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Aleksy Kwiliński

REFLEXIVE MANAGEMENT

Lublin 2021

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This book is devoted to considering reflexive processes in information management and strategic management. Describing models of informational and strategic reflection makes it possible to set and solve the tasks of reflexive management associated with latent management in organizational, economic, social and other systems. The book is addressed to university students and post-graduates, as well as specialists in the field of decision-making and managing the systems of interdisciplinary character.

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Table of contents

Introduction

Transformation of the world economic system in the context of the information technology development, the crisis of capitalism, the struggle for human rights and environmental protection were the reasons for establishing the corresponding structures of the network society and the information economy[1]. The logic embedded in these phenomena has become the basis for conceptualizing and developing certain approaches to modeling reflection in management.

One of the fundamental properties of human existence is that along with the natural reality, there is its reflection in consciousness. At the same time, between natural reality and its image in consciousness (we will consider this image as part of a special – reflexive reality) there is an inevitable gap, a discrepancy.

The purposeful study of this phenomenon is traditionally associated with the term "reflection" (Latin Reflexio – turning back), which means mirroring. This term was introduced by J. Locke, but in different philosophical systems (J. Locke, G. Hegel, D. Hume, G. Leibniz, etc.) it had a different meaning. The systematic description of reflection from the viewpoint of psychology began in the 1960s. In addition, it should be noted that reflection is also understood in the meaning related to the reflex – "the body's response to the excitation of receptors". This book uses a philosophical definition of reflection.

To clarify understanding of the essence of reflection, let us consider the situation with one subject. He has beliefs about natural reality, but he can also be aware of ('mirror', reflect) these beliefs, as well as perceive the awareness of these beliefs, etc. This is how reflexive reality is formed. Reflection of the subject regarding his own beliefs about reality, the principles of his activity, etc. is called self-reflection or reflection of the first kind. Let us note that most humanitarian studies are talking, first of all, about self-reflection, which in philosophy means the process of an individual’s reflection in his mind on what is happening.

Reflection of the second kind takes place in relation to beliefs about the reality, principles of decision-making, self-reflection, etc. of other subjects.

In order to describe reflexive "mirroring", psychology uses, in particular, the following approach. Let us consider the relationship among three elements: the subject of activity (SA), the object of his activity (OA) and other subjects (OS) (Fig. 1). The arrows in the figure conventionally denote individual acts of "consideration" ("reflection").

The relationship among the elements can be described by a sequence of letters "SA", "OA" or "OS", and the order of their sequence corresponds to who "reflects" what or who reflects about what. The object of activity is assumed to be "passive" and cannot reflect.

[1] Castells M. (2010), *The Information Age: Economy, Society, and Culture, Volume III. End of Millennium. Second Edition*, Oxford, United Kingdom: Blackwell Publishers.

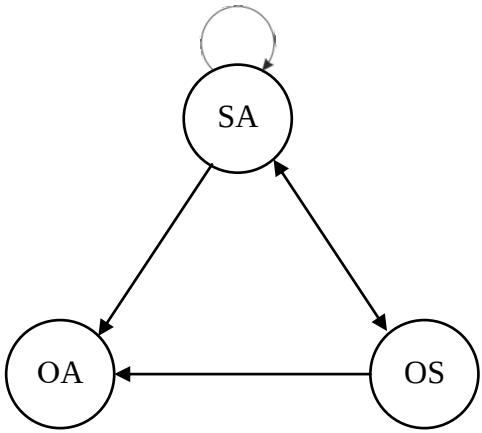

Figure 1. Evaluation options

The first order relation (zero rank of reflection, there is an estimate):

- SA-OA – the subject's evaluation of the results of his activities (self-evaluation of results);
- SA-SA – the subject's evaluation of himself (self-assessment of himself as a personality);
- SA-OS – the subject's evaluation of other subjects – people (as personalities);
- OS-OA – evaluation by other subjects of the results of the subject's activity;
- OS-SA – evaluation of the subject (as a personality) by other subjects (people).

These five relations exhaust possible combinations of the first-order relations (the object, due to its passivity, is not capable of evaluating; we do not consider other subjects' self-esteem (OS-OS)).

The relationships depicted in Figure 1 can become the object of reflection for the subject of activity, as well as for other subjects. Reflection of the first rank emerges.

Relations of the second order (reflection of the first rank). Here you need to differentiate between:

I. Auto-reflection (reflection of the first kind), to which the sequences beginning with "SA-SA" correspond, that is, those related to the subject's thoughts about his self-esteem, his self-evaluation of his results:

- SA-SA-OA – the subject's reflections on self-evaluation of results;
- SA-SA-SA – the subject's reflections about his self-esteem.

II. Reflection of the second kind (all other sequences):

- SA-OS-OA – the subject's reflections about other subjects' evaluation of his activity's results (what others think about my activity results);

- SA-OS-SA – the subject's reflections on other subjects' evaluation of himself (what others think of me);
- OS-SA-SA – other subjects' reflections about the subject's self-esteem;
- OS-SA-OA – other subjects' reflections about the subject's self-evaluation of his activity results;
- OS-SA-OS – other subjects' reflections about their evaluation by the subject.

Relations of the third order (reflection of the second rank). There are already more options here. Here are some of them: SA-OS-SA-OA – the subject's reflections on other subjects' thoughts about the subject's self-evaluation of his own results (what others think about how I evaluate my results); OS-SA-OS-OA – other subjects' reflections about the subject's reflections on other subjects' evaluation of the results of his activity, etc.

Other, higher ranks of reflection are described similarly.

Here are some classic examples of reflection of the second kind, illustrating that in many cases, one's own correct conclusions can be made only if the position of other subjects is taken and their possible reasoning is analyzed.

Example 1. Dirty Face Game[2] (sometimes this problem is called "about husbands and cheating wives")[3].

Imagine Bob and his niece, Alice, are in the compartment of a Victorian carriage. Both have their faces stained. However, no one blushes with shame, although any Victorian passenger would blush knowing that the other person sees him dirty. From this, we conclude that none of the passengers knows that their face is dirty, although everyone sees the dirty face of their companion.

At this time, the conductor looks into the compartment and announces that there is a person with a dirty face in the compartment. After that, Alice blushes. She realizes that her face is stained. But why does she understand this? Hasn't the conductor said what she has already known?

Let us trace Alice's line of reasoning. Alice: "Suppose my face is clean. Then Bob, knowing that one of us is dirty, must conclude that he is dirty and blush. Since he does not blush, it means that my premise about my clean face is false, my face is dirty and I should blush".

The conductor added information about Bob's knowledge to the information Alice had known. Before that, she hadn't known that Bob knew that one of them was dirty. In short, the conductor's message turned the knowledge that there was a person with a dirty face in the compartment into common knowledge.

Example 2. The second proverbial example is the Coordinated Attack Problem[4]. There are also similar problems about the optimal information exchange protocol: Electronic Mail Game[5] and others[6, 7, 8].

[2] Gamov G., Stern M. (1958), *Puzzle Math*, N.Y.: Viking Press.
[3] Myerson R. (1991), *Game Theory: Analysis of Conflict*, London: Harvard Univ. Press.

The situation looks as follows. There are two divisions located on the tops of the two hills, and the enemy is stationed in the valley. You can win only if both divisions attack the enemy at the same time. The general – the commander of the first division – sends to the general – the commander of the second division – a messenger with the message: "We'll attack at dawn". Since the messenger can be intercepted by the enemy, the first general must wait for the note from the second general that the first message has been received. But since the second message can also be intercepted by the enemy, the second general needs to receive confirmation from the first one that he received confirmation. And so on ad infinitum. The task is to determine after what number of reciprocal messages (confirmations) it makes sense for the generals to attack the enemy. The conclusion is as follows: under the described conditions, a coordinated attack is impossible, and the way out is to use probabilistic models[9, 10].

Having considered the examples of reflection of the second kind, let us discuss in which situations reflection is essential. If the only reflexive subject is an economic agent that seeks to maximize its objective function by choosing one of the ethically acceptable actions, then natural reality is included in the objective function as a certain parameter, and the results of reflection (beliefs about beliefs, etc.) are not arguments of the objective function. Then it can be said that self-reflection is "unnecessary", since it does not change the action chosen by the agent.

Let us note that the dependence of the subject's actions on reflection can take place in a situation where actions are ethically unequal, that is, along with the utilitarian aspect, there is a deontological (ethical) one[11, 12]. However, economic decisions, as a rule, are ethically neutral, so we will consider the interaction of several subjects.

If there are several subjects (the decision-making situation is interactive), then the objective function of each subject includes the actions of other subjects, that is, these actions are part of natural reality (although they themselves, of course, are conditioned

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[4] Gray J. (1978), *Notes on Database Operating System*, In: R. Bayer, R.M. Graham, G. Seegmüller (Eds.), *Operating Systems: An Advanced Course*, Lecture Notes in Computer Science, Vol. 66, pp. 393-481, Berlin: Springer-Verlag.

[5] Rubinstein A. (1989), *The Electronic Mail Game: Strategic Behavior under "Almost Common Knowledge"*, American Economic Review, 79, pp. 385-391.

[6] Fagin R., Geanakoplos J., Halpern J., Vardi M. (1999), *The Hierarchical Approach to Modelling Knowledge and Common Knowledge*, International Journal of Game Theory, 28, pp. 331-365.

[7] Halpern J., Moses Y. (1990), *Knowledge and Common Knowledge in a Distributed Environment*, Journal of Assoc. Comput. Mach., 37(3), pp. 549-587.

[8] Strzalecki T. (2010), *Depth of Reasoning and Higher Order Beliefs Working Paper*, Harvard: Harvard University.

[9] Morris S., Shin S.S. (1997), *Approximate Common Knowledge and Coordination: Recent Lessons from Game Theory*, Journal of Logic, Language and Information, 6, pp. 171-190.

[10] Morris S. (1999), *Approximate Common Knowledge Revisited*, International Journal of Game Theory, 28, pp. 385-408.

[11] Lefebvre V.A. (1998), *Sketch of Reflexive Game Theory. Proc. of Workshop on Multi-Reflexive Models of Agent Behavior*, Los Alamos, New Mexico: Army Research Laboratory.

[12] Lefebvre V.A. (2010), *Algebra of Conscience*, 2nd ed. N.Y.: Springer.

by reflexive reality). In this case, reflection (and, therefore, the study of reflexive reality) becomes necessary.

Before considering the main approaches to modeling reflexive processes, let us briefly present the basic category "management" and its relationship with reflection.

At its core, we can define the category "management" as an element, a function of organized systems of various nature: biological, social, technical, ensuring the preservation of their certain structure, maintaining a certain mode of activity, the implementation of the program, the goals of the activity. Or, in other words, management is an impact on a controlled system in order to ensure its required behavior.

Let us discuss a qualitatively general formulation of the management problem. Let there be a subject of management and a system managed (a managed object or a managed subject). The state of the system managed depends on external influences, influences (management) from the governing body, and, perhaps (if the subject of management is active), the actions of the managed system itself (Fig. 2). The task of the governing body is to implement such managing actions (bold line in Fig. 2) so that, taking into account information about external influences (dashed line in Fig. 2), to provide the state of the managed system required from their point of view.

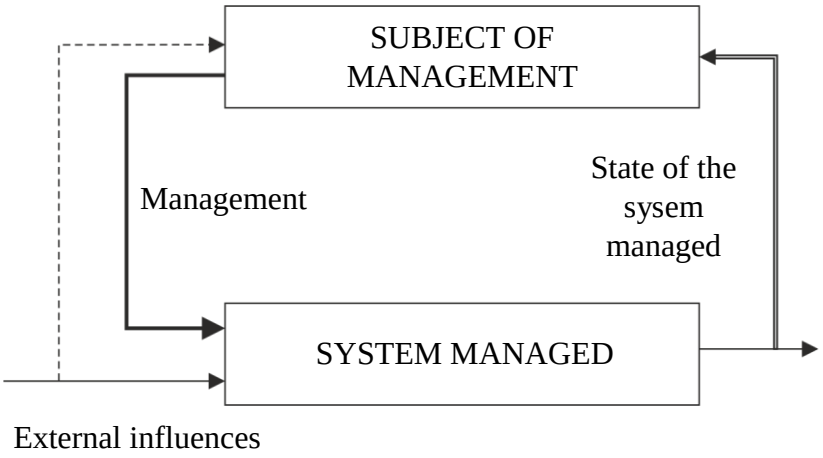

Figure 2. The Structure of the Management System

It should be noted that the so-called input-output structure, shown in Figure 2, is typical for management theory, which studies the tasks of managing systems of various nature. The availability of feedback (see the double line in Fig. 2), which gives information about the state of the system managed, is a key, but not mandatory feature of the management system. Some researchers interpret the feedback as reflection (reflection by the subject of management of the state of the system managed). This is the first aspect of the mutual relationship between management and reflection.

The interaction and activity of the subject of management and the system managed is the subject of research in a number of scientific areas. The science of management (management theory) focuses mainly on the interaction of the subject of management and the system managed (Fig. 3).

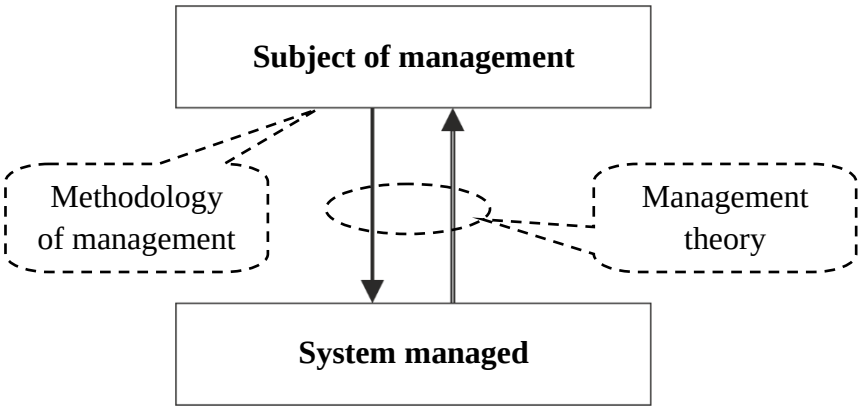

Figure 3. Methodology of Management and Management Theory

Methodology of management is the doctrine of organizing management activities, that is, the activity of the subject of management. It should be noted that activity can only be spoken of in relation to active subjects – a person, a group, a collective, etc. In the case of passive systems, for example technical ones, they speak of their functioning. In the course of the material's further presentation, it will be assumed that both the subject of management and the system managed are active. Consequently, each of them can carry out at least self-reflection, "reflecting" the process, principles of organization, and the results of their own activities. This is the second aspect of the relationship between management and reflection.

To search for the optimal (most effective permissible) management, the subject of management must be able to predict the reactions of the system managed to certain managing actions. This requires one or another model of the system managed. A model – in a broad sense – can be represented as any image, an analog (mental or conditional: an image, description, diagram, drawing, graph, plan, map, etc.) of an object, process or phenomenon (the original of this model) or as an analog of a certain fragment of natural or social reality – a substitute for the original in knowledge and practice. Relatively speaking, the model can be considered an image of a system managed as perceived by the subject of management. The process of modeling – "reflection" –, that is, the construction of this image, can also be considered as reflection. Moreover, the system managed can also predict and evaluate the activities of the subject of management. All this can be attributed to the third aspect of the relationship between management and reflection.

The fourth aspect is associated with the "reflection" by the subject of management or the system managed (reflection in relation to) of subjects or objects external to them, phenomena or processes, their properties, and patterns of their activity or functioning. For the subject of management, this can be, for example, the external environment; for

an element of the system managed – the external environment and/or other elements of the system managed. Indeed, if a system managed includes several active agents, then, in the general case, each of them can reflect on the others. It is this aspect – the mutual reflection of subjects managed – that is discussed in detail in this textbook.

The four aspects listed correspond to the zero rank of reflection – evaluation. By analogy with the construction shown in Figure 1, it is possible to uniformly describe the reflection of the first, second and other higher ranks. For example, the first-rank reflection will be the beliefs of the subject of management about the evaluation of other agents by one or another subject managed (agent). The second-rank reflection will be the evaluation by the system managed of these beliefs of the subject of management, and so on.

The following is essential: *the process and/or the result of reflection can be a subject of management*, that is, a purposefully changeable subject of management by a component of the activity of a system managed. It is this interconnection of management and reflection that makes it possible to talk about information management and reflexive management, which are discussed in detail in this book, which, in fact, contains theory and examples of how to manage reflection.

In turn, the results of modeling information/reflexive management obtained for social, economic, organizational and other systems, including a person, are widely used in the fields of artificial intelligence[13, 14, 15] and cognitive technologies[16, 17]. These can be exemplified by the so-called multi-agent systems[18], which consist of a large number of interacting autonomous agents of a technical or information nature. Such properties of multi-agent systems as a decentralized character of interaction and multiplicity of agents give them qualitatively new important emergent properties (autonomy, less vulnerability to adverse influences, etc.). Thus, having analyzed the fundamental categories of reflexive management, let us proceed to considering the main opportunities of using the proposed method in management.

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[13] Lakhno V., Malyukov V., Bochulia T., Hipters Z., Kwilinski A., Tomashevska O. (2018), *Model of Managing of the Procedure of Mutual Financial Investing in Information Technologies and Smart City Systems*, International Journal of Civil Engineering and Technology, 9(8), pp. 1802-1812.

[14] Kuzior A., Kwilinski A., Tkachenko V. (2019), *Sustainable Development of Organizations Based on the Combinatorial Model of Artificial Intelligence*, Entrepreneurship and Sustainability, 7(2), pp. 1353-1376, http://doi.org/10.9770/jesi.2019.7.2(39).

[15] Tkachenko V., Kuzior A., Kwilinski A. (2019), *Introduction of Artificial Intelligence Tools into the Training Methods of Entrepreneurship Activities*, Journal of Entrepreneurship Education, 22(6), pp. 1-10.

[16] Kwilinski A., Tkachenko V., Kuzior A. (2019), *Transparent Cognitive Technologies to Ensure Sustainable Society Development*, Journal of Security and Sustainability Issues, 9(2), pp. 561-570, http://doi.org/10.9770/jssi.2019.9.2(15).

[17] Kwilinski A., Kuzior A. (2020), *Cognitive Technologies in the Management and Formation of Directions of the Priority Development of Industrial Enterprises*, Management Systems in Production Engineering, 28(2), pp. 119-123, http://doi.org/10.1515/mspe-2019-0020.

[18] Shoham Y., Leyton-Brown K. (2009), *Multiagent Systems: Algorithmic, Game-Theoretical and Logical Foundations*, Cambridge: Cambridge University Press.

Chapter 1. Game theory and reflexive management

The advent of the new millennium has brought many changes and served as an impetus for developing such areas as knowledge economy, information economy, digital economy, new economy, big data, virtual economy, synthetic economy, emerging economy, network economy, Web economy, sharing economy, Internet economy, electronic economy, information network economy, Industry 4.0, electromobility, gig economy, e-commerce, e-business, platform economy, algorithmic economy, cyber-physical systems, blockchain technology, the Internet of things, cloud computing, cognitive technologies, artificial intelligence.

Such systems are characterized by a complex hierarchical internal structure. For example, using a multi-agent system (MAS) as an example, let us consider a typical functional structure of an agent, which has several hierarchical levels (Fig. 4).

At the operational (executive) level, the implementation of actions is carried out, such, for example, as stabilization of movement along a given trajectory. At the tactical level, the choice of actions is carried out (for example, the planning of such actions as choosing trajectories or solving the tasks of distributed optimization), including taking into account interaction with other agents. The strategy level is responsible for decision making, training and adaptability of agent behavior, as well as for management cooperation – a coordinated solution of a single task by a set of agents. Here, the agent's ability to make strategic decisions, adapt, and learn reflection becomes essential. And finally, the conceptual level corresponds to the principles of goal-setting. At each level, one or another research apparatus is applied. As a rule, methods applicable at one of the levels can be used at higher hierarchical levels.

One of the current trends in the theory of multi-agent systems, game theory, artificial intelligence and cognitive technologies is the researchers' desire to integrate these scientific areas.

At the same time, game theory (within the framework of algorithmic game theory) is focused on the upper levels of the agent's architecture moving "top-down" – from a single description of the game to its decentralization and the study of the possibility of autonomous implementation of the behavior mechanisms of the equilibria realization. And the MAS theory, moving "bottom-up", that is, in a parallel, but due to the localization of scientific communities – in a different way, tends to increasingly allow for the strategic behavior, intellectuality, and cognitive capacity of agents, including their ability to reflect.

In turn, it should be noted that the active subjects' behavior and interaction is described within the framework of game theory, which today is one of the main tools in the theory of systems' management that include a human being.

Formal (mathematical) models of human behavior have been created and studied for more than a century and a half and are increasingly used both in management theory, economics, psychology, sociology, etc., and in solving specific applied problems. The most intensive development has been observed since the 1940s – the moment of the game theory emergence, which is usually dated to 1944 (the first edition of the book by John von Neumann and Oskar Morgenstern "Game Theory and Economic Behavior").

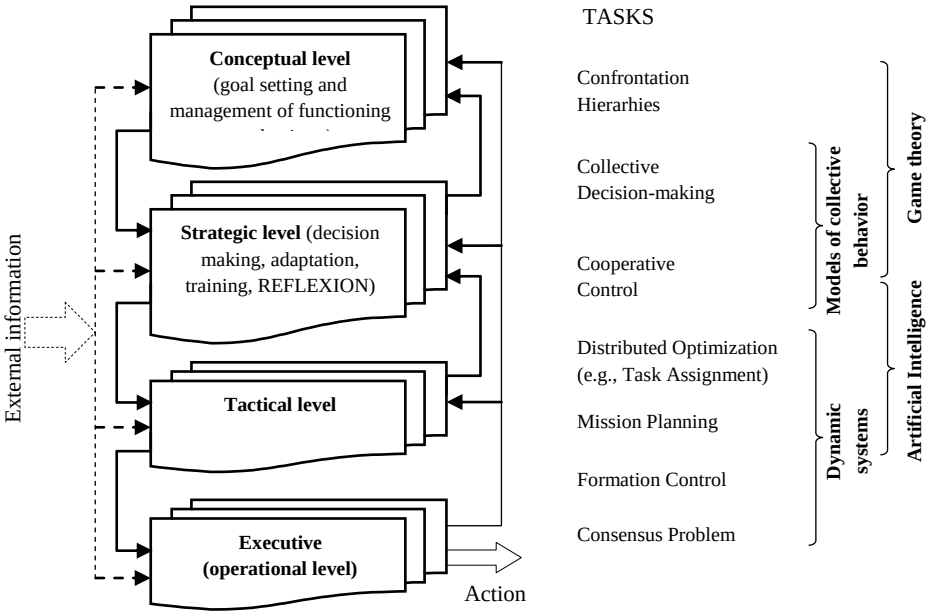

Figure 4. Hierarchical Architecture of an Agent in a Multi-Agent System

In this book, by the game we mean the interaction of subjects whose interests do not coincide. Let us note that a different understanding of the game is possible – as a type of unproductive activity, the motive of which is not in its results, but in the process itself, and the concept of the game, in this case, is interpreted much more broadly.

Game theory is a branch of applied mathematics that studies decision-making models in conditions of mismatch among the parties' (players') interests, when each party seeks to influence the development of the situation in its own interests. Further, to denote the decision-maker (player), the term ‘agent’ is used. The present book considers mainly noncooperative static games in normal form, that is, games in which agents choose their actions once, simultaneously and independently.

Thus, the main task of game theory is to describe the interaction of several agents whose interests do not coincide, and the results of activity (payoff, utility, etc.) of each depend, in the general case, on the actions of all[19]. Such a description results in the forecast of a reasonable and "sustainable" outcome of the game – the so-called game solution (equilibrium).

The description of the game consists in setting the following parameters:

- a multitude of agents;
- agents’ preferences (dependencies of payoffs on actions): it is assumed (and this reflects the purposefulness of behavior) that each agent is interested in maximizing his payoff;

[19] Myerson R. (1991), *Game Theory: Analysis of Conflict*, London: Harvard Univ. Press.

