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Simulation Modelling as a Tool for Design and Development in Large-Scale Automated Systems: Smart City Application in Terms of Lack of Statistical Information

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Abstract: Design and development of large-scale automated systems (AS) is always associated with overcoming a large number of uncertainties, which structuring often through the using of practice standards and modeling at the Systems & Software Engineering. Methods of analysis of large systems (LS) involve their decomposition in the context of structural and/or functional paradigms, which allow us to consider the obtained components as objects for modelling: functional modelling, simulation etc. Design the automated control system (ACS) of region (SmartCity project) need to optimize the decisions. In this paper we propose the new methods of determining the parameters of project in terms of lack statistical information based on the simulation model.

Keywords: ACS Automated Control System, life cycle, modeling, Smart City.

1. INTRODUCTION

Already at the initial stages of Systems Engineering, different models and methods of mathematical science are used. These are: mathematical statistics, discrete mathematics, game theory etc. Advantages in area of information technology has allowed to bring to the practice of creating LS such powerful tools as simulation. In many cases simulation is the only one way to get any notion of the behavior of a complex system and to conduct its analysis. The ACS in the crisis and emergency situations is a big complex system (BS), in the nodes of which are located decision-making centers, related with the aid of information flows with operating forces and resources from the state and municipal institutions. The complexity is due to the fact that the organization of such systems does not have a straightforward structural implementation and is determined by many factors (availability of communication channels, level of automation, duty services, interaction between departments, the level of financial support, etc.). Therefore the design of such BS is connected with the decomposition of the general problem at the level of paradigm life cycle (LC) [1] in the context of structural-functional component hierarchy, which have a nodes (Fig. 1) as the duty dispatcher service (DDS) or command control centers(CCC). The problem of simulation of the overall structure of the system is the lack of sufficient statistical

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information for all DDS. The authors propose a method, which ensures a sufficiently adequate model in these limits.

2. FUNCTIONAL AND STRUCTURAL ANALYSIS FOR DESIGNING ACS OF REGION

The function "to manage the life cycle stage" on the stage of the lifecycle "design" solves a non-trivial problem of building a hierarchy of command control centers and decision-support centers. The situation with organization of this structure differs from region to region. As a rule the hierarchy of divisions in the area is formed from the newly created command control centers (CCC) at the level of municipal districts from the unified duty dispatcher service (UDDS) and existing CCC (utilities and other emergency services, Fig. 1).

