Research article

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FORMATION OF EFFECTIVE ORGANISATIONAL MANAGEMENT SYSTEMS

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Abstract

The success of modern enterprises is largely determined by the organisation of their management systems. In such systems, the elements have unique behavioural characteristics and form complex connections within the framework of the redistribution of powers. This research is aimed to identify such a structure of relations between the elements of the system that would most effectively ensure the fulfilment of the goals set for the organisation's goals under conditions of interaction with a changing external environment. In this work, we examines the existing methods for assessing the effectiveness of organisational management systems, noting that a set of quantitative performance evaluations can be obtained using organisational modelling. For this, we propose that the processes involved in the systems of organisational management are considered in the context of queuing theory. At the same time, the assumption is formulated that the use of an agent-based approach will allow for obtaining the best results. Based on this, the main goal of the study presented in this article was to adapt the mechanism for assessing the effectiveness of the functioning of organisational management systems toward an agent-based approach, assess the adequacy of such models, and determine the boundaries of their capabilities. In this study, an organisational system constructed for processing citizens' appeals was chosen as the modeling subject. The following developed models are presented: analytical, discrete-event in the GPSS World environment, and agent-based in the AnyLogic environment. The results of a computational experiment using these models allow us to conclude about the adequacy of using an agent-based approach within the framework of the author's concept of assessing the effectiveness of the functioning of organisational management systems. At the same time, when using an agent-based approach, to a certain extent, it is possible to eliminate the limitations of other approaches related to both the complexity of modelling systems consisting of many organisational elements and performing a variety of tasks as well as the inability to display the individual characteristics of the system elements. The scientific novelty of the presented work lies in the development of an agent-based modelling of organisational management systems within the framework of the queuing theory to assess their efficiency.

Keywords: management innovation, performance indicators, organisational management system, organisational modelling, decision support

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ФОРМИРОВАНИЕ ЭФФЕКТИВНЫХ СИСТЕМ ОРГАНИЗАЦИОННОГО УПРАВЛЕНИЯ

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Аннотация

Успех функционирования современных предприятий, их конкурентоспособность, во многом определяется эффективностью организации их систем управления. В таких системах элементы имеют индивидуальный характер поведения и формируют сложные связи в рамках перераспределения полномочий. Задача заключается в нахождении такой структуры отношений между элементами системы, которая бы наиболее эффективным образом обеспечивала выполнение целей, поставленных перед организационной структурой в условиях взаимодействия с изменяющейся внешней средой. Инновации по адаптации системы управления должны быть неотъемлемой чертой любой организационной системы. Автором рассматриваются существующие методы оценки эффективности систем организационного управления. Отмечается, что набор количественных оценок эффективности можно получить с использованием организационного моделирования. Для этого процессы в системах организационного управления предлагается рассматривать в нотации теории систем массового обслуживания. При этом формулируется предположение о том, что использование агент-ориентированного подхода позволит получать наиболее адекватные результаты. Исходя из этого, основной целью исследования, представленного в статье, являлась адаптация механизма оценки эффективности функционирования систем организационного управления под агент-ориентированный подход, оценка адекватности таких моделей и определение границ их возможностей. В качестве опытного объекта моделирования была выбрана организационная система, осуществляющая процесс обработки обращений граждан. Представлены разработанные модели: аналитическая, дискретно-событийная в среде GPSS World и агент-ориентированная в среде AnyLogic. Результаты вычислительного эксперимента с использованием данных моделей позволяют сделать вывод об адекватности использования агент-ориентированного подхода в рамках авторской концепции оценки эффективности функционирования систем организационного управления. При этом при использовании агент-ориентированного подхода в определенной степени можно снять имеющиеся у остальных подходов ограничения, связанные как со сложностью моделирования систем, состоящих из множества организационных элементов и выполняющих множество разнообразных задач, так и с возможностью отображения индивидуальных особенностей элементов системы.

Ключевые слова: управленческие инновации, показатели эффективности, система организационного управления, организационное моделирование, поддержка принятия решений

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1. Introduction

An organisational management system (OMS) is understood as groups of people united by common goals who operate together under certain regulations (Koshkin, 2014). Such systems are complex, encompassing many heterogeneous elements that can situationally form a certain connection structure (Burkov and Novikov, 2019). This explains why the state of the system can hardly be predicted in advance in terms of its temporal and spatial changes.

The processes that occur in organisational management systems depend on planning as well as the meaningful, controlled transformation of resources into specific results (Pisariuk, 2019). In this case, both material objects and services can be considered results. A specific feature of management processes is their continuous, cyclic nature (Kolesnichenko et al., 2018); they break down into a number of consecutive phases. The composition of these phases can vary by case, but, as a rule, there are objective, descriptive, prescriptive implementation and retrospective phases. During the objective phase, the management goal is formed based on an analysis of the current situation, while the descriptive phase is the time to determine the sequence of actions necessary for reaching the goal. The prescriptive phase is necessary for forming management procedures that would lead to certain actions (Rodionov et al., 2021). The implementation phase is the time to take action, specifically actions planned in accordance with the adopted management procedures. Last, the results obtained are analysed during the retrospective phase. The analysis may be related to several processes. Overall, based on the analysis, it is possible to set new objectives, which in turn trigger new processes. This is the essence of the continuity and cyclicality of management processes.

