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The Experimental Model of Procurement in Public Administration

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Abstract*: Public procurement has two main objectives. On the one hand, competitive procedures are designed to ensure maximum efficiency in meeting the needs of budgetary institutions, on the other hand, cost savings are in the vast majority of cases the main criterion for the effectiveness of purchases. Actual is the development of tools that would allow for scenario-based modeling of procurement using economic-mathematical, in particular imitation, experimental models. The purpose of the study was to develop an experimental model that allows to increase the effectiveness of the contract system in the field of public procurement of goods, works, services through reengineering of processes related to procurement activities and conducting scenario experiments. The proposed experimental model with the help of the developed interface allows you to visually monitor the progress of its implementation, and also allows to conduct a series of experiments to test the model in the implementation of various options for effects on the contract system in the procurement.

***Keywords* : Experimental Model, Procurement, Public Administration.**

I. INTRODUCTION

Currently, public procurement is carried out in the country, taking into account one of the main principles - the principle of efficient use of budgetary funds, which is observed through the procurement of goods, works, services of the best quality at the lowest possible cost. Public procurement has two main objectives. On the one hand, competitive procedures are designed to ensure maximum efficiency in meeting the needs of budgetary institutions, on the other hand, cost savings are in the vast majority of cases the main criterion for the effectiveness of purchases [1-3]. In this regard, it seems that its improvement in terms of supporting procurement participants embedded in the production chains of manufacturing high-tech products will improve the functioning of entities capable of performing a full cycle on their territory [4-6].

It seems relevant to develop tools that would allow scenario-based modeling of procurement using economic-mathematical, in particular imitation, experimental models. Currently, studies are gaining relevance, allowing to obtain a quantitative assessment of the results of the functioning of complex and dynamic socio-economic systems. One of the most modern and promising tools for analyzing the behavior of complex systems is a new class of simulation models, called agent-based modeling.

A key feature of this approach is that the agent-based model allows you to simulate a real system with any level of detail, and the only limitation of this tool is the computing power and performance of computer equipment. In addition, it is worth noting the flexibility of this approach, since the created "model core" is easily amenable to further improvement and refinement, and also allows the introduction of promising technologies in the model, such as, for example, geographic information systems and supercomputer modeling.

Despite the high involvement of the scientific community in research [7-10] related to public procurement, ways to solve some of the key problems of the contract system are currently unknown. So, for example, on the one hand, the procurement of goods, work, services should be carried out on a competitive basis, which is fully consistent with the economic theory in terms of achieving an efficient allocation of resources and ensuring competition between procurement participants in order to save budget funds [11-12].

On the other hand, the empirical material obtained during the procurement process indicates that the developed procedure for conducting competitive procedures very often not only does not lead to effective decisions, but also forces them to make purchases that are obviously ineffective in economic terms. So, in modern realities, "quality" and "saving" often turn out to be incompatible in the procurement of goods, work or services. When conducting purchases in which the only criterion for determining the winner is price, the greatest savings are achieved. However, in practice, often procurement participants become winners precisely due to the low quality of the delivered goods, work performed, or services rendered.

The purpose of this study is to develop an experimental model that allows to increase the effectiveness of the contract system in the field of public procurement of goods, works, services through reengineering of processes related to procurement activities and conducting scenario experiments.

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II. CONTRACT FORM OF PUBLIC PROCUREMENT

The ability to model large socio-economic systems that can take into account a large number of complex interactions between their entities is due to the emergence and development of computer tools.

The procurement contract system as an element of the public administration institution is one of the tools for optimizing budget expenditures. It is important to note that the system of rules laid down in the contract system allows us to consider it as a new independent institution. Since the procurement of goods, work, services is one of the highest priorities of government, world practice shows that there are various approaches to the formation of the contract system.

The main principles of the contract system include (Fig. 1).

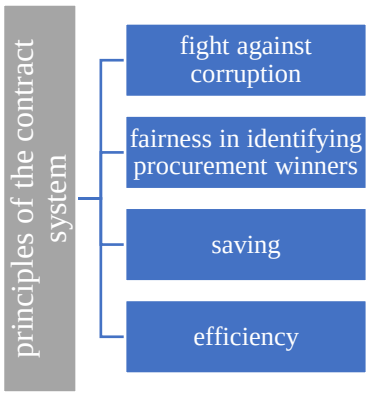

Fig. 1.The main principles of the contract system.