- sets of agents' admissible actions;
- agents' awareness (of the information about essential parameters that they have at the time of making decisions about the chosen actions);
- the order of functioning (order of moves – sequence of choosing actions).

Relatively speaking, the set of agents determines who participates in the game. Preferences reflect what agents want, sets of acceptable actions – what they can, awareness – what they know, and order of functioning – when they choose actions.

The listed parameters define the game, but they are insufficient to predict its outcome – the solution of the game (or the equilibrium of the game), that is, a set of agents' rational and sustainable actions from one point of view or another. To date, there is no universal concept of equilibrium in game theory – by making certain assumptions about the principles of decision-making by agents, various decisions can be obtained. Therefore, the main task of any game-theoretic research is to construct the concept of equilibrium.

Chapter 2. Informational and strategic reflection

Before proceeding to the presentation of the main content of the book, let us discuss, at a qualitative level, the main approaches for describing information and strategy reflections.

As defined above, a reflexive game is the one in which the agents' awareness is not common knowledge and the agents make decisions based on the hierarchy of their views. From the point of view of game theory and reflexive decision-making models, it is expedient to separate strategy and information reflections.

Information reflection is the process and result of the agent's reflections about what the values of undefined parameters are, what his opponents (other agents) know and think about these values. In this case, there is no actual "game" component, since the agent does not make any decisions.

Strategy reflection is the process and result of the agent's reflections on what principles of decision-making are used by his opponents (other agents) within the framework of the awareness that he attributes to them as a result of information reflection.

Thus, information reflection is usually associated with a lack of mutual awareness, and its result is used when making decisions (including strategy reflection). Strategy reflection takes place even in the case of complete information awareness, anticipating the agent's decision on the chosen action. In other words, information and strategy reflections can be studied independently, however, under conditions of incomplete and insufficient information awareness, both of them are available.

Reflection takes place when an agent has and uses a hierarchy of beliefs when making decisions – his own beliefs about the beliefs of other agents, their beliefs about his beliefs and beliefs of each other, etc. The analysis of beliefs about uncertain factors corresponds to information reflection, and beliefs about the principles of decision-making correspond to strategy reflection. In terms of subjective equilibrium, strategy reflection corresponds to the agent's assumptions that the opponent will calculate something specific, for example, something subjective that guarantees equilibrium, and information reflection is what specific assumptions about the situation the opponent will use.

Let us consider the currently known approaches to describing the hierarchy of views and common knowledge.

There are discerned two approaches[20, 21, 22] to describing information awareness – syntactic and semantic. Let us recall that syntactics is the syntax of sign systems, that is, the structure of signs combination and the rules for their formation and transformation, regardless of their meanings and functions of sign systems, while semantics studies sign systems as means of expressing meaning, its main subject being the interpretation of signs and their combinations. The foundations of these approaches were laid in mathematical logic[23, 24].

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[20] Aumann R.J., Brandenbunger A. (1995), *Epistemic Conditions for Nash Equilibrium*, Econometrica, 63(5), pp. 1161-1180.

[21] Aumann R.J. (1999), *Interactive Epistemology I: Knowledge*, International Journal of Game Theory, 28, pp. 263-300.

[22] Heifetz A. (1999), *Iterative and Fixed Point Belief*, Journal of Philosophical Logic, 28, pp. 61-79.

[23] Kripke S.A. (1959), *Completeness Theorem in Modal Logic*, Journal of Symbolic Logic, 24, pp. 1-14.

[24] Hintikka J. (1962), *Knowledge and Belief*, Ithaca: Cornell University Press.

In the syntactic approach, the hierarchy of views is described explicitly. If beliefs are defined by a distribution of probabilities, then hierarchies of beliefs at some level of the hierarchy correspond to the product's distribution of many states of nature and distributions reflecting the beliefs of previous levels[25]. An alternative is to use "formulas" (in the logical sense), that is, the rules for transforming the elements of the original set based on the use of logical operations. At the same time, knowledge is modeled by sentences (formulas) constructed in accordance with certain syntactic rules.

Within the framework of the semantic approach, the agents' beliefs are specified by probability distributions on the set of nature states. In this case, the hierarchy of beliefs is generated proceeding only from these distributions. In the simplest deterministic case, knowledge is represented by a set of possible values of an undefined parameter and partitions of this set. The partitioning element represents the agent's knowledge – a set of values of an undefined parameter, indistinguishable from his point of view, given a known fact[26, 27].

This brief review suggests that there are two extremes. The first is common knowledge, the second is an infinite hierarchy of coordinated or inconsistent beliefs.

Thus, both the study of strategy reflection and the construction of a solution to a reflexive game and the study of its dependence on the hierarchy of agents' beliefs are relevant.

Traditionally, game-theoretic models and/or models of collective decision-making use one of two assumptions about mutual information awareness of agents. Or it is believed that all the essential information and principles of decision-making by agents are known to all of them, everyone knows that everyone knows this, etc. ad infinitum. Or it is assumed that each agent, within the framework of his awareness, follows a certain procedure for making individual decisions and almost "does not think" about what the other agents know and how they behave. The first approach is canonical for game theory, while the second is for models of collective behavior. But between these two "extremes" there is a wide variety of possible situations. Let us suppose that, in conditions of common knowledge about essential external parameters (there is no information reflection), some agent performed an act of strategy reflection: he tried to predict the behavior (lack of awareness, but also the principles of decision-making) of other agents and chooses his actions taking into account this forecast (we will assume that such an agent has the first rank of reflection). Another agent (possessing the second rank of reflection) can know about the existence of the first-rank agents and predict their behavior, etc. Several questions arise: "How does the behavior of an agents' collective depend on their distribution according to the ranks of reflection, that is, on how many agents of this or that rank there are in the collective? If the shares of reflexive agents can be managed, then what are these shares that are optimal from the point of view of one or another efficiency criterion, defined on the set of agents' actions?".

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[25] Mertens J.F., Zamir S. (1985), *Formulation of Bayesian Analysis for Games with Incomplete Information*, International Journal of Game Theory, 14, pp. 1-29.

[26] Aumann R.J. (1976), *Agreeing to Disagree*, The Annals of Statistics, 4(6), pp. 1236-1239.

[27] Aumann R.J. (1999), *Interactive Epistemology I: Knowledge*, International Journal of Game Theory, 28, pp. 263-300.

In classical game-theoretic models, it is assumed that in the game in normal form, agents will choose equilibrium actions. However, research in experimental economics suggests that this is not always the case. There can be several possible explanations for the difference between the behavior observed in experiments and the one predicted by the theory:

- the agents' limited cognitive capabilities;
- the need for every agent to be confident that all his opponents can calculate an equilibrium (in which a one-sided deviation is not beneficial for one of the agents) and will do it;
- incomplete information awareness;
- the occurrence of several equilibria.

Thus, there are at least two bases, theoretical and experimental, for considering models of collective behavior of agents with different ranks of reflection.

In contrast to game theory, the theory of collective (group) behavior studies the dynamics of the rational agents' behavior under rather weak assumptions about their awareness. So, for example, it is not always required that the agents have a common knowledge about the set of agents, sets of admissible actions and objective functions of opponents. Or it is believed that agents do not predict the behavior of all opponents, as is the case in game theory. Moreover, often when making decisions, agents may "not know about the existence" of some other agents or have aggregated information about them.

For completeness, we note that there is another approach in the theory of collective behavior – evolutionary game theory[28], which studies the behavior of large homogeneous groups (populations) of individuals in typical repetitive conflict situations, and each strategy is used by many players, and the payoff function characterizes the success of individual strategies, not individual participants in the interaction.

Thus, relatively speaking, game theory often uses the maximum assumptions about the agents' information awareness (for example, the hypothesis of the common knowledge existence), while the theory of collective behavior uses the minimum ones. Reflexive models occupy an intermediate place; therefore, let us move on to discussing the role of reflection – information and strategic – in decision-making by agents.

Reflection in game theory and models of collective behavior: the structure of the subject area. Game theory and collective behavior theory study the interaction patterns of rational agents. The approaches and results of these theories can be regarded from the viewpoint of three interrelated epistemological levels (Fig. 5):

- the phenomenological level at which the model is built in order to describe and/or explain the behavior of the system under research (a team of agents);
- the predictive level (the goal is to predict the behavior of the system under research);
- the normative level (the goal is to ensure the required system behavior).

For game theory, the traditional scheme is when the "game model" (phenomenological level) is first described; then the concept of equilibrium is selected, which determines

[28] Weibull, J. (1995). Evolutionary Game Theory. Cambridge: MIT Press.

what is meant by a sustainable outcome of the game (predictive level); after which one or another management task can be formulated – the choice of values of the controlled "game parameters" leading to implementing the required equilibrium (normative level).

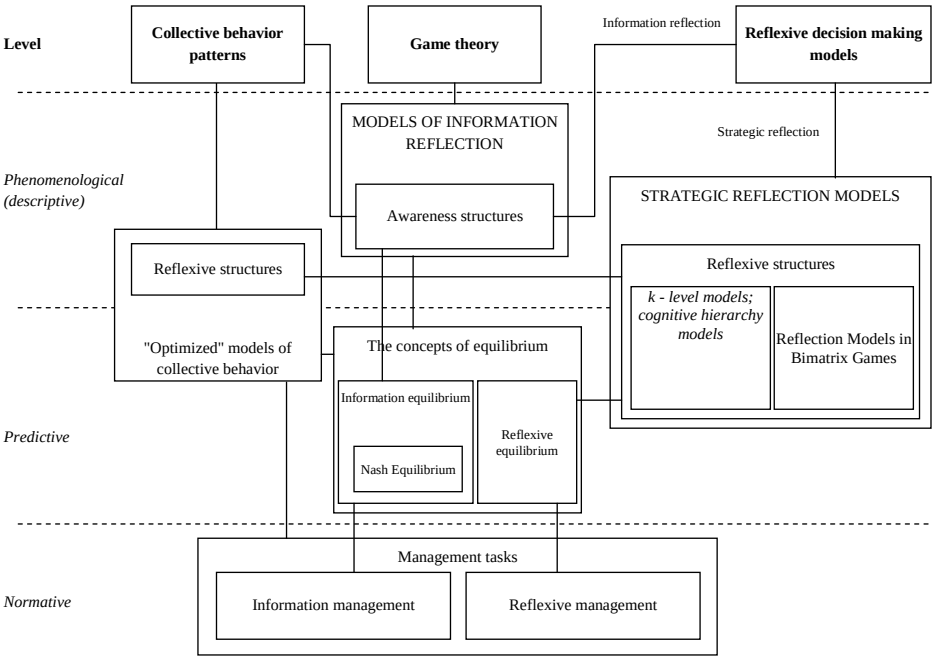

Figure 5. Descriptive and Normative Models of Information and Strategic Reflections.

Allowing for information reflection leads to the need to build and analyze information awareness structures, which ultimately makes it possible to determine information equilibrium and, in the future, to set and solve information management tasks.

Taking into account strategic reflection leads to a similar chain: "models of strategy reflection" – "reflexive structure" – "reflexive equilibrium" – "reflexive management".

Comparison of approaches to modeling information and strategic reflections is carried out in Table 1.

Table 1. Comparison of Approaches to Modeling Information and Strategic Reflections

PARAMETER	INFORMATION REFLECTION	STRATEGY REFLECTION
Game Model	Information Awareness Structure	Reflexive Structure
Equilibrium	Information Equilibrium	Reflexive Equilibrium
Management	Information Management	Reflexive Management

Chapter 3. A coevolutionary approach in decision – making processes

In practice, in order to make timely, balanced and effective decisions in conditions of conflict and uncertainty, intelligent decision-making systems are increasingly used, which are human-machine interactive systems that help a responsible and competent person justify and make rational management decisions, in the development of which artificial intelligence enhancers are engaged. The basic tools of such intelligent systems are expert systems, neural networks, population methods and optimization models, fuzzy sets and fuzzy logic, which can be considered separately or in interconnection with each other.

Population methods and optimization models are locally stochastic, heuristic optimization methods and models based on the principles of Charles Darwin's evolutionary theory: only those individuals survive in populations of living organisms that are most adapted to environmental conditions. Studies have shown that these methods are effective in solving multidimensional, multi-extreme tasks; in cases where variables are set discretely; when the objective function of the optimization problem is set implicitly. Population methods and optimization models can be divided into evolutionary and coevolutionary. Evolutionary methods and models are divided into classical (genetic algorithms, evolutionary strategies and evolutionary programming) and modified classical (genetic programming, evolutionary programs, and others). Coevolution ones include cooperative coevolution with one population, cooperative coevolution with two populations, cooperative coevolution with a given number of populations, support of diversity.

All evolutionary methods and models are based on the classical genetic algorithm. It underlies various genetic algorithms that are used to solve problems in the following areas: extremal tasks (finding points of minimum and maximum), problems of optimal distribution of investment funds, problems of the shortest path (traveling salesman problem), problems of layout, scheduling, approximation of functions, selection (filtering) of input data, settings of artificial neural networks, bioinformatics, game strategies, nonlinear filtering, etc. Genetic algorithms are capable of not only reducing enumeration in complex problems, but also being easy to adapt.

Although the model of evolutionary development used in genetic algorithms is rather simplified in comparison with its natural analogue, nevertheless, genetic algorithms are powerful tools and can be successfully employed in a wide class of applied tasks, including those which are difficult and sometimes impossible to solve by other methods. However, in genetic algorithms, there is one significant assumption about the independence of a particular individual’s fitness in a population from the availability of other individuals in the population, as well as from the external environment.

If you look at nature, at natural processes, then all organisms develop in interaction with others. For example, a plant produces substances that are poisonous for caterpillars, but certain types of caterpillars in the course of evolution have acquired insensitivity to plant poisons, moreover, they accumulate them in their body and themselves become inedible for birds. Thus, the development of some individuals can cause the development of others. This phenomenon was called coevolution, which was first used by ecologists P. Ehrlich and P. Raven in 1964 to describe the coordinated development of various species within one ecosystem.

On the other hand, in the genetic algorithm, although selection is carried out in different ways, it is inherently artificial, as opposed to natural selection, when individuals survive

depending on the composition of their population, which can both help them in development and hinder it. In addition, predators may be present in natural selection. Thus, natural selection is completely dependent on the environment.

In optimization tasks, coevolution occurs when the fitness of individuals in a population depends on the presence of other individuals in this population, i.e., the development of an individual depends on its environment. In this case, we should already speak not just about fitness, but about relative fitness, based on how a given individual performed in comparison with others in the same context of the optimization process. As a result, the following significant problems arise. Given that in the usual genetic algorithm at each step the best individuals are selected, and this eventually leads to an improvement in the absolute fitness of individuals in the population, during coevolution it is more likely that individuals improve, but their relative fitness will remain approximately at the same level, since their environment also improves.

Another problem is the difficulty in the work of selection, which can cause incorrect operation of the system, since a situation is possible when individuals cannot be distinguished only by relative fitness.

To solve these problems, a distinction is made between internal fitness, which is used directly by the system to carry out selection, and external fitness, which is used to determine the quality of an individual to regulate the operation of the algorithm. Internal fitness can be both absolute and relative, and external fitness is only absolute.

Internal relative fitness varies depending on the composition of the population and the tests used to find the fitness of individuals.

It should be noted that the fitness of an individual can be evaluated using a multitude of tests, which are a set of some tests for individuals in the population. Such an evaluation will result in the sum or average of the results of these tests, etc. This approach allows electing the best among the many individuals.

In general, coevolution is understood as a system of interacting subpopulations, which develop to one degree or another being isolated from each other. Individuals of subpopulations are possible solutions to the optimization problem.

As mentioned earlier, the main methods of coevolution are: cooperative coevolution with one population, cooperative coevolution with two populations, cooperative coevolution with N populations, support of diversity (niching).

Cooperative coevolution with one population. This type of coevolution is commonly used to find the best (competitive) strategy of behavior (optimization of potential solutions) for various situations (for example, in the game of chess, checkers, football, poker, etc.). The fitness of each individual is evaluated by the results of its game (competition) against other individuals from the population in a given situation. The content of the idea of such coevolution is to improve the learning gradient in the search space. Both the strategies themselves and the carriers of these strategies act as an individual, but in this case one behavior strategy corresponds to one individual.

The fitness of individuals from the same population is based on the results of the games that these individuals play against each other. It is commonly used for the evolutionary search for a competitive strategy.

Cooperative coevolution with two populations. Here the population is divided into two subpopulations. The fitness of an individual from the first subpopulation is determined depending on how many individuals from the second subpopulation he wins in some competition.

Cooperative coevolution with N populations. The task to be solved is divided into N subtasks, each of which has its own subpopulation. The fitness of an individual is determined by choosing individuals from other subpopulations and grouping them with this individual in the form of a combined solution, for which fitness is calculated. This method is appropriate to use in order to reduce the dimension of large tasks by breaking them up into simpler subtasks.

There are various ways to maintain population diversity in order to expand the search capabilities of the algorithm and prevent convergence to a suboptimal solution, in particular, increasing the population size, adding random restarts to the algorithm, etc. Coevolutionary methods include the following. The first method is associated with the idea of penalizing individuals in the case they are very similar to each other, the second – with the idea of rejecting individuals based on their similarity to descendants in a stable algorithm. Such methods affect the survival of individual A (versus individual B) depending on whether individual C (similar to A) already exists in the population or can be added.

But today there is no unambiguous classification of coevolution as a metaheuristic concept for solving stochastic optimization tasks. So, some scientists divide coevolution into cooperative and competing. In cooperative coevolution, the optimization task is decomposed (a set of parameters and/or an objective function), which simplifies the solution of complex tasks. Competing coevolution is understood as several approaches at once: interaction of two populations according to the "host-parasite" scheme, the method of competing subpopulations differing in the search area, and the method of competing subpopulations differing in the search strategy.

Several scientists are of the opinion that when the goal is to form a final solution from various components (by analogy with cooperative coevolution with N populations), then such coevolution should be called compositional; if the goal of one of the populations is to find an adversary for the other (by analogy with cooperative coevolution with two populations), then it is advisable to call it coevolution based on examples (tests).

In coevolution, as in other population methods and models, various genetic operators are used, the purpose of which is to improve the fitness of individuals in the next generation. The selection mechanism consists in choosing the most adapted individuals of the current generation, who will participate in creating offspring. Reproduction means the formation of new individuals as a result of the recombination of the genes of the parental chromosomes. Recombination is a process that results in new combinations of genes. For this, two operations are used: 1) crossing, which allows you to create two entirely new chromosomes of offspring by combining the genetic materials of a pair of parents;

2) a mutation that causes changes in an individual chromosome. In addition, there is such a genetic operator as inversion, the essence of which is that the sequence of the alleles changes between two randomly selected positions (loci) in the chromosome. But this operator is not as widespread as those mentioned above.

The process of convergence due to selection must be more pronounced in comparison with the scatter of points as a result of using mutation and inversion operations, otherwise convergence to the extremum will not occur. This led to the fact that in population methods the probability of crossing is much higher than the probability of mutation. But the convergence due to selection should not be too fast, otherwise all points may gather near a local extremum, and another, possibly a global one, will never be found.

From generation to generation, the characteristics necessary for "survival" are distributed throughout the population. The combination of such characteristics from different parental individuals can sometimes lead to the emergence of an over-adapted offspring, whose fitness may be greater than the fitness of any of his parent individuals. Cross-breeding of the fittest individuals leads to the fact that the most promising areas of the search space are explored. Finally, the population comes to an optimal solution to the task.

As a result of using genetic operators, there arise some situations which require additional actions that are artificial and not characteristic of natural evolution. If a step-by-step mechanism for solving an optimization problem is applied, then it is desirable that at each step the possible solution of the problem at least does not deteriorate. But in population methods, a situation is possible when the next generation may be worse than the previous one, i.e., the fitness of the next generation individuals is worse than the fitness of the previous generation individuals and, accordingly, the potential solution of the task deteriorates. In this case, it is possible to use an elite reproduction strategy, which implies protecting the best individuals at the next iterations of population methods. This strategy is applied in order not to lose the best fit individual in the next step. It ensures that the best individual of the current generation will be a member of the population in the next generation.

In the coevolution algorithm as an optimization method, the concept of coevolution itself is used in a narrow sense – when the development of certain populations (systems) occurs jointly, and in a broad sense – when such development is mutual. The use of genetic operators corresponds in a narrow sense to the concept of coevolution, and the definition of the individuals' fitness – in a broad sense. In our opinion, the concept of "coevolution", in particular, reflects the dynamics, i.e., constant mutual change, and the concept of "fitness", in particular, reflects the statics, i.e., states the result. Therefore, it is necessary not only to determine the fitness of an individual depending on his environment but also to allow for the influence of this environment on the individual's development. The development of an individual can be influenced by both individuals of his population and individuals of populations to which he does not belong.

To take this influence into account, we consider it expedient to use the genetic operator of reflexivity. The essence of this operator lies in the fact that as a result of its application, an individual develops own properties or acquires some new properties inherent in another individual, i.e., there is reflexivity of one individual to another. Thus, by refle-

xivity in the context of this operator, we mean the ability of one entity to acquire certain properties as a result of another entity's action, in particular, in order to increase fitness.

In population methods, an individual of a population is a set of chromosomes with sets of task parameters encoded in them, i.e. solutions. Individuals are points in the search space.

It is assumed that an individual consists of one chromosome; accordingly, the chromosome will determine the point of the search space and represent a potential solution to the problem. In what follows, we will also use this assumption.

Each parameter of the problem, which is allowed for optimization, corresponds to a certain gene of the chromosome. If binary coding is used, then the chromosome is a bit string consisting of 0 and 1. This string is divided into sections corresponding to genes. The length of genes can be the same or different. It depends on the task parameter that needs to be encoded.

In the process of solving the optimization task, the following situations may arise. Some gene has reached the best value or some value, which satisfies the researcher to a certain extent and does not require further modifications. However, in the next iterations of population methods, it is not guaranteed that such a gene will remain unmodified. These changes can either improve it or worsen it. Therefore, there is a need to preserve it in future generations. By the best value of a gene, we mean such a value that maximally improves the fitness of the chromosome.

In multi-criteria tasks, not always all criteria have the same effect on the result. Sometimes for a researcher, the main thing is one or more criteria that dominate others, and their achieving a certain value can be considered a rational solution to the problem when other criteria reach values no worse than a certain critical value. If such criteria correspond to some genes of the chromosome, then, in the context of population methods, the researcher is interested in the gene's achieving a certain value and preserving it in subsequent generations until the final solution of the problem.

In population methods, a situation is possible when, for one part of the population, some chromosome genes reach the best value, and for another part of the population, other genes reach the best value, and as a result of using genetic operators, there are formed no chromosomes in which the best genes from both parts would be available. In the context of a multi-criteria task, this situation can be formulated as follows: for some potential solutions, some criteria take the best value, and for other potential solutions, it is other criteria that take the best value, and they do not intersect.

Such problematic situations can be solved, in particular, by applying the genetic operator of reflexivity. If natural development is considered, then in the population it is possible to find an individual that will be better developed and adapted than others. And to preserve his own species, he can induce the development of properties and qualities necessary for survival in other individuals.

We will call such an individual a "teacher", who is a kind of a benchmark, a carrier of the desired properties and qualities to which one must strive. In addition, an individual-"teacher" can teach not all individuals of the population, but those that satisfy certain conditions. In population methods, such conditions can be: achievement by an individual

of a certain fitness value, or an individual as a point in the space for finding a solution is located at a given distance from the "teacher"-individual; certain genes of an individual have reached a certain predetermined value.

On the other hand, in nature, the development of an individual is primarily influenced by parents, that is, there may be reflexive management by the parents of their own children. In population methods, parental individuals (chromosomes) for their offspring are proposed to be called individuals of the first-order reflexivity. Then the "teacher"-individual who is not the parent of the studied individual, will be called the second-order reflexivity individual. The rest of the individuals of this population, who can affect the development of the individual studied, will be called individuals of the third-order reflexivity. In the coevolutionary approach, individuals of other populations that influence the development of the individual studied will be called fourth-order reflexivity individuals. Thus, depending on the proximity of the environment to the individual studied, we identified four possible levels of reflexivity. The higher the order, the less should be the impact "power". In the context of population methods, this can be transformed into the probability of applying the genetic operator of reflexivity among individuals.