The efficiency of the processes within an organisational management system should be assessed in a comprehensive way, taking into account all phases of the management cycle. The assessment should measure the speed at which the system responds to significant changes in the controlled environment as well as the quality of the results obtained (Solovyeva, 2018). Determining degree to which the process complies with the requirements laid down for its organisation is essential (Savelyeva, 2014). The adequacy of the organisational structure ultimately determines the quality of the results obtained (and, in many cases, the possibility of achieving the objectives that have been set). The literature often references a concept of organizational efficiency, which is generally understood as the performance of the organisational management system (Bozhko, 2013). In practice, some relative characteristics are often used for measuring organisational efficiency, reflecting the degree to which the results obtained match the goals given the resources spent accordingly (e.g., material, labour, financial, time resources).

The more flexible and adaptive the system, the more variants of its possible architecture can be obtained. This is especially true for organisational management systems experiencing continuous changes in a controlled environment. Innovations designed for the better adaptation of the management system should be an inherent feature of any organisational system (Sharapov et al., 2012). Multi-variance increases the possibility of identifying the most effective structure. At the same time, the multifactorial content of management structures predetermines a variety of principles for their optimisation (Klimova and Smirnova, 2010). The main scientific challenge is developing tools that can ensure an optimal process for identifying the most efficient architecture of the organisational management system.

To address this challenge, it is necessary to define a set of criteria for evaluating the efficiency of the functioning organisational management system as well as mechanisms for determining which values of the criteria are calculated. Today, subjective assessments are most commonly used in this way, with standards for individual operations also widely used. This makes the assessments somewhat more objective, but only in terms of individual sub-processes. Any comprehensive assessment in this case is difficult. In addition, it is becoming increasingly popular to use indirect assessments based on a variety of indicators that characterise management processes in terms of the achieved goals. But in this case, the assessment of organisational efficiency will be indirect too. Therefore, it is quite important to form objective criteria for measuring the efficiency of the organisational management system. The author considers using the tools of the queuing theory as a methodological basis for tackling this problem (Ventzel, 2007). Previous research studies (Shvetsov and Dianov, 2015) have developed a set of criteria and tested a certain approach using a case study of a real organisational management system. There is a need to further develop questions related to the formal representation of the general concept that could be used to form the model as well as provide flexibility in setting its parameters. This would provide organisations operating in various fields with a tool for synthesising efficient organisational management systems.

An agent-oriented approach can be used as the main paradigm underlyin is to implement the agent-oriented approach in measuring the efficiency of organizational management systems g this model. In this way, adaptive models can be built. In addition, the processes can be described more adequately, including in terms of their informal component that manifests itself during the interaction among the organisational elements of the management system. Thus, the main purpose of the this study is to adapt the mechanism for measuring the efficiency of organisational management systems (OMS) toward an agent-oriented approach as well as assess the adequacy of such models and determine their limits.

The scientific novelty of this work is the developed concept of an agent-based modelling of organisational management systems that relies on the queuing theory to assess their efficiency.

2. Literature Review

To properly assess the efficiency of an OMS, it is essential to establish a set of objective indicators. It should be sufficient for evaluating operating systems in an ongoing way and assess possible changes. Thus far, there is no generally accepted assessment methodology despite consistent research being done in this field. Yet, questions related to improving the functioning efficiency of the OMS are considered in various studies (Solovyeva, 2018; Savelyeva, 2014; Bozhko, 2013; Sharapov et al., 2012; Klimova and Smirnova, 2010; Asaul et al., 2009; Tarasov, 2012; Dezhkina and Potasheva, 2008). At the same time, this problem still remains one of the most acute problems in this particular field — both nationally and internationally (Tarasov, 2012). The solutions suggested in the literature basically rely on the following approaches (Dezhkina and Potasheva, 2008):

- Use comprehensive assessments that integrate various economic, production, and other indicators;
- Apply indicators that characterise the achievement of management goals with the best use of resources;
- Use an expert evaluation method to measure various aspects of OMS operation;
- Use transitive assessments with the aid of the enterprise’s performance indicators;

Make assessments based on three interrelated groups of indicators: resource efficiency, qualitative parameters characterising the organisation and the content of the management process, parameters for measuring the rationality of the organisational structure as well as its technical and organisational level.

The last of the presented approaches is potentially the most accurate. A special role is assigned to the assessment of the adequacy of the organisational structure, given the forecasted changes in the external environment and adaptation to the market changes in the external environment (Burton and Obel, 2018). There are various methods for structuring the OMS, including the expert method, the method of analogies, the method of tasks, and the method of goal structuring. Their common weakness is a lack of quantitative estimates (Asaul et al., 2009). To obtain quantitative estimates of the efficiency of the organisational structure, organisational modelling methods are used; these are mathematical multifactor models. Some researchers highlight the following advantages of this method (Krivoruchko and Sukach, 2015): its capability of covering various aspects of the formation of the management structure (e.g., managerial, informational, socio-psychological); its potential application in the resolution of problems, the main parameters of which are the direct characteristics of the organisational structure; and its potential application in measuring changes in the organisational structures. However, for complex subjects, including the OMS, mathematical modelling methods can hardly be used (Burton and Obel, 2018). This is due to the fact that the overall results of control systems are formed by the results of many interacting processes. Traditional approaches have a limited ability to analyse multiple interdependent processes that occur simultaneously. In these cases, a good alternative may be simulation modelling (Harrison et al., 2007).

Simulation models can enhance the processes in existing and persistent organisational mechanisms and systems as well as generate new approaches to organising and managing people's joint activities, such as the design of organisational systems with predefined properties. This can all be done in an environment with a large number of elements, complex connections between them, and courses of events (Parinov, 2007). The models built can be used to carry out computational experiments with various organisational configurations. In addition, new organisational structures can be synthesised to greatly differ from their traditional counterparts, with the capability of reacting promptly to changes in the external environment (Burton and Obel, 2018).

