

# Analysis of the Principle of Multiagent System Functioning in Assessing the Effectiveness of Regulatory Legal Acts

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**Abstract** — Despite economic and legal measures that have been taken by the state in recent years, effective regulation of many economic processes is at the stage of formation. Absence of adequate economic policy and creation of balanced legislation regulating these processes impedes sustainable economic development of both the regions and state as a whole. It is possible to solve the problem through natural science methods in the Humanities, as well as new approaches to assessing the effectiveness of current legislation regulating economic processes, by means of its mathematical modeling. There is a need to develop a methodology for modeling multi-agent systems as a tool for assessing the effectiveness of regulatory legal acts restricting socio-economic processes. The study analyzes multi-agent system functioning as a tool for assessing the effectiveness of regulatory legal acts, it presents the participants of legal relations as agents characterized by a certain model of behavior, pursuing different goals in content, leading to a conflict of interest, but being able to integrate into systems that jointly solve complex problems. Using the above strategy of agents synthesizing, it is necessary to take into account the ability of agents to perceive and process inaccurate, fuzzy and contradictory information, which the current legislation represents. The authors conclude that the participants of administrative relations are characterized by centralized multi-agent system functioning, with a coordinator who manages all agents and coordinates their actions by creating legislation trying to keep the status of internal and external environment in balance. The quality of decisions of a large initial problem should be evaluated using some global function, the value of which depends on local decisions of the agent, often in a rather complex way. In particular, such a function can be a vector one.

In the end, based on the behavior of agents of the system, it is reasonable to build a payoff function and find the so-called "equilibrium point" (Nash equilibrium). When constructing the current legislation in the suggested format, most of the problems of regulatory enforcement will disappear spontaneously, because another model of behavior of agents will not be beneficial to them.

**Keywords:** *game theory, multi-agent systems, subjects of law, efficiency of regulatory legal acts, payoff function, legislative imbalance.*

## I. INTRODUCTION

Despite the economic and legal measures that have been taken by the government in recent years, in the regions effective multi-layered economy is still being formed. Absence of adequate economic policy and creation of balanced legislation regulating these processes impedes sustainable economic development of both the regions and state.

There is a need to develop a methodology for modeling multi-agent systems as a tool for assessing the effectiveness of legal acts regulating socio-economic processes at both the federal, and regional levels.

It is possible to solve the problem through natural science methods in the Humanities, as well as new approaches to assessing the effectiveness of current legislation regulating economic processes, by means of its mathematical modeling. Unfortunately, most studies on sustainable economic development do not take into account the problems of legislative imbalance, which does not resolve the arising contradictions in public relations, and leave mathematical models in law without adequate consideration.

Participants of legal relations performing their functions pursue different goals. The legislation is aimed at resolving the contradictions arising between different groups of society, which are parties to the relationship. To describe this situation is possible through mathematical game theory, however, it requires consideration of several theoretical questions: description of payoff functions, description of possibilities of cooperation, identification of external and internal factors affecting the behavior of system agents. It is worth noting that qualitative solution of these problems requires knowledge of legal norms. Constructing payoff

functions requires methods of statistical analysis, as well as optimization methods.

## II. MATERIALS AND METHODS (MODEL)

The construction of multi-agent systems is one of the fundamental and scientifically based research methods. Analysis of multi-agent system functioning is one of the most important and promising areas of society development. This situation is determined by the increasing complexity, spatial distribution of the studied phenomena. The multi-agent approach is used to study processes in which the monolithic and strictly hierarchical structure of the system constantly faces certain problems. In economic processes modeling, optimization modeling dominated previously, with strict subordination of individual economic entities to the general will expressed by some center, but now there are more and more widespread decentralized models with divergence of interests of economic entities and selfishness of their behavior. To identify a group of multi-agent systems and study further its properties is a promising method of study.

However, many models constructed using the agent approach are purely simulation, and the algorithms of their functioning are purely heuristic. One of the key tasks of theoretical justification of their effectiveness and detailed analysis of their behavior still remains unsolved. This situation emphasizes theoretical and practical significance for further study and analysis of multi-agent systems functioning, forming new approaches, defining new groups and development of the means of their descriptions, research, techniques and methods, as justifying the use of existing systems and defining direction of improving them and creating new systems with certain properties [1].