The mechanism of the genetic operator of reflexivity consists in replacing a specific gene or specific genes of the individual studied with the corresponding gene or genes of other individuals with a given probability.

Suppose there are two individuals (chromosomes) 20 bits long. Every four bits make a certain gene, correspond to some criterion of the optimization task, that is, the first four bits on the left are the coded value of criterion 1, the next four bits are the coded value of criterion 2, and so on.

An individual (chromosome) 1: 0001 0101 0000 1100 1010.

An individual (chromosome) 2: 0000 0000 1100 0011 1010.

For example, an individual 1 is the one that carries out reflexive management of an individual 2 upon reaching the required value according to criterion 2. Then the result of such management will be as follows:

An individual (chromosome) 1: 0001 0101 0000 1100 1010.

An individual (chromosome) 2: 0000 0101 1100 0011 1010.

As you can see, an individual 1 has not changed, and in an individual 2, bits from the fifth to the eighth, which correspond to the coded value of criterion 2, have changed.

When applying the genetic operator of reflexivity in population methods, a situation may arise when new individuals of the population will not enter the space of feasible solutions.

The problem of using adequate methods and models for substantiating decisions, in particular, in economics will always be relevant. Constantly changing conditions for decision-making require the improvement of existing tools and the use of new, more effective ones. One of such tools can be the toolkit of population methods and models, in particular, genetic algorithms and coevolution.

Chapter 4. Information management

Since reflexive games are defined as the agents' interactive mutual activity, in which they make decisions based on the hierarchy of their beliefs, the agents' information awareness is essential. Therefore, let us dwell on the qualitative discussion of information awareness and common knowledge in more detail.

In game theory, philosophy, psychology, distributed systems, and other fields of science[29, 30], not only the agents' beliefs about essential parameters are vital, but also their beliefs about other agents' beliefs, and so on. The totality of these beliefs is called the hierarchy of beliefs and is modeled by the tree of the reflexive game's information structure. In other words, in situations of interactive decision making (modeled in game theory), before opting for his own action, each agent must "predict" the behavior of opponents. To do this, he must have certain beliefs about his opponents' vision of the game. But opponents must do the same, so uncertainty about the game to be played creates an endless hierarchy of beliefs for the participants in the game.

Let us exemplify a hierarchy of beliefs. Given that there are two agents – A and B, each of them can have their own non-reflexive beliefs about the indefinite parameter S, which we will further call the state of nature (state of the world). Let us denote these beliefs as SA and SB, respectively. However, each of the agents within the framework of the first rank reflection process can think about the opponent's beliefs. These beliefs (beliefs of the second order) will be denoted by SBA-SAB, where SAB are beliefs of agent A about beliefs of agent B, and SBA are beliefs of agent B about beliefs of agent A. Nevertheless, this is not the end of the matter – each of the agents, in the process of further reflection (reflection of the second rank), can think about what the opponent's beliefs about his own beliefs are. This is how third-order beliefs are generated – SABA and SBAB. The process of generating higher order beliefs can continue indefinitely (there are no logical restrictions to increasing the rank of reflection). The sum total of all beliefs forms their hierarchy.

Common knowledge is a particular case of information awareness when all beliefs, beliefs about beliefs, so on ad infinitum, coincide. More correctly, the term "common knowledge" is introduced to denote a fact that meets the following requirements:

1. All agents know about it.
2. All agents know 1.
3. All agents know 2, etc. to infinity.

The formal model of common knowledge has been developed in a variety of works[31, 32, 33, 34, 35].

[29] Geanakoplos J. (1994), *Common Knowledge*, In: R. Aumann & S. Hart (Eds.), *Handbook of Game Theory with Economic Applications*, Vol. 2, pp. 1437-1496, Amsterdam: Elsevier.
[30] Morris S., Shin S.S. (1997), *Approximate Common Knowledge and Coordination: Recent Lessons from Game Theory*, Journal of Logic, Language and Information, 6, pp. 171-190.
[31] Aumann R.J., Brandenbunger A. (1995), *Epistemic Conditions for Nash Equilibrium*, Econometrica, 63(5), pp. 1161-1180.
[32] Aumann R.J. (1999), *Interactive Epistemology I: Knowledge*, International Journal of Game Theory, 28, pp. 263-300.

From the viewpoint of systems analysis, any system is specified by listing its composition, structure, and functions. Therefore, the model of the organizational (OS – organizational system), social, economic (active) system is determined by specifying:

- the composition of the OS (participants included in the OS, that is, its elements);
- OS structure (a set of information, management, technological and other links among OS participants);
- sets of admissible strategies of OS participants, reflecting, inter alia, institutional, technological and other limitations of their joint activities;
- target functions of OS participants, reflecting their preferences and interests;
- awareness of the information that OS participants have at the time of making decisions about the strategies being chosen;
- the order of functioning: the sequence of obtaining information and choosing strategies by the OS participants.

The composition determines "who" enters the system, the structure specifies "who interacts with whom" (from this point of view, the order of functioning is closely related to the structure of the system, since the former determines the cause-and-effect relationships and the order of interaction), admissible sets state "who can do what", target functions determine "who wants what", information awareness means "who knows what".

OS management, understood as an impact on a managed system in order to ensure its required behavior, can affect each of the six listed parameters of its model. Consequently, the first basis for the classifications system of OS management mechanisms (procedures for making managerial decisions) is the subject of management, which is the OS component changed in the process and as a result of management. According to this basis, it is possible to distinguish between: composition management, structure management, institutional management, motivational management (management of preferences and interests), information management (management of information possessed by OS participants at the time of making decisions), and management of the order of operation (management of the sequence of obtaining information and choosing strategies by OS participants). It should be noted that, usually within the framework of game-theoretic models, the managing of the order of operation is considered as management of the structure, therefore, this type of management may not be considered separately.

Let us briefly discuss the specificity of some types of management. Institutional management is the most rigid and consists in the fact that the center purposefully restricts the set of possible actions and results of the agent's activity. Such a restriction can be carried out by means of explicit or implicit influences – legal acts, orders, directives, etc., or moral and ethical standards, corporate culture, etc.

Naturally, in practice, it is sometimes difficult to distinguish explicitly between the management of one type or another, since they are used (and should be used!) simultaneously.

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[33] Fagin R., Halpern J., Moses Y., Vardi M. (1999), *Common Knowledge Revisited*, Annals of Pure and Applied Logic, 96, pp. 89-105.

[34] Hintikka J. (1962), *Knowledge and Belief*, Ithaca: Cornell University Press.

[35] Simon R. (1999), *The Difference of Common Knowledge of Formulas as Sets*, International Journal of Game Theory, 28, pp. 367-384.

Motivational management is "softer" than institutional, and consists in a purposeful change in the agent's preferences (utility function). Such a change can be carried out by introducing a system of penalties and/or rewards for choosing certain actions and/or achieving certain results of the activity. Planning and incentive tasks represent a wide class of examples of motivational management models. In the case, for example, of the stimulation task, motivational management means a direct (additively included in the utility function) reward of the agent for choosing certain actions.

Information management is the "softest" (indirect), in comparison with the institutional and motivational ones, and at the same time the least studied (from the viewpoint of formal models).

The proposed general model of information management is shown in Figure 6 and includes the agent(s) and the managing body-center. Each agent is characterized by the cycle "the agent's information awareness – the agent's action – the result observed by the agent – the agent's information awareness", and these three components of the cycle are different for different agents.

At the same time, and this is reflected in the inscription "Agent(s)" (Fig. 6), this cycle can be considered common for the entire subsystem managed, i.e. for the entire set of agents.

As for the interaction of the agent(s) and the center, it is characterized by:

- the informational influence by the center, which forms this or that awareness of the agent(s). It should be noted that it is also possible to consider the influence of the center on the result observed by the agent(s), that is, "the center" – "the outcome observed" (Fig. 6);
- the actual result of the agent's/agents' action, which influences the interests of the center.

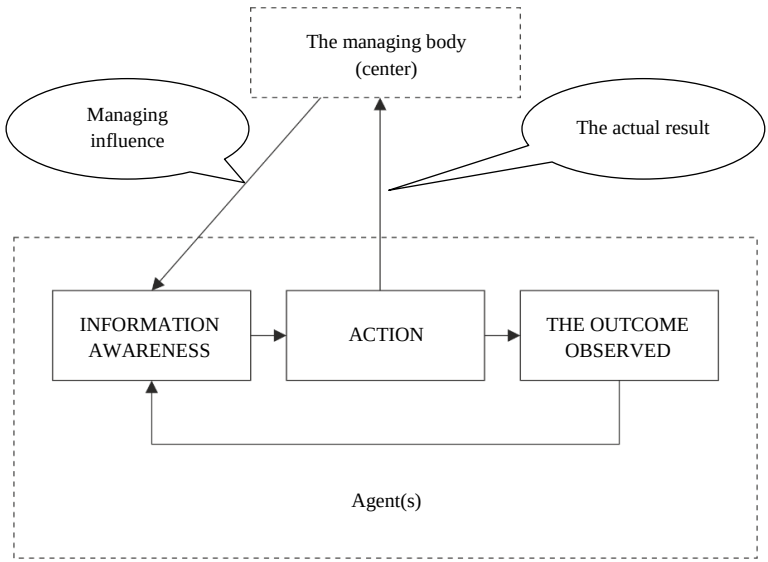

Figure 6. Information Management Model

Let us discuss the model shown in Fig. 6 in more detail. The mathematical apparatus that simulates the game-theoretic interaction of agents comprises reflexive games in which agents choose actions based on their information awareness structures – a hierarchy of beliefs about the essential parameters of the situation ("state of nature"), beliefs about the beliefs of opponents (other agents), etc. Thus, in terms of reflexive games, the agent's information awareness is simulated by means of his information awareness structure (accordingly, the information awareness of the entire subsystem managed is simulated by means of the game's awareness structure, which is a combination of agents' information awareness structures).

Based on his information awareness structure, the agent chooses one or another action. For a given structure of information awareness, the agents' actions are the components of information equilibrium, which is a solution to a reflexive game. Information equilibrium is a generalization of equilibrium, the most common concept for solving non-cooperative games.

The agent's information awareness of the situation and of the opponents' beliefs may, generally speaking, be inadequate. Therefore, the result of a reflexive game observed by an agent may or may not correspond to his expectations. Compliance is determined by two factors:

- how adequately the agent is informed at the time of choosing his action, and
- what a detailed information about the results of the game he observes.

For example, the outcome observed may be the value of its objective function, the opponents' actions, the true value of an undefined parameter, etc. In the general case, the agent observes the value of a certain function that depends on the state of nature and the actions of opponents. This function is called an observation function, and the effect of its value on awareness is shown in the figure by the fragment "the action observed" – "information awareness". If all agents observe exactly the result they expect (that is, the real value of each agent's observation function is equal to the expected one), then it is natural to assume that the structure of information awareness does not change. In this case, the information equilibrium is stable.

Let us now consider the interaction of agents with the center. In carrying out information management, the center seeks to maximize its utility (of course, this also applies to other types of management). If we assume that the center can form any structure of information awareness from a certain admissible set, then the information management task can be formulated as follows: to find such a structure of information awareness from the admissible set of structures so that the center's utility in information equilibrium is maximal (perhaps, taking into account the center's costs for structure formation). A more formal definition of the information management task is explained in this section below.

Let us emphasize the following important circumstance: within the framework of the proposed model, we proceed from the assumption that the center can form any structure of agents' information awareness. The question of how the center should "persuade" agents that there are certain states of nature and the opponents' beliefs remains beyond the scope of our consideration. The question of how the center should form the appro-

priate structure requires special consideration with the involvement of data from psychology and sociology.

Let us present a general scheme for studying information management tasks. Without claiming to be exhaustive coverage of all possible cases, this diagram describes the general logic of game-theoretic analysis (Fig. 7).

Step 1. Describing the set of managed subjects (agents), their permissible actions, and target functions. Let us note that this step is necessary for a game-theoretic approach to managing (not only informational) socio-economic systems.

Step 2. Formalizing the uncertainty existing in the situation – an undefined parameter, the value of which is not common knowledge among agents. If the set of possible values of an undefined parameter is not restricted in advance, then it can be always assumed, for example, that this parameter is an argument of the agents' target functions.

Step 3. Determining the set of information structures that can be formed by the managing body (center).

As a result of these three steps, which constitute the preliminary stage of research, we obtain a game-theoretic description of the situation. It is important to note that in this work, as a rule, it is assumed that the center knows the true value of the undefined parameter.

Step 4. Calculating (for the structures defined at the previous step) the information equilibrium – the dependence between the information structure and the agents' actions.

Step 5. Studying stability of the information equilibrium. If the equilibrium is stable, to establish its validity or falsehood.

Step 6. Determining the most appropriate definition of the problem with managing information and finding the information structure that is its solution. Finding this solution, as a rule, is facilitated in the case when the reflexive mappings are stationary and, therefore, the required information structure is rather simple.

As a result of steps 4-6, which constitute the main stage of the study, we obtain an information structure that must be formed in agents in order to achieve the goals facing the managing body.

Step 7. Developing informational influence on agents, leading to forming the information structure found at step 6.

Step 7 which constitutes the completion stage of the study, largely lies outside the framework of the game-theoretic approach and belongs to the field of psychology and sociology. This textbook describes only some types of informational influences that change certain components of the game's informational structure.

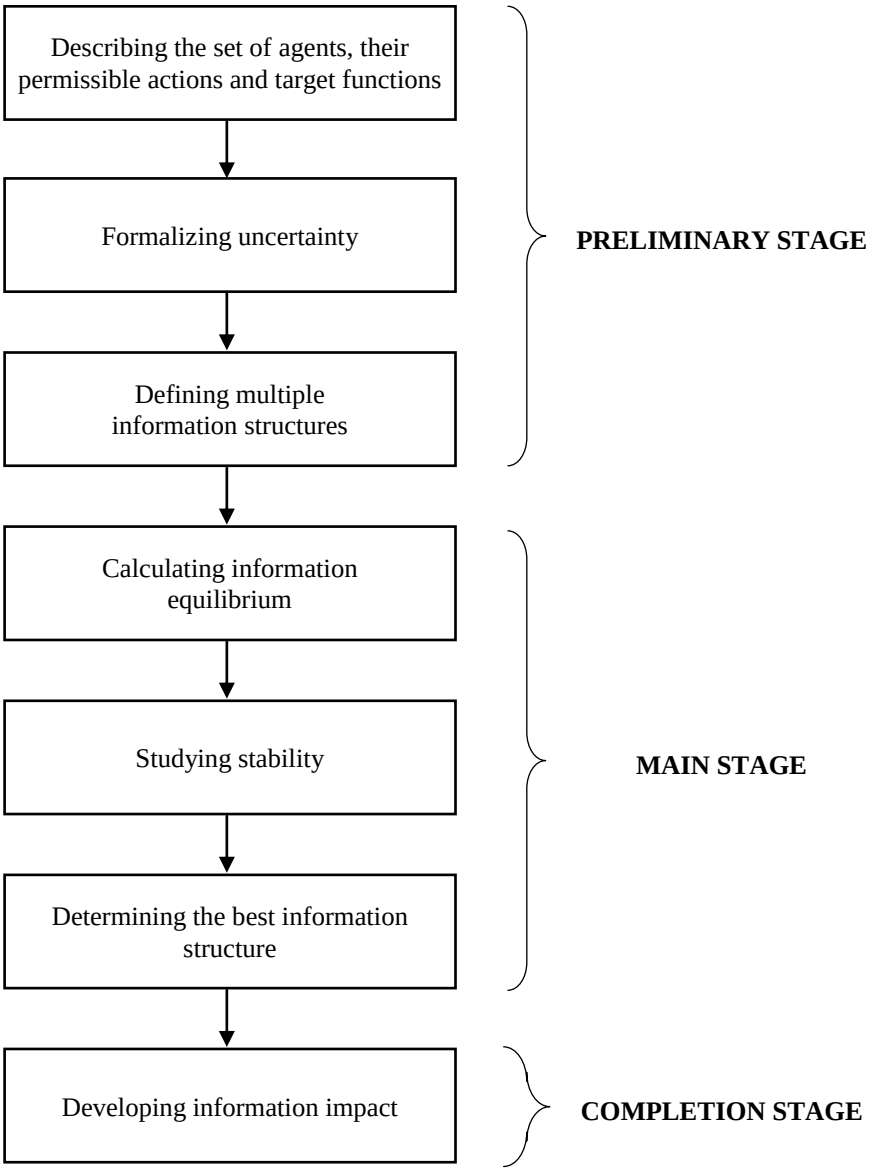

Figure 7. Steps of Studying Information Management Tasks

Chapter 5. Information support of reflexive management methods

Another definition of management can be represented as a process of management and analysis of information. The quality of the management decision depends on how high-quality the information is in terms of content, time, and processing capability. Information by its nature is diverse. To identify the necessity and features of information and analytical support of reflexive management methods, it is necessary to define how the information to support reflexive management methods differs from the rest of the classification features.

The ever-increasing role of information determines the need for effective information support for all processes.

An important problem in studying information support is to single out the components that determine the quality of information support. Heading towards solving this problem, it is, first of all, necessary to analyze the essence of the concept "information support".

Information support is understood as an integrated system of knowledge about an object which implies all types and forms of knowledge application. It also combines a set of methods and means of a single system for organizing and storing, accumulating and updating, accessing and receiving, processing, and using production information. Information support can include the following three components: an information system, a set of data, and information activity.

Thus, information support should be considered as a system of qualitative and quantitative indicators characterizing the level of satisfaction of the management activity subjects with management information and information technologies in order to implement the goals and tasks of the information system. The implementation of the concept of reflexive management methods at an enterprise concerns all aspects of its activities. However, since information is the subject of managerial labor, and most of the levers of influence by the subject of management on the object are of informational nature, it is necessary to redesign the existing information system thoroughly in order to create information and analytical support of reflexive management methods according to the strategies chosen.

So, when considering resource, functional and complex tasks, it is necessary to (a) determine the type and amount of information necessary for reflexive activity; (b) develop an effective system for collecting, processing, using and storing information; (c) take measures to prevent the negative effect of the inaccurate information influence on decisions, and (d) create conditions for the effective use of the necessary information for making management decisions.

Information and analytical support of reflexive management methods is a system that unites all other elements of the organization into a single whole, allows forming the reflexive management process as a continuous series of management decisions aimed at achieving goals.

It will not be superfluous to recall that the classical management process consists of several stages: "goal – situation – problem – solution". With reflexive management, this system is transformed in the following direction: "goal – reflexive analysis and situation diagnosis – development problems – reflexive solutions".

Reflexive information is characterized by a number of differences due to the nature of the process of making managerial decisions: orientation not only "inside" the organization, but rather on its external and intermediate environment; analysis of information in terms of representative probability; predictive nature of information processing results; high probability of subjective interpretation of informative indicators; the cross-functional nature of information (the need for information support of individual business processes), which leads to the need to operate with large volumes of analytical and financial information.

Based on reflexive information, management decisions are made, which are then embodied in organizational, financial and economic, socio-psychological, methodological and other tools, owing to which the management process is carried out. Management decisions directly determine the fate of the enterprise, affecting its development and viability. The validity of the decisions made depends on the information on which they are based, and the cost of mistakes is constantly growing.

Allowing for the specific features of reflexive information, the predictive nature of the data necessitates their constant receipt and analysis for making decisions of administrative nature.

The majority of domestic and foreign authors recognize the need for constant monitoring of a certain set of environmental parameters, but there exists no definite answer to this problem.

A qualitatively new stage in developing the means of information and analytical support of reflexive management is associated with the emergence of a variety of technical and software solutions that implement the concept of distributed data processing within management structures. There increases consistency, which implies not only the acceleration of many operations, but the integration of all management processes into an integrated multi-level informational and analytical system.

Information systems in reflexive management should have a two-level hierarchical structure and consist of a subsystem of coordination and reflexive information and a system of tactical and operational information.

Level 1: a subsystem of coordination and reflexive information uses textual and quantitative information coming from all available sources.

Level 2: a subsystem of tactical and operational information using data from the activity analysis.

In the process of harmonizing the activities of these two levels, there arise rather big problems associated with the possibilities to obtain "non-core", redundant and even harmful information by various users.

Based on this, the essence of reflexive management can be interpreted as information management, which provides for an iterative assessment of the economic agents' behavior, allowing for their economic behavior, which, as a set of actions, deeds and moves, is formed under the influence of the human factor based on the information received and transmitted, the constant awareness by the management subject of actions and patterns of

both their own behavior and the behavior of hierarchically related objects of subordination.

Applying a reflexive mechanism for coordinating management flows at the enterprise studied lays the foundation for its effectiveness due to the ability to work without direct information contacts among its structural elements and at the same time maintain the integrity of the system with information completeness. But this opportunity does not arise automatically. We need mechanisms for coordinating management flows, which are formed and implemented within the organizational structure based on a reflexive approach.

To minimize subjective factors, it is desirable to use a reflexive approach to planning. With an ineffective motivation system, uncoordinated strategic and tactical goals of enterprises, as well as the goals and motives of employees at various levels, the role of subjective factors in planning at enterprises increases. Besides, various opportunities for distortion or special interpretation of information used in planning open up. The concept of reflexive management of planning processes allows for these aspects and favors developing procedures for reducing ambiguity and preventing information warping, ultimately improving the quality of plans.

Establishing interactions of planning subjects associated with the information distortion, and the reflexive influences of planning subjects on each other can lead to a deterioration in the quality of plans.

To counteract the threat of information distortion and reflexive influences in planning, an effective mechanism for reflexive management of planning processes is needed, which implies a comprehensive improvement of the management and motivation system.

It should be noted that the means of reflexive analysis allow, probably, objective studying the behavior of not only individuals, but also mass decisions based on the same (or similar) decision-making procedures by many agents.

Thus, the concept of reflexive management makes it possible to approach the problem of determining the value of information in a new way.

It becomes obvious that the same message can be evaluated differently from the viewpoint of the sender and the recipient of the information. Moreover, the value of the message is determined not by the degree of truthfulness of the content contained in the message, but by the ratio of the ranks of reflection. For example, the sender might send a true message on the assumption that it will be perceived as false. If such an unaccustomed deception succeeds, the adversary recipient suffers damage by receiving the true message.

On the other hand, if false messages have been sent and if the recipient has reconstructed the sender's intention, then false information acquires a positive value for him. Recording the fact of scientific disinformation serves as an example.

It can be assumed that any theories dealing with the problem of determining the value of information should be built taking into account the schemes of reflexive interaction.

Chapter 6. A cognitive function of reflexive management

The intensity of scientific and technological progress is characterized by rapid changes and by creating interaction in the "win-win" relationship.

These dynamic changes have led to the need to have the ability of "learning to learn". Modern methods of thinking and management are the most important, but often unconscious, resources necessary for development in conditions of fierce competition and imperfect market institutions. Metaphorically, they are presented as "learning what to do and how to do it". In the words by A. Einstein, "our thinking creates problems that cannot be solved with the help of thinking of the same type".

From this position, the concept of management expands from the key one as "impact on factors and conditions" to "cognition of the situation and decision-making to influence the situation based on its model representation". The influence of a real situation on the participants' thinking and behavior, and the influence of their thinking and behavior on the development of a situation in which they participate, is often referred to as a reflexive process.

Understanding interaction, in which both the situation and the thinking of the situation's interpreters are dependent variables, and cognitive and influence functions interfere with each other, is referred to the category of reflexive management.

As yet, there has been achieved no uniform understanding of the concept of "reflexive management". This is largely due to the very phenomenon of reflection, studied by various scientific disciplines, and due to obtaining the corresponding results, based on the naturalistic methodological approach used by many of them.