At the same time, the determination of suppliers and contractors is ensured through procurement procedures such as quotation requests, tendering, conclusion of framework agreements for the supply of homogeneous products, competitive negotiations, etc.

An important feature of procurement is their centralized nature, which is achieved through the functioning of a specialized organization – the General Services Administration. The advantages of such a centralized approach include the reduction of total procurement costs due to the organization of large deliveries of consignments of required goods, works, and services. Nevertheless, the state supports small businesses and entrepreneurship by providing certain advantages.

In addition, the implementation of competitive procedures is governed by a single methodology: the description of the subject of procurement is allowed only using standard specifications, and contracts must be concluded in accordance with the standard form.

III. AGENT-BASED APPROACH TO MODELING THE PUBLIC PROCUREMENT SYSTEM

From the point of view of agent interaction, it is worth highlighting the following types of agent-based models:

• models of direct interaction;

• indirect interaction models. Below is a classification of the currently existing models of agent interaction (see Fig. 2), which systematizes prospects and issues from a conceptual and technical point of view related to this area.

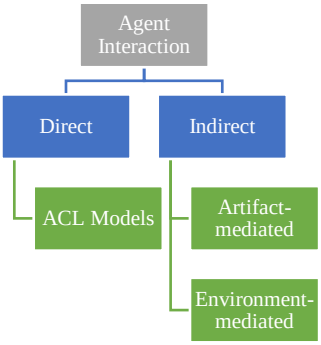

Fig. 2. Classification of agent interaction models.

To assess the effectiveness and adequacy of various management decisions, as well as their successful implementation, applied research, combining various methods of economic and mathematical modeling of complex systems, allowing to conduct a system analysis of the studied object and obtain a quantitative assessment of the decisions, is becoming most relevant.

However, when choosing an approach to modeling the public procurement system, it is necessary to take into account the boundaries of application and limitations of the tools used. So, for example, the classical methods of mathematical optimization are not effective enough for complex multi-criteria problems.

The disadvantages of graph theory include the fundamental impossibility of modeling continuous processes, and existing network models do not have sufficient flexibility with respect to their extensibility.

Econometric methods allow taking into account an unlimited number of factors, but the main drawbacks of the approach include the high sensitivity of estimates to the sharp emissions that are found in the source data and are caused by constantly occurring market changes in the country's economic processes.

Despite the advantages of IDEF0 and BPMN 2.0 notations, which allow us to consider and conceptualize complex business processes from the point of view of functions and interactions, using these tools to model the public procurement system is not enough, since their application does not allow to obtain a quantitative assessment of the results of implementing various management decisions. Predicting the elements of a country's socio-economic system using neural networks "trained" on statistical data seems possible, however, the construction of such networks is possible only if there are arrays of consistent statistical data that cannot be obtained.

The solution of this problem is possible due to the combination of an agent-based approach into a single model and instrumental complex, which is currently one of the most promising approaches to simulation, with IDEF0 and BPMN 2.0 notations.

For further development of the model-instrumental complex, we will dwell in more detail on the features of the agent-based approach, which today is one of the most promising and actively developing tools in simulation. Appearance in the early 1990s.

personal computers, as well as the ability to conduct computer simulations, helped the agent-based approach to be widely adopted and applied.

During its development, agent-based modeling has found wide application in solving a wide range of problems, including:

- optimization of the number of personnel;
- transportation planning;
- development of production;
- forecasting the development of socio-economic systems;
- optimization of the supplier network;
- forecasting sales and demand for products;
- modeling of migration processes;
- imitation and optimization of pedestrian and traffic flows.

The environment in the agent model usually allows you to:

- reflect, specify and manage the structure of the system as a whole in the physical and social aspect;
- implement and maintain regulated access to objects and system elements that are not agents;
- maintain the ability to perceive the received signals and a specific action in accordance with their processing;
- support internal dynamics algorithms (for example, resource growth, signal propagation from other agents);
- definition / compliance with the rules.

So, after justifying the choice of an agent-based approach as one of the tools for the further development of the model-instrumental complex for the functioning of the contract system, we will move on to the specifics of applying this approach and the practical implementation of the agent model of public procurement.