In the study, when analyzing multi-agent system functioning as a tool for assessing the effectiveness of normative legal acts, participants in legal relations can be represented as agents characterized by a certain model of behavior, pursuing different goals in their content, leading to a conflict of interest, but having the property to integrate into systems that jointly solve complex problems.

## III. RESULTS AND DISCUSSION

Participants of legal relations are persons connected among themselves by subjective rights and legal obligations. In terms of legal language, they are called subjects of law.

In the course of any activity, they perform certain actions, pursuing their specific goals, while coming into contact with other participants in legal relations, pursuing their own goals. Thus, each participant of legal relations, achieving the purposes, is compelled to consider interests and possible acts of other participants of legal relations, sometimes choosing the partners with similar interests and cooperating with them.

This is what the game is an attempt to achieve their goal by having multiple participants interacting with each other with opposite, sometimes close, but almost never identical goals.

Scientists always mentally divide complex diverse phenomena and interactions into small links (elementary

particles), analyzing the work of these small links, and then try to understand by what laws the whole chain is assembled from these small links [2]. With such a simple link of interaction with conflicting interests, we begin our discussion of games in our study.

It will be a game of several participants of legal relations participating in it as agents. We consider construction of a multi-agent system by the example of administrative law subjects.

A subject of administrative law is a natural person (an individual subject) or an organization that can be participants in administrative-legal relations, i.e. endowed with specific rights and obligations contained in the norms of administrative law, implemented both at the will of the subject and at the will of other subjects. This concept takes into account all main features of subjects of administrative law: 1) it is a natural person or organization; 2) they are endowed with the norms of administrative law, relevant rights and obligations; 3) these rights and obligations can be granted and implemented at the request of the subject, and against his/her will.

In addition, such subjects of law as the state, subjects of the Federation, municipalities have a special status. Therefore, it is reasonable to combine them into an individual group [4].

In our study, to build a multi-agent system, we will unite the subjects of legal relations into certain groups pursuing different interests.

A state is a political form of society organization in a certain territory, a political-territorial sovereign organization of public power, possessing the apparatus of management and coercion. In this paper, the Russian Federation is considered as a state.

Public authorities are executive bodies endowed with certain powers (competencies) in relation to other subjects, performing functions of the state.

Legal entities are organizations that have separate property and are responsible for their obligations, they may acquire and exercise civil rights and bear civil obligations on their behalf.

Natural persons are individual subjects of legal relations that include citizens of the Russian Federation, foreign citizens and stateless persons [4].

Basic properties of multi-agent systems behavior are borrowed from the technical sciences [5]. With some degree of conditionality, research of constructing the desired function (desired status) of multi-agent systems in the analysis of their functioning in order to assess the effectiveness of regulatory legal acts can be divided into the following main areas:

- theory of agents – in relation to the behavior of subjects of law we will consider formalisms and mathematical methods to describe the payoff function and to express desired properties of agents, as well as analysis of dynamic aspects of functioning of both the individual agent and their community;

- methods of agents cooperation (organization of cooperative behavior) in the process of joint problem solving or in any other variants of interaction (in the event of certain relationships between the subjects of law);
- the architecture of agents and multi-agent systems – which is the process of building a system that satisfies certain properties expressed by means of the theory of agents (social relations, which the subjects of law enter).

The construction of multi-agent systems is a research area that serves to solve complex problems and issues, these systems involve a variety of interacting agents. In practice, multi-agent systems are based on the opposite principle. It is assumed that the agent has only a point representation of the global problem, which means that it can only partially solve the general problem. For this reason, solving high complexity tasks requires organizing a certain set of agents and to establish interaction of increased efficiency between them, enabling a unified multi-agent aggregation. Multi-agent systems have a maximum range of tasks, which are distributed among all agents according to specific rules. Agents are considered as members of an organization or group. Task distribution assigns a role to agents, its complexity can be determined by capabilities of the agent [6].

An agent is an entity that resides in some environment from which it receives data and that reflects events occurring in the environment, interprets them, and executes commands that affect the environment [7].

Several definitions should be introduced in the study, based on the standard understanding of the construction of a multi-agent system, borrowed from technical and physical and mathematical sciences:

Environment is a set of specific conditions, the specifics of which are represented by legal relations of people with each other, their forms of interaction and association due to coming into legal force of a legislative act (as well as on introduction of changes and additions to the current legislation, abolition of legislative act).