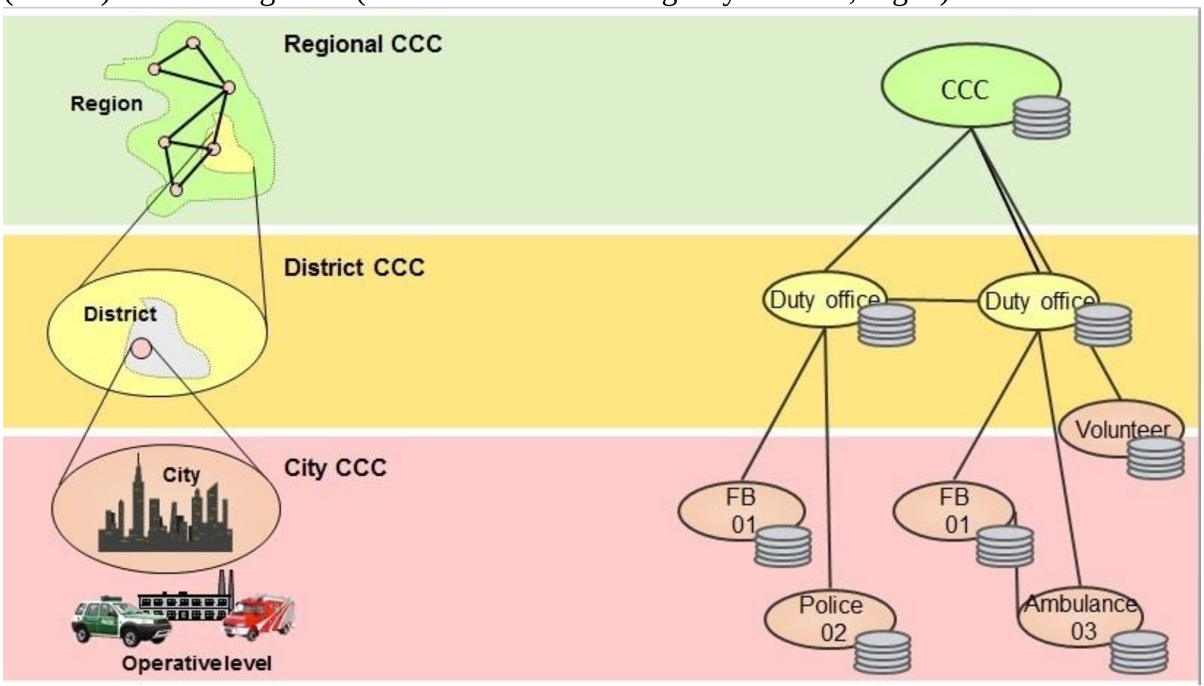

Fig. 1. Structural Analysis of System

Often due to lack of technical capacity information can be transmitted not to the main samples but in any of the duty services. The task of designing the structures contains many elements of uncertainty. The requirements of operators, resources, emergency response number, power and performance of computer systems and throughput of communication channels in the project document do not have a clear quantitative and scientific basis and developed at best on the basis of comparative assessments of the operational histories of the existing call centers (CC). However it is not a sufficient basis for parameters definition of the designed system. Underestimation of requirements for operators, resources, the quantity and quality of technical means cannot lead to lower response time, but rather its can increase it. Such approaches may lead to waste of millions of dollars during the construction of such systems.

3. TASK DEFINITION FOR SIMULATION MODELLING

We need to offer a science-based method of assessment requirements for the resources CCC/UDDS, guaranteeing the fulfillment of key performance indicators (KPI) the system functioning in framework the main operational process, under limited amount of statistically reliable data and uncertain structure that represents a hierarchy of decision-support centers, communicate links and the management links.

3.1. Building the base model class of CCC

As already noted, CCC is defined as the basic element of the system in context of structural-functional decomposition. The CCC model is used also to model the main operational process which uses a discrete event simulation model on the basis of libraries of standard classes of the system modeling AnyLogic. AnyLogic allows presenting the CCC functionality in an object-oriented paradigm. Discrete event simulation model on the basis of libraries of standard classes AnyLogic is used for modelling the main process, which implements the basic blocks at the level of mechanisms described in the theory of mass service: event sources, the queue, processing servers, etc. You can pick up an optimal set of characteristics for the compilation of parameters for the specifications a particular system by manipulating the parameters of the objects based on the implementation of these classes, as well as analyzing the statistical dependencies. The designed system, as already noted, is a hierarchical structure of control centers interacting with each other to coordinate control of forces and means of response.

4. METHODS FOR EVALUATION OF THE STOCHASTIC CHARACTERISTICS OF THE MODEL

As the main stochastic characteristics of the basic simulation model of the considered functional unit (CCC) allocated:
- intensity of input flow requests;
- the length of the intervals between user requests of call centers automated dispatch control system (ADCS) one of the CCC;
- the temporal characteristics of requests processing;
- actions of emergency response services.

For each of these parameters were applied a method involving the following steps:
- pre-selection of a family of theoretical distribution;
- estimation of parameters (position, scale, and shape) of distributions;
- testing of hypotheses about the correctness of the choice one;
- verification of the results obtained by comparing the estimated and real data, using statistics on one of the nodes (CCC).

4.1. Estimation the intensity of input flow request

At the Fig. 2 - the first result obtained in the evaluation of the intensity the input flow of requests CCC. It needs the separation the original time series from non-random components.

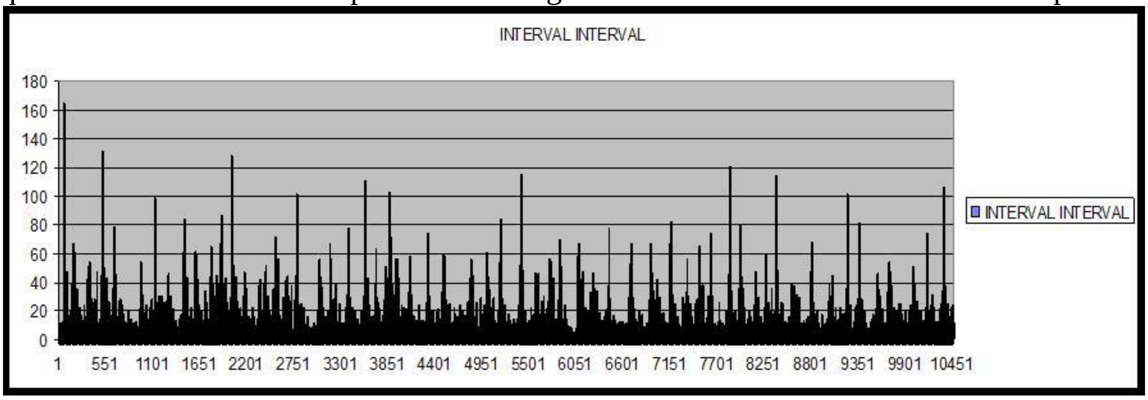

Fig. 2. Lengths of the intervals between the requests ones of the CCC

At first we accept for an initial hypothesis about the probability distribution of the lengths of the intervals between the receipts of requests in the CCC in accordance with the theoretical recommendations. This assumption is the exponential character of this distribution.
The program package STATISTICA was used for the test and analyze these hypotheses based on the data for 2013 year. The result being analyzed with the Kolmogorov-Smirnov criterion histogram of distribution density of time intervals between receipts of bids (Fig. 3).