IV. Practical Implementation of the Experimental Model for Public Procurement

A. Methodology

Most often, in the models of direct interaction of agents, the principle of information exchange between agents is used. This approach ignores communication channels that provide interactions between agents, and does not even include it as an element of an abstract interaction model. Typically, such mechanisms provide a point-to-point message transfer protocol that regulates the exchange of messages between agents. There are many methods for modeling communicative acts, but in general, such a protocol in most cases does its job. Although this approach has been well studied and can be effectively implemented (especially since it is mainly used in computer network protocols), it is necessary to develop specific architectural and conceptual solutions to issues related to the familiarity / learning algorithm of agents and ontology in direct interaction models. The agent's intuitive communication language (ACL) provides them with a means of exchanging information and knowledge (see Figure 3).

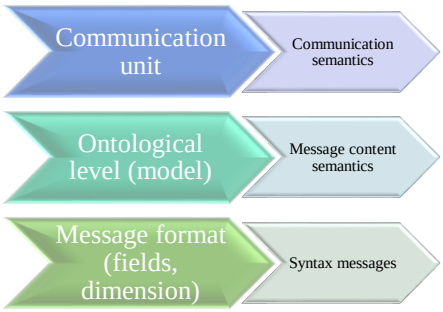

Fig. 3. Layers and departments of the language of communication agents.

While models of indirect interaction generate artifacts for agent interaction, simulating actual concrete objects of the real world, another approach creates an imitation of the agent environment, taking into account its spatial features (see Fig. 4).

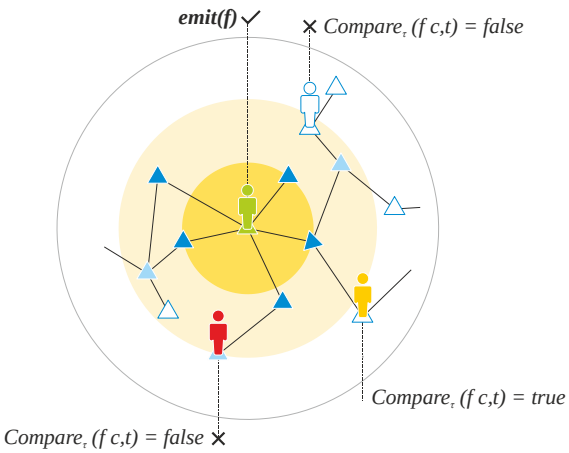

Fig. 4. A simplified diagram of an environment mediated from interactions

In this approach, agents are located in an environment whose spatial features are clearly represented and affect their behavior. The concept of perception, which is abstract in the model of direct interaction and has little in common with the material world (in models, agents have their own "mood", which changes as a result of the data received, which are perceived as new facts in their knowledge base), is associated with more than straight-line modeling, called the "local point of view". In fact, these approaches allow the implementation of infrastructures for communication of agents, allowing them to "feel" the state of the environment (as well as the surrounding area). Agents are also able to change the state of the environment by generating signals similar to physical phenomena (for example, the production of pheromones), or simply by observing the actions of other agents and reacting to them according to the "implicit behavioral communication" scheme.

B. Implementation of the experimental model. Input data.

The developed agent-oriented model is represented by two types of economic agents:

1. type of economic agents No. 1 – customers. The model considers the procurement process by a state enterprise;

2. type of economic agents No. 2 – suppliers.

These agents are generated with specified parameters and perform actions under the influence of the external environment.

Agents in the model using Java code are placed in a geospatial environment, which is specified using a GIS map. Thanks to the support of GIS maps, the model allows you to place agents in a new place, receive information about their current location, move agents to a given location at a given speed, perform certain actions upon arrival, display animations of agents, establish connections between agents depending on their location, etc.

Providers are placed on a GIS map within regions using executable Java code that assigns random coordinates to each agent. The number of suppliers is set manually using the sliders located on the main window of the model.

The customer is located on the map in accordance with the actual location of the enterprise. Implementation of geographic information systems is implemented in the AnyLogic program using OpenMap Gis technology. GIS map in AnyLogic contains a layer of tiles - separately connected images, the number of which depends on the selected scale on the map. The coordinates of the customer agent are loaded into the model from a separately created Excel file.

Reading the coordinates of the agents of the customers (customers) and suppliers (suppliers) populations is carried out using the implemented algorithm - the action diagram (Fig. 5).

Then iterates over the Customers agent population using loops *for (int i = 0; i < nCity1; i ++)*, and *for (int j = nCity1; j < suppliers.size(); j ++)*.

