system influences this factor significantly and factor strengthens the system. The consonance of the factor and the system are equivalent, that is, it is necessary to strengthen the degree of reliability of the information;

B_9 – “the level of information and communication technologies development” - the system has no influence on this factor, but the dissonance of the influence of the factor on the system is of the highest;

B_{10} – “cognitive limitations of the user” the system affects the factor strongly and reduces the user's cognitive skills;

B_{11} – “the level of information use efficiency” has a significant impact on the system. The ratio of the consonances of influence indicates unused opportunities to increase the efficient use of information;

B_{12} – “the level of information and communication security” influences negatively on the system. The ratio of the consonances of influence indicates unused opportunities to increase the level of information and communication security

B_{13} – “the level of corruption reduction” the ratio of the consonances of influence indicates unused opportunities to reducing corruption;

B_{14} – “risk of information” has a significant negative impact on the system. The system diminishes the value of this factor. The dissonance of the influence of a factor on the system is of sufficient importance (0.418).

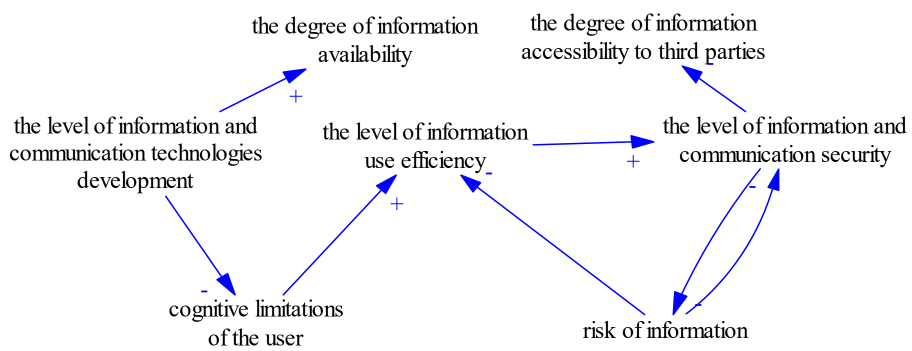

Fig. 6. Digraph of consonance of the influence of system on the factor (slice level 0,7).

A mathematical instrument of impulse processes is used to obtain a forecast of the development of the situation when implementing various alternatives. It allows you to predict the values of factors at discrete times. The “Igla” decision support system was used for modeling [28]. The initial values of the factors and the expected range of the initial values of the factors are determined by the following levels (see Table 4).

Table 4. Initial values of variables and expected area.

Variables	Initial value	Expected values
1. information transparency	“low”	“average”
2. the degree of confidence	“low”	“high”
3. the degree of responsibility	“low”	
4. the scope of information visibility	“average”	
5. the degree of information availability	“average”	
6. the degree of information accessibility to third parties	“average”	
7. approval to disseminate information	“average”	
8. the degree of information reliability	“average”	
9. the level of information and communication technologies development	“low”	
10. cognitive limitations of the user	“average”	
11. the level of information use efficiency	“below average”	-
12. the level of information and communication security	“below average”	-
13. the level of corruption reduction	“low”	“high”
14. risk of information	“high”	-

The program “Igla” has generated over 600 alternatives. The choice of alternatives is carried out per the purpose of the study. Let's consider the selected alternatives in more detail.

The diagram 7 shows the dynamics of the influence that alternatives 522, 537, 558, 567, 570 have on the target factor “information transparency”.

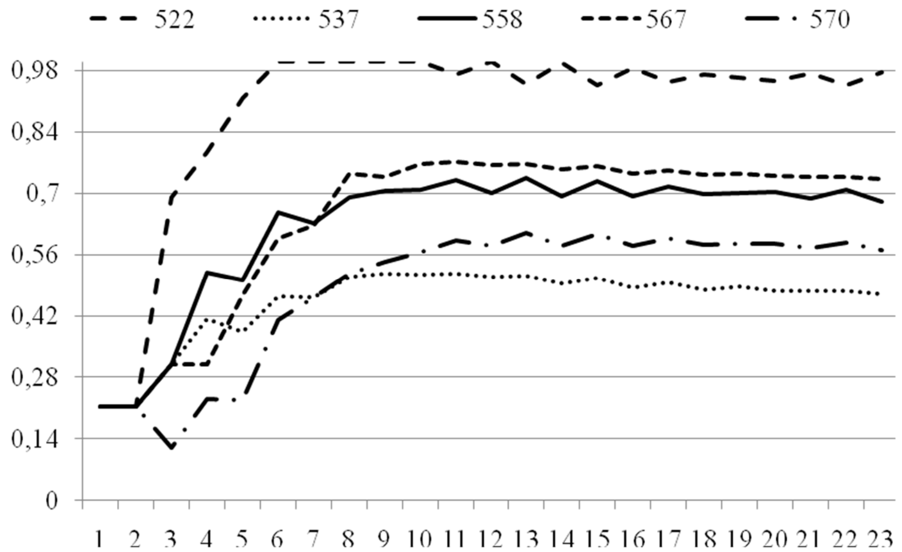

Fig. 7. The dynamics of the value of "information transparency" under the influence of alternatives 522, 537, 558, 567, 570.