There are two opposite approaches to the simulation of an OMS (Gerasimov et al., 2005). The first uses an initially well-planned model architecture as a basis. All the elements and their interrelations are identified, and the guidelines for selecting the parameters of the organisational management system are described in the form of determinate patterns. Such models are used for studying the behaviour of the system under various control and input parameters. The outcome is the measured quality of the system as it functions under certain criteria. Regression and optimisation models can be highlighted among the methods used in this approach.

Regression models are developed for use in combination with standard structures. This method is applicable for determining the limits of the centralisation of management functions, staffing number standards; developing subdivision structures; and determining the number of rational hierarchy levels (Gerasimov et al., 2005). The use of the regression model was presented by Abrosimova (2015), who developed a multifactorial regression model for assessing the performance of the personnel management system within the organisation.

Optimisation models can be commonly formed using the queuing theory. The organisational elements of the system, which process the flows of various applications, are considered service channels. Chernyakhovskaya et al. (2016a, 2016b) and Galiullina (2015) consider the system for providing state and municipal services a queuing system. The structure of the service system is defined by the number and mutual arrangement of service channels. The system options are assessed according to the following criteria: technical characteristics (the length of time to service an application, service channel capacity, service channel downtime, probability of an application being serviced); economic characteristics (cost of the OMS, maintenance costs, system support costs); reliability characteristics of the OMS (system success probability, system operational state restoration probability). Examples of the practical use of models based on the queuing theory were presented by Okemiri (2018) and Amiens et al. (2020).

Li et al. (2015) suggested using genetic programming for optimising the organisational structure of multi-agent systems, as this method can be applied to a wide range of organisational forms and entails lower computational costs in comparison with exact methods. Khosraviani et al. (2004) described an optimal design model implemented at design organisations based on genetic programming methods. The model is an optimiser for the design simulator of organisational projects. During modelling, the decision-making policies and individual characteristics of subgroups vary, while the impact on the quality and duration of the project is compared using the fitness function. Then, the solutions obtained are compared to the best developments created by humans.

Another approach to modelling an OMS is based on its display as an open self-organising system. The ability of the system to adapt to changing conditions in the environment is modelled by taking into account the presence of a subjective element in the system: a person and their potential arbitrary behavior (Gerasimov et al., 2005). The model should include typical actors in the system along with their inherent behavioural attitudes and the environment in which they operate. Such models are studied under various environmental configurations. The results of the modelling are identification of the most optimal structure for the organised interaction of the actors and their characteristics given the specified criteria of efficiency. Here, with attention given to microstructures, a large number of possible system states are achieved. With the various aggregations of many micro-level mechanisms, several macro-level organisational forms can be synthesised. At the same time, special attention is paid to the behavioural aspects of the system elements at various levels as well as the organisation of their interaction. These modelling methods have resulted in a new field of research in which several design options can be considered simultaneously. With these new tools, it has become possible to conduct systematic studies on a large number and variety of designs in terms of performance implications (Joseph et al., 2019).

This shift in theoretical focus is confirmed by a wider use of agent-oriented models in the literature (Dutta et al., 2015; Crowder et al., 2009; Quillinan et al., 2009; Chang and Harrington, 2006; Secchi and Neumann, 2016; Wall, 2016; Gomez-Cruz et al., 2017). The researchers highlight that such models are well-suited for a 'bottom-up' modelling of complex distributed systems and, especially, social systems, where we have to consider the specific behaviour of individuals interacting with each other to achieve their goals (Sayama, 2015). Such systems can hardly be modelled using other approaches. Given the challenge of forming an organisational structure, agent-oriented modelling allows us to flexibly define individual and team models as well as task workflows and simulate diverse variants of organisational structures to assess their performance (Dutta et al., 2015).

The work of Stanojevic et al. (2019) can be considered an example of approaches to organisational design based on agent-oriented modelling, with the authors presenting a methodology that relies on the following basic ideas:

1. Advanced software (simulation) technologies are used toward the object-oriented modelling of the behaviour of elements in the organisation (managers, technological resources, etc.).

2. The organisation is considered an information processing system. Managers in the organisation are modelled as interacting rational agents. The agents make decisions based on incoming messages and existing decision-making procedures and send messages to their organisational environment. Their resources for performing their functions are limited.

3. Various messages (information) are used to describe all the requirements of prospective consumers and all types of activities. Each message relates to a specific process in the organisation. The original message changes according to the process.

4. Modified organisational matrix-tables are introduced to link the processes and agents/objects. These help overcome the complexity of communication system modelling.

5. Important quantitative indicators are monitored to measure the efficiency of the model for a certain period of time.

The analysed agent-based models show that the weak application of even a randomly chosen formal bottom-up structure can be useful for guiding the emerging upward networks of intra-organisational interactions between agents (Clement and Puranam, 2017) (Levinthal and Workiewicz, 2018). If a formal structure is absent, interactions within the organisation tend to decline, since interactions require coordination to be maintained, while no coordination is required for stopping them. A formal structure restores a network of interactions between agents, who can then determine which interactions to keep and which to discard.