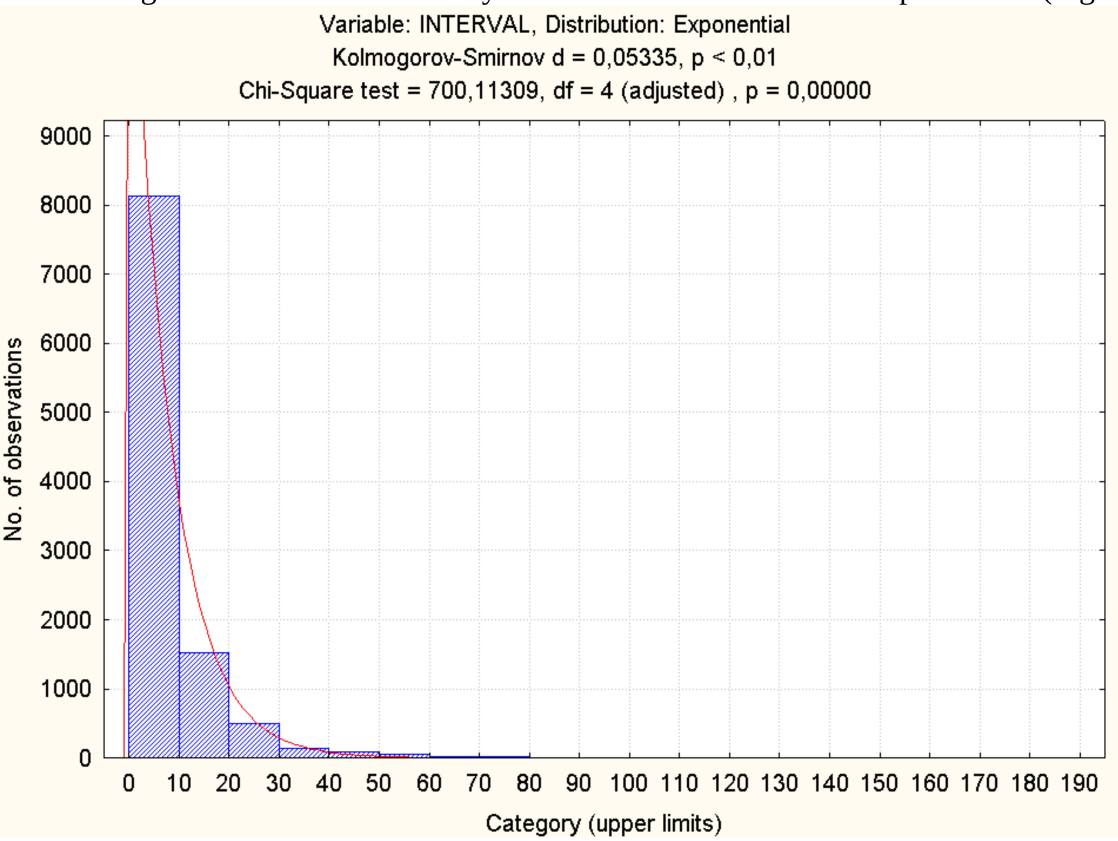

Fig. 3. The gistogramm analyze in the programm STATISTICA

Thus we obtain the average value of the intervals between receipt of bids is equal to 7.8 min., the dispersion of the intervals of the arrivals of 10.12, the value of the Kolmogorov-Smirnov 0,05335. Hypothesis of an exponential distribution is confirmed.

4.2. Estimation the temporal characteristics request processing

The gamma distribution is the most "suspicious" law from the perspective of better applicability for estimating parameters of a stochastic variable of type "duration of service". Scale parameter b and shape parameter a of this distribution are connected by a system of equations.