The diagram 8 shows the dynamics of the influence that alternatives 574, 525, 542, 575, 541 have on the target factor "information transparency".

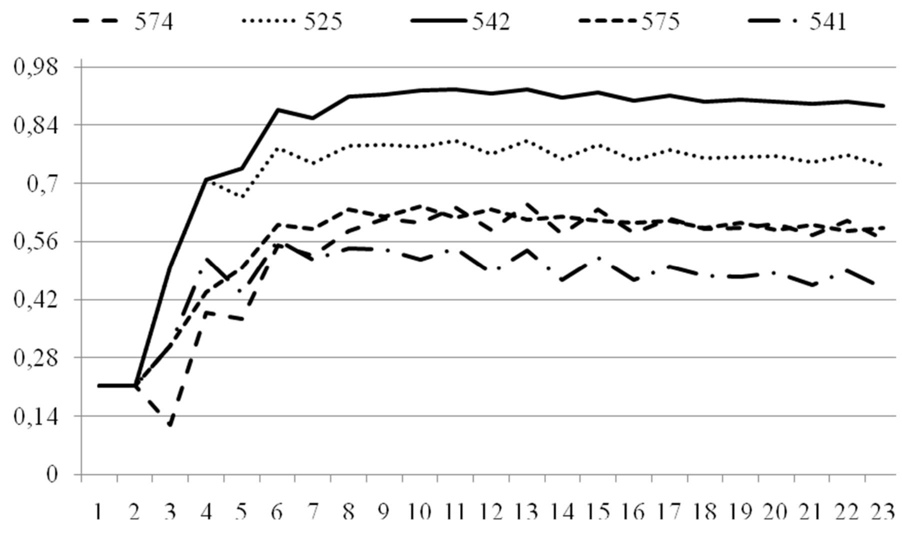

Fig. 8. The dynamics of the value of "information transparency" under the influence of alternatives 574, 525, 542, 575, 541.

Since previous research by specialists has shown that a high level of information transparency leads to an increase in the risk of misuse of information. Therefore, we consider those alternatives in which the level of information transparency corresponds to the average value. These are alternatives to 537 and 541.

The diagram 9 shows the dynamics of the influence that alternatives 537 and 541 have on the factor “the degree of confidence”.

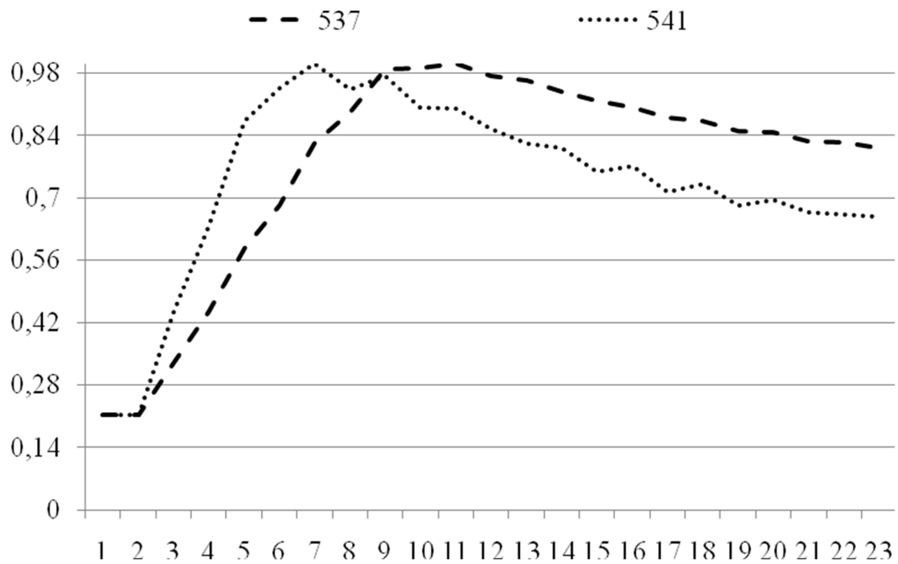

Fig. 9. The dynamics of the value of “the degree of confidence” under the influence of alternatives 537 and 541.