Along with the prospects of an agent-oriented approach to OMS modelling, researchers have highlighted a problem related to correlating the models with reality (Chang and Harrington, 2006). The reliability of a model depends on the assumptions made within it. Given the complexity of organisational systems, it is quite difficult to ensure an acceptable level of reliability of an agent-oriented domain model. Therefore, before they are used in practice, it is proposed they should be compared with the results of the existing positive experience in the OMS simulation. This will not only foster a greater confidence in the model, but may also contribute to proposals for their useful modification.

Many researchers have emphasised the need for additional studies to coordinate two competing but complementary approaches to OMS modelling (Hunter et al., 2020). All approaches to designing organisational systems that exist today share several common characteristics: they simulate smaller, flexible and, consequently, more successful parts that are connected to the general network of the organisation. There has also been a constant shift in the form of structures from vertically tall and functionally aligned to horizontal and process-oriented networks. Under these conditions, it is difficult to choose an adequate methodology for organisational design. There are many possible solutions, yet all have some constraints or pose obvious implementation problems. This is why organisational design is still considered both an art and a science (Stanojevic et al., 2019).

3. Materials and Methods

Organisational systems aim to fulfil the flow of tasks coming to them. Depending on the size and complexity of the tasks, organisational structures are formed to determine the rights, powers, and responsibilities of their elements (Talanova and Alekseeva, 2015). The author proposed to evaluate the efficiency of such structures using the methods of the queuing theory (Ventzel, 2007; Shvetsov and Dianov, 2015). For clarity of this approach, let us consider an OMS dealing with citizens' applications (Valov et al., 2020). Most agencies, institutions, and enterprises must work with people's applications and complaints. Given the importance and scope of this work, organisational structures are created to ensure the efficient execution of processes related to the management of these applications. The articles solve the following problems: application registration; preliminary analysis for the competence of content consideration; controlling the time within which applications are considered; substantive analysis of the quality with which an application has been processed; and general analysis of the processes in which applications are considered.

This system interacts with both the external environment (citizens, agencies, enterprises) and internal environment. At the same time, it serves many information flows of messages coming from these two environments. These flows concern a certain list of the types of work carried out by employees of the OMS engaged in the organisation of procedures according to which citizens' applications are considered. In this context, the system can be regarded as an open multichannel system with an unlimited queue (Fig. 1).

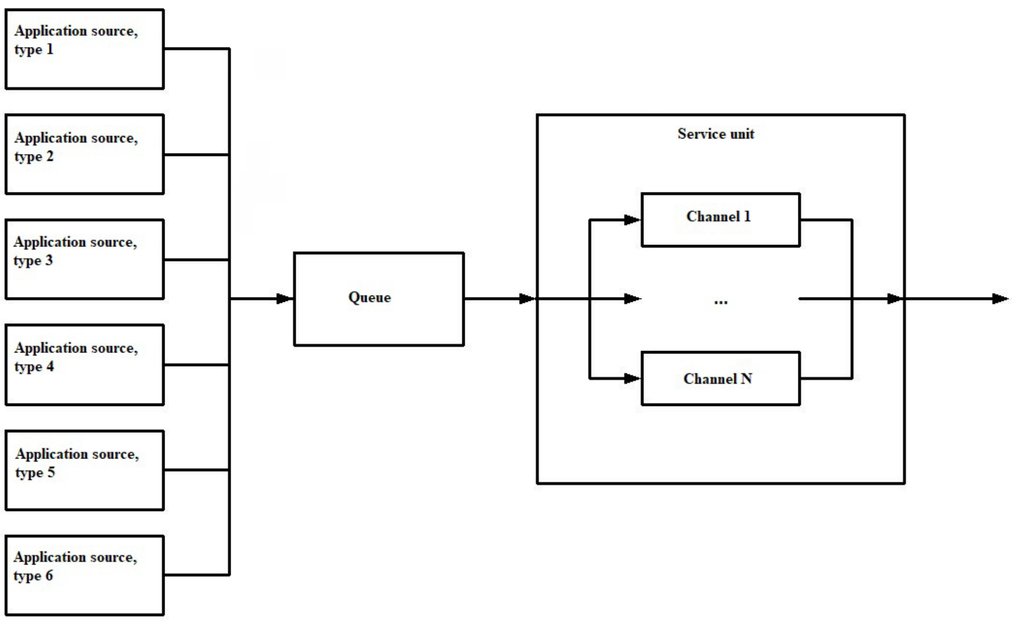

Figure 1. Queuing system structure

Typical operations carried out by employees are considered as applications, while employees are seen as service channels. The following sources of application types are considered: 1) registering and determining the procedure according to which the applications are considered; 2) changes in the control terms; 3) removal from control; 4) control of the execution course; 5) the generation of periodic reports; 6) reporting on applications.

The system is characterised by the following parameters (Shvetsov and Dianov, 2015): the number of service channels (N); the application receipt intensity ; the application service intensity (λ). The application receipt intensity is defined as the inverse of the average time between the receipt of two related applications $(t_p) : \lambda = 1/t_p$): . The application service intensity is defined as the inverse of the service time spent on one request $(t_o) : \mu = 1/t_o$): .

The following parameters can be defined for the existing operation mode of the system:

1) The overall intensity of the received applications:

$$\lambda_o = \sum^{6}_{i=1} \lambda_i , \quad (1)$$

where is the receipt intensity of an application of the i-th type.

The total intensity of the application servicing is:

$$\grave{\imath}_o = \sum_{i=1}^{6} \grave{\imath}_i \quad (2)$$

where is the servicing intensity of an application of the i-th type.