As a result of enumerating all agents using local variables, the suppliers are sequentially placed on the map in two regions – City 1 and City 2:

d1 = suppliers.get(i).setLatLon(d1.getX(),d1.getY());

q1 = customers.city1.add(q1);

d2 = suppliers.get(j).setLatLon(d2.getX(),d2.getY());

q2 = customers.city2.add(q2);

As a result of the Java code execution, the *excelFile.getCellNumericValue* function returns the read numerical value from the cell of the Excel file, the location of which is defined in brackets. The functioning of the customer agent is implemented using the state diagram.

The customer cyclically performs the following operations (Fig. 7).

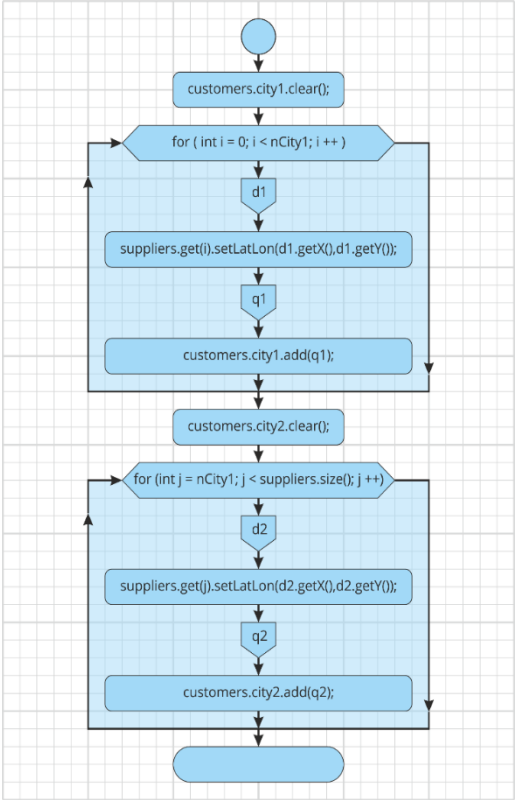

Fig. 5.Activity diagram

The initial parameters of the model are configured on the initial screen (see Fig. 7). At the initial stage, the researcher, using the sliders, indicates the number of suppliers in City 1 and City 2, and also sets the "level of complexity" of the purchase, that is, the possible proportion of suppliers who can submit a quotation request. In addition, the model implements the possibility of carrying out a series of experiments.