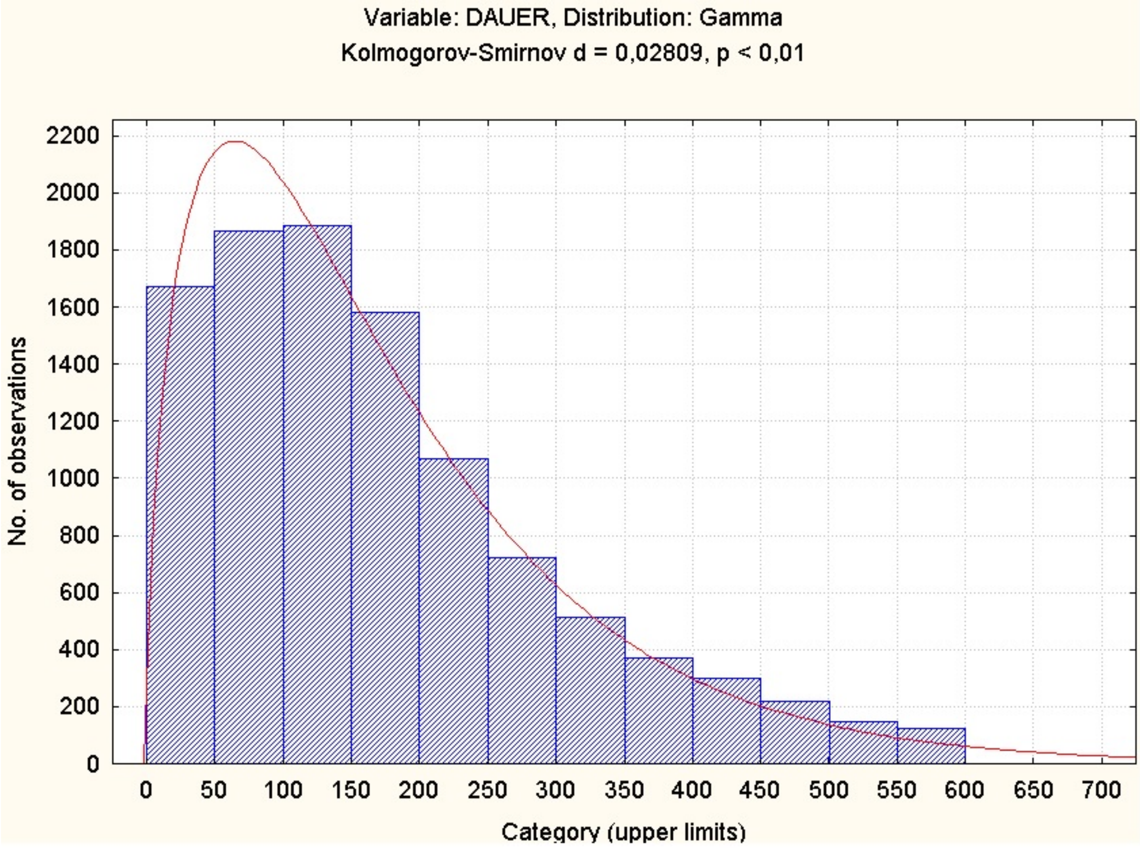

Fig.4. The histogram analysis of duration time bids service

$$\begin{cases} ab = M(x) \\ ab^2 = D(x) \end{cases} \quad (4.1), \text{ thus}$$

M(x) – expected value ($\bar{x}$); D(x) – distribution (s^2);
The solution of system equations (4.1) allows you to determine the most plausible values of the parameters of the gamma distribution. Accordingly, the parameter estimates have the form:

$$\hat{a} = \frac{(\bar{x})^2}{s^2}, \hat{b} = \frac{\bar{x}}{\hat{a}} = \frac{s^2}{\bar{x}}, \quad (4.2)$$

The data for 2013 and the criterion of Kolmogorov-Smirnov have been used to test the hypothesis about the applicability of the gamma distribution for estimating the processing time of applications in the Executive division of CCC (Fig.4).

When we checked these parameters on the model (Fig.5) we get the deviation from the actual number of filings for the same period in 2014 year of no more than 12%. Fig.5 clearly shows that the model graphs of the probability density the service requests and interval requests are almost identical with the statistics (Fig.3, Fig.4).

5. DEVELOPMENT THE BASE CCC MODEL ON THE DATA OF THE INPUT STREAMS

Queueing system modeling each of the call centers should be provide for: classification of bids according degree of service complexity (which service responds, how many services respond etc.); possibility of information exchange according applications between CCC, both vertically and horizontally (Fig.1).