As mentioned earlier, the word "reflection" and words related to it and derived from it are used in the meanings used by all the main types of modern sciences: natural, technical, biological, and humanitarian.

According to the generally accepted definition – reflection is a form of theoretical human activity aimed at comprehending the person's own actions and their laws; the activity of self-cognition, revealing the specificity of the person's spiritual world.

The brightest representative of the reflexive approach to social psychology is V.A. Lefebvre, a Russian and American psychologist and mathematician, the founder of the reflection theory and "calculable psycho-phenomenology", a professor at the University of California. The role of V. Lefebvre in the science of reflection is unique. By the early sixties of the last century, he developed the idea that the traditional natural science approach was insufficient for studying complex systems. He introduced such concepts as the ability to reflect, reflexive management (the process of transferring the grounds for making a decision by one of the characters to another), the rank (zero, first) of reflection, otherwise the level of reflection possessed by the "opponent", reflexive games (the activity of the conflicting parties in which opponents imitate each other) and others, which have become common. An important achievement of V. Lefebvre was the introduction of the concept of a reflexive system.

A reflexive system is understood as a system of mirrors that repeatedly reflect each other. Each mirror is an analogue of a "character" endowed with his own special position. The entire complex stream of mirrors' reflections in each other will be an analogue of

a reflexive process. It was this concept and the theoretical schemes proposed by the author that made it possible to represent large-scale social phenomena (for example, information wars) in the form of interaction of macro-subjects capable of cognizing each other's behavior and influencing the "opponent" in the best way. This approach opened up completely new opportunities for predicting strategic decisions. Therefore, the growing interest of specialists in the field of politics, economics, combat simulation, and other fields of science and practice in reflexive management is not accidental.

The market is also a sphere of active interaction among subjects. It is no coincidence that one of the most successful stock market players of our time, George Soros, generalized his experience of the world stock markets actions into concepts that essentially coincide with those previously introduced by V. Lefebvre. J. Soros brought the problem of reflection closer to the generally accepted understanding, namely, he presented reflexive management as the interaction of interfering cognitive and influence functions.

The idea underlying almost all of Soros's conceptual constructions is ingeniously simple: the psychology of the participants in any historical process is its integral component and, being in continuous interaction with reality, forms a reflexive process.

The relationship between the subject’s thinking and the situation in which he participates is represented by two functional dependencies: cognition of the situation as a cognitive function, and the impact of inferences on the situation in the real world as an influence or active function. In the cognitive function, the participant’s perception of the situation depends on the situation; in the influence function, the participants’ perception influences the situation.

Thus, the management process can be characterized as a permanent solution to the flow of problems that are generated by a dynamically changing external and internal environment, as well as the result of iteration of the cognitive and influence function. Hence, management exists in the problems’ space.

In this context, defining the "problem space" is a key element in solving any type of problem effectively. The problem space is not just the physical space associated with the problem – it can include relationships, values, perceptions, and beliefs. The problem space is defined by all elements of both physical and non-physical nature which create or contribute to the problem. In order to solve the problem, it is necessary to find a "solutions’ space". The solutions space contains alternatives and resources to overcome, transform, or avoid a problem. However, if the formed solution space is directed only to a part of the problem space elements, an insufficient solution arises. The solution space should be wider than the problem space. Otherwise, the solutions may turn out to be inadequate.

Today, in order to fulfill their responsibilities, managers need to process a huge amount of information every day, often to make decisions based on intuition due to the lack of time for a detailed study of the problem space. Against the background of constantly increasing competition, the risk of making the wrong decision increases, that is, the solution space is obviously narrower than a problem space, the consequence of which may be a general decrease in competitiveness.

To reduce the possible risks of making a wrong decision, it is necessary to introduce an element of reflexivity into this process, that is, to make management reflexive. Expanding the available space requires certain cognitive interactive skills. They are also required to detect and define the original problem space. Thus, effective problem solving involves two stages:

1. expanding and deepening the perception of the problem space;
2. defining or creating some area of the solution space that is large enough to cover all significant aspects of the problem space.

The basic principle of searching for a "space of solutions" is that a problem cannot be solved with the same thinking or the same "map" of the world that created it. The overall challenge of effective problem solving is to find a way of thinking that is not identical to the one that created the problem. In this case, it is expected that a different way of thinking will lead to the solution space that is at least as wide as, or wider than, the problem space and will provide the necessary alternatives and resources.

The modern view in management consists in expanding and deepening the perception of the problem space, and what is perception – it is reflection. Reflexive management requires a transition from a situation to a problem space through reflexive perception. Perception must be interpreted into knowledge as a tool in order to make the right decision.

The narrowing of the problem space during its cognition has stages with direct and inverse connections. Inverse connections reflect the iterative cyclical nature of the relationship between stages. Iterations in the process of identifying and describing a problem situation are conditioned by the need to clarify and correct data after performing certain procedures and returning to work at any previous stage. A brief explanation of the stages is shown below.

The problem space is a combination of conditions and circumstances in which a problem of both physical and non-physical nature arose.

The perception of the problem space is a complex system of processes of receiving and transforming information, providing a reflection of reality, that is, what generated the situation.

The problem space perception properties comprise:

1. Systemic nature: when not only elements are perceived, but also the structure as a whole.
2. Objectness: when the perceivable properties of an object are associated with all other properties.
3. Selectivity: when the same subject is perceived differently.
4. Awareness (apperception): when our perception depends on our experience, interests, attitude to life.
5. Consciousness and generality: the state of seeing the whole based on fragments.
6. Constancy – the relative constancy of the perceived size, shape, and color of an object when changing the distance to it, angle, illumination.

Pre-reflexive perception is perception beyond the ability to take the position of an "observer", "researcher" or "controller" in relation to one's own body, one's own actions, one's own thoughts.

Cognition of the problem space (lat. *Cognitio* – cognition) is a cognitive function or a function of thinking and understanding the problem space.

Identification (from Lat. *Identificare* – to identify) is recognition, discernment of something, someone, and shaping the object into some model. Basic identification procedures are matching, comparison of one object with another based on some feature or property, as a result of which their similarity or difference is established.

Logical analysis of the situation from the position of cognition is an analysis based on the forms, methods, and laws of intellectual cognitive activity, formalized by means of a logical language.

An influence function is a function in which the participants' perceptions influence the situation.

Analysis of the influence function effectiveness for the organization is the analysis of the relative effect, the effectiveness of the process, operation, project, defined as the ratio of the effect/ result to the expenditures/costs that caused/ensured it.

The reflexive process unfolds under the influence of two inextricably linked sources – activity one (an influence function) and mental one (a cognitive function) – all the time influencing (interfering) each other. Each "action move" is followed by a reaction generated by the participants' thinking and, ultimately, embodying the initial actions in concrete events in the practical area.

In conclusion, we note that the presented reflexive funnel of perception (interpretation) of the problem space reveals the mechanism of its cognition and construction of the solutions' space. In fact, it is an integrated algorithm for approaching the disclosure and solution of complex, unstructured problems, which, by their nature, belong to the class of non-recurring problems that are characteristic of both strategic and operational management of organizations.

Chapter 7. Cognitive technologies in strategic management

In this section of the book, we will consider the process of strategizing for the enterprise, using cognitive technologies of artificial intelligence. It should be emphasized that modern business entities operate in an environment of growing uncertainty and increasing international competition. Unstable economic conditions, growing consumer demands, the development of information technology all lead to rethinking of the concepts of strategic development based on advanced technologies in the field of artificial intelligence. In a dynamically changing environment, any company needs to constantly evaluate its economic activity, financial condition, the degree of influence of the external environment, as well as its competitiveness.

Today, the digital economy is actively developing and in the coming years will be the most important engine of innovation, competitiveness, and economic growth in the world. Several indicators are used to measure and determine the countries' success on the path of digital transformation of the economy to the principles of introducing artificial intelligence, one of which being the index of digital innovations. Digital innovations contribute to developing productions of efficient products and services. They can be considered as one of the drivers toward resource efficiency and sustainable development.

Let us consider how strategic connections can be used while developing a system of stochastic business management models. It is known that economic systems, presented in the form of enterprises, are complex, probabilistic, dynamic systems with feedback (Fig. 8).

The availability of this connection allows the active management system to adjust the management actions depending on the resulting values of the initial parameters, and thus, to provide more efficient management and optimize the structure when using artificial intelligence[36].

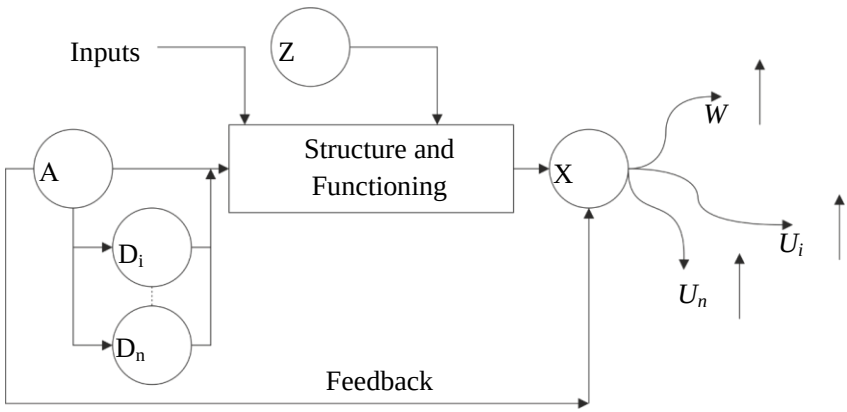

Figure 8. A General Scheme of the Cognitive System of Business Management with a Feedback Artificial Component

[36] Schmidhuber J. (2015), *Deep learning in neural networks: An overview*, Neural networks, 61(1), pp. 85-117.

Where *Z* is stochastic factors; *A* is a production process management body; D_i, …, D_n are local management units; *W* is a weight of the governing body's advantages; U_i …, U_n are a scale of advantages of local management units.

The proposed scheme universally describes the operation of any simulated object, dividing it into management and operation structures.

In turn, the scheme of the two-step process of business management is the basis and structure of the two-stage task of stochastic programming using an artificial intelligence algorithm (Fig. 9).

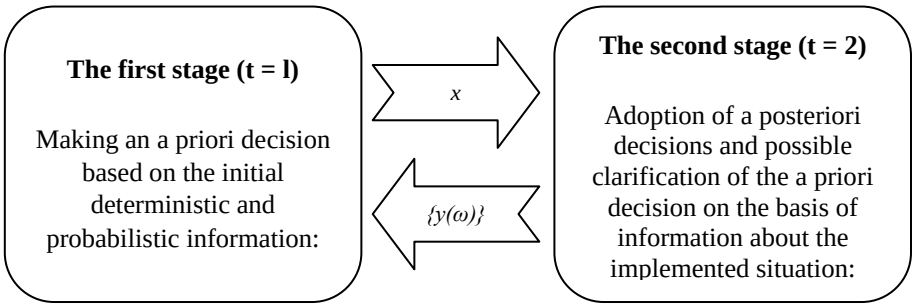

Figure 9. The Scheme of a Two-Stage Process of Business Management Using an Artificial Intelligence Algorithm

In general, the two-stage task of stochastic programming using an artificial intelligence algorithm is mathematically represented as follows:

$$\max_{x\in X} f_0(x) = \max_{x\in X}\left[\varphi(x) + M\max_{\omega}\max_{y(\omega)\in Y_\omega(x)}\varphi_0(x, y(\omega))\right],$$

where *X* is a convex closed bounded set, which specifies the area of a priori selection of the programming solution *x; y(ω) = y₁(ω), y₂(ω)…yₙ(ω)* is a *k*-dimensional vector of a posteriori solution in a situation $\omega \in \Omega$; $Y_\omega(x)$ are convex bounded closed sets that define areas in R^k of a posteriori solution selection in a situation due to solution selection conditions *x; φ(x)* is a function of an a priori solution effect *x;* φ_0 is the function of the indicator that determines the quality of the solution *x* under the condition that the situation *ω* was realized and the a posteriori solution *y(ω)* was made.

Therefore, in two-stage problems, a priori solutions have the status of strategic management, while flexible a posteriori solutions *y(ω)* have the meaning of tactical managements. As follows from the scheme, the primary basis for the differences of phased managements is the degree of their flexibility, the time of their action. From this point of view, for multi-step management processes, a priori $y(\omega^{t-1})$ and a posteriori $y(\omega^t)$ solutions may not differ in the time of their action. In this case, both relate to tactical decisions in relation to a more strategic decision *x*. In this case, the a priori solution *x*, which contains

the structural parameters of the system, sets certain limits for the adoption of flexible operational managements within the component of artificial intelligence[37].

There is introduced the component H_ω – an operator that reflects the points of the set Y_ω in the points of the set X in the previous task:

$$H(\omega)y(\omega) = x; y(\omega) \in Y_\omega(x), \omega \in \Omega$$

Where the H_ω operator is a matrix of a special row-diagonal structure that reflects many tactical decisions in many strategies. This formula means that the tactical solution $y(\omega)$ is related to the strategic x and that the latter sets some framework for variations of the tactical decisions $y(\omega)$. The content of some inertia of strategic decisions is dictated by the structure of the task and reflects the fact of the vector's x independence from the probabilistic limitations of the task at the initial stage. On the other hand, this ratio reflects the fact that strategies are invariant with respect to the implementation of situations, and tactical ones are flexible and can vary depending on the situation. In a multi-stage task, tactical a priori decisions depend on the situations implemented in the previous moments: $y(\omega^{t-1})$, and tactical a posteriori decisions depend on the situations, including those implemented at the current time: $y(\omega^t)$. In the proposed interpretation of the previous problem with linear constraints it will be written as follows:

$$\max_{x \in X} f_0(x) = \max_{x \in X} \left[\varphi(x) + \underset{\omega}{M} \max_{\substack{y(\omega) \in Y_\omega(x) \\ Hy(\omega) = x, \omega \in \Omega}} \varphi_0(x, y(\omega)) \right],$$

under conditions that:

$$1) A^0 x \le b^0;$$
$$2) A(\omega)x + B(\omega)y(\omega) \le b(\omega);$$
$$3) Hy(\omega) = x;$$
$$4) x \ge 0; y(\omega) \ge 0; \omega \in \Omega$$

where: f_0 is a management purpose function; $\omega \in \Omega$ is a random system situation in a continuous states space; C^0 is a vector of strategic coefficients; $C(\omega)$ is a random vector of tactical coefficients; $A^0 b^0$ is the matrix and the vector of, respectively, the deterministic constraints of the first stage; $A(\omega), B(\omega),$ are random matrices of cost standards and operational technological methods, respectively; $b(\omega)$ is a random vector of restriction at the second stage; H is a matrix of strategic connections; conditions: 1) deterministic constraints of the strategic vector; 2) probabilistic constraints of tactical and strategic vectors; 3) strategic ties.

The latter task is called the task of stochastic programming with strategic connections. Let us consider a linear two-stage stochastic problem with strategic connections and

[37] Deco G., Schermann B. (2000), *A Hierarchical Neural System with Attentional Top-Down Enhancement of the Spatial Resolution for Object Recognition*, Vision Research, 40(20), pp. 2845-2859.

a finite set Ω. This requires implementing the following conditions[38]. Let in (3) the set X and $Y_\omega(x)$ be convex polyhedra set by systems of linear inequalities; the functions $\varphi(x)$, $\varphi_0(x, y(\omega))$ are linear, and the set of random situations $\Omega = \{1, 2, \ldots N\}$ is finite, and the situations are distributed with probability $p_1, p_2, \ldots, P_n$. Then the third task in full interpretation, taking into account the limitations, takes the following form:

$$\max_x f_0(x) = \max_x \left[(C^0, (x) + \sum_{v=1}^{N} p_v \max_{yv} (C_v, y_v) \right];$$

under conditions that:

$$1) A^0 x \le b^0;$$
$$2) A_v x + B_v y_v \le b_v; v = 1....N;$$
$$3) H y_v = x; v = 1....N;$$
$$4) x \ge 0; y_v \ge 0; v = 1....N.$$

According to research, it is found that any business is an open system that exchanges information with the external environment and is not a self-sufficient entity.

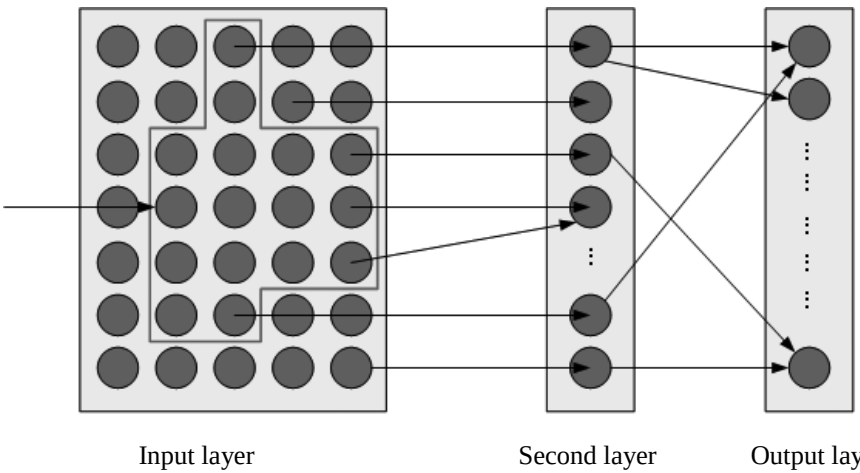

Figure 10. The Structure of the Perceptron as a Model of Cognitive Business Management

Let us now consider cognitive technologies in the form of a perceptron model, namely its methodological factor, in business management. The main object for considering this issue will be a neural network, which is a complex visualized model consisting of a set

[38] Wauters M., Vanhoucke M. (2015), *A Comparative Study of Artificial Intelligence Methods for Project Duration Forecasting*, Expert Systems with Applications, 46, pp. 249-261.

of homogeneous elements – cybernetic neurons (nodes). The scheme of connecting neurons to a network forms a multilayered structure. The neural network aimed at describing the functioning of a business always has: one input layer, one output layer, many intermediate functional layers. The perceptron model is a neural network of a developmental system with a "change management unit". The structure of the perceptron for an industrial enterprise can be three-layered and have the following form (Fig. 10).

The specific feature of the model lies in describing the relationship among the layers. Relationship lines between the elements of the first and second layers are established randomly. The relationship coefficients *"e"* between the 2nd and 3rd layers are fixed. The outputs of each element have two values: 1 or 0. The flexibility of the perceptron structure is provided by changing the relationship coefficients *"e"* between the elements of the second and third layers. To form a perceptron recognition, the first layer is shown these images. For each layer they indicate the image – the reaction that the specified layer should give. Perceptron, according to the set rules, forces the coefficients of connections to be changed until the required management response is obtained at the enterprise[39].

Neurons are organized into a network due to the fact that the output of the *i-th* neuron (y_i) is connected to one of the inputs (x_j) of another *j-the* neuron. The output variable y_i is identified with the input variable x_j. The weighting factor c_{ij} characterizes the sign and the strength of the relationship between the variables x_i and x_j. Feedback is also possible when the output of the *i-th* neuron is connected to the *j-th* input of the *j-th* neuron. As a rule, the coefficients $c_{ji} \neq c_{ij}$.

An important property of the neuron is its plasticity, i.e. the ability to change parameters in the management process. We distinguish between two types of plasticity: synaptic (change c_{ij}) and neuronal (change in the height of the neuron threshold c_{0j}). Threshold plasticity is reduced to synaptic by means of the following action. To the number of j-th neuron inputs they add another fictitious one; the input x_0 is applied a constant signal equal to +1 (Fig. 11). The weight coefficient of this input c_{0j} is modified in the course of process management in the enterprise. Modification of the coefficient is equivalent to the shift of the neuron threshold.

[39] Russell J., Peter S.N. (2016), *Artificial Intelligence: A Modern Approach*, Malaysia: Pearson Education Limited.

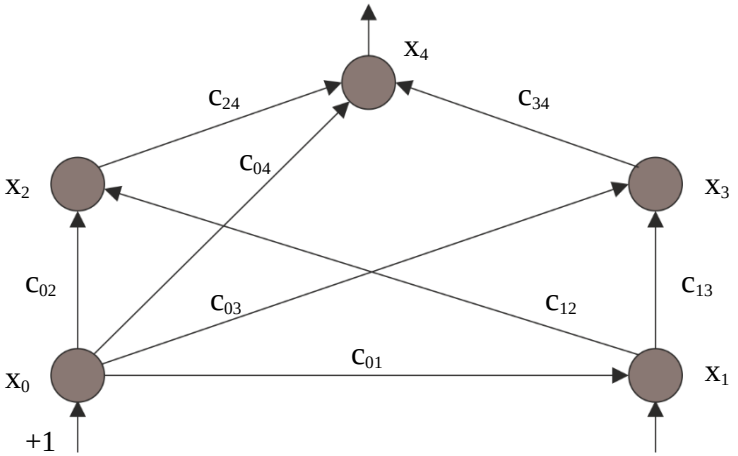

Figure 11. A Variant of the Neural Network of Sustainable Development Management of the Enterprise

The rule of modifying weight coefficients was proposed by the researcher D. Hebb and can be formally described as follows. Let the time of management reaction at the enterprise be divided into strokes and in the *k-th* stroke two variables of the neural network have the values x_i^k and x_j^k. Then the weight of the relationship among the variables increases by the value:

$$\Delta c_{ij}^k = x_i^k x_j^k$$

In the case of binary variables, the increment is equal either +1 (when the signs x_i^k and x_j^k match), or - 1 (when the signs are different). If the initial weight of the relation was 0, then the weight of the relation to the *p-th* stroke will then be equal to:

$$c^{pij} = \sum_1^p x_i^k x_j^k ,$$

where x_i^k and x_j^k are the states of two neurons in the *k-th* cycle; *p* is the number of strokes of managerial influence.

Thus, we obtain a model of a neural network (perceptron), which describes the management process in the enterprise.

Table 2. The Basic Assessment Matrix of Implementing Cognitive Technologies in the Enterprise

# of neural communication	Name of indicator (form)	Levels of assessment			The task inappropriate for implementation
		Low (bottleneck)	Median	High	
Section 1. Assessing the level of cognitive technologies implementation in the enterprise					
1.	Assessing the level of automation of cognitive management stages taking into account the efficiency of resource provision	*V*	*V*	*V*	*V*
2.	Assessing the level of automation of data transmission from the neural network to the next stage of management	*V*	*V*	*V*	*V*
3.	Assessing the level of cognitive management effectiveness in the new products development	*V*	*V*	*V*	*V*
n		*V*	*V*	*V*	*V*

The method of determining the priority areas of implementing cognitive technologies in the enterprise establishes the main approaches to analyzing the achieved depth of their penetration (based on the forms of self-assessment), and their resource provision. It also gives recommendations based on the analysis results for forming the list of cognitive technologies to be immediately implemented at the enterprise, which ensure receiving the planned organizational and economic effect. Table 2 presents a variant of the resulting matrix of the level of implementing cognitive technologies in the enterprise.

The resulting matrix is formed and filled on the basis of final generalized assessments of economic and organizational effects of management at the enterprise (production, marketing, financial, personnel effects). The obtained assessment is entered in the corresponding fields of the matrix[40]. The calculation of the relative normalized level of cognitive technologies implementation is carried out according to the formula:

$$P = \frac{3 \times n_b + 2 \times n_c + 1 \times n_n}{3(m - n)}$$

where:

P is a relative standardized level of cognitive technologies implementation;

n_b is the number of highly rated indicators;

[40] Hofacker I., Vetschera R. (2001), *Algorithmical Approaches to Business Process Design*, Computers & Operations Research, 28, pp. 1253-1275.

n_c is the number of indicators that received an average grade;

n_n is the number of indicators that were scored low;

n is the number of indicators mentioned in the column "the task inappropriate for implementation" (rated "0");

m is the number of indicators in the form.

The resulting matrix allows presenting a picture as a whole and noting "bottlenecks" which mean the directions on introducing the cognitive technologies of the enterprise which have been scored "low". The sequence of forming the matrix determines the priority areas of implementing cognitive technologies in the enterprise.