2) The load factor of the unit:

$$\psi = \lambda / \mu = t_o / t_p, \quad (3)$$

3) The total load factor of the system unit:

$$\psi_o = \sum^{6}_{i=1} \psi_i, \quad (4)$$

where ψ_i is the unit load factor for servicing an application of the i-th type.

The system is presented as a labelled graph. The graph nodes define the possible states of the system:

P_0 – the system has no applications, and all the channels are at a standstill;

P_1 – there is one application in the system;

P_n – there are n applications in the system.

Two situations are defined for a multi-channel system:

1) The number of requests n arriving in the system is smaller than the number of service channels N (all applications are being serviced):

$$P'_n = P_0 \times (\psi^n_o) / n! \quad (5)$$

2) The number of requests n arriving in the system is larger or equal to the number of service channels N (N requests are being serviced, while the others are waiting in the queue):

$$P_n^{''''} = P_0 \times (\psi^n_o) / N! \times N^{n-N} \quad (6)$$

The probability of no applications in the system:

$$P_0 = (1 + \sum_{n=1}^{N-1} \psi^n_o / n! + \sum^{\infty}_{n=N} \psi^n_o / (N! \times N^{n-N}))^{-1}. \quad (7)$$

The efficiency criteria of the system:

1) Average load of the system channels:

$$\gamma = \sum^{N}_{n=1}(1 - \sum^{n-1}_{k=0}P_k) / N. \quad (8)$$

2) Average length of the queue:

$$L_q = \psi^{N+1}_o P_0 / (N-1)!(N-\psi_o)^2. \quad (9)$$

3) Average number of applications in the system:

$$L_s = L_q + \psi_o. \quad (10)$$

4) Average length of time an application remains in the queue:

$$W_q = L_q / \lambda_o . \quad (11)$$

5) Average length of time an application remains in the system:

$$W_s = W_q + 1 / \mu_o . \quad (12)$$

The system can be considered optimally efficient if 1) the values of the average length of the queue, the average number of applications in the system, the average length of time an application stands in the queue, and the average length of time an application remains in the system are within the range of the desired values, and 2) the highest indicator of the average load of the device channels is observed.

Simulation modelling environments are often used to resolve problems presented in the form of queuing systems. One of the most popular queuing systems is GPSS World (Tomashevsky and Zhdanova, 2003). With the authors' participation, a discrete-event simulation model was built in this modelling environment to present the process of work organised to consider citizens' applications. A real entity existing at the time the model was created, the Department of Letters and Reception of Citizens of the Government of the Vologda Region (DLRC) was chosen as the object of modelling (Dianov and Shvetsov, 2004). The following parameters were set for the model:

- An exponential distribution of the time intervals for the receipt of neighbouring applications of the same type (each type of application comes from a large number of independent sources within a certain time interval);
- The length of time for servicing applications is subject to an indicative law (the amount of time for servicing applications in the system is random, with most spreading around average values);
- Each service channel can accept any application and has the same characteristics for servicing applications;
- There is a single queue in the system for applications of all types. The waiting method of the system is non-priority and organised according to the First In–First Out (FIFO) rule.

Table 1 shows the characteristics of the DLRC operation used in the model and obtained by the author as a result of experiments, surveys, statistical analysis of databases, and observations of the work of department employees:

- To determine the average service time, methods such as interviewing the employees in the DLRC and monitoring their work were used;
- The average interval for periodic reports was obtained based on an analysis of the organisational documentation (work regulations);
- The average intervals of registration and determining the procedure for considering applications, changes in the terms, and removal from control were obtained based on an analysis of the database of the automated system for recording citizens' applications;

The average intervals for monitoring the progress of executed resolutions following applications and reports created on the requests of agencies, organisations, and citizens were obtained using surveys and observing the work of the DLRC employees.

Table 1. Characteristics of the work of the Department of Letters and Reception of Citizens

Application type	Average receiving time, min.	Average servicing time, min.
1. Registering and determining the consideration order	19	35
2. Change in the terms	96	5
3. Removal from control	40	7
4. Control of the execution process	480	60
5. Periodic reporting	9600	120
6. Reporting per requests	3200	25

Figure 2 presents the text of the simulation model program. The program consists of eight segments: segments 1–6 describe the order according to which applications of various types are created; segment 7 determines the order according to which an application enters or leaves the general queue and the order for servicing applications by a multi-channel unit; and segment 8 sets the simulation time.

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********************************************************************************
*   The Model
********************************************************************************
*   6 segments are created that simulate six types of service applications,
*   seventh segment - common blocks for the six previous segments,
*   the eighth segment is the timer segment responsible for the simulation time.

*T_1  TABLE M1,0,10,12       ; table for monitoring the time spent by applications in th
*T_4  TABLE Q1,0,1,12        ; table for monitoring queue length
*T_2  TABLE MP2,0,10,12      ; a table for monitoring the time of applications stay in t
*T_3  TABLE MP3,0,10,12      ; table for monitoring the time of applications stay under

F_A   FUNCTION P1,D6                 ; a function that, according to the type of applic
      1,35/2,5/3,7/4,60/5,120/6,25   ; gives the average service time

USTR  STORAGE 2    ; selecting the number of the device's channels

* 1 section: Registration and consideration of applications
      GENERATE 19,(EXPONENTIAL(1,0,1))
      ASSIGN 1,1            ; remember the type of application in the parameter with the
      TRANSFER ,L_1         ; click on the label L_1