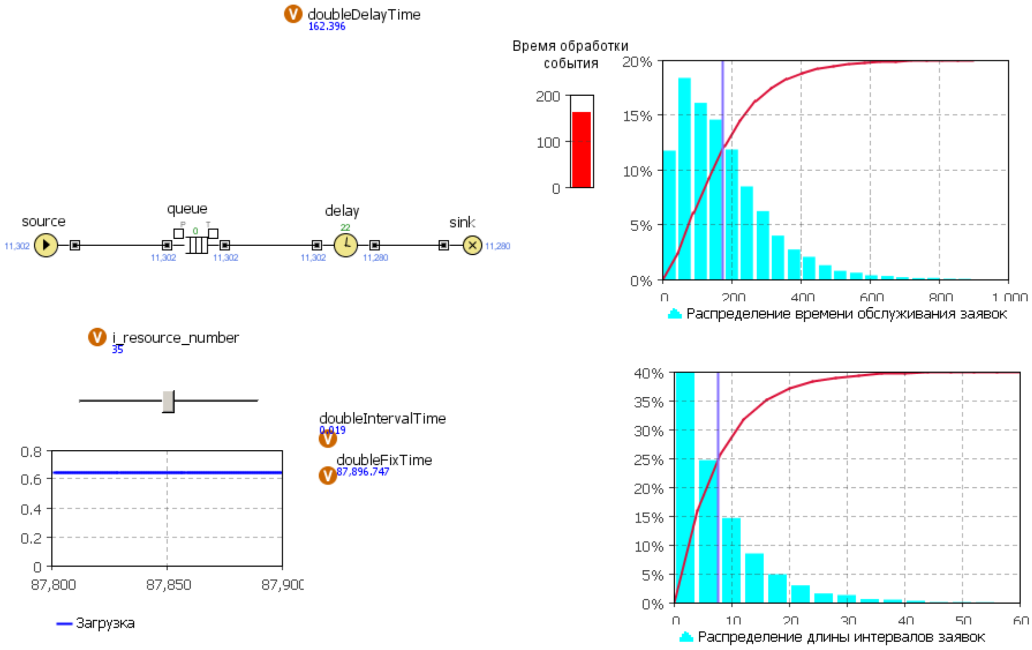

Fig. 5. The test of CCC simulation model

5.1. Partitioning the original input stream requests on the substreams

In order to be able to draw conclusions about the all participating CCC, for which we have no statistics, and the capacity of inter-node relationships, you have to divide the available input stream on certain types:

- 01 – only required response of forces and means of DDS 01,
- 02 – CCC 02,
- 03 – CCC 03,
- 0103 – CCC 01 and 03, respectively etc.

On this base being made the conclusion about the streams of 01, 03 and then created the simulation model of common CCC. Thus "traces" of the joint activity is possible to estimate the parameters of the "missing statistics".

Fig. 6 shows the identification of distribution laws for each of the "substream". Way above is also the identity of the distribution laws for the service interval for each of the selected types substream.

The experiment confirms that the splitting of the flow of requests into classes with the corresponding parameters of the distribution does not change the parameters of the distribution of initial flow. Thus the basic universal template (class ComplexSource) simulates a typical CCC.