Thus, this section of the textbook considers cognitive technologies in strategic management and provides a list of measures to organize the implementation of cognitive technologies in the enterprise relying on the perceptron model in order to improve management decision-making in the framework of the business development program and its technical re-equipment. There was offered organizational and economic mechanism of business functioning, which includes new means of implementing administrative actions using a matrix to assess a level of cognitive technologies implementation. There was considered a method of determining the priority areas of cognitive technologies implementation at the enterprise, based on the results of assessing the depth of cognitive technologies penetration and the result obtained from their implementation, which additionally allows for the coefficient of resource provision of implemented technologies defined as an assessment correlation of the actual level of competencies and the one needed to work with new cognitive technologies, which allows obtaining the planned economic and organizational effect.

Chapter 8. A system of goal setting in reflexive management

The goal is the key idea of the organization, which determines its structure, development, and system of its interactions. Later, cybernetics developed this idea of the organization, presenting it as a system, in which the special interaction of elements (structural components) among themselves contributes or does not contribute to achieving the goals of the organization. Working within the cybernetic approach, we can say that each individual element of the system has only a certain amount of information, which is not enough to comprehend, formulate and achieve the development goals of the whole system. This ability of the system to obtain a new quality based on generalizing the informative particles of each element is called emergentness.

To explain how the organization unfolds, what affects the achievement of its goals, and what arises in its structure, form, and methods of work depending on the initial goal, there was engaged a situational approach, which relies on the idea that the forms, methods, systems, management styles depend on the current situation, and, therefore, differ significantly in various organizations, adjusting their target guidelines.

This approach, apparently, gave rise to Gareth Morgan's theory of organizational metaphors, who proposed his own models of organizational behavior, allowing not only for the current situation but also for implicit imprints of reality and metaphors that reflect the organization's original goals. Owing to the latter, he figuratively presented possible models of organizations such as a machine, organism, brain, culture, political system, mental prison, flow, and transformation. He went on to describe in detail the key strategies, possible organizational transformations, and limitations that this metaphorical characteristic imposes on the organization. This theory in its practical use allows understanding that each model of organization and organizational behavior has: a) its limitations (they will be established when the organization gains sufficient strength and activity); b) its pros and cons, which means that for the same organizational model, you can use different tools and methods[41].

In the theory of management, goal setting is also justified as the main stage of the management cycle. Even more, the very concept of management in most scientific works is defined as the process of purposeful influence of the management system on its object to achieve its effective functioning and development[42]. It should be noted that a well-formulated goal of the organization (system) should reproduce not only its tasks (current and future), but also focus on maintaining its integrity, optimal functioning, and development.

The latter means that the desired, possible and necessary state of the object of management is the task of goal setting, considering it the process of substantiation and formation of goals for enterprise development based on analyzing consumer needs for products and services, in terms of the real opportunities of their most complete satisfaction.

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[41] Salikhova N.R. (2015), *The Comparison of Substantial and Dynamic Parameters of Personal Value Meaning Systems of American and Russian University Students*, Review of European Studies, 7(4), pp. 117-123.

[42] Mandler G., Nakamura Y., VanZandt B.J.S. (1987), *Nonspecific Effects of Exposure on Stimuli that Cannot Be Recognized*, Journal of Experimental Psychology: Learning, Memory, and Cognition, 13, pp. 646-648.

The quality of the goal-setting process is determined by how fully and meaningfully the needs and interests of all economic entities (we mean consumers, contractors, partners, owners, etc.) that are in the orbit of the organization (system) are expressed in view of the purposes of the organization.

But this completeness and intentionality cannot be determined through formal procedures. For example, the stages of goal setting are correlated with the scheme of system analysis and are defined as such a sequence: identification of issues; identification of goals; defining criteria, agents, and their interests. The set of these stages can be further analyzed in the categories of targeted change management, in such areas as vectors of development and definition of the overall goals of the organization; including mission and corporate (organizational) values. The next, narrower line of analysis should be to clarify the criteria, objectives, and standards of management at each level of the hierarchical management system. An even more specific step in the analysis should be to establish the organizational units that directly carry out, or are responsible for, a particular management process, the boundaries of their interaction, and to provide feedback and transfer information from lower to higher levels of management hierarchy.

Based on this, we make a preliminary conclusion that goal setting should be based on the initial analysis of the internal environment in the organization, monitoring changes in the internal and external environment, application of theoretical knowledge to the actual state of the enterprise, and designing forecasts and possible alternatives. Only in this way can goal setting become an effective and concrete tool for influencing business entities, their behavior, decision-making, attitude to fulfillment of their obligations, change of interests, values, beliefs, understanding of business processes, etc.

Thus, if, based on the system of goals, the organization creates a functional structure and improves and reorganizes it to achieve them, the goal-setting process can be considered the main condition for an effective development of the organization (system).

Implementing a system of goals in a real-time process of the organization's activity brings to life various positions, means, and viewpoints of the subjects of management, caused by different visions of the situation. They have an impact on strategic and tactical management decisions, which either shorten or complicate the organization's path to its goals. Thinking like this, we move into the field of reflection and reflexive management, which is understood as a constant solution to the flow of problems caused by the changing external and internal environment and results from the iteration of cognitive and influence functions of consciousness. Cognitive function means dependence on the existing situation, while influence function denotes the position above the situation, as a result of which the situation can be changed by subjective influence.

Such general considerations about reflexive influence actually fit into a wide variety of conceptual approaches and positions regarding reflexive management itself and the role of reflection in it.

Let us take a closer look at some of the functions of the management entity that affect or may affect the goal-setting process in the organization. They are related, as we mentioned above, to the cognitive and influence functions of consciousness. If the management of the organization consciously constructs its image and images of the external environment,

then occasionally it realizes the content and methods of its own activity in the organization development and in building relationships with the environment. Experts call this an expanded form of reflection, when the main moments of decision-making are recorded by the decision-maker and become the so-called "datum points" in the organization development[43].

If the leader makes spontaneous decisions on the organization development, being inside the situation, and guided by his own experience, knowledge, preferences, intuition, then such reflection is defined as rapid and is a product of cognitive consciousness[44].

In the practice of management, both forms of reflection are used, because the analysis of existing problems by a manager is based on knowing the previous state of affairs in the organization and on interpreting opportunities and ways (strategies) of enterprise development. This allows the transition from the current state into a necessary (or acceptable) state for a certain period of time. The latter allows assuming that an important tool of managerial reflection is goal-setting, which not only determines the desired state of the organization but also identifies possible ways and means to achieve it.

In addition, the analysis of the previous state of the organization and tracking the dynamics of its development, along with the subjective interpretation of its current state and assessments of development prospects are a source of reflection on the management of organizational development.

As mentioned above, the conclusion of management on changing the strategy of the organization development based on the analysis of its current state and previous development history is the result of conscious reflection, when the leader is above the situation, consciously constructs and calculates possible options of events development. Conscious reflection is a useful tool in identifying problem situations, errors, risks, patterns and trends for developing a concept, approaches, and methods of development management.

Management's intuitive predictions about probable management mistakes, problems, or threats are the result of unconscious reflection, which occurs impulsively. It is also useful when there is a necessity to react quickly to the situation, use the moment to gain an advantage in a process, save time and more. The lack of tools for reflexive management, or their insufficient use cause the action of many destructive factors in the management system of the organization, which hinder its progress and achievement of goals. Such factors may, for example, comprise: violation of the organizational structure, negative perception of innovations by the staff, the destruction of a rational management model and others. These factors can result in incomprehensible management errors, inability to adequately assess threats and problem situations, risks, weak level of control.

The destruction of the organization's cognitive structure can lead to a blockage of reflection, which is expressed in the inability of the company management to adequately perceive and assess the current situation, inability to set operational goals and coordinate actions with each other and with the external environment.

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[43] Rozin V.M. (2000), *Concept of Reflex ion in Philosophy and Contemporary Methodology*, Moscow: Reflexion CONTROL.

[44] Seamon J.G., Brody N., Kauff D.M. (1983), *Affective Discrimination of Stimuli that are not Recognized: Effects of Shadowing, Masking, and Cerebral Laterality*, Journal of Experimental Psychology: Learning, Memory, and Cognition, 9, pp. 544-555.

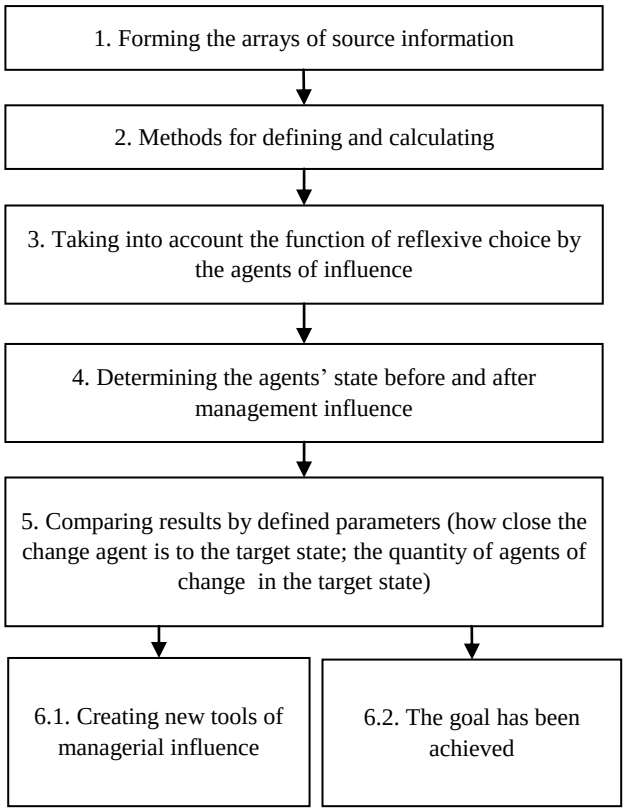

Figure 12. A Scheme of the Goal Setting Process Taking into Account the Reflection

If the company management is able to choose a priority development goal and justify the organization's ability to achieve this goal, we can talk about reflexive choice and that management seeks to develop such plans and development programs through which the organization can achieve a well-thought-out and reasonable state.

Figure 12 presents a diagram of the goal-setting algorithm based on the leader's reflexive choice.

As shown by V. Lefebvre, the central mechanism of managerial reflection is the comparison of the situation existing in the organization and the manager's theoretical program. The latter, embodied in real life, is subject to adjustment due to certain obstacles and risks, due to concessions and losses, which the organization consciously experiences in order to eventually move to a qualitatively new state or significantly improve the existing one[45].

[45] Lefebvre V.A. (2001), *Algebra of Conscience (2nd enlarged edition*, Dordrecht, Holland: Kluwer Publishers. 2001.

Risks can be predicted in the same way as the desired outcome of the organization's operation. It should be noted that the nature of the risks is characterized by the predicted probability of certain events occurrence, accompanied by losses and deviations in the conditions and indicators of the tasks of the company operation and development goals within specific conditions. But it is possible to assess the possibility of their occurrence in the organization (system) development, only under condition of allowing for the properties of the situation that is expected as a result of changes planned in the organization. That is, the manager thinks: what can happen if we use one or another tool of influence, add resources to a particular sector of work, and reduce some sector of work in general, because for the overall goal of the organization it is not relevant.

The concept of environment is used to interpret the conditions of the external environment, their impact on the enterprise, and the ability (competence) of the enterprise to resist, adapt and gain benefit.

Information support of enterprise planning and development processes also carries certain risks caused by the so-called "interference of reflection" – from those who collect information and the appropriate level of skills to process, summarize and present it, to those who transmit and submit it to management or investor for the final decision.

Criteria of efficiency, characteristics and indicators of development, principles, and approaches to setting goals – these are the key elements that are understood by the decision maker in the context of possible achievement of leadership positions in its sector, industry, the economy as a whole.

However, it should be noted that just following the leaders is not the only key to success, as it is important to allow for current environmental factors (they are always changing), organizational culture and system of limitations and capabilities of the business management system. The attitude of consumers to producers of one industry is also different. All these remarks give grounds to assert that the consumer value of the enterprise's products is largely subjective, which cannot be clearly formalized.

Next, we should consider the organizational relationship in the enterprise itself, which can also affect the definition of its key goals and directions of development. If we go from specific to general, we should start with specific agents of change (we mean specific employees), whose position in the company can be dual. On the one hand, it may be constructive, i.e., promoting their further development, while on the other hand, it may be completely or partially destructive (conservative), aimed at consolidating the current state of affairs and stable organizational relations.

Vertical and horizontal connections within the organization, the relationship of centralism or autonomy, subordination or coordination, responsibility, competition, etc. also affect the management process as a whole and at all its stages, because they are always based on the conflict of interests of an enterprise and economic entities in the external environment, owners and management, management and employees, the difference in perceiving goals, understanding of the situation, prospects for its development, commitment to different management technologies.

The goal-setting process is inextricably linked with stimulation, on which the effectiveness of management processes directly depends. Incentives, in this case, should be

understood as external and internal, positive and negative, material and spiritual, conscious and unconscious, rational and irrational.

The condition for the effectiveness of an active object of management in economic systems is the achievement of the necessary degree of coordination with its goals, the development of acceptable and at best motivating "images" of managerial influences on its activities in order to improve the efficiency of the economic system as a whole. Therefore, in reflexive models of managing the enterprise development, the goal-setting system can combine the parameters of target and undesirable states of the enterprise as a whole and of its individual structural components from the standpoint of both the management system (board and senior management) and active management objects (business entities).

Figure 13 presents a scheme of reflexive management, complicated by a situational approach to management decision-making.

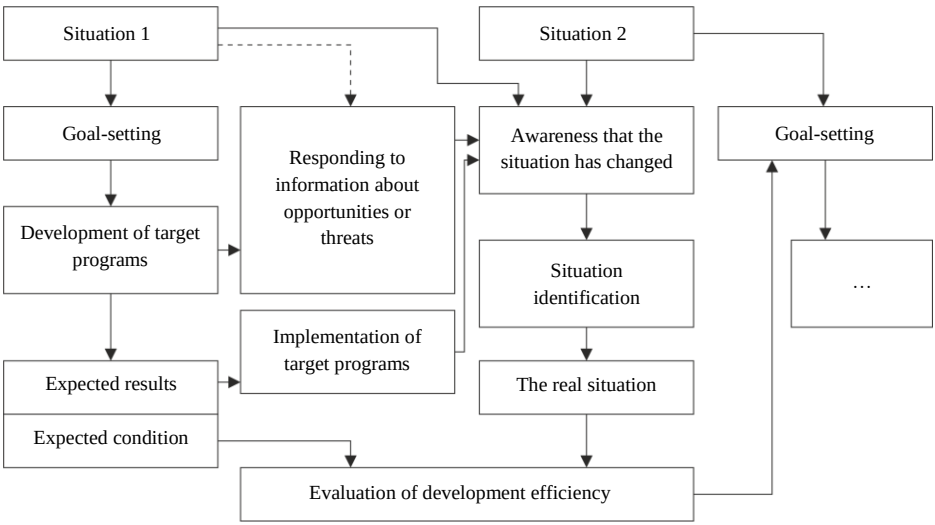

Figure 13. A Scheme of Reflexive Management of Enterprise Development Taking into Account the Situational Approach

The goal-setting stage, as we can see from the figure, is a central point in the management cycle of enterprise development and it is based on the results of the evaluation of development efficiency.

It is assumed that changes occur constantly under the influence of internal and external factors of the enterprise, but the "situation" as such begins only the moment managers comprehend these changes. Then, there is initiated the task of identifying a new situation, its formalization, and development of a descriptive model ("image") with qualitative and quantitative characteristics.

In response to current events and weak signals about the opportunities and threats of enterprise development, the management apparatus is guided by the model of the previous situation, earlier approved by the system of goals and the program of their implementation.

The planned outcomes from implementing the steps of the company development can often be found in its target programs. If, for some reason, the implementation of a point of the plan does not occur, it indicates the availability of certain deviations from the planned result or from the expected planned effect. Then we can talk about the disparities between the real conditions of the enterprise and the model that will be embedded in the target program.

After some time, the reflection is manifested through understanding of how it "had to" be done, and this indicates that the decisions made are comprehended in a new way in terms of adequacy, relevance and rationality, or, given what happened before the decision came into force or after the decision was taken, what the forecast would be regarding the situation development. At present, this knowledge is used to develop goals more realistic from the viewpoint of the subjects of management, logical and rational strategies to achieve them. However, the reverse side of the accumulated knowledge is managerial inertia, backwardness of economic policy, resistance to innovation. Internal motives, conflicts of goals, interests and understanding of the external environment and the place of the enterprise in it, uncertainty and contradictions in subjective perceptions of "ideal" development can significantly deflect new or revised goals setting from "correct and necessary" or closest to it.

However, the negative manifestation of the reflex effect is the doubts of the decision maker when the knowledge gained, and especially negative experiences, provoke a decrease in the necessary measures' (projects') utility, doubts about the importance and achievability of goals set, more in-depth economic analysis of the history of enterprise development. In addition, constant reflection and further revision of targeted guidelines can increase the duration of projects, increase their implementation costs, waste of time and reduce competitiveness in their field, and so on.

However, uncontrolled blocking of the reflex effect makes the company's management more inclined to make decisions characterized by high risk.

Thus, goal-setting in the reflexive management of enterprise development provides a continuous link between formalized models of the situation and the real state of affairs in the enterprise. Adjusting and setting goals become possible due to the fact that the decision maker is constantly provided with the results of retrospective analysis (what was before), information about the real state of the object, as well as is able to form his own idea of target and expected results of the work according to the scheme drawn.

Chapter 9. Artificial intelligence and sustainable development of society: modeling of reflexive processes

In this section of the book, it is proposed to apply knowledge about reflexive processes to artificial intelligence in order to form a sustainable development of society.

It is known that modern real systems (technical, economic, social, environmental, etc.) in the global world system are imperfect due to the complexity of internal relationships and the influence of numerous parametric factors, whose impact is not always possible to predict and to take into account. In this case, the society development systems can change the regime (in a planned or random way), the structure of the elements that determines the new states of the system, which are qualitatively different from the previous ones, determining the unstable and unsteady development of all social processes. These problems do not allow describing in detail the processes using traditional approaches, in particular, causal description in the form of comparative systems and theoretical models.

Nowadays, to design and use reflexive management algorithms, there is being actively developed a new scientific direction, which is based on the representation of multidimensional social and economic processes in the form of cognitive models and connections. Their use allows describing the dynamics of complex social systems and predicting their future behavior and sustainable development.

The methodological basis is determined by interpreting the forecasting methods and the features and patterns of the studied processes. Let us highlight the following techniques we need:

1) Formalized thinking. The essence of the method lies in the following: the determining value of the ratio between the value of the forecast horizon (warning period) Δt and the evolutionary period (retrospective period) of the social process t_x is determined by the formula[46]:

$$\tau = \frac{\Delta t}{t_x}$$

If $(\tau << 1)$ (the forecast horizon is within the evolutionary cycle), it is recommended to use formalized methods. When $(\tau \sim 1)$ abrupt changes in development are possible, intuitive methods are significant and more effective.

Formalized methods can be used before and after turning events[47]. If the period of public research comprises several evolutionary periods $(\tau >> 1)$, then intuitive methods are used to develop forecasts.

2) Intuitive methods[48, 49]. Intuitive methods are used when the object of forecasting is either too simple, or so complex and unpredictable that it is almost impossible to

[46] Beatty I.D. (1995), *Neural Network Dynamics, Complexity and Cognition, Physics Education Research Group*, USA: University of Massachutes.

[47] Krippendorff K. (2004), *Content Analysis: An Introduction to its Methodology*, Thousand Oaks, London, New Delhi: SAGE.

[48] Fernández-Rodríguez F., González-Martel C., Sosvilla-Rivero S. (2000), *On the Profitability of Technical Trading Rules Based on Artificial Neural Networks: Evidence from the Madrid Stock Market*, Economics Letters, 69, pp. 89-94, http://dx. doi.org/10.1016/S0165-1765(00)00270-6.

analytically allow for the influence of many factors. The individual and collective expert estimates obtained in such cases are used as final forecasts or as initial data in complex forecasting systems for sustainable social development. The content of intuitive forecasting methods is to intuitively choose from many circumstances the most important and decisive ones.

3) Methods based on nonlinear models[50] that remove the constraints inherent in statistical methods and meet the above requirements. Most of these methods belong to the category of artificial intelligence technologies. These are artificial neural networks and the latest optimization tools in determining the development and safety of social processes.

The research of the properties of macroeconomic systems[51, 52] shows that it is possible to identify repetitive patterns of local social systems' behavior, and on their basis to make predictions on preserving or reversing the trends. For the macroeconomic systems researched, it makes sense to develop forecasting models able to "remember" past societal situations and their corresponding consequences (i.e., their continuation) in order to further compare with the situations that occur in the evolutionary movement of the society.

Let us consider artificial intelligence in the model of sustainable social development. This problem may be possibly solved with a database in which social situations and manifestations encoded in a certain way can be recorded. To make a forecast, it would be necessary to review all the records, which must contain a huge background data to achieve the forecast of sustainable development, of the required accuracy. This idea cannot be perceived as constructive due to the complexity of data access, the complexity of the criteria for comparing information and more. The ability to "remember" is inherent in technologies that are combined under the name Computational Intelligence,[53] which allows getting continuous or discrete solutions as a result of modeling from available data.

One of the subclasses of the discussed group of methods are neural networks (NN), which use stochastic algorithms to predict and manage the safe development of social processes through self-organization[54]. These methods do not impose any restrictions on the nature of incoming public information. These can be both indicators of this temporary series, as well as information about the behavior of other public objects.

The processed information about the data of social processes is of numerical character, which allows using NN, for example as a model of systems with completely unknown characteristics. NN is a collection of neurons that are interconnected in some way.

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[49] Watts D.J. (1999), *Networks, Dynamics, and the Small-World Phenomenon*, American Journal of Sociology, 105(2), pp. 493-527.

[50] Poteete A.R., Janssen M., Ostrom E. (2010), *Working Together: Collective Action, the Commons, and Multiple Methods in Practice*, Princeton, New Jersey, USA: Princeton University Press.

[51] Goodfellow I.J., Bengio Y., Courville A. (2016), *Deep Learning*, Massachusetts, USA: Massachusetts Institute of Technology.

[52] Ostrom E. (2009), *A General Framework for Analyzing Sustainability of Social-Ecological Systems*, Science, 325, pp. 419-422, http://dx.doi.org/10.1126/science.1172133.

[53] Laurier E., Brown B., McGregor M. (2016), *Mediated Pedestrian Mobility: Walking and the Map App*, Mobilities, 11, pp. 117-134, http://dx. doi.org/10.1080/17450101.2015.1099900.

[54] Coppin B. (2004), *Artificial Intelligence Illuminated*, Mississauga, Canada: Jones and Bartlett Publishers, Inc.

A neuron is an elementary particle of transformation that has a non-empty set of inputs, which receive signals $x_1, x_2,\ldots,x_n$ (Fig. 1), a summing unit, a signal conversion unit using an activation function and one output – Y.

Each input has its own "weight" w_i which corresponds to the "strength" of the synaptic connection. The neuron functions in two phases. During the first one, in the block of addition, the size of the excitation received by a neuron is calculated:

$$S = \sum_{i=1}^{n} x_i \times w_i = (X, W)$$

which is convenient to represent in the form of a scalar vector of input signals to the weights vector. During the second phase, the total excitation is passed through the activation (converting) function F, as a result of which the output signal $Y=f(S)$ is determined.