Data are information, presentation of facts, concepts or instructions in a form acceptable to the company, in the form of a regulatory document (legislative act).

Coordinator is a legislator, state authority whose powers include the adoption, modification and repeal of legislative acts. In our study, we will equate this term with the concept of "state".

Player is a party to legal relationship (the subject of administrative law).

Game is the interaction of subjects of administrative legal relations in the exercise of their functions (implementation of rights).

Based on the above, the concept of "agent of the legal system" should be formulated.

An agent of the legal system (hereinafter, ALS) is a subject of administrative law (legal entities, state organizations represented by ministries and departments

having influence (exerting influence, exercising authority over other participants who are parties to legal relations), located in the society (some environment), from which he/she receives data (information about current legislation).

Fundamental requirements for the architecture of agents used in the development of multi-agent systems involve:

1) autonomy – ability of ALS functioning without intervention of any other participant of legal relations, at the same time, ALS exercises control over its actions and conditions [8];

2) public behavior – the ability of ALS to interact with other ALS, on the basis of current legislation. This behavior of ALS involves the exchange of information, coordination, approval decisions, etc. The ability of ALS interaction is crucial because in most cases it depends on the ability to ensure the quality implementation of all other properties. It should be noted that the effectiveness of interaction of elements of real systems most directly determines the effectiveness of current legislation and legal system functioning as a whole;

3) reactivity – the ability of ALS to perceive the condition of the environment and respond to its change (adoption of a new legislative act, amendments or additions to the current legislation, repeal of the law, etc.);

4) purposefulness – the ability of ALS not only to respond to the environment status, but also to express initiative, showing purposeful behavior. The set of subjects that form real systems can, in most cases, change over time. The consequence of this is the need to constantly search for new relationships (in particular, legal relations). For example, changing the current legislation is characterized by a constant search for new subjects of legal relations. At the same time, it is apriori unknown with whom such legal relations will be carried out in the future;

5) pro-activity – the ability of ALS to take the initiative, i.e. the ability to generate goals and act rationally to achieve them, and not just respond to external events. In accordance with this, ALS can proactively (on their own initiative) make decisions to perform certain actions, depending on the situation;

In addition to the above properties, agents of the legal system are inherent in several others, the main of which is that ALS has at least some subset of so-called "mental properties", also called intensional concepts, which include the following:

- knowledge – a permanent part of ALS knowledge about themselves, environment and other agents, i.e. the part that does not change in the course of its functioning;
- beliefs – the ALS knowledge of the environment, in particular of other agents; knowledge that can change over time and become incorrect, but the ALS may not have information about it and continue to be convinced that it is possible to base its conclusions on it;
- desires (belief, conviction) – conditions, situations, achieving them for various reasons is desirable for

ALS, but they can be contradictory and, therefore, the agent does not expect that all of them will be achieved;

- intentions – this is what the ALS is either obliged to do due to obligations to other agents ("it" is entrusted to him/her and he/she manages this task), or what follows from his/her desires (i.e., a consistent subset of desires, chosen for one reason or another, and which is compatible with the assumed obligations);
- goals – a specific set of final and intermediate conditions, achieving of which ALS adopted as the current strategy of behavior;
- commitments – obligations in relation to other ALS or tasks that an agent undertakes at other agents' request (assignment) within the cooperative goals or goals of individual agents within cooperation.

The first two of these concepts are called the "position of the agent", his/her "point of view" (attitudes), the rest are characterized by the general term "pro-attitude", the essence of which is that they "direct" the behavior of the ALS in such a way as to make the corresponding term meaningful and formal statements true [9].

Using the above strategy of synthesis of ALS, it is necessary to consider the ability of agents to perceive and process inaccurate, fuzzy and contradictory information, which is the current legislation, often representing legislative imbalance in its content.

Russian legislation is currently a huge legal and regulatory body, in which vertical and horizontal links are intertwined, with acts differing in level and legal force that have been adopted and are functioning in parallel, and there are processes of specialization and unification that are opposite in nature. In such a situation, legislative imbalance is almost inevitable. In legislation, the concept of imbalance covers such characteristics as inconsistency, asymmetry, incoherence, tautology, imperfection of legal technique, etc. [10]

In practice, one of the two main models of multi-agent systems are implemented:

- decentralized multi-agent system, also called the system of equal agents (figure 1);
- centralized multi-agent system (figure 2) [11].

