# REALIZATION OF ALGORITHMS OF IMITATING MODELING OF TECHNICAL AND ECONOMIC SYSTEMS

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ABSTRACT

Due to rapid and drastic changes in economy and technologies managing directors and heads of departments are forced to make crucial decisions focussing attention on the overall performance of their enterprises. Modeling is frequently used when researching the mechanisms of functioning of economic systems and optimization of their activity. Investigating the economic systems making use of analytical methods of research, the whole process of research of the given systems becomes more complicated and the system modeled collects, the so-called, system's complexity.

System's complexity grows by increasing the number of blocks and factors included in the model. By using random inputs x_1, x_2, ..., x_n you are essentially turning the deterministic model of the system into a stochastic model (see Figure 1).
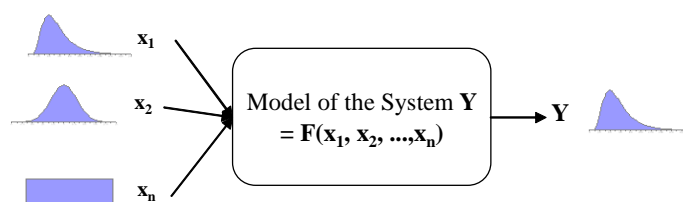
Figure 1: Scheme showing the principles of stochastic uncertainty propagation

Simulation method is just one of the many methods for analyzing uncertainty propagation, where the goal is to determine how random variation, lack of knowledge, or error affects the sensitivity, performance, or reliability of the system that is being modeled.

The steps in simulation corresponding to the uncertainty propagation shown below are fairly simple, and can be easily implemented in Excel environment for simple models. All we need to do is to follow the five steps:

Step 1: Create a parametric model, $y = f(x_1, x_2, …, x_q)$.

Step 2: Generate a set of random inputs, $x_{i1}, x_{i2}, …, x_{iq}$.

Step 3: Evaluate the model and store the results as y_i.

Step 4: Repeat steps 2 and 3 for $i = 1$ to n.

Step 5: Analyze the results using histograms, summary statistics, confidence intervals, sensitivity analysis, etc.

Analyzing the received information, we can more precisely describe the behavior of technical and economic systems researched at various values of parameters of its functioning. Imitating modeling is very important in the cases when extreme values of parameters of these systems are investigated. In practice it enables the company heads and managers make adequate decisions in critical situations, thereby raising the effectiveness of the performance of enterprises.

Due to rapid and drastic changes in economy and technologies managing directors and heads of departments are forced to make crucial decisions focussing attention on the overall performance of their enterprises. The young experts starting to work at the enterprises are compelled to actively participate in decision-making at their level and are involved in the process of implementing the decisions they are responsible for. The higher educational institutions and universities are responsible for providing their graduates both with professional knowledge in their field and abilities to generate ideas, make decisions and successfully realize these ideas and decisions in practice. Taking all this into consideration the universities and other educational establishments are searching for new approaches in training their graduates and trying to focus on enhancement of the professional skills and qualifications as well as practical skills required in their future careers. Training involves more intensive use of statistical methods of modeling, namely, computer modeling.

Modeling is frequently used when researching the mechanisms of functioning of economic systems and optimization of their activity.

A lot of economic systems researched are systems of mass services connected with services of certain requirements. We constantly collide with such economic systems in our daily life.

Let us consider an opportunity and expediency of use of imitating modeling for investigation of the work of technical and economic systems.

We shall use the method of Monte Carlo (MC) as a method of modeling.