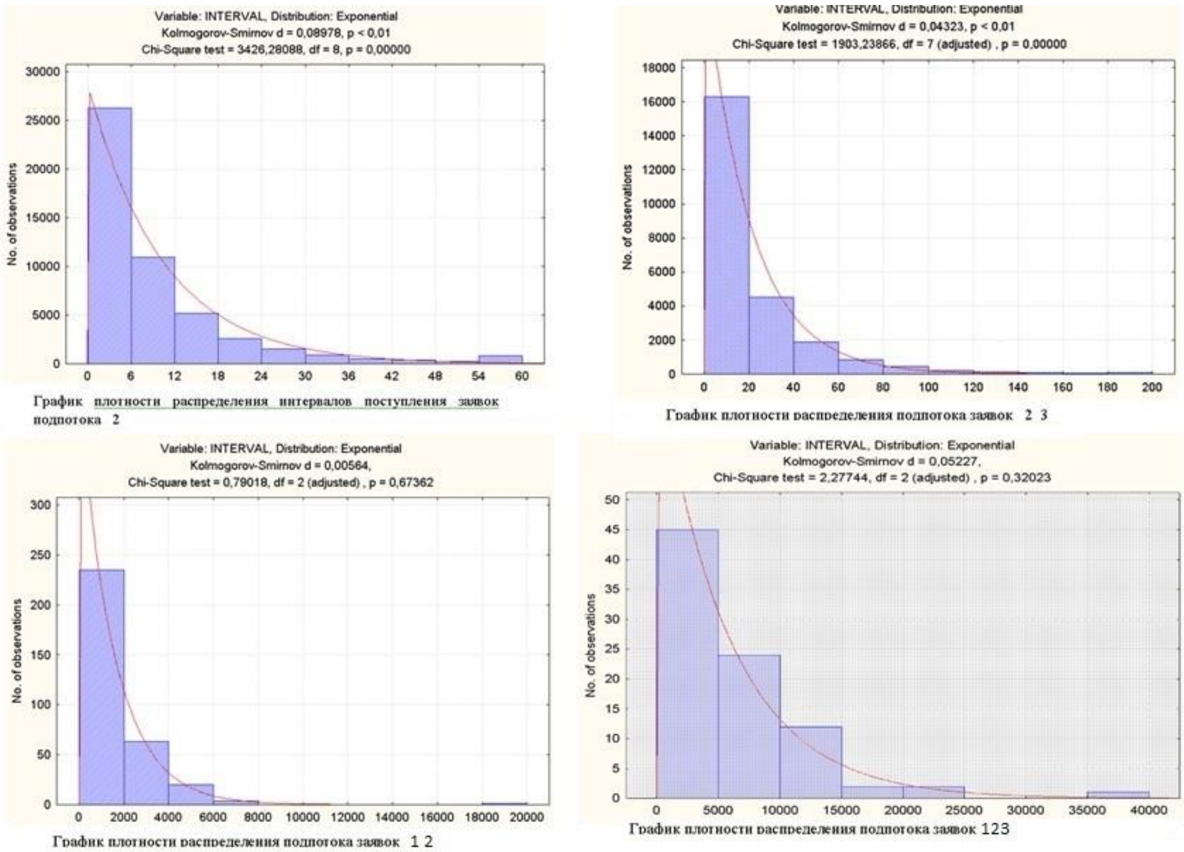

Fig. 6. Identification of distribution laws for each of the "substream"

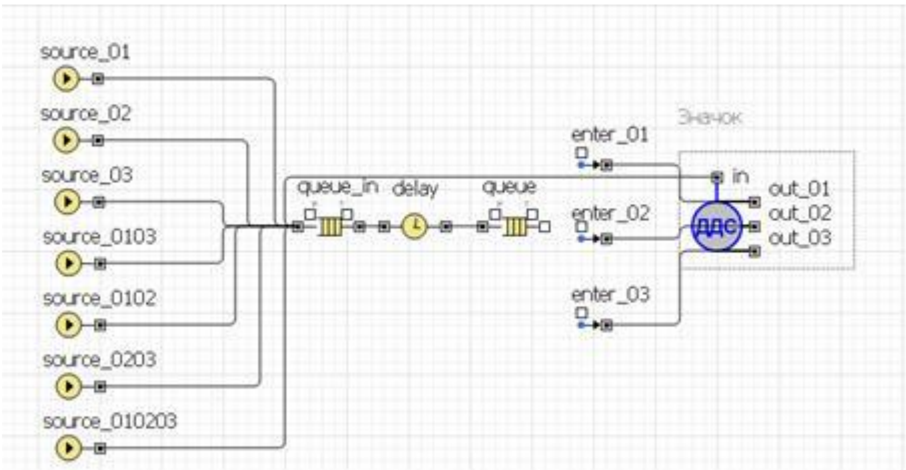

Fig. 7. The common universal simulation model integrated DDS/CCC with distributed input streams in terms of AnyLogic

5.2. Development the base simulation model CCC

Standard model of CCC (base class) with split input and output, generating a request to CCC 01, 02, 03 (Fig. 7), allows testing the hypothesis that the model Command Control Center by splitting the input stream will be adequate in terms of the formation the final steam model without splitting (Fig. 8).