* 2 section: Changing the terms of appeals consideration
      GENERATE 96,(EXPONENTIAL(1,0,1))
      ASSIGN 1,2            ; remember the type of application in the parameter with the
      TRANSFER ,L_1         ; click on the label L_1

* 3 section: Withdrawal from control
      GENERATE 40,(EXPONENTIAL(1,0,1))
      ASSIGN 1,3            ; remember the type of application in the parameter with the
      TRANSFER ,L_1         ; click on the label L_1

* 4 section: Monitoring the progress of execution
      GENERATE 480,(EXPONENTIAL(1,0,1))
      ASSIGN 1,4            ; remember the type of application in the parameter with the
      TRANSFER ,L_1         ; click on the label L_1

* 5 section: Creating periodic reports
      GENERATE 9600,(EXPONENTIAL(1,0,1))
      ASSIGN 1,5            ; remember the type of application in the parameter with the
      TRANSFER ,L_1         ; click on the label L_1

* 6 section: Creating reports on queries
      GENERATE 3200,(EXPONENTIAL(1,0,1))
      ASSIGN 1,6            ; remember the type of application in the parameter with the
      TRANSFER ,L_1         ; click on the label L_1

* 7 section: The general part
L_1   QUEUE 1                          ; the application is entered in the queue
*     MARK 2
```

Figure 2. Software implementation of the simulation model

The challenge with the formation of models of organisational systems is aggravated by the fact that their elements (people) behave actively (Koshkin et al., 2014). From the author's point of view, this feature can be taken into account if agent-oriented models are built. To assess the adequacy of the agent-oriented approach, the author built a model of the process of organising work based on the consideration of citizens' applications in the AnyLogic agent-oriented modelling environment (Borshchev, 2013), which is based on the approaches used for creating the respective model in the GPSS World environment. Figure 3 shows the main diagram of the model.

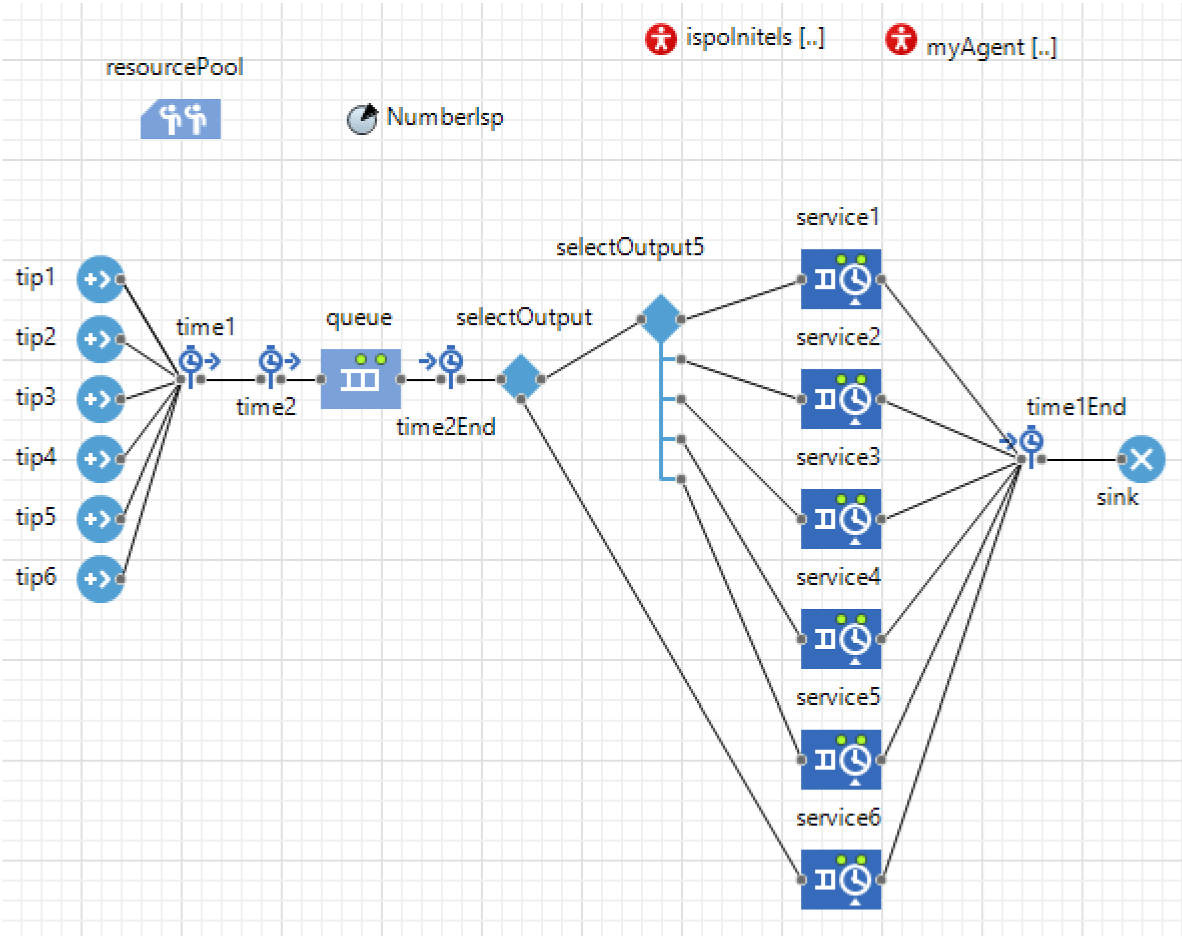

Figure 3. Main diagram of the model of the process of organising work on the consideration of citizens' applications in the AnyLogic environment

There are two types of agents in the model: myAgent, applications (Application Agent), and ispolnitels, employees of the DLRC (Executor Agent). Executor Agents represent the servicing channels. At the level of an Application Agent, a variable is determined, the value of which indicates the type of application. Six elements of the 'Source' type (tip1–tip6) generate Application Agents of the relevant type. Application Agents arrive at the common queue, which is organised according to FIFO rule. The applications are served by 'Service' type blocks (service1–service6). Each block serves only its own type of applications. The appropriate redistribution is made by two SelectOutput elements (selectOutput and selectOutput5). The Executor Agents are determined as the consumed resources during servicing (resourcePool element). The NumberIsp parameter sets the number of Executor Agents to be created. At the end of the service, the Application Agents are destroyed by the 'Sink' type block (sink). The TimeMeasureStart (time1 and time2) and TimeMeasureEnd (time1End and time2End) elements are used to determine the timers that set the time during which an application can remain in the queue and in the system.

In order to visually display the simulation results, five elements of the 'Bar Chart' type are created.

These can be used to track the average number of applications in the system, average length of the queue, average load of the channel, average amount of time an application stands in the queue, and average amount of time an application remains in the system.

4. Results

The simulation environments allowed us to conduct the necessary experiments using fairly simple means and, ultimately, obtain results that can be applied for assessing the efficiency of the DLRC. Figure 4 shows an example of the results obtained in the GPSS World simulation environment.