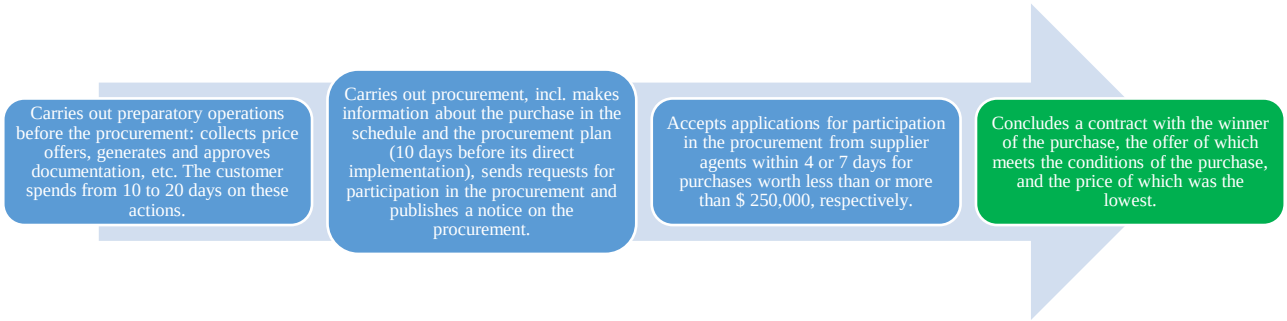

Fig. 6. Customer Status Cycle

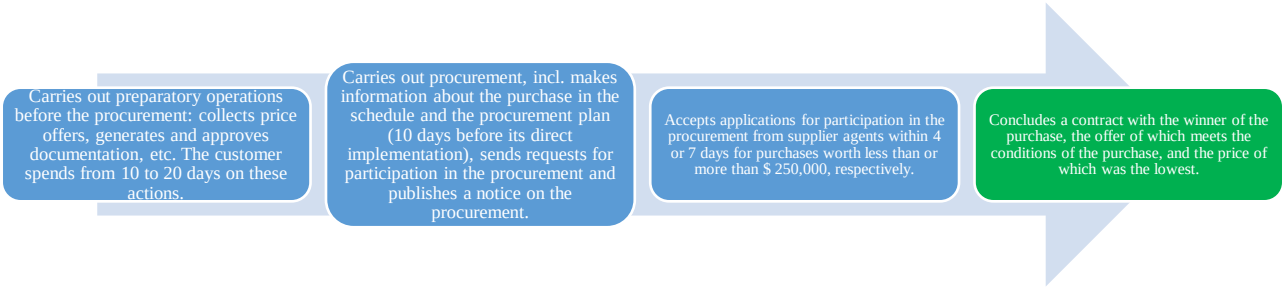

Fig. 7. Customer Status Cycle

The process of executing the agent model can be described as follows:

1. the customer, after concluding the next contract, decides to make a purchase with an intensity corresponding to a uniform distribution over the time interval [a, b]:

$$f(x) = \begin{cases} \frac{1}{b-a}, x \in [a,b] \\ 0, x \notin [a,b] \end{cases} \quad (1)$$

where a = 10, b = 20;

2. 10 days before the start of the purchase, the customer enters in the schedule the relevant information in the UIS, which becomes available for review to all suppliers;

3. depending on the initial maximum price of the contract, the customer accepts applications (within 4 days when making purchases for an amount not exceeding $ 250,000, and 7 days for purchases for more than $ 250,000);

4. suppliers, if they comply with the terms of the purchase, become participants in the purchase and submit applications with price offers;

5. The procurement participant, who submitted the application with the best price offer, becomes the winner and within 10 days concludes a contract with the customer. At the beginning of the model execution, as well as in the case of a change in the number of suppliers during its execution, the position action diagram is triggered, which positions the agents on the map and also fills the collections using the following algorithm:

```
customers.city1.clear();
for ( int i = 0; i < nCity1; i++)
  {d1= City1.randomPointInside();
   suppliers.get(i).setLatLon(d1.getX(),d1.getY());
    q1= suppliers.get(j);
     customers.city1.add(q1);
};
customers.city2.clear();
for ( int j = nCity1; j < suppliers.size(); j ++ )
  {d2= City2.randomPointInside();
    suppliers.get(i).setLatLon(d2.getX(),d2.getY());
    q2= suppliers.get(j);
     customers.city2.add(q2); };
```

As can be seen from the presented code, suppliers are located at random points inside the areas of City 1 or City 2 depending on their affiliation. Counting the participants of each purchase is carried out at each step of the model using the following code:

```
if (nPart! = 1) {
  statVisibility = true; }
else {
   statVisibility = false; }
nPart = count (postavs, p-> p.inState (Suppliers. Member)) + count (Suppliers, p-> p.inState (Suppliers. Winner));
```

The process of determining the winner is carried out using the following algorithm:

```
for (Postav q: main.postavs)
    if (q == top (main.postavs, p -> p.nPrice))
          send ("R", q);
```

So, a procurement participant who has proposed a minimum price offer in his application is sent a corresponding trigger message. At the same time, this operation is performed by calling the top method. Upon transition to the "Contract" state, which corresponds to the "conclusion of the Contract" procedure, the total number of procurement participants is calculated, and the serial number of the supplier who turned out to be the winner of the procurement is identified: status = "Contract"; main.nPart = count (main.postavs, p-> p.inState (Postav. Participant)) + count (main.postavs, p-> p.inState (Postav. Winner)); main.nParticipate.add (main.nPart);

results

The proposed experimental model using the developed interface allows you to visually monitor the progress of its implementation. So, the experiment window contains the following blocks:

1. block charts, which reflects the dynamics of changes in average savings from the procurement procedures and the number of participants in the procurement;

2. An information block containing information on the territorial affiliation of the procurement winners, and also reflects indicators on the current procurement, including its status, serial number, number of suppliers and participants in the procurement, etc.

3. A GIS map on which all agents of the model are located inside two regions (Moscow and Zhukovsky). It is worth noting that the location of the agents is tied to specific coordinates, in connection with which it becomes possible to scale and move the map itself.

The developed experimental model also allows one to conduct a series of experiments, which allows testing various options for influencing the contract system in the procurement sector during the execution of the model.

V. RESULT AND DISCUSSION

The proposed experimental model using the developed interface allows you to visually monitor the progress of its implementation. So, the experiment window contains the following blocks:

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