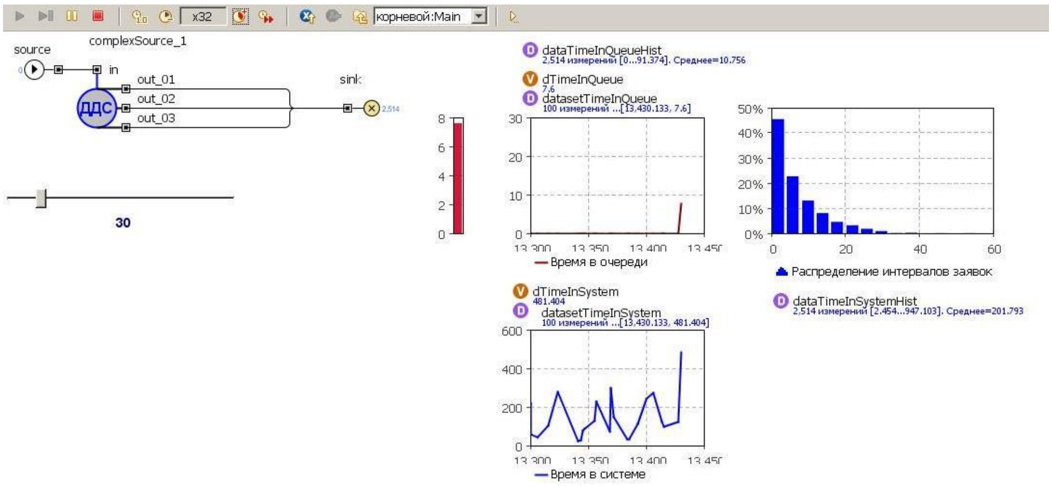

Fig.8. Experiment

6. DEVELOPMENT THE MODEL OF REGIONAL GOVERNMENT SYSTEM BASED ON THE BASE (UNIVERSAL) MODEL FOR LOCAL CCC

As node objects being used the entities which classes are inherited from the base class of the model local CCC/DDS (Fig.7).

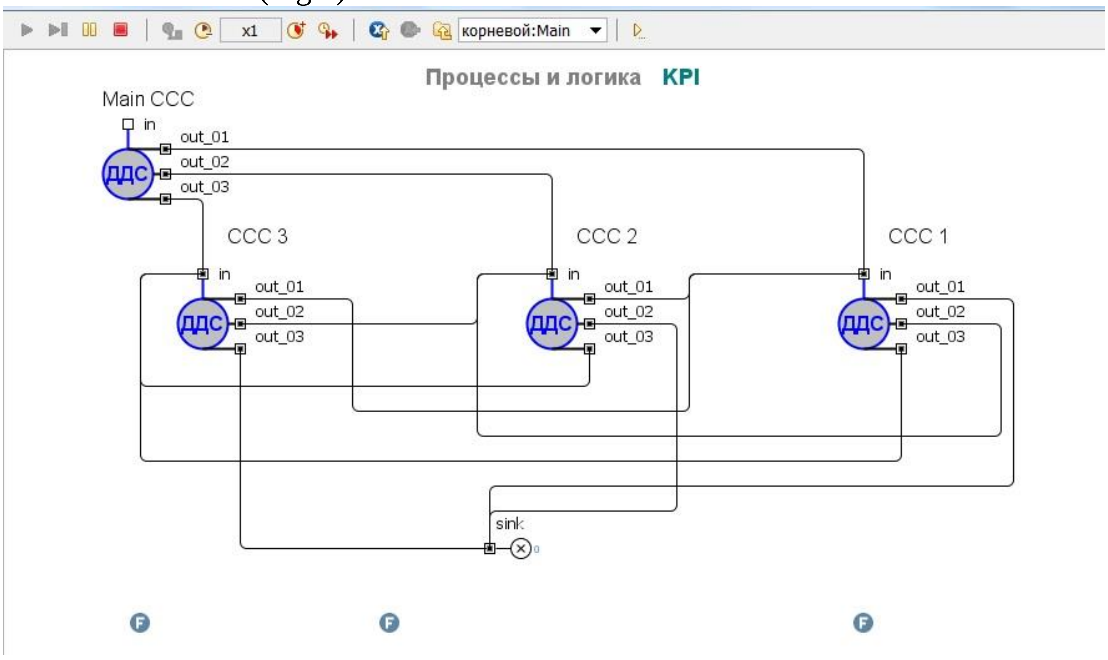

Fig. 9. Graphic interpretation the common simulation model on base universal CCC(ComplexSource) class

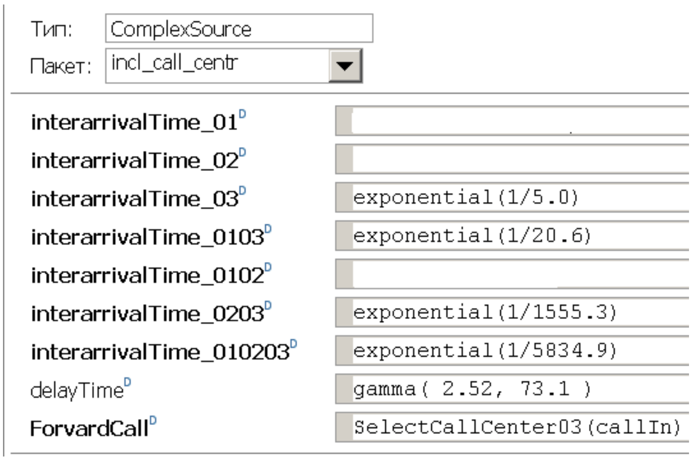

Fig. 10. The parameters of local model CCC 03.