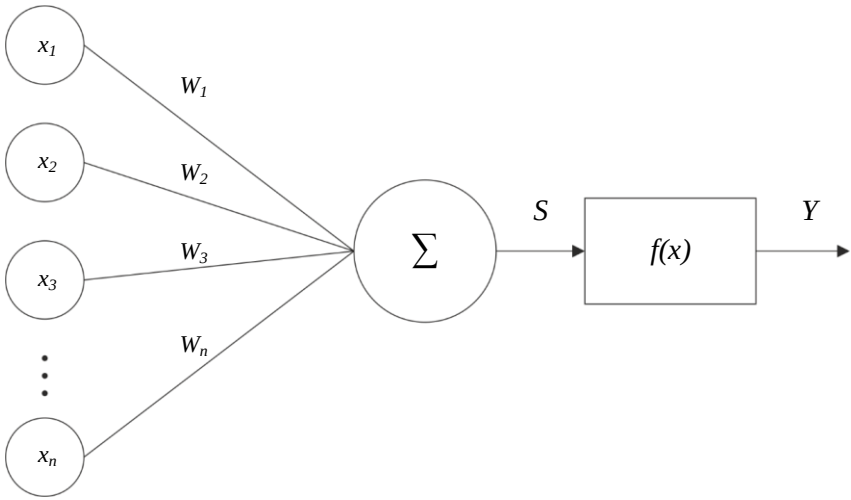


Figure 14. An Artificial Neuron to Describe the Model of Social Development

The multilayer network can form any multidimensional function on an output with the corresponding choice of the number of layers, the range of signals' and neurons parameters' changes. The neural network implements the following transformation of the initial function:

$$y = f(x) = F\left\{\sum_{iN} w_{i_N j_N N} \ldots \sum_{i2} w_{i_2 j_2 2} F\left\{\sum_{i1} w_{i_1 j_1 1} \times x_{i_l j_l 1} - \theta_{j_1 1}\right\} - \theta_{j_2 2} \ldots \theta_{j_N N}\right\}$$

where:

i is the input number;

j is the number of the neuron in the layer;

l is the layer number;

N is the quantity of layers;

x_{ijl} is the i-th input signal of the j-th neuron in layer l;

w_{ijl} is the weighting factor of the i-th input signal of the j-th neuron in the layer l;

θ_{jl} is the threshold level of neuron j in layer l.

Due to the alternate calculation of linear combinations and nonlinear transformations, an approximation of an arbitrary multidimensional function is achieved with the appropriate choice of network parameters.

In this case, adaptability means the process of changing the parameters and structure of the model formed with the initial uncertainty in the conditions of work, which is of a volatile nature, based on current input management information, in order to achieve a certain state characterized by a threshold of a given accuracy. Mechanism of adapting models formed by means of artificial intelligence system (AIS). In this case, as a rule, the network topology is considered to be constant, and the parameters that are adjusted, usually include the parameters of neurons and the magnitude of synaptic weights.

At present, there are many variations of neural networks capable of performing various operations with the initial information. The most acceptable paradigm for predicting the dynamic state of non-stationary macroeconomic systems is AIS with the following features[55]:

a) by the method of teaching: models with a social direction or vectors of development, to identify internal potential based on the analysis of the society history;
b) by the nature of propagating information in networks: recurrent networks based on the algorithm of propagating error signals from the outputs of the neural network to its inputs, in the direction opposite to the direct propagation of signals in normal operation.

This paradigm allows the use of neural networks as a "black box", which "is presented" the input data of the problem and the answer that corresponds to this data, found earlier, while forming the parameters of the social model development. In the process of safe development, AIS must itself build within the "black box" of the studied process (detect dynamics) to give an answer that coincides with the correct one. The more various pairs of "initial data" of sustainable social development – the "answer" will be presented to NN, the more adequate, logical target function of decision-making within the model of social development it will create.

The content of such a neural network concept relating to the task of predicting the safety of development is determined by the general principles of multilayer perceptrons' operation and includes three stages: 1) collection and preliminary conversion of input

[55] Gevrey M., Dimopoulos I., Lek S. (2003), *Review and Comparison of Methods to Study the Contribution of Variables in Artificial Neural Network Models*, Ecological Modelling, 160(3), pp. 249-264, http://dx.doi.org/10.1016/S0304-3800(02)00257-0.

data; 2) perceptron training; 3) recognition (forecast) of the model of society's sustainable development[56].

The scheme of solving the problem of forecasting macroeconomic and social processes on the principles of sustainable development can be represented as a sequence of stages (Fig. 15).

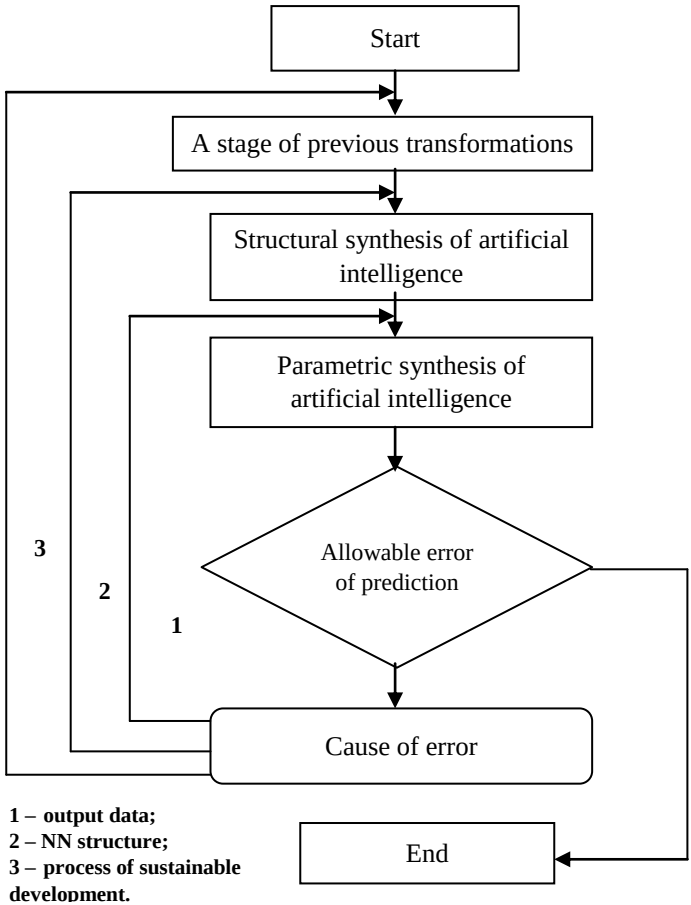


Figure 15. An Algorithmic Scheme for Solving the Problem of Forecasting Sustainable Development of Society Using the AIS Apparatus

At the initial stage, NN restores the target function by a set of macroeconomic samples, i.e. solves the problem of sustainable development interpolation. At the stage of using the generated NN model (obtaining a forecast), the network will use the restored dependence for forecasting, i.e., to solve the extrapolation problem.

[56] Hamill J. (2017, September 19), *Artificial Muscle Could Make Robots 15 Times Stronger than Humans*, New York Post, Retrieved from https://nypost.com/2017/09/19/artificial-muscle-could-make-robots-15-times-stronger-than-humans/.

The ability to abstract at the stage of previous transformations allows AIS to ignore the secondary properties of the studied data set and makes it possible to identify the main within the model of society's sustainable development. Although these properties, taking into account the task of forecasting, may be a disadvantage because sometimes one small property of the studied non-stationary processes in rapidly changing economic situations can have a significant impact on sustainable social development in the future. In addition, the process of setting the parameters (stage of parametric synthesis) of the neural network model is of non-deterministic nature, does not always converge, requires numerous different heuristic tricks, depends on the complexity of the initial data, the chosen network architecture (structural NN synthesis stage) and computing resources.

Let us consider the process of optimizing the algorithms of neural networks in creating an expert system for forecasting sustainable social development.

The stages of preliminary NN transformation and parametric synthesis determine the main points, allowing for which favors creating expert systems for forecasting by means of the apparatus of artificial neural networks.

The stage of preliminary transformations is necessary for the neural network, while solving the interpolation problem of the transformed values of factors, can solve the problem of initial values' extrapolation. It should be noted that an important stage of neural network calculations is the stage of preliminary data conversion. It is the form of data presentation, the way how they are initially selected that significantly determines the speed of modern learning algorithms, the ability of the neural network to memorize (highlighting the characteristic patterns in the instructive data) and generalize (adequate processing of input signals unused for sustainable development). In addition, the preliminary transformation allows ensuring the invariance of feature sets, which is determined by the fact that the signals distributed over the neural network should be limited by the space determined by the asymptotic interval of activation functions of network neurons in the current model of social development.

The values of the signals of the first output layer NN may lie in the range [- 2, 2]. Transformations produced in the second layer within activation functions in the interval [- 1, 1] "cuts" the informative part of the signal values above or below this interval. In this case, the values that do not fall into this interval are approximated by the neural network with the values of the asymptote of the activation functions.

These problems generally impose defining constraints on the input and output samples of the values given for the NN operation and determine, in general, the NN capacity to generalize – NN can predict the behavior of a particular social model of sustainable development only in the activation function space. The set must contain the behavior of the indicator throughout the space. Only with these limitations taken into account NN is able to generalize, and in accordance with the forecast. Thus, at the stage of previous transformations, it is necessary to ensure the invariance of the set of features so that they are located within the activation function[57].

[57] Scarselli F., Gori M., Tsoi A.C., Hagenbuchner M., Monfardini G. (2009), *The Graph Neural Network Model*, IEEE Transactions on Neural Networks, 20(1), pp. 61-80.

Let us consider a simple way to form invariant images. The basic concept here is a "window" ("immersion depth"), i.e., the number of time periods (or other parameters by which the extrapolation is performed), which the vectors formed at the input and output of the network fall into, for which there are allocated respectively *n* input neurons and *m* of output neurons.

The data of each of these vectors are restricted by the range [*Min… Max*]. The simplest way to form a "window" within the activation function of an artificial neuron will be the transformation by the formula:

$$X = \frac{x - Min}{Max - Min},$$

where

x is an initial vector;

X is a scalable vector;

Max and Min are the maximum and minimum values of the "window" respectively.

After this transformation, each vector consisting of *n(m)* consecutive values is normalized so that all its values lie in the range from 0 to 1. The values of the input and output images are embedded in hypercubes of dimension $[0,1]^n$ i $[0,1]^m$.

Although this transformation using the formula guarantees the invariance of the initial vectors of the instructive samples, it is not optimal. The activation function, which ultimately determines the specified values, must also be symmetrical. Thus, the initial value of the features must be translated into the space {-1.1}. Scaling is performed according to the following formula:

$$X = (x - m) \times c$$

with the appropriate choice of the scale factor *c* allows performing the specified transformation; *m* is the average value of the set of input data.

However, when using the following formula, it is necessary to select the value of the scale factor, which is not convenient in most cases. In the course, an empirical formula was used that scales the vector from the range *[MinR, MaxR]* to the range *[MinC, MaxC]:*

$$X = MinR + \frac{(x - MinC)}{(MaxC - MinC)} \times (MaxR - MinR)$$

The transformation according to this formula removes these shortcomings of the previous formulas and can be recommended when calculating the parameters of safe development. It should be noted that the sampling image interval during scaling should not coincide with the asymptotic interval of activation functions. You need to choose a slightly smaller value of the window interval (in practice, limited to 5% barrier) – this action improves the quality of NN application, because the activation function, in this

case, will not try to approximate the values underlying the asymptote of activation functions.

Thus, forecasting based on elementary "windows" implies the use of two windows W^{in} and W^{out} with fixed sizes n and m, respectively.

These windows are able to move with some step in the sequence of features, starting from the first element of the sample under research, and are designed to access the data of the time series, and the first window W^{in}, receiving such data, transmits them to the neural network input and the second W^{out} to the output. Thus, at each step, the W^{in} / W^{out} pairs form a set of samples of sustainable development of the system.

If we assume the presence of hidden dependencies in the studied sample sequence as a multitude of observations, then by teaching NN on these observations we can obtain the necessary dependence, based on which a predictive model of artificial intelligence for sustainable society can be built.

Further research of the processes of modeling sustainable development of society are determined by the very structure of the cognitive network based on the procedure of reverse propagation of network error, identification of signal distribution scheme, proposed error criteria that improve the quality of network operation. Promising are the works in the field of assessing the impact of modifying the basic backpropagation algorithm on the speed and quality of sustainable development of social systems and formations, in particular in the direction of implementing the accumulation of a total gradient on a sample of indicators and minimizing of the total quality criteria on all errors of separate images of development, which will allow increasing the convergence rate 4-5 times compared to the basic algorithm and speed up neural network optimization and training methods.

Thus, the use of artificial neural networks mechanism makes it possible to create functional models for predicting reflexive processes of society's sustainable development, which are not set in advance, but are generated by the data itself – sets on which the network learns, but at the same time, several disadvantages do not allow using NN fully for forecasting non-stationary macroeconomic and social processes, conditioned by significant distortion of results at the stages of model adjustment.

Such recommendations concern the main stages of determining the quality of the formed models of forecasting reflexive processes of sustainable development on the basis of the AIS apparatus. The creation of invariant images by using "window" transformation operations and discrete differentiation determines the possibility of extrapolation (forecasting) for the studied non-stationary samples. The use of anti-gradient network-tuning methods based on nonlinear optimization algorithms allows successful approximation of the NN target function at the points of local minima of the error function, which improves the quality of the model formed by the network.

Chapter 10. Cognitive technologies of artificial intelligence in entrepreneurship

In modern conditions of transient information processes in business, decision-making is based on human-machine procedures in the form of a cyclical process of human-computer interaction (artificial intelligence systems). As a rule, an action, decision-making is analyzed in advance and formed by the regulatory framework of the information system, which performs the functions of an expert of the person's actions, namely the entrepreneur. In the process of doing business, the business owner deals with abnormal situations that arise in conditions of uncertainty in the operational work with large flows of commercial information in real time[58, 59]. And that is why the introduction of a decision-making training system does not exclude the right to make decisions and the degree of responsibility for a person, but reflected the practical feasibility and necessity of creating artificial intelligence shells to solve problems of choosing alternative "joint actions" and training in entrepreneurship.

It is this approach that can provide a representation of mental business models and artificial intelligence systems in the form of concepts and rules of a cognitive nature.

The research methodology is formed in the context of analytical groups of approaches to developing entrepreneurship training:

1. *Hypertext learning systems*. Modern trends in open education are focused on creating and applying effective educational systems that use a hypertext system of material presentation. Artificial intelligence systems are a complex dialogic system that combines components which reflect different forms of human expression[60, 61, 62]. Such integration allows achieving the effect of learning entrepreneurship by using all multimodal forms of expression, in contrast to only oral and written expression of knowledge – the characteristic components of the classical education system.
2. *Methods of index calibration (addressing) of the subject area.* With the development of information systems, it turned out that this form was not the only form of intellectual choice and search. In addition to the text form, there came into use non-text search methods based on the properties of cognitive (figurative) perception by visualizing data with human spatial memory through symbols, sounds, geometric relationships, etc. A number of researchers[63, 64, 65] point out that such cognitive

[58] Cooke P. (2002), *Knowledge Economies: Clusters, Learning and Cooperative Advantage*, London: Routledge.
[59] Dirican C. (2015), *The Impacts of Robotics, Artificial Intelligence on Business and Economics*, Procedia-Social and Behavioral Sciences, 195, pp. 564-573.
[60] Davis C.H., Creutzberg T., Arthurs D. (2009), *Applying an Innovation Cluster Framework to a Creative Industry: The Case of Screen Based Media in Ontario*, Innovation: Management, Policy & Practice, 11(2), pp. 201-214, http://doi.org/10.5172/impp.11.2.201.
[61] Felt U., Fouché R., Miller C.A., Smith-Doerr L. (2016), *The Handbook of Science and Technology Studies (4th Ed.)*, Cambridge, MA: MIT Press.
[62] Martinez-Lypez F.J. (Ed.) (2014), *Handbook of Strategic e-Business Management*, Heidelberg-New York-Dordrecht-London: Springer-Verlag.
[63] Brynjolfsson E., McAfee A. (2014), *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*, New York, NY: WW Norton & Company.
[64] Duncan T.E., Duncan S.C., Strycker L.A. (2013), *An Introduction to Latent Variable Growth Curve Modeling: Concepts, Issues, and Application*, New York: Routledge.

methods form an active developing vector of applying artificial intelligence technologies in learning, as they have proven to be more effective for learning computer systems in business than oral or written forming of the search direction.

The development of annotated link technology is possible when creating intelligent tools for "joint learning in entrepreneurship" based on various models of knowledge, different types of reasoning, as well as image processing.

Let us consider the cognitive neuro-fuzzy model of learning in entrepreneurship. It was mentioned above that one of the neural networks' disadvantages is the poor interpretation due to the distribution of information stored in them, resulting in the following: a) it is almost impossible to understand how a large learning network solves the problem set to it and b) common knowledge about the method of solving the problem cannot be introduced in the network. The advantage of fuzzy systems in entrepreneurial education is their ability to represent and use the business knowledge of the entrepreneur, expressed in the linguistic form natural to him, which makes it possible to describe complex economic and business processes. However, fuzzy models from the standpoint of cognitive understanding of information (information presented through the image) are the basis for formalization and manipulation of symbols without appealing to their meaning. At the same time, neural networks, represented as a graph image, can be the basis for appealing to meaning through the prism of a cognitive image in entrepreneurship education. The sequence of developing a cognitive neuro-fuzzy model of learning in entrepreneurship is presented in table 3.

In the general case, artificial intelligence learning systems include: a) a linguistic processor of communication with the user; b) a "bulletin board" that serves as a communication medium; c) a knowledge base containing heuristic knowledge; d) a database containing a catalog of subsystems and elements included in the object; e) an interpreter, which, relying on input data, knowledge base and database based on input data, knowledge base and database, forms a solution to the problem, i.e., determines the information from the knowledge base to be used, selects the necessary data from the database, and draws conclusions Table 3. The Sequence of Developing a Cognitive Neuro-Fuzzy Model of Learning in Entrepreneurship about the situation (Salamzadeh, Kesim (2015)).

Table 3. The Sequence of Developing a Cognitive Neuro-Fuzzy Model of Learning in Entrepreneurship

Stage	Actions
1. Identifying	Determining the characteristics of the task
2. Conceptualizing	Searching for concepts to represent knowledge
3. Formalizing	Developing structures to organize knowledge

[65] Siau K., Yang Y. (2017), *Impact of Artificial Intelligence, Robotics, and Machine Learning on Sales and Marketing*, In: *Twelve Annual Midwest Association for Information Systems Conference (MWAIS 2017)*, Springfield, Illinois, May 18-19.

4. Implementing	Formulating rules that embody knowledge
5. Testing	Evaluating the rules in which knowledge is embodied

We propose to further modify the architecture of the fuzzy regulator system by introducing training neural networks in business. This modification allows presenting additional adaptive parameters-images to take into consideration their significance at the level of a cognitive image. A distinctive feature of this model of neuro-fuzzy regulator is the ability to incorporate the entrepreneur's knowledge in the form of images and the ability to learn through experience. Here it is important to emphasize that we are talking about the presenting information through the image of the graph[66]. This remark made, a restriction was introduced on the way of presenting information for the cognitive neuro-fuzzy model of learning. Using the distribution of the graph form of the image on a grid of scales further enhances even more the cognitive significance of such images in terms of distribution and differentiation of information.

Graph models in the form of a semantic network carry a huge cognitive "charge" for figurative thinking of the entrepreneur. This is especially important in conditions when the classical analytical approaches to solving problems do not allow describing the real world through the integro-differential equations and take into account many parameters of the initial conditions.

The proposed model of cognitive neuro-fuzzy learning systems in entrepreneurship suggests that the above-mentioned problems of traditional approaches to solving complex modeling tasks can be removed or significantly reduced by allowing for the figurative thinking of a man in the human-machine interface.

The book proposes developing the concept of *M*-automata and networks to solve a fundamentally different problem aimed at "including" the figurative thinking of the user of the artificial intelligence model in the contour "management object – learning system"[67]. The semantic *M*-network is a static model that reflects the set of objects (*i*-models) and their relationship (Fig. 16).

Features describing the law of the *i*-model operation allow considering the *M*-network as a neural network. Presenting information through the *M*-network bears the imprint of the classical paradigm of modeling by decomposing a complex object into parts and establishing the relationship of each part of the object with the physical meaning of each neuron or neural ensemble separately.

It is important to note that such a representation of the neural network in the form of a semantic graph is actually a process of neural network learning from the standpoint of the cognitive image.

[66] Snow C.C., Fjeldstad Ø.D., Langer A.M. (2017), *Designing the Digital Organization*, Journal of Organization Design, 6(7), pp. 1-13.

[67] Ford M. (2015), *The Rise of the Robots: Technology and the Threat of Mass Unemployment*, London: Oneworld Publications.

***M – network architecture*:**
– topological structure (a graph of network *i*-models' connections);
– logical structure (rules for establishing connections and the logic of the network).

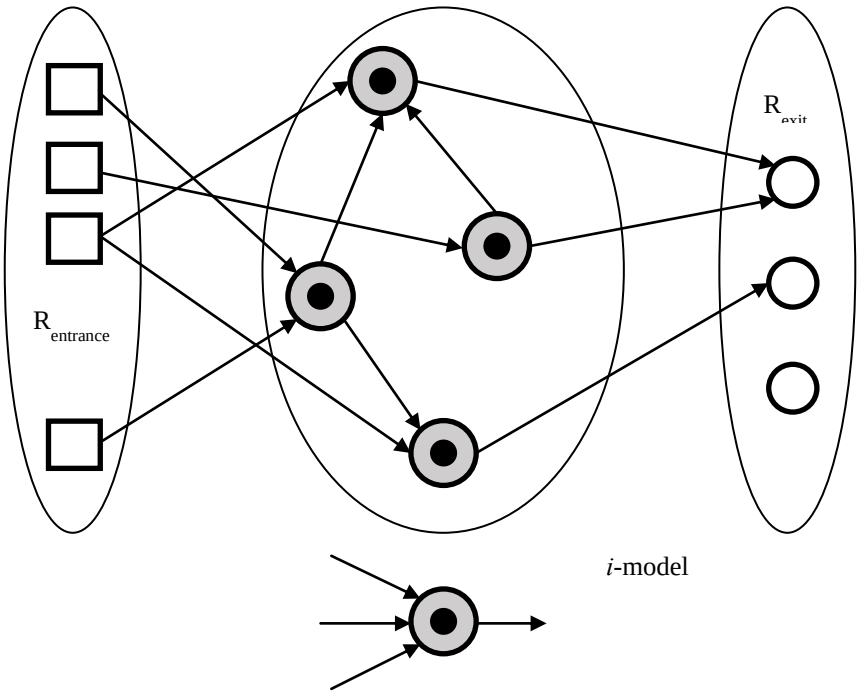
M = (R, A, D)

where:

R ={ri}, i=1,..., n is a finite multitude of $R_{entrance}$ and R_{exit} receptors;

A ={ai}, i=1,..., k is a finite multitude of *i*-models;

D ={di}, *i =1, ..., e* is finite multitude of arcs connecting *i*-models and receptors.



$a_i = (P, K)$

де:

P = {Pi}, i=1,..., k, P is a threshold of the vertex excitation (*i*-model) a_i;

K = {Ki}, i=1, ...,w, is a multitude of weight coefficients (k_i can take positive and negative values)

Figure 16. The M – Automation Concept for Developing Artificial Intelligence Technology to Ensure the Quality of Entrepreneurship Education

Let us call such training a cognitive training of a neural network. This definition of the learning process is essentially different from the learning process of classical neural networks owing to the instructive samples – "input-output" relationships[68].

Cognitive learning in entrepreneurship is basically determined by two successive procedures: 1) learning through forming many objects and determining their significance through the thresholds of neuro-like elements; 2) learning through forming many relations among objects by setting the weights of connections among objects, and thus setting the weights of the synapses of neuro-like elements. It should be noted that the second factor of cognitive learning in its essence, but not in procedure, resembles the learning of classical neural networks.