When analyzing multi-agent systems, we should introduce conditional symbols denoting the participants of legal relations (subjects of law):

- Agent of legal system 1 (ALS1) – coordinator (state);
- Agent of legal system 2 (ALS2) – public authorities;
- Agent of legal system 3 (ALS3) – legal entities;
- Agent of the legal system 4 (ALS4) – natural persons.

In a decentralized multi-agent system, all ALS interact with each other without participation of a coordinator, while maintaining relationship with external environment.

The ALS of such system interact through information exchange, and / or their interaction is indirect, when the ALS do not exchange information directly, but perceive the presence of other ALS through changes in the external environment that the agents perceive, and they affect.

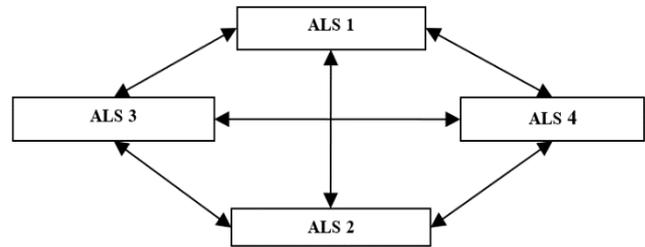


Fig. 1. Decentralized multi-agent system

A decentralized multi-agent system comes into balance without involvement of a coordinator. If such a system comes into balance (self-organizes), then this system suits all participants in legal relations.

The interaction of ALS determines their collective behavior. The interaction of ALS, and hence their collective behavior, can have a different character. ALS can interact to cooperatively solve some common complex or large-scale problem. In this case, the original task is divided in some way into simpler ones, which are assigned to a separate specialized agent. At the same time, the interaction of the ALS is aimed at coordinating local solutions to achieve some required quality of solving the problem (administrative and legal regulation of any process that suits all subjects of law).

This coordination can be achieved through public administration carried out by a specially designated ALS (coordinator).

If a coordinator is introduced into a decentralized multi-agent system, creating legislation, the system moves to a centralized multi-agent system, the participants of which interact through the coordinator.

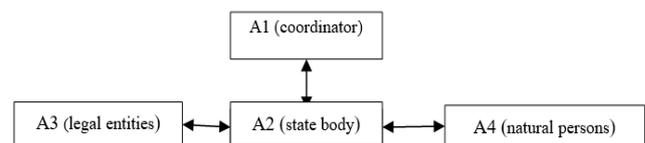


Fig. 2. Centralized multi-agent system

A centralized multi-agent system is characterized by a coordinator who manages all ALS and coordinates their actions by creating legislative acts while trying to keep the condition of internal and external environment in balance.

The quality of solutions of a large initial problem is estimated with the help of some global function (global

utility function), the value of which depends on the local solutions of the [12] ALS, often in a rather complex way. In particular, such a function can be a vector one.

Such behavior of ALS takes place when each subject of the right has the purposes, however, he/she for any reasons is unable to solve a problem independently and therefore is compelled to apply for help of other ALS. For example, he/she may not have the necessary information, and therefore, forced to request it from another (other) ALS. Such interaction of ALS should be attributed to cooperation. In such tasks, collective behavior of ALS is determined by some additional agreements between ALS, which are called mutual obligations (commitments). Mutual obligations of legal entities may meet different levels of obligation to perform them. There are three types of ALS associations related to mutual obligations:

- alliance, when mutual obligations of ALS are relatively weak; in this case, ALS "help" each other not to the disadvantage of their own interests (representatives of such "alliance" can be individuals and legal entities);
- coalition, when ALS unite in groups with enough "strong" mutual commitments, typically, to help each other "to survive" in conflict situations with other ALS and / or their coalitions. Coalitions within the system of administrative legal relations include informal associations of individuals. Coalition agents usually do not have a common goal, each of them has its own local indicator to assess the quality of achieving their goals, as well as clearly defined conditions that determine when and how they help each other;
- team - if a group of ALS solving common task functions as one agent. While none of the ALS pursues their own global objectives, different from the goals of society; at the same time, the local goal of ALS is aimed at achieving a common goal [13], i.e. at forming a system of legal relationship regulated by administrative law and mutually beneficial to all entities. Such teams can be public (self-regulatory) organizations, public associations of citizens, public institutions, etc.