Thus, during the first 10 months, under the influence of both alternatives, the factor “the degree of confidence” gradually increases to a maximum. But in the following periods, under the influence of Alternative 537, the factor takes on a higher level than under the influence of Alternative 541. The diagram 10 shows the dynamics of the influence those alternatives 537 and 541 have on the factor “the level of corruption reduction”.

Thus, under the influence of both alternatives, the factor “the level of corruption reduction” gradually increases to a maximum. But under the influence of Alternative 537, the factor takes on a higher level than under the influence of Alternative 541.

Therefore, the best Alternative is 537, which meets the conditions. It was constructed as follows: in the first step and for one month it is necessary “the scope of information visibility” lower to “below average”, “the degree of information availability” increase to “above average”, “the level of information use efficiency” to leave at the level of “below average”. In general, it is necessary to increase the degree of information reliability and take measures to increase the level of information accessibility, including for third parties. Providing the required level of information reliability remains a difficult issue due to the weak structuring of this category.

Reliability is defined as a feature that allows to characterize the content of information on the presence of errors, distortions, biases, the degree of reflection of reality, the combination of which directly affects management decisions and their effectiveness. It influences the usefulness of financial statements. Its level is revealed due to additional, clarifying characteristics, in particular: "completeness, neutrality, discretion, the prevalence of essence over form and correct presentation" of information. Reliability is determined using other clarifying information, which is explained by the established relationship between information sources.

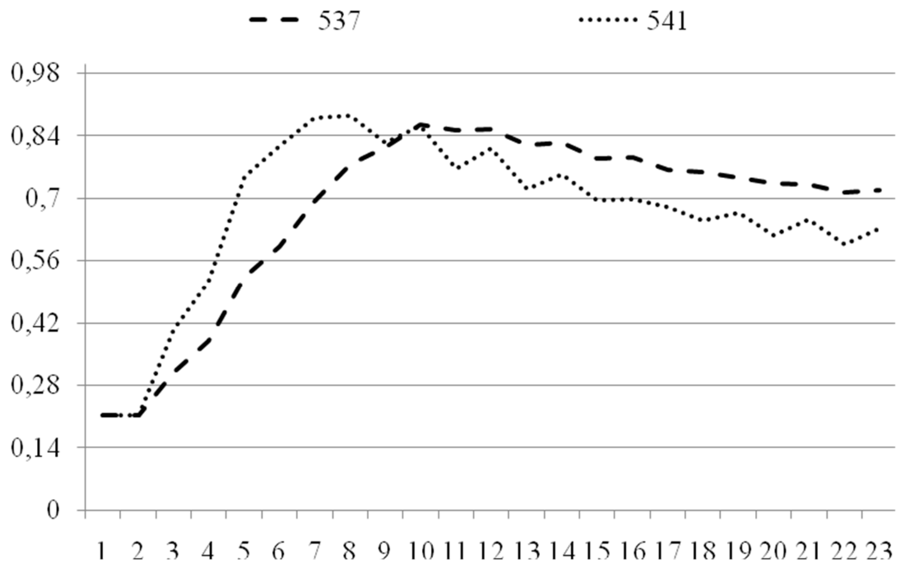

Fig. 10. The dynamics of the value of "the level of corruption reduction" under the influence of alternatives 537 and 541.

Reliability characterizes the authenticity of facts, phenomena, processes in terms of their subjectivity and variability of definition. It is determined according to the scale of the decision-maker by using available information, which may be limited. For its quantitative calculation, scientific methods and empirical research are used. The results of these studies are convincing enough to make the user feel trust to them. The expert verifies the information fact using expert research methods. The interpretation of the results of these studies is influenced by the subjectivity and competence of the evaluator.

Therefore, the results of assessing the reliability of information are taken into account with the assumptions that underlie the applied methods of expert research. First, they are regulated by regulatory and legislative acts for economic experts, both state and non-state. Second, the expert himself accepts the assumptions to generate conclusions.

Thus, the availability of information is a subjective-objective category. It is determined not only by the sphere of financial and economic relations since it is closely related to its reliability, persuasiveness of fact. But accessibility can only exist if there are an object and subject of research. The subject is an expert, based on his knowledge, skills, experience, abilities, considerations, as well as the information he has, makes decisions on the degree of correspondence of the fact being investigated to reality.