Let us remark that assigning certain values of synapse and threshold weights to *M*-network *i*-models is a time-consuming and heuristic procedure, which is undoubtedly related to the specificity of entrepreneurial activity. In fact, each concept (object) of the *M*-network corresponds to a fuzzy concept, defined through expert estimates, expressed in the values of synapse weights and threshold values. This allows describing a formal model of the *M*-network mathematically, with the help of fuzzy logic, as a neural network in the essence of its structure, and a fuzzy system – in the process of functioning. In this case, we can conditionally consider the source layer as an aggregator and diffuser, which summarize the fuzzy information coming from the neurons. In this case, the parameters of all neurons-objects of the middle layer are fuzzy concepts, the membership function of which is determined by the system "gain-inhibition"[69].

The above analysis on this issue allows describing the essence of the *M*-network functioning in entrepreneurship education. Let us look at the *M*-network as a cognitive neural network to manipulate the meaning of symbols. So, there is a semantic network in the form of a graph image: vertices correspond to some objects, connections determine the relationship among objects. The "gain-inhibition" system controls the excitation process of *i*-models of elements-objects (Fig. 17). The principle of management is simple: if the excitation of an element is higher than some given parameter or higher than the excitation of other elements, the threshold of such an element decreases. As a result, the initial semantic graph can be represented by a subgraph consisting of vertices, which have increased excitement, and the connections among them[70]. If, near each vertex-object, we display the significance of its excitation through a number, color, or another visual method, we get a cognitive graph-image.

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[68] Russell S.J., Norvig P. (2010), *Artificial Intelligence: a Modern Approach (3rd Ed.)*, Upper Saddle River: Prentice-Hall.

[69] Walker I. (2010), *Research Methods and Statistics: Palgrave Insights in Psychology Series*, 1st Ed. New York: Palgrave Macmillan.

[70] Hengstler M., Enkel E., Duelli S. (2016), *Applied Artificial Intelligence and Trust – The Case of Autonomous Vehicles and Medical Assistance Devices*, Technological Forecasting & Social Change, 105, pp. 105-120.

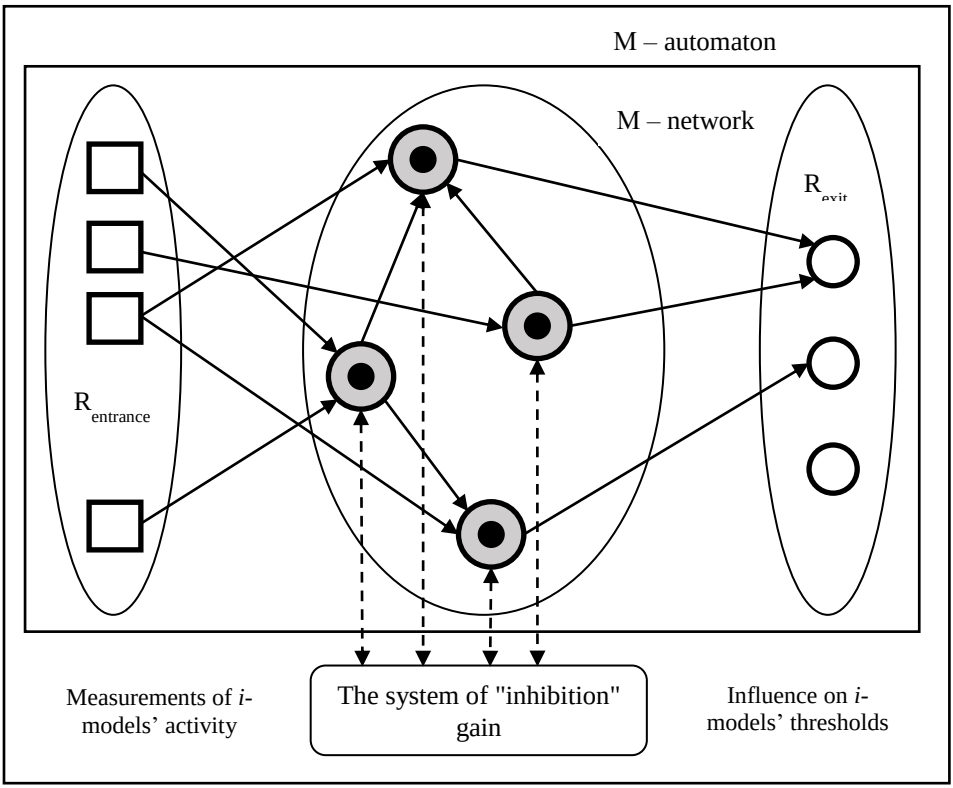

Figure 17. The "Gain-Inhibition" System's Influence on the Values of the *i*-Models' Activity Thresholds

Visual analysis of such a graph allows the entrepreneur to understand, on a conscious or subconscious level, the situation, assess it, and take appropriate decisions and actions. Since the action of the system "gain-inhibition" is a continuous process[71], it can be argued that the cognitive neural network carries in time information about the processes of change in the situation. In this case, the visual representation of the semantic graph will be transformed into the image space. In addition, the significance of the graph's elements, expressed in cognitive form through numbers, symbols, colors, annotated reference texts, etc., also changes. The "gain-inhibition" system, influencing the neural *M*-network, each time shows the entrepreneur the most active cognitive information and the process of its change over time for self-learning.

Given the possibility and specificity of presenting the initial cognitive network (semantic graph) through the hierarchy of neural ensembles, the entrepreneur has the opportunity to control the details when looking at the cognitive graph depending on the purposes and

[71] Jarrahi M. (2018), *Artificial Intelligence and the Future of Work: Human-AI Symbiosis in Organizational Decision Making*, Business Horizons, 61(4), pp. 577-586.

features of information perception, allowing for the specificity and nuances of his image thinking. The analysis of the entrepreneur's activity by calculating the control criterion and the genetic algorithm allows correlating (connecting, uniting) his actions and the system of artificial intelligence in learning[72]. In addition, it is important to note that the entrepreneur's image thinking affects the system as a whole through cognitive changes either in the semantic network, or the flow of input information, or other parameters of the cognitive neuro-fuzzy regulator. Thus, the model of cognitive regulator allows combining subjective and objective, not only declarative, knowledge, but also procedural knowledge (actions)[73, 74].

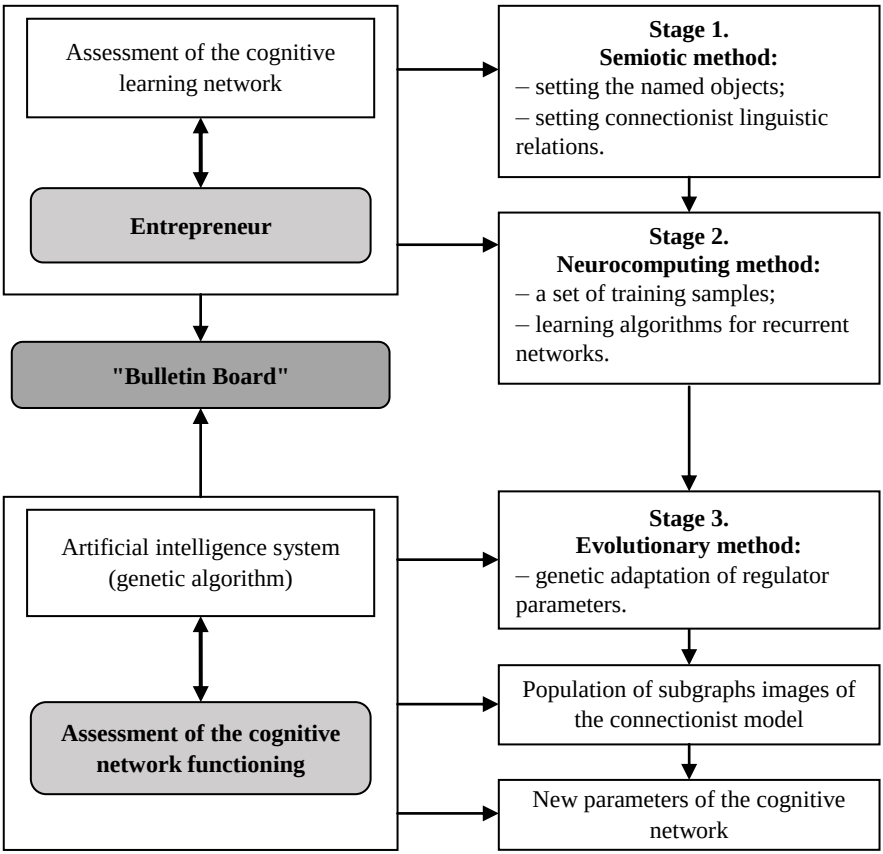

Figure 18. Stages of Learning Cognitive Neural Networks in Business

[72] Wauters M., Vanhoucke M. (2015), *A Comparative Study of Artificial Intelligence Methods for Project Duration Forecasting*, Expert Systems with Applications, 46, pp. 249-261.
[73] Epstein S. (2015), *Wanted: Collaborative Intelligence*, Artificial Intelligence, 221, pp. 36-45.
[74] Rainer K., Cegielski C. (2011), *Introduction to Information Systems: Enabling and Transforming Business*, Third Edition. London: Jonh Wiley & Sons Inc.

The above considerations determine the general idea and features of the cognitive neural network's design and operation. If the design of graph vertices and connections among them is intuitively understood in terms of learning through semantic network tasks, then the issue of adjusting the neural network parameters (weights *i* of the *M*-network thresholds) is quite complex and important. Therefore, in scientific work, it is proposed to use the mechanism of adjusting classical neural networks for adjusting the cognitive neural network parameters. This mechanism considers the neural network as a model that reflects only the simulated object's behavior and does not allow for the internal detailing (semantics) of the neural network (Fig. 18).

The procedure of forming such a model is, in fact, a procedure of cognitive compression of information about the object through training the neural network in accordance with a given instructional sample. The task of neural network synthesis has its difficulties because it is impossible to predict in advance which neural network architecture will be the best to implement the necessary mapping of input signals into output signals in solving the problem of interest.

In general, it should be noted that the difficulty and complexity of pre-tuning cognitive neuro-fuzzy systems significantly depends on the nature of the problem. If the cognitive neuro-fuzzy system is used in the control circuit of a dynamically changing environment, then all the dignity of cognitive neural networks can only be manifested over time. In other words, the entrepreneur's image thinking in the learning process can be used only after a certain period of time working with the object of management within the normative principles of building the decision support systems or advisory systems.

The increase in the level of neuro-fuzzy systems' efficiency significantly depends on the efficiency of the instructional neural network algorithm.

Developments in the field of adaptive models for optimizing the operation of neuro-fuzzy systems using a genetic algorithm are promising. The search can take place without using a priori knowledge about the nature of the criterion of quality management, but only based on its values, obtained by the genetic values of the parameters advanced by the genetic algorithm. As a result, it will be possible to improve the methodology of entrepreneurship education by finding a set of parameter values, the quality of the training itself, which optimizes the linear criteria.

From the standpoint of cognitive understanding of the information presented through the image fuzzy models are the basis for formalizing and manipulating symbols without appealing to their meaning. At the same time, neural networks represented as a graph image can be the basis for appealing to content through the prism of a cognitive image. The approach based on the "combined" synthesis of artificial neural networks and fuzzy systems generates a model of a cognitive neuro-fuzzy regulator, which has the ability to incorporate the entrepreneur's knowledge in the form of images and the ability to learn. The model of the semantic *M*-network in the form of a graph carries a cognitive "charge"; in visualizing information in order to "include" the entrepreneur's image thinking. Repre-sentation of a neural network in the form of a semantic graph is in fact a process of learning a neural network from the standpoint of a cognitive image. The system of

"gain-inhibition", influencing the neural M-network, each time shows the entrepreneur the most active cognitive information and the process of its change over time. The distribution of the graph image on the grid of scales further enhances the cognitive significance of such images in terms of separating and differentiating information.

The cognitive model suggests that the above problems of traditional approaches to solving complex modeling problems can be removed or significantly reduced by semiotic modeling, provided that the entrepreneur is able to control the scrutiny of the cognitive graph depending on the nuances of its image learning. The processes of adaptation to external conditions and changes in the internal parameters of the integration computer system are achieved owing to the genetic mechanisms of birth and death of objects' populations and solutions at the levels of symbolic and image thinking.

Chapter 11. Examples of reflexive management

11.1. Covert management

Currently, there is a significant number of works on the so-called covert management of people (and, accordingly, counteraction to this management), which means a disguised management influence that does not cause objections to the managed entity. A special case of covert management is manipulation – "covert management of a person against his will, which brings certain advantages to the initiator". The analysis of existing works in this area allows putting forward the formal model of covert management considered in this section, described in terms of reflexive games as a kind of reflexive management.

First, let us note that, first, the subject of influence in covert management is the information used by the managed entity in decision-making. Therefore, in terms of the classification system, covert management is information management.

Secondly, it should be emphasized that in the vast majority of known situations in which covert management takes place, only two subjects (perhaps collective) interact. Hence, in the first approximation, it is sufficient to distinguish between a managing entity, whom we will conditionally call an active agent, and a managed entity, whom we will conditionally call a passive agent.

Third, it is considered that the active agent is adequately informed about the passive agent, which means that he is able to I correctly predict the behavior of the latter in any information situation. Moreover, first, it is believed that the active agent knows the true value of the indeterminate parameter, and, secondly, the passive agent in most cases believes that the active agent is adequately informed about it.

If the active agent can change (influence, modify, etc.) the passive agent's information awareness structure, then the purpose of the active agent's reflexive management is to impose on the passive agent such an information structure that the decision taken in its framework is most favorable for the active agent. That is, the criterion for the information impact effectiveness (covert management) is the value of the gain received by the active agent.

Thus, covert management can be represented in terms of the reflexive game as follows. Suppose there are two agents (active and passive), their target functions and the set of permissible actions are known. The information awareness structure is such that the active agent is adequately informed about the passive agent, knows the true meaning of the indeterminate parameter, while the passive agent, unless otherwise specified, believes that the active agent is adequately informed about it.

Suppose that there is specified a set of valid passive agent's awareness structures. The task of synthesizing the optimal (from the viewpoint of the active agent) information influence (more precisely – influence on awareness) consists in finding such admissible information structure of the passive agent (we will thereby remind that according to the input assumptions the information structure of the active agent is fixed) that its corresponding informational equilibrium is most beneficial to the active agent (provides the maximum value of its target function).

A crucial and the one that significantly simplifies the model is the fact that in all models of covert management known to us, the rank of reflection does not exceed two (that is,

the maximum length of an essential sequence of indices describing an element of the information structure does not exceed three).

The solution of the covert management problem formulated in terms of a reflexive game makes it possible to determine, from a normative point of view, the structure of information awareness that an active agent must impose on a passive agent. But beyond the framework of the considered formal models, there remains the technology of covert management, understood as a set of methods, operations, techniques, stages, etc., the sequential implementation of which ensures the solution of the task set. Applied information management technologies are studied and applied in economics, social psychology, neuro-linguistic programming, psychotherapy, etc.

In other words, within the framework of a reflexive game-theoretic model, it is possible to recommend an active agent to form a certain information structure in a passive agent. However, nothing can be said about how to do this. On the other hand, the variety of impact methods described in the above-mentioned works on covert management concerns namely the technology of forming an information structure of a passive agent by an active agent for known purposes of influence. Consequently, formal models allow getting an answer to the question "what should an active agent do in the framework of information management?", while social psychology and other humanities accumulate and generalize empirical material about effective ways to achieve a goal.

The number of possible real situations in which information management can be used is so vast, and the situations themselves are so heterogeneous (the situation is somewhat simplified by the fact that in known works the passive agent does not question the information reported by the active agent, that is, the problem of trust is practically not considered) that to date, no universal recipes have been found and the technology of covert management is an art. Its transformation into a science (through systematization, development of normative models of the influence process itself, their research, identification, etc.) is a promising and urgent task.

11.2. Neuromarketing

Continuing our consideration of reflexive management processes, it would also be interesting to give an example of how they function in neuromarketing.

A human being has five natural senses that allow him to navigate the environment. When in contact with stimuli such as an image, sound or smell, the senses (eyes, ears, nose, mouth, and fingers) send a signal to the brain in the form of sensation. At the same time, the process of perception, which is the comprehension and generalization of sensations, itself consists of three phases: receiving signals, their organization into a certain set and system, and interpretation. Our five senses can be perceived alternately, independently, or simultaneously. As a result of the process of perception, various decisions may arise, depending on the individual, his memory of previous experience, and the associations that arise in him.

Consumer choices are strongly influenced by incentives that can act depending on the individual characteristics of the consumer.

A stimulus, in most of its interpretations, is defined as a factor capable of initiating a physiological or psychological response. Emotional stimuli include auditory, visual, olfactory, gustatory, and tactile stimuli. The consumer receives a signal in the process of getting to know the goods. The attributes of goods, their emotional components "capture" the attention of the consumer, they organize the process of perceiving the goods as a whole, persistently form its image. The received complex signal is processed in the conditional phase of "integration", goes into the cognitive stage of comprehending the received sensory information.

In a split second, according to psychologists, all information is combined into a common, simultaneously sensual and emotional message, the recipient of which is most often unable to recognize the components. This phase corresponds to awareness and understanding, it confirms the receipt of the message and determines the processes of storing and inputting data from the senses.

The interaction between the collection of information from the senses and their processing by the individual depends largely on the context of the emotions experienced, especially when there is no direct effect on the psyche. The complex impact of heterogeneous information on the consumer is the basis of the modern direction of the economy – neuromarketing.

Let us consider sound stimuli – "sounding" a product. In the conditions of products' abundance, entrepreneurs make great efforts to ensure that the sound accompanying the sales process is most appropriate for each product and is pleasant for the buyer. After designing a form, industrialists and other brand names manufacturers are now engaged in a sound or music design.

This trend underlies the emergence of sound marketing, which, using the sound accompaniment of a product, aims at creating excitement in the consumer, motivating him to buy. Entrepreneurs ask, for example, the question: to what extent does a mobile phone ringtone (and in a broad sense – a musical message or some sound sequence) influence the choice of a customer in a store? For example, such a joke is related to sound associations: if you want to find out how your friend treats you, call him in his presence and listen to what melody will sound.

In the food industry, for a long time there have been carried out works on the sounds accompanying products: pouring milk or cereals, the noise of chewing, the crunch of chips. On the lid of a small jar of Blédina – French food for children – you can read that "pop sound at opening is our guarantee", thus a special sound assures the consumer that he has bought a top-quality product.

The Dior brand even worked on the sound of the mascara brush coming out of its case.

Appliance manufacturers, on the other hand, try mainly to eliminate the most dissonant noises. For example, manufacturers of hair dryers offer silent models, such as the BaByliss – Silence Collection. Electrolux R&D has developed a silent system for opening and closing the door (hatch) of their washing machines, which typically clap with a metallic noise. It is enough to press a button to open the hatch slowly and silently.

These and other various sounds produced by equipment are specially studied to serve as an incentive for the consumer while advertising and selling a product, as well as to add value to the product in the eyes of the buyer. For example, the car producer Renault is also working on its sound palette to appeal to the consumer. Noises of a seat belt, turn indicators, doors should emphasize the quality of the car, its safety and promise pleasure to the driver.

Dupont lighters are another example. At the Annecy plant owned by the company, the valve sound and the flame size of the lighters are regulated at the end of the conveyor, depending on the recipient country: the strong, resonant, ostentatious clap of the lighter is acceptable for Asia; in France, on the contrary, it should be quiet and dull.

Sound marketing should be given a lot of attention, as the first reaction of a customer is the wish to try the product before buying it. Unpleasant noise, squeakiness accompanying the sample can be alarm signals for the consumer. The sound produced or the accompanying sound should evoke a sense of confidence in the quality and safety of the product.

The sound environment at the point of sale. Music can be considered as one of the means of sales management, the distinctive quality of the store and its positioning in the market. S. Runier also believes that the sound environment creates a sound image of the store, and is its identifier[75].

The musical and overall sound environment of the point of sale is an integral part of its physical environment, which includes various elements that affect the feelings of individuals. Currently, the importance of this factor is so highly appreciated that special companies specializing in musical design have appeared (for example, Mood Média, the American company Muzak, and others).

Music acts both as a means of influencing the consumer's purchasing decision, and as a means of differentiation for distributors. Therefore, it is advisable to conduct research in this direction, to carry out an appropriate selection (or even a special synthesis) of musical works.

Some neuroeconomists even talk about the consumer's musical programming. The musical environment is able to produce certain types of the consumers' reactions, becoming a significant factor influencing their behavior. The musical environment at the point of sale can pursue the following goals: emotional – to establish trust and a sense of pleasure, as well as initiate some joy in the buyer; cognitive – music should inform the client about the store specialization: what age of consumers, what gender, social and professional group it is focused on, as well as about the world of the store itself, the specific identity of the brand, its geographical position.

Music should attract buyer's attention to the product category and create a festive atmosphere at the store; behavioral – music should slow down the rhythm of a visit to the store, help to relax, or, on the contrary, convey dynamism and energy to the client, it should help create impulses for purchases.

[75] Rieunier S. (2002), *Le marketing sensoriel du point de vente*, Paris: Dunod.

Let us consider visual stimuli. Appearance or the visual image created, of course, exert the greatest impact on perceiving an advertisement or the product itself. According to the definition given in the dictionary of the French language, "sight is a sense, the organ of which is the eye, by which we sense light, colors, shapes and distances". According to the definition given in another dictionary, "color is one of the characteristics of light, the surface of an object, perceived independently and irrespective of its form, which is identified due to a special visual impression".

Despite the existence of different definitions and interpretations, the following aspects of the color perception process can be distinguished.

Color activation level (physiological and psychological function). Physiological function: colors can activate physiological reactions, that is, change the state of equilibrium of an individual's body. Psychological function: different colors of objects attract attention and excite the consumer. Color primarily affects emotions. Color displays improve attitudes towards the respective brand, but draw less attention to the "informational" characteristic of the brand. Research shows that individuals who prefer warm colors have shorter reaction times and appear more receptive to advertising stimuli, while individuals who choose cooler colors try to be selective in their purchasing preferences.

Attracting attention with color (marketing function). Marketing uses colors primarily to grab the consumers' attention. In a commercial context, when it comes to impulse buying, it is necessary to use warm colors in the store, and with rational choice, cold colors are rather to be used. In advertising, color plays a significant role in the visual presentation of brands and, when it comes to packaging, for chromatic selection.

French marketers showed that on a white background, there is the following classification of colors in descending order of choice: orange (21.4%), red (18.6%), blue (17%), black (13.4%), green (12.6%), yellow (12%), violet (5.5%) and gray (0.7%). Some colors seem to bring the product closer to the consumer – these are warm, bright colors, such as orange or red; cool colors create an image that escapes the customer.

Research has also shown that the background, the backdrop used in product advertising, affects trust and relationship structures, even if the color does not convey any product information. Color causes not only emotional excitement, but also a cognitive reaction; colors have symbolic and emotional meanings, while forms have only intellectual meanings (studies also covered the influence of a coffee bag color on assessing and choosing a coffee brand).

Each color has its own meaning and influence, but not all colors have an effect on behavior. Red, for example, is a dynamic and exciting color. Blue is the color of rest and has a calming effect. White is the color of purity or innocence.

Color influences the choice of shapes, volumes and surface areas. The visual image created by color carries information even about the weight of an object, whether it is heavy or light. Indeed, a single rose, for example, seems lighter than a chestnut, even though they have the same surface area and the same color.

Color can even change the idea of a time span: if the surrounding objects are painted in warm colors, the period of time seems to be shorter, and if in cold colors, it seems to be longer.

Color can be used when: labeling a product (drawing attention); indicating belonging to a particular trademark ("color code"); evaluating the range used by the consumer.

Color, as well as other factors of the senses ("sensory" variables), can be used to influence the consumer: color changes his sensations when he sees images of a given trademark, can renew or enhance them.

Color is also used to better position a product in the market in relation to competing brands. Color and the consequences that it generates in the choice of goods made can affect consumer preferences and contribute to the classification of goods he makes. Furthermore, color can be used to transform a banal product into a fashion accessory.

For example, to strengthen its position in the soft drinks market (carbonated water with various fillings), Perrier launched the Perrier Fluo series of drinks aimed at young people. Through the use of vibrant colors and improved taste characteristics of the products, Perrier has managed to reinforce its brand again.