```
START TIME           END TIME  BLOCKS  FACILITIES  STORAGES
     0.000         121440.000    27         0          1


QUEUE              MAX CONT. ENTRY ENTRY(0) AVE.CONT. AVE.TIME   AVE.(-0) RETRY
 1                1173 1173  10995       8 | 592.286  6541.809   6546.572   0


STORAGE            CAP. REM. MIN. MAX.  ENTRIES AVL.  AVE.C. UTIL. RETRY DELAY
 USTR                2    0    0    2     9822   1    1.999  1.000     0 1173


TABLE              MEAN     STD.DEV.       RANGE           RETRY FREQUENCY SUM.%
 T_1             6572.726 3822.693                            0
                                 0.000  -       10.000                  5     0.05
                                10.000  -       20.000                  2     0.07
                                20.000  -       30.000                  1     0.08
                                30.000  -       40.000                  2     0.10
                                40.000  -       50.000                  2     0.12
                                50.000  -       60.000                  5     0.17
                                60.000  -       70.000                  2     0.19
                                70.000  -       80.000                  3     0.22
                                80.000  -       90.000                  4     0.26
                                90.000  -      100.000                  6     0.33
                               100.000  -  _                         9788   100.00
```

Figure 4. An example of the output of the results from the simulation modelling of the process of organising work on the consideration of citizens' applications in the GPSS World environment

Figure 5 shows an example of the model execution in the AnyLogic environment.

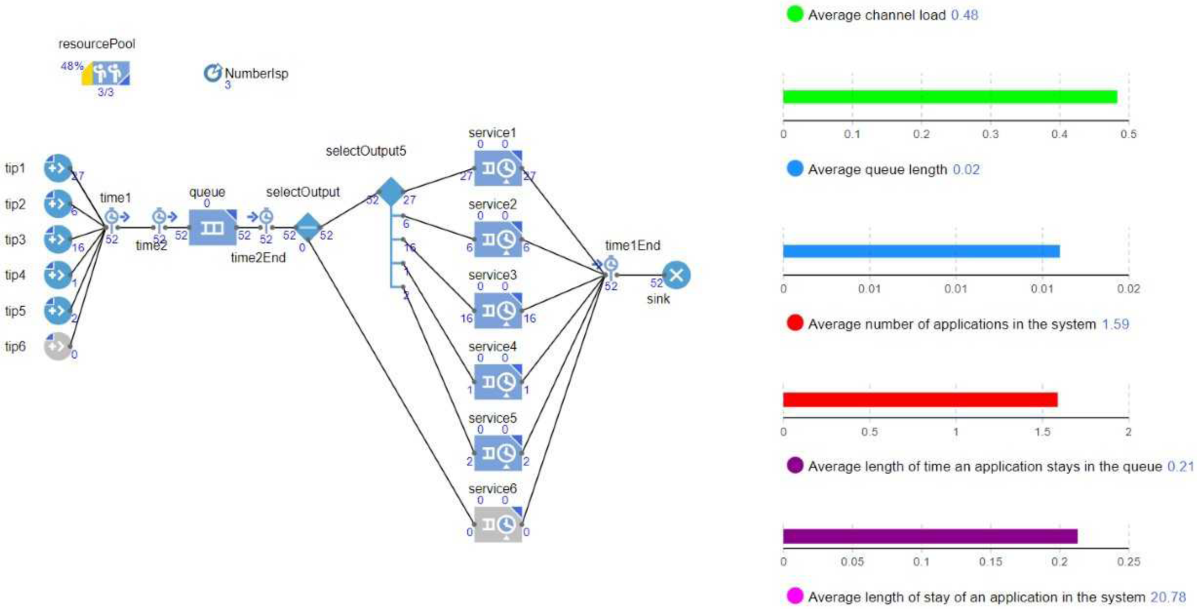

Figure 5. An example of the model of the work organised for considering citizens' applications in the AnyLogic environment

To determine the adequacy of the agent-oriented model of the process of work organised around considering citizens' applications, a computational experiment was carried out. Using an analytical model, a simulation model in the GPSS World environment and a simulation model in the AnyLogic environment, efficiency indicators of the DLRC were obtained for different numbers of channels. The simulation time of the system operation was set as the working time for one year: 253 x 8 x 60 = 121,440 minutes. Table 2 shows the results obtained.

Table 2. The results of the efficiency indicator calculation

Number of channels	Indicator	Analytical model	Simulation model	
			GPSS World	AnyLogic
2	Average load of channels	-	1	1
	Average length of the queue	-	592.286	370
	Average number of applications in the system	-	594.859	373.73
	Average time an application stands in the queue, min.	-	6541.809	4296.62
	Average time an application remains in the system, min.	-	6572.726	4341
3	Average load of channels	0.738	0.747	0.71
	Average length of the queue	1.464	0.854	1.09
	Average number of applications in the system	3.644	3.095	3.82
	Average time an application stands in the queue, min.	16.2	9.435	12.52
	Average time an application remains in the system, min.	41.2	34.194	43.65
4	Average load of channels	0.5425	0.561	0.53
	Average length of the queue	0.28	0.134	0.13
	Average number of applications in the system	2.48	2.377	2.43
	Average time an application stands in the queue, min.	3.1	1.48	1.53
	Average time an application remains in the system, min.	28.1	26.25	27.86

The indicators of both simulation modelling types imply a low efficiency of the system. The values of all indicators—except that of the average load—are quite different. However, it should be noted that the ratios of the parameters are proportional: the ratio between the indicator of the average load of the channels and the average number of applications in the system is 1.6; the ratio between the indicator of the average time an application stands in the queue and the average time an application remains in the system is 1.5.

In general, comparable indicators were obtained for all models for systems with three and four channels. First, this refers to the indicators' values regarding the average load of the channels. As for the remaining indicators, in most cases, the values obtained using the agent-oriented model were between the values obtained using the analytical model and those obtained from the simulation model implemented in the GPSS World environment.

Based on the results obtained, it can be concluded that the agent-oriented approach can be adequately used within the author's concept of assessing the efficiency of organisational management systems.

5. Discussion