Schemes of MC methods used in the investigation of Basic Science and Technical Economic Systems are presented in Figures 1 and 2.
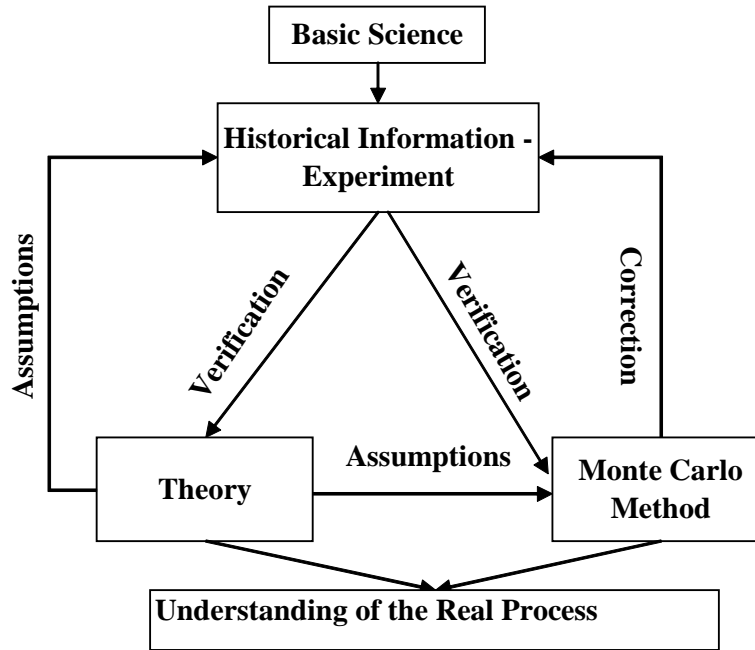
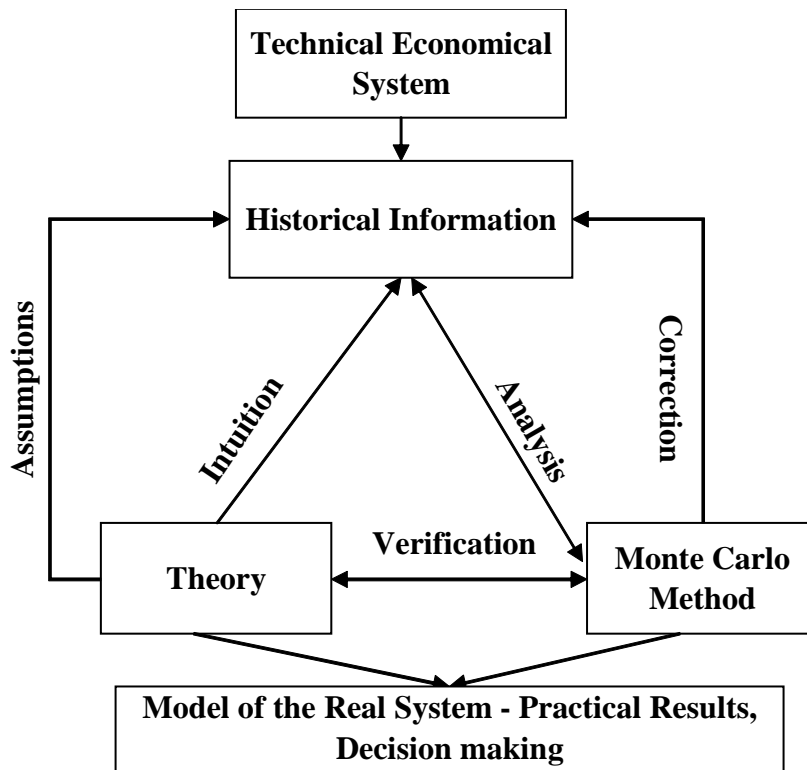**Figure 1. Scheme of using the method of MC in basic science**

Figure 2. Scheme of using the MC method in the investigation of technical and economic systems

With growth of complexity of technical and economic systems being investigated, time of research of the given systems with the help of traditional analytical (deterministic) methods promptly grows.

Investigating the economic systems making use

of analytical methods of research, the whole process of research of the given systems becomes more complicated and the system modeled collects, the so-called, system's complexity.

System's complexity grows by increasing the number of blocks and factors included in the model.

Modeling of complex technical and economic systems when using statistical methods (the method MC), frequently allows to avoid the increase of the modeling time.

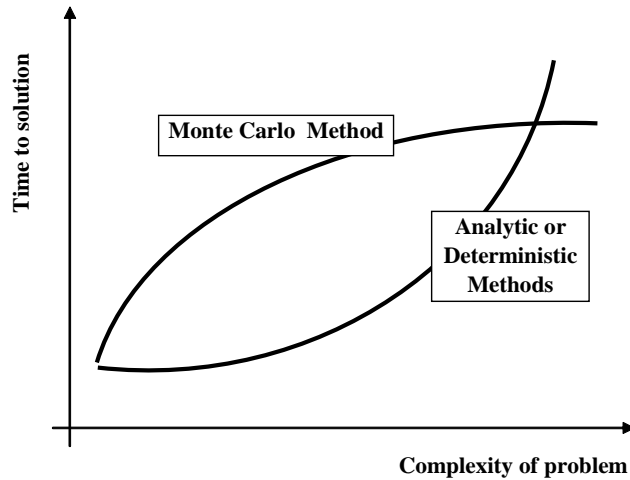Time of modeling using different methods is presented in Figure 3.

Figure 3. Time of modeling using different methods

MC simulation is a method for iteratively evaluating a deterministic model using sets of random numbers as inputs. This method is often used when the model is complex, nonlinear, or involves more than just a couple of uncertain parameters (see Figure 4).
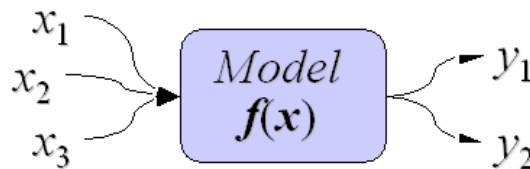

Figure 4. Parametric deterministic model maps a set of input variables to a set of output variables

By using random inputs, you are essentially turning the deterministic model into a stochastic model. Before describing the steps of the general MC simulation in detail, some words about uncertainty propagation:

- MC method is just one of the many methods for analyzing uncertainty propagation, where the goal is to determine how random variation, lack of knowledge, or error affects the sensitivity, performance, or reliability of the system that is being modeled:

- MC simulation is categorized as a sampling method because the inputs are randomly generated from probability distributions to simulate the process of sampling from an actual population. So, we try to choose a distribution for the inputs that most closely matches data we already have, or best represents our current state of knowledge. The data generated from the simulation can be represented as probability distributions (or histograms) or converted to error bars, reliability predictions, tolerance zones, and confidence intervals (See Figure 5).
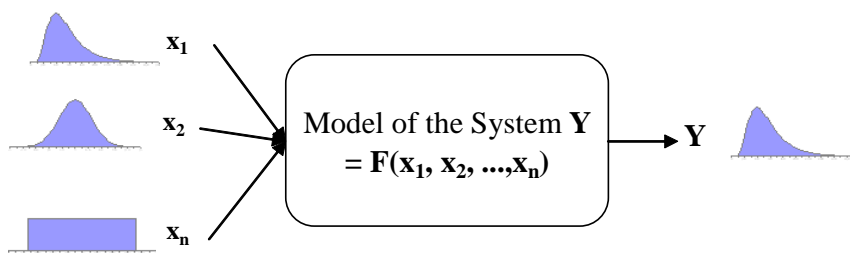

Figure 5. Scheme showing the principles of stochastic uncertainty propagation

The steps in MC simulation corresponding to the uncertainty propagation shown in Figure 5 are fairly simple, and can be easily implemented in Excel environment for simple models. All we need to do is to follow the five steps:

Step 1: Create a parametric model,

$y = f(x_1, x_2, ..., x_q)$.

Step 2: Generate a set of random inputs, x_{i1}, $x_{i2}, ..., x_{iq}$.

Step 3: Evaluate the model and store the results as $\mathbf{y}_i$.

Step 4: Repeat steps 2 and 3 for $i = 1$ to n.

Step 5: Analyze the results using histograms, summary statistics, confidence intervals, sensitivity analysis, etc.

For realization of the Step 2 in MS Excel environment the simplest way is to use the inverse function method.

This method is based on the following finding in mathematics - if F^{-1} is a function inverse to the distribution (integral) function F, the random variable $X = F^{-1}(U)$ is the distribution function F(x). The argument U is a random variable U that is equally distributed in the interval [0, 1].

Let us assume that it is necessary to generate the values of the random variable X which is continuous and has the distribution integral function F, which in its turn is continuous and increasing in

case $0 < F(x) < 1$. It follows that in case $x_1 < x_2$ and $0 < F(x_1) \leq F(x_2) < 1$, then $F(x_1) < F(x_2)$. Suppose that F^{-1} is an inverse function in relation to F. In such a case the algorithm of generating the value x for the random variable X with the distribution integral function F would be the following (the symbol «~ swung dash» means «having the distribution»):

- we generate the value u for the random variable U ~ U(0, 1), that is equally distributed in the interval (0, 1);

- we calculate x = F^{-1}(u) and consider that X =x.

Thus, the main element in the modeling algorithm x of the random (stochastic) variable X values is its distribution integral function

$$F(x) = P\{X \leq x\}.$$

The essence of this algorithm is shown graphically (see Figure 6) and in this case the variable X may have both positive and negative values depending on the interval (0, 1) of the specific value of variable u. In Figure 6 you can see that the variable u_1 makes the value of the random variable X negative which is equal to x_1 but the variable u_2 makes the value of the random variable X positive which equals x_2.
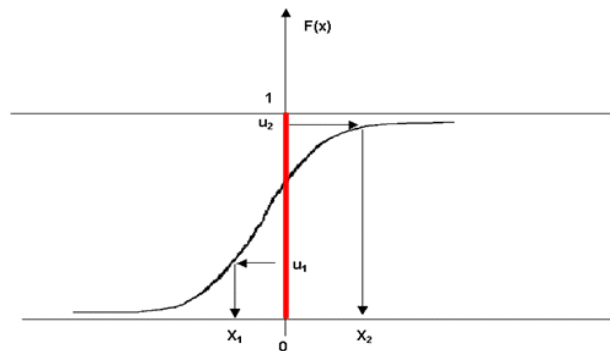

Figure 6. Illustration for using the method of inverse function

In MS Excel environment the MS Excel function VLOOKUP may be used to realize the method of inverse functions, in particular, when the number of the possible random values of X is considerable. The function VLOOKUP searches for the adequate value of the random variable X in box 2, making use of the value u = RAND() from the Table (Figure7).

Examining the problem of modeling the process of service of a technical system we mean, that the technical economic system can be any serving device with constant characteristics of service, for example machine tools, cash dispensers, automatic devices

for selling tickets, etc. The basic characteristic of the automatic serving device which will be used in a problem is the servicing time $\mathbf{t}_s$. We shall consider an example of modeling the work of a technical system with two automatic devices of service in the system. The scheme of service and the components of the servicing system are shown in Figure 8.

The algorithm of the process of imitating modeling the work of technical systems is presented in Figure 9.

We shall consider separate stages of modeling the functioning of