To meet consumer requirements, it must be borne in mind that the color assessing criteria may vary depending on the importing country, they are related to institutional factors, including culture, as well as traditions and the mass media used.

A product shape and design. Nowadays, the consumer is looking for special features in each product: creativity, originality, poetry, interactivity, participation, and accessibility. The shape of the product became the bearer of the emblems. A simple modification in the packaging shape can significantly increase the net profit and market share of a given product. Designers combine aesthetics with functionality: the product should be pleasant to look at and be in the spirit of its time. One of the design goals is to grab attention in stores. The designers, thus, present original and easily identifiable shapes for the buyer. Differentiation of shapes is all the more necessary in the context of an increase in the same type of products, when the buyer must somehow distinguish their appearance. However, the shape of certain products is typical, which makes it possible to identify them as a trademark or as an individual product.

Design and consumer behavior. Design and a form have a significant impact on the mechanisms of consumer behavior. As noted by J. Caron, modern people bear a great emotional load: every day they are exposed to 20,000 visual stimuli, 800 different words and information about 150 trademarks, and all just to buy only a dozen goods at the end of the day[76]. When a consumer finds himself in a certain trading environment, such as a shopping center or a shopping street in the city center, the emotional load becomes even higher, since the given indicators in places of trade concentration are several times higher. What needs to be done to draw the consumer’s attention to the product in such conditions, to distinguish it from the huge mass?

[76] Caron G. (2002), *Sur le sens des couleurs*, Paris: Admirable Design.

The goal of design is to create a shape that matches the tastes and desires of some hypothetical consumer group. The means used by designers relate to the realm of sensations, instincts, prototypes, new ideas that attack the individual. Consumers do not have a standard behavior associated with certain products. The irrational element is mixed with the rational one in the purchasing decision process. Often, manufacturers change only the packaging design, while the content remains the same. In this regard, four types of consumer behavior can be distinguished.

Functional relationship. The consumer takes into account the purely utilitarian and functional aspect of the product. Any suggestion, any appeal to an imaginary consumer is useless in this case. In this case, the buyer is only interested in the functional value of the product (here we are talking about consumer goods). But even with the most important food staples such as salt, marketing can make wonders happen, as in the case of the French brand Guérande, which has been able to restore its historical position in the salt market, renew its offer and design, and achieve new successes.

Analytical attitude. The consumer weighs, compares, analyzes the quality, characteristics of goods, their prices, the degree of novelty. Here products of the highest quality, having a high reputation among consumers, play an important role; they are a kind of standards. Nevertheless, design still has the advantage of being an element that determines consumer choice, since it is added to other rational arguments.

Relation to certain created image. It is the image that connects products with some fashion trends, with new behavior, with a strong consumer identification of a given trademark. Here, design can be fashion-related; it is directed, first of all, to the conformity of the appearance of the goods to the declared general trends of fashion. This category includes numerous products for teens.

Game attitude. The buyer is withdrawing from his daily life, he is looking for pleasure, humor, epatage. In this case, we are talking about impulsive purchases of "fun" goods, technical innovations or exclusive things.

To awaken the senses of the consumer, the designer must use all means available: color, shape, words, substances, and objects that excite the organs of vision and touch.

There are prerequisites, signs for any purchase act, which must be analyzed when developing any new marketing concept. In design, it should be taken into account that it is the emotional and subjective aspects that generate the purchase act, while its rational and functional aspects only confirm the purchase decision. The designer must find a balance between these two aspects.

Each individual creates his own idea of colors and shapes, which is recorded in his long-term memory. J. Caron’s research suggests that the buyer decides to buy in a fraction of a second when moving through a hypermarket (a large shopping center) at a speed of one meter per second and during this time covers with a glance about sixty items. The average customer spends about fifty minutes in the store (fifteen years ago, a customer spent an average of one and a half hours in the mall). This may be explained by the fact that today consumers are driven more by their feelings than by their thoughts and, as a result, it takes a customer one and a half times less to make a decision.

Tactile stimuli. Touch is one of the senses that has been recognized as particularly important in neuromarketing in recent years, and more and more research is being dedicated to this aspect of consumer impact. There can be numerous challenges associated with consumer behavior, because even if the purchase begins on a virtual trading floor and the buyer only selects the product while sitting in front of the display screen, it ends up with an intuitive desire to touch the material thing – touch it and hold it in his hands. Tactile feelings are the final stage in making a buyer's decision, the completion of the buyer's impulse. Consumers appear to be very sensitive to both the shape and the substance from which the surface of the product is made. As in the case of visual marketing, tactile marketing plays up the feelings of the consumer, in this case – his touch.

Touch is the feeling that is the most differentiable and, in each case, a combination of different attributes of goods can cause a different feeling in the consumer. Such attributes include, for example, cold, heat, pressure, pain, each of them transmits its message from the peripheral nervous system to the brain. Touch is a feeling that is technically difficult to explore. Literature on this topic is still not sufficient, even though the impact of touch on consumer behavior and their decision to buy has already been proven. In some specific industries, such as the textile industry or the chemical industry that produces indoor coverings (carpets, wallpapers, decorative items), this sense of the consumer is the predominant factor when buying.

Recently, the "Consumers' Tactile Sense Classifier" was developed and released to help entrepreneurs better determine the expectations of their clients.

Presented in the form of a suitcase, the Sensotact® Classifier consists of 50 substances (objects) and is used as the "alphabet" of the touch, which makes it possible to create a description of the touch, with scores ranging from 0 to 100 (for example, on such indicators as flexibility, hardness, roughness) and, as a result, to obtain a characteristic for any product. The proposed classification allows different manufacturers to use a common language in developing new products in which the tactile sensations of consumers play an important role.

New goods. Different manufacturers pay great attention to the factor of touch in their production. Thus, car manufacturers conduct research important for selling their goods about the driver's touch of the steering wheel and gear shifter, with the aim of arousing his sense of well-being and reliability. The very appearance of the car provokes the desire to touch it, and it is for this reason that Renault is developing its "Touch Design" program. In this program, it is marked that the appearance of the car allows analyzing its advantages, but when the buyer touches its parts, body, various handles, it is as if he receives confirmation of his first conclusion; this confirmation also applies to the rational conclusion, although it is received haptically.

Similar studies are conducted by the French airline Air France: in order to make flights more pleasant for passengers, to create maximum comfort for them, the company's employees began to allow for their touch, among other things. In this case, the choice of the objects used and the substances from which they are made is essential: the company uses leather coverings and thus plays on a whole range of sensations – cold, warmth, quality, softness, durability.

Touch remains an important factor even in computer games played in a virtual environment. In the new Nintendo DS video game remote control, this marketing tool has been fully integrated. The developer company used a touch screen, a simple contact of players' fingertips with which can change the course and plot of the game. The motto of the innovation – "power at the fingertips" – made it possible to combine the TV and Internet in the development. This invention was also widely spread in cell phones and tablet computers.

Tactile sensations at the point of sale. The tactile aspect is also present at the point of sale. When selling goods, it is necessary to use substances and objects pleasant to touch, such as shopping carts, fitting room curtains, etc. It is also necessary to give consumers the opportunity to rest, to sit down; if the store has allocated a place to rest, installed soft and comfortable chairs or benches, customers will want to go back there again. Thus, the French chain of perfume and cosmetics stores "Séphora", for example, uses a soft red carpet, which creates additional comfort for consumers. Comfortable coverage encourages them to spend more time in the store, walking around and looking at the exhibited goods. In the "Apache" store, in the exhibition of goods created for children aged 3 to 12 years, all products are located low so that children can touch them themselves. For children, touch is of primary importance, it is emotionally very active and dominates over other feelings, so the importance of touch, the ability to hold the goods in person, feel their texture, plays an important role for young customers.

Olfactory stimuli. A person has 10 million olfactory receptors, and can distinguish up to 4,000 pairs of different scents. Smell is a sense that undoubtedly remains one of the most amazing ones. The role of smell today is highly appreciated not only by specialists in the perfume industry, but also largely by marketing practitioners. Perfumes and scents open up new creative horizons for marketing, both at the level of the product itself, as well as at the point of sale and in general communication. The inclusion of sense of smell in marketing research implies a real rethinking of the role of collection and training, memory and excitement in consumer behavior. From a psychological point of view, smells directly affect digestive and sexual systems, as well as emotional behavior in general. In the beginning, smell causes excitement. Sensing a smell, a person experiences various emotions expressed in mimics, exclamations of pleasure or disgust, and other external manifestations.

First in the 1920s, and then again in 1970-1980s, researchers described the physical changes that occurred in humans immediately after smelling some volatile oils and proved what calming or energizing result certain oils and their mixtures have.

There are internal processes and internal mechanisms that explain the impact of scents on the individual, and these include:

Perception: perceiving and interpreting the subject, starting with the sensations. It should be noted that there is no generally accepted developed olfactory codification, as a rule, only the individual's olfactory experience can be interpreted.

The process of learning olfactory stimuli is a very personal process, for smells there are no absolute gauges and boundaries, because there is an infinite number of fragrance shades, and not all of them can naturally be within the reach of a particular person.

Olfactory memory and the process of memorizing is associated with excitement. The scent requires an accompanying association that favors its entry into the memory and

further storage. Therefore, every time a new smell is perceived, the initial association arises, which, in turn, recalls the existing scents from the memory, and a new smell will either be assigned to a group or, with its association, placed in the long-term memory of the individual.

Subsequently, the anxieties experienced by the individual, as well as the associations related to them, will trigger a scent from his memory, and vice versa, the smell may trigger the anxieties and associations related to it.

Effect of olfactory stimuli on consumption. People will perceive smell much earlier than they can distinguish colors, sounds, or even different designs. In some primitive societies, a scent has been a powerful means of communication.

Since 1990, there has been a growing focus on research of the olfactory function in marketing. In general, research on smells has started relatively recently, mainly in the United States. Studies of the influence of the only present olfactory stimulus have shown that there is a positive relationship between the existing smell and the evaluation of perfume products. The following positive effects of pleasant environmental scents on consumer behavior can be observed: brand evaluation and memorization; evaluation of the store and some of the products available; intentions of a new visit to the store; intentions to purchase; a re-creation of impressions from a previous visit to the store that is almost a really perceived experience; excitement experienced at the point of sale.

There are olfactory characteristics of goods that affect consumer behavior. The smell is naturally invisible, but can sometimes give rise to the consumer's physical choice, of which he is not aware. In some cases, the smell has an impact on the disturbances being experienced, on relationships being built or existing, and even on the behavior of individuals. There has been recorded a negative impact of unpleasant environmental odors on mood, on the situation assessment by various individuals who have described or orally expressed their feelings. Some studies have shown the importance of associating a scent with signals received from other senses. It has been confirmed that a scent amplifies the message with which it is associated, as if to deepen its meaning, and also influences the appropriate assessment of the perfume by linking it to an individual's previous olfactory experience.

11.3. Reflexive management in motivating corporate social responsibility of a company

Processes of international cooperation today intensively affect spheres of people's life. The problem of the global increase of requirements to the quality of human environment finds its solution in different activity areas of the world community, on macro and micro levels, in public and industrial sphere, in transnational corporations and individual companies. There are various ways to involve companies and organizations in solving the problem of social welfare – from direct (or indirect) government regulation to various social insurance systems. They all involve some social obligations of companies to society. However, international experience shows that better results in social protection can be achieved through social partnerships – voluntary cooperation among the state, the employee, and the company. One of the practical approaches in the process of social partnership implementation, adopted at the level of the world community and successfully implemented in national and corporate structures, is the concept of CSR – corporate social responsibility.

The purpose of creating this document at a high international level – the global concept of the UN – is to motivate business structures of various levels to participate in creating a comfortable social environment for both the population and company personnel. Initially, the task was to create a mechanism that would streamline the corporations' activities on social investing and allow assessing and controlling these activities. Today CSR has become one of the main areas of coordinated cooperation among the government, corporate and public institutions to implement the concept of the welfare state. To promote the CSR concept successfully, it is necessary to develop an effective motivational mechanism that would allow involving not only large national corporations, but also individual large and medium-sized companies.

It should be noted that the very concept of CSR implies voluntary participation of organizations in solving social problems. However, the question arises: how to encourage company management to voluntarily invest in the social sphere? This is not a one-time initiative, but a systematic, controlled and accountable activity: companies implementing CSR programs are required to submit annual reports. This is especially true for countries with a complicated economic situation and complex interactions between business and government agencies. Perhaps, one of the options to resolve this contradiction is to introduce the principles of reflexive management into the mechanism of interaction among the state, the company and public institutions. For this purpose, let us define the place and capabilities of the reflexive approach in the process of managing the company's CSR motivation.

One of the important factors for successful business development today is the organization's image. Brand management specialists note that a positive image allows increasing the market value of the company, attracting the best specialists, increasing the efficiency of marketing activities. That is why the activity on image building and preservation is always included in the strategic plan of companies' development. Let us reveal the elements of the company's image: 1) management image; 2) personnel image; 3) social image; 4) product (commodity) image; 5) corporate culture; 6) corporate identity; 7) a business component of the organization's image.

In order to manage the companies' motivation in the field of CSR, first, it is necessary to analyze such an image component as the social image. It comprises a set of beliefs of the public and various social groups about an enterprise (firm, organization). The social image can be formed by introducing into the minds of people in target groups the concepts of social goals and the role of the organization in the economic, social and cultural life of society. In this case, we get a reflexive interaction of three subjects: the government, the company, and the society, which is presented in Fig. 19. The diagram shows that the company, while trying to build its positive image, attempts to influence both by information flows and by reflexive influence. On the other hand, in order for the company to make decisions corresponding to the interests of the government and society in the sphere of social responsibility, the government may try to influence the company reflexively.

In order to develop an effective reflexive impact, it is necessary to design an adequate reflexive model of managing the companies' motivation in the field of CSR.

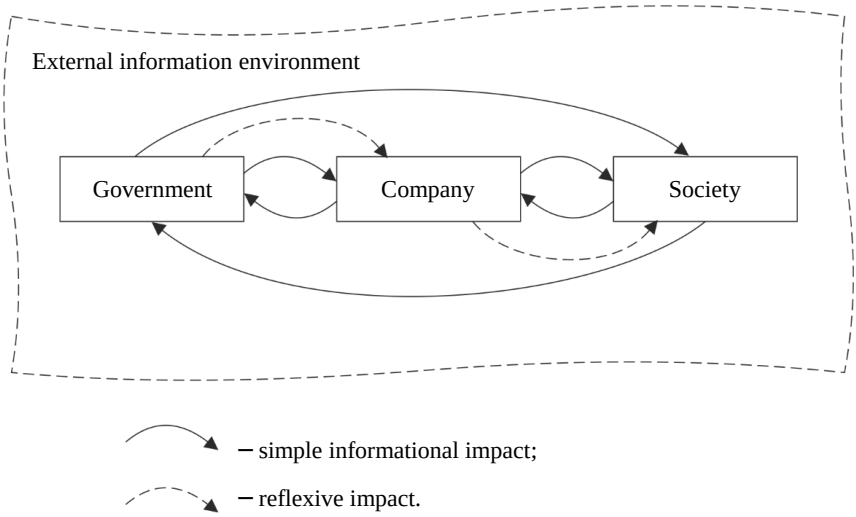

Figure 19. A Scheme of Information Interaction in the Process of Managing Companies' CSR Motivation

Reflexive management in the process of motivating companies in the CSR sphere includes the following main elements:

- studying and accounting for the objects of reflexive management, namely, companies potentially capable of implementing CSR principles in their activities;
- studying the companies' motives in the sphere of social activity;
- research and analysis of social sphere problems, identification of the main directions to be addressed by the objects of reflexive management;
- research and analysis of all alternative ways to solve the identified social problems; identification of the most effective ways to motivate companies to engage in CSR activities.

In the process of studying companies potentially able to implement CSR principles in their activities, the structure of businesses' behavioral reactions to various methods of impact is determined. Companies' activities in the sphere of charity, social assistance and past experience of social partnership are studied. Before launching the process of reflexive management, the government should study the object of management and its behavior model.

The key issue in the companies' information management is to study the potential partner's motives in implementing CSR principles. Within the framework of motives analysis, typical reactions, stereotypes of company managers' behavior (thinking stereotypes) are studied, which allows forecasting the behavior characteristics of certain groups of companies for the future and conducting an adequate motivational policy.

The purpose of the research and analysis of social sphere problems is to identify areas of the most effective application of companies' CSR efforts. At this stage, it is necessary to

determine the capacity of the "social responsibility market", the limits of CSR, and the criteria for optimal CSR. If the market is oversaturated, there is no need for new participants and activities – there may be a backlash, i.e., a balance is needed. Certain restrictions are imposed by the socio-cultural characteristics of the country: different criteria/ boundaries of social responsibility have historically been established for different types of society.

One of the important aspects of motivating companies to engage in CSR is the study of all alternative ways to solve the social problems identified. It is logical to assume that any problem can be solved in various ways, and the company will choose the least expensive of them. In order to motivate company management to implement CSR principles, it is necessary to investigate alternatives in advance and identify their strengths and weaknesses for all social partners.

Based on the collected and processed information, a set of models and methods of reflexive management of companies' CSR motivation is created. The government and public organizations are tasked with implementing several measures to interest companies and encourage them to implement CSR principles in their economic and social activity.

The main goal for the government is to involve the company in CSR activities, and the criterion for achieving this goal, in this case, will be the company's compliance with CSR principles. For the company, the main goal is to make a profit, and the criterion will be to maximize the latter. Each of the social partners has its own vision of the current situation, i.e. their information spaces are different. Partners also have different methods of achieving their goals.

Thus, we have found out that in the current economic situation, it is not enough for companies to achieve success just by production or organizational improvements, as the most important component of success today is a positive image of the company. One of the ways to improve the company's reputation in the market may be the CSR activity. Such activity may be considered as a basis for social partnership between the government, business and society. The reflexive approach can be used to persuade enterprises to implement CSR principles. For this purpose, a reflexive model of CSR motivation management has been proposed.

Chapter 12. A moral dimension of reflexive management

Considering the issues of reflexive management, one cannot but address the moral aspect of this process. Reflexive management, in its essence, is an implicit involuntary orientation that deprives the subject, making his choice, of his freedom of choice, rigidly leading to the desired solution, while maintaining the belief that the choice is free.

Besides, in some cases reflexive management was considered as managing the opponent's decision in conflict situations. Any deceptive movements, provocations and intrigues, disguises, shenanigans, creation of false objects (and, in general, lies in any context) are implementations of reflexive management. Any technique applied on its own can be easily detected. But if they are applied in combination and so subtly that the methods replace each other continuously, and the intensity remains at the perception boundary all the time, almost one hundred percent precision of manipulation is achieved with its complete discreetness.

Thus, the key word – manipulation – has been pronounced. For centuries, people have been and still remain the object of manipulative influences. Manipulative influences on an individual, on his beliefs and emotional-volitional sphere, on individual, group and mass consciousness are the tool of psychological pressure with the purpose of obvious or latent inducement of individual and social subjects to decisions, and consequently to actions, to the detriment of own interests in interests of individuals, groups or the organizations carrying out these influences.

It should be noted that interest in studying the mechanisms of manipulative influences has persisted for many decades. Two main contexts prevail. The first is psychological and psychiatric. The leaders here are E. Shostrom and E. Bern. Both of these authors are focused on psychotherapeutic practice and do not look deep into the mechanisms of manipulation. The second context is political and ideological, describing, first of all, the informational and propaganda arsenal. G. Schiller, the author of "Brainwashing", for example, focuses on brainwashing techniques, which is what the mass media are actually doing.

The original sense of the term itself – manipulation – contains a negative, provocative context. Certain types of manipulative impacts (be it blatant propaganda or sophisticated PR activities), addressed to the population as a whole or addressed to specific individuals, social strata and groups, political parties, and movements, can seriously disrupt the normal functioning and vital functions of social institutions, government structures, public organizations, citizens' associations, and individuals.

These influences should be qualified as negative because they cause psycho-emotional and socio-psychological tension, distortion of moral criteria and norms, moral and political disorientation and, as a result, inadequate behavior of individuals, groups and masses. Summing up, we can come to serious consequences – deep transformations of individual, group and mass consciousness, changes in the moral-political and socio-psychological climate in society.

Manipulative influences are the core of reflexive management. If in 1967 V.A. Lefebvre placed this core in the context of decision-making in a conflict, today reflexive management has a broad political and socio-cultural meaning. Lefebvre describes it in the following way: "Reflexive management is an informational influence on objects for the

description of which such notions as consciousness and will should be used. The objects of this kind are both individuals and associations of people: family, group, strata, nation, society, civilization. The term "reflexive management" can be understood in two ways. First, as the art of manipulating people and associations of people. Second, as a specific method of social control".

Reflexive management is the influence on subjects, inducing them to make decisions prepared in advance by the managing party. Lefebvre distinguishes four types of reflexive management:

- manipulation through influence (direct influence);
- manipulation by changing relations (among individuals in a group);
- manipulation with the order of significance;
- influencing the unconscious sphere of subjects.

As it has been shown by practice, the Chinese stratagems and the life of literary heroes, manipulative technologies are most often based on lies and deception, on the desire to fool the other party, naturally, the question arises about the moral assessment of one or another manipulative influence.

Perhaps, one of the main merits of V. Lefebvre was that he had been the first to pay attention to the need to record the moral dimension of a man in precise scientific terms and at the same time to abandon the idea of a man as a purely rational (pragmatic) creature. He developed the concept of moral consciousness, which includes the evaluation mechanism "good vs evil" in evaluating the situation. It is through this mechanism that psychological phenomena are generated, which we realize as feelings of guilt, compassion, condemnation and the like, and thus important sources of internal motivation for human actions.

The question of whether it is possible to deceive others to achieve a certain result and, at the same time, to remain a moral person in their eyes and the eyes of society, is not so simple. For example, for children, the use of social intelligence in the form of deception of an adult is a necessary prerequisite for the emergence of free moral choice and the subsequent emergence of internal moral motivation. At the same time, for adults, the use of social intelligence in the form of deception and manipulation does not contradict morality, if such application is aimed at achieving the benefits of others and is aimed at countering evil. It seems that such formulations look deliberately abstract. Resolving such moral dilemmas seems to require a more subtle distinction between the original assumptions – different ethical systems.

Conclusion

Dissociation of theoretical knowledge about reflection is a general scientific problem, and this mismatch is manifested at two levels: interdisciplinary, where each science explains it in its own way, and intradisciplinary, where different positions compete within the scientific branch.

This leads to the objective need to systematize scientific knowledge about reflection and to update the theoretical foundations of reflexive management. Studying the problems of management from the viewpoint of the reflexive approach makes it possible to assert that in economics any "viable" system has an internal potential for self-development, which becomes possible only when management parameters change.

Today, it is necessary to make a qualitative transition to new managerial thinking and consciousness – to a new managerial paradigm: the basis for self-development. It is a reflexive process, and each reflexive conclusion is a step of development; nevertheless, the resource potential of the economic agents' reflexive component is often not recognized as topical and not perceived as real sources of production systems' efficiency.

Since reflection is all-pervasive, reflexive management is not a specific type, but an archetype of modern management as such in all its completeness and diversity. The phenomenon of reflexive management is revealed through analyzing two interrelated contexts: reflection as a general scientific category and the modern managerial paradigm. The fundamental condition for this transition should be reliable scientific and theoretical knowledge in its unity with practical world experience.

This book is focused on systematizing knowledge of the theoretical and applied foundations of reflexive management. Integrating the models of information and strategic reflection, i.e., building a language of uniform joint description of information and reflexive structures, can be called a strategic task of future studies.

It should be noted that the conceptual directions, modeling, and applied aspects proposed in this work are not yet harmonized into an integral and complete theory of reflexive systems in economics, but they are an important unifying step in the system of forming the mainstream of economics.

The scientific arguments described in this paper are intended to serve as a certain theoretical guideline for further practical implementation of the theory of reflexive management.

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