The concept described in this paper propels the integration of two approaches in the model simulation of an efficient OMS: one focused on the initial use of a clear model architecture and another defining an OMS as an open self-organising system in which many active elements interact. Some foreign authors believe that research in this area is promising (Hunter et al., 2020). This is due to the fact that none of the above-mentioned approaches alone can adequately display and evaluate the totality of the processes occurring in OMS. The author is interested in combining the queuing theory and agent-oriented modelling. The separate application of these methods is considered in the works of various authors. Specifically, the use of the queuing theory for measuring the efficiency of an OMS is presented by Chernyakhovskaya et al. (2016a, 2016b), Galiullina (2015), Okemiri (2018), and Amiens et al. (2020), while agent-oriented modelling is discussed by Dutta et al. (2015), Crowder et al. (2009), Quillinan et al. (2009), Chang and Harrington (2006), Secchi and Neumann (2016), Wall (2016, 2021), Gomez-Cruz et al. (2017), Reinwald et al. (2021), Adomavicius et al. (2021), Wall and Leitner (2021). According to the results of these studies, we can assert that the chosen area of research has considerable prospects.

The author considers the results obtained in the course of this research as the first step towards enhancing the tools used for evaluating the efficiency of organisational management systems. It should be noted that the very concept of efficiency—defined with the queuing theory—should be preserved, as it is useful for assessing organisational structures in an adequate way. The original tools developed previously have limitations, as it is difficult to model large systems (i.e., those consisting of many organisational elements and requiring the performance of a variety of tasks) and display the individual traits of employees. The author believes these challenges can be addressed to a certain extent with the implementation of an agent-oriented approach. The subsequent steps for its implementation should consist of the following:

- Creating a flexible mechanism for Application Agents (a large number of Application Agents with various parameters can be created);
- Forming the structure of the parameters of Executor Agents to determine the possible range of Application Agents they serve;
- Creating a flexible mechanism to facilitate the Application Agents' redistribution for being serviced between Executor Agents.

If implemented, this functionality can help not only in achieving better results in determining the efficiency of organisational management systems but also in choosing their most effective structure under specific conditions.

In addition, there is a need for tackling the methodological aspects related to the construction of agent-oriented models for assessing the efficiency of the functioning of organisational management systems.

6. Conclusion

Within this research, some work was done to adapt the queuing theory-based mechanism for assessing the efficiency of the functioning of the OMS within the framework of an agent-oriented approach. The aim was to build an agent-oriented model for assessing the efficiency of the OMS and to evaluate the adequacy of such models.

The following are the main conclusions of the study:

- One of the urgent challenges to be resolved by various institutions is developing a mechanism for adapting to changing environmental conditions, which is possible only through implementation of rational and timely organisational changes of management subsystems;
- To tackle this problem, it is necessary to establish a set of criteria for evaluating the efficiency of the functioning organisational management system as well as mechanisms for ensuring the process in which the values of the criteria are calculated;

- Simulation modelling is the most effective method that provides ample opportunities for studying and designing organisational management systems;
- In terms of the challenge related to the formation of an organisational structure, agent-oriented modelling can be used to flexibly define individual and team models as well as task workflows, and simulate many variants of organisational structures to assess their performance;
- Agent-based modelling is an adequate tool for measuring the efficiency of organisational management systems.

The practical significance of the results obtained in this study revolves around their potential use among enterprises, organisations, and institutions in various fields as a tool for forming the organisational structure of the management subsystem.

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