Another type of ALS interaction occurs when legal entities compete. In this case, each ALS has its own purpose and is self-interested ("selfish").

Further, it is necessary to identify one more model of ALS interaction among themselves, without submitting to rules of the coordinator (the legislation). The goal of the coordinator is to preserve the equilibrium system.

The coordinator can change behavior of ALS system by changing its impact on them (introduction of a new law, amendments and additions to the current legislation, repeal of the law, etc.).

Through this influence, the coordinator regulates the interaction between the ALS of the system up to the complete exclusion of such interaction.

A multi-agent system can initially be centralized. At the same time, the goal of the coordinator is to preserve the

equilibrium system, which is not always possible. In this case, there is a conflict of interest between the ALS in legislative imbalance. Thus, there may be interaction between system agents bypassing the coordinator (figure 3).

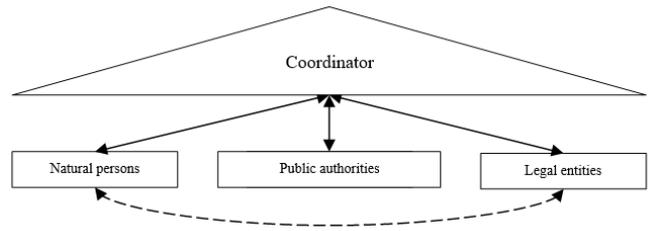


Fig. 3. Centralized multi-agent system interacting with ALS<sub>3</sub> and ALS<sub>4</sub> without coordinator

This status brings the whole system out of equilibrium. Within one system there are two autonomous subsystems.

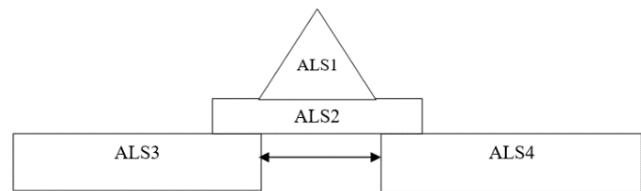


Fig. 4. Subsystems of legal multi-agent system

Both the coordinator (state) and ALS 2 (public authorities) do not benefit from such system condition (ALS behavior model), so they can begin to influence other agents of the legal system through creation of new or transformation of existing legislation, use coercive measures against agents, etc. Thus, the coordinator tries to achieve his/her main goal, i.e. bringing the system into equilibrium, because this equilibrium is beneficial to him/her [14]. However, this position of the coordinator may not be beneficial to other agents of the system, so, pursuing their goals, that often do not coincide with goals of the coordinator they begin to form their model of behavior, trying to "retreat" from coordinator's influence (violate the law, try to "circumvent" the law, using legal methods, go into the "shadow", etc.).

The current situation brings out of balance the entire system of law functioning for the following reasons: the rule of law as a whole is not effective, all norm-making work of the coordinator as a whole is not effective, the costs of creating legislative acts and regular amendments and additions to them exceed the economic effect of the coordinator from their application, corruption manifestations appear, shadow economy develops, etc.

#### IV. CONCLUSION

The results of the study indicate that mathematical modeling in law, the construction of multi-agent systems and the game theory are one of the most promising areas in the analysis of the legal system of society. When developing legislative acts, the state (coordinator) should take into account the goals of each subject of legal relations, since not always strict compliance with the legislation can be

beneficial to all agents of the legal system pursuing different goals in the exercise of their functions (legal relations).

Jurisprudence is a wide field for formalized, abstract-scientific methods of thinking, methods of mathematical apparatus, enabling us to find unambiguous, accurate solutions.

In the end, based on the behavior of agents of the system, it is reasonable to build a payoff function and find the so-called "equilibrium point" (Nash equilibrium). When constructing the current legislation in the suggested format, most of the problems of regulatory enforcement will disappear spontaneously, because another model of behavior of agents will not be beneficial to them. When constructing the payoff function, it is quite logical to have a detailed analysis of each agent behavior in the legal system on "receiving benefits – neutral position – lack of benefits", which will be reflected in subsequent studies of the authors.

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