This category is not normatively regulated, it cannot be measured quantitatively, and expert methods are used to study it. Experts research this category in the context of a certain area, which is regulated by the relevant regulatory legal acts, and the object of which is the results of the financial and economic activities of the entity. But is it possible to talk about one hundred percent reliability of the results of the entity's activities presented in the financial statements. Since this reporting is made and evaluated by specialists who are subjective, and the influence of the human factor, opportunistic behavior in general, gives rise to the risk of errors, fraud, and the like.

Thus, we can say with a certain degree of probability that all information that has not been fully verified, and is not generated and processed automatically, is partially reliable.

The characteristic principle of reliability is manifested by establishing a minimum deviation between the actual data and the results obtained. It determines the close relationship of the studied category with the comparability of the data, and only together with the usefulness and materiality, the reliability ensures the quality of information.

In [22] it was proved that the reliability is divided into three categories. The first, internal, which reflects the generally accepted characteristics of knowledge about the obtained facts. The second, relative, which indicates the compliance of the facts with the requirements of the information user. The third, absolute, which determines the level of similarity of the facts with the really possible. Thus, information is characterized by the formal features of its construction, by the value for the person and by the reality of the existence of the given facts.

The reliability is determined by three criteria. The first is the validity that is the sources of information confirm the facts or phenomena under investigation. The next one is the consistency that is a fact or phenomenon in its manifestation does not create contradictions with other proven facts or phenomena. The third is the credibility, according to which the sources of information are verified and correspond to realities, and the information carrier is sufficiently protected. Therefore, the level of reliability can be assessed by the results of the ratio of the number of facts that do not correspond to reality to the total number of facts, by calculating the “probability of errors in the transmission of information”. It is advisable to highlight the boundaries within which the results are assigned a certain degree of reliability: full or partial, or establish the level at which a fact or phenomenon is determined unreliable. In this case, it is necessary to take into account the specification of information, the sources of its formation, the method of analysis of results, users, the consequences of its use in different scenarios. Thus, information can become, in one situation and for one user, reliable and valuable, and in another situation and for another user – partially reliable, or in general – unreliable, invaluable.

5 Conclusion

It involves structuring knowledge about the factor environment, identifying strategic changes in the level of information transparency and the levels of influence of its factors. Information transparency is defined as a poorly structured category which nevertheless acts as a qualitative characteristic of information, a certain level of which forms an additional spectrum of properties of information which has been adequately perceived or processed. In the course of the study, a cognitive model of information transparency was constructed in the form of a weighted digraph. The results of its structural analysis revealed that the degree of transparency and information and communication security have the most powerful influence on the state of the system. The results showed that higher levels of information and communication security lead to lower risks, lower degree of information accessibility to third parties and information transparency in general. At the same time, only the high level of information and communication security is associated with an increase in the degree of information reliability, the level of visible information use efficiency and information transparency. The analysis of the cognitive model factors which affect the level of information transparency showed that its level is most significantly decreased by the growing level of information and communication security, while it is most significantly increased by the growing efficiency of visible information use, higher level of technological development and reduced scope of information visibility. The results of this study allow us to identify the strategic elements of managing information transparency as a tool for economic entities to achieve their goals in the information environment.

At the same time, it is necessary to take into account the initial levels of factors that influence information transparency. Because the researched categories are poorly structured, the methodology of fuzzy cognitive modeling was used. The fuzziness of the system is manifested in the level variation of factors and the relationships between them, which allows simulating the scenarios of its development under conditions of various levels of initial data.

For static analysis of the situation, the consonance and dissonance of the cognitive model are calculated, it is determined how justified the presence of factors in the system is and how well-argued the influence of the system on each of the factors is. Analysis of the dissonance of the influence of the system on the factor revealed the need to increase the degree of confidence in the medium and source of information, and the need to expand the boundaries of permission to disseminate information. All these actions, in general, lead to a decrease in dissonance. The highest values of the dissonance of the influence of factor on the system are such indicators as the level of information and communication technologies development and risk of information.

A mathematical instrument of impulse processes is used to obtain a forecast of the development of the situation when implementing various alternatives. It allows you to predict the values of factors at discrete times. The “Igla” decision support system was used for modeling scenarios of the situation, more than 600 alternatives were analyzed, in accordance with the purpose of research were chosen the best.

The best alternative is constructed as follows: in the first step and for one month it is necessary the factor “the scope of information visibility” lower to “below average”, "the degree of information availability" increase to "above average", "the level of information use efficiency" to leave at the level of "below average". It is necessary to increase the degree of information reliability and take measures to increase the level of information accessibility, including for third parties. Providing the required level of information reliability remains a difficult issue due to the weak structuring of this category and the associated risks, which are the focus of further research.

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