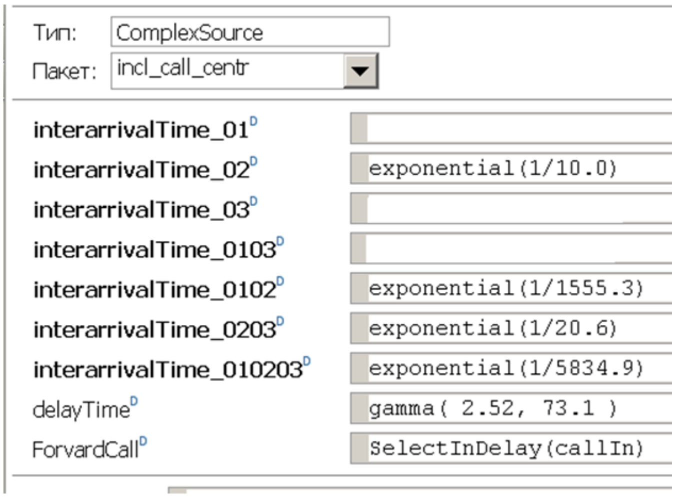

Fig. 11. Parameters of the model CCC 02 service

In figures 10 and 11 it is seen that the input streams of an object that models behavior of some local CCC 03 differ from the object of the same class modeling of local CCC 02. The specificity of 03 is reflected by the fact that is dominated by flows associated with the receipt of events including type 03 (for more details see above) which is reflected by the intensity of the exponential distribution. Streams which do not fit the specifics of CCC 03 are ignored because their intensity is negligible. Such techniques are used to describe the specifics of 02 CCC too (see the parameters of the object complexSource_02 Fig. 9). Here you can see that are significant the streams that have type of applications including reaction units 02. The highest intensity has a flow of "clean" applications 02.

Graphics System allows you to choose the optimal resource values that manipulating it is easy to identify the processes mutual influence in the work of each of the nodes on other subsystems (Fig.12).

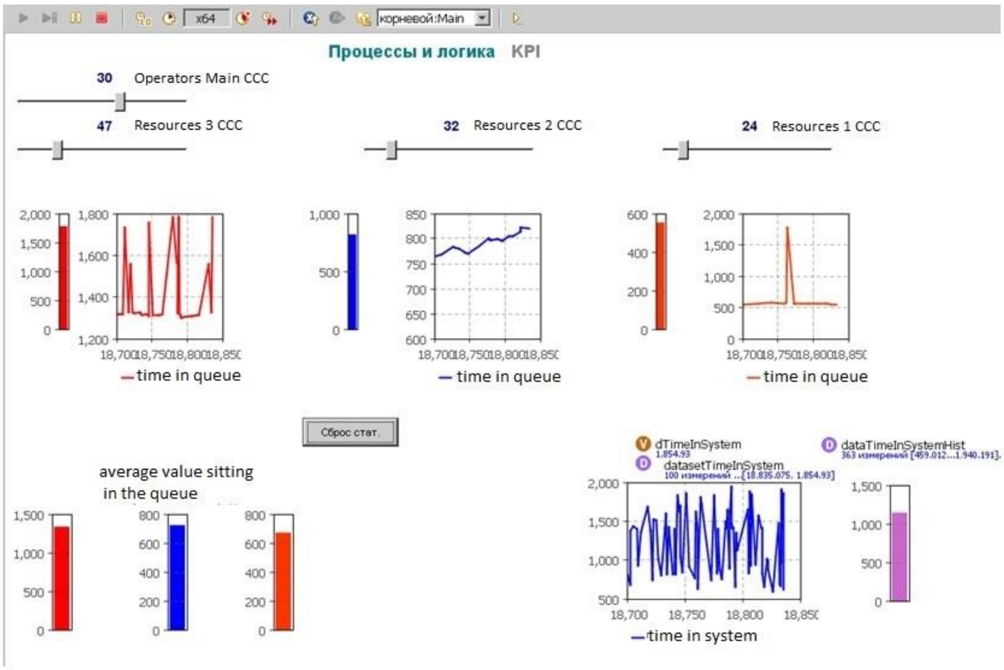

Fig. 12. The identification of optimal resources for each local CCC through simulation model.

5. CONCLUSION

Thus the authors proposed the formulation of the problem, which served as the basis for the construction of a simulation model. This allows you to determine the required amount of SmartCity system resources to perform key performance indicators within the existing constraints. The presented material can be useful for designers and developers of large automated systems which include the ACS of the SmartCity, as well as the ACS of the regional and municipal level, large sports events of international and state scale, situation centers of regional and municipal governments including such a specific area as public authorities and management.

The following articles will discuss the problems of system design from the point of view of functional modeling in the life cycle including obtaining an adequate structure of the model as well as approaches related to multivariate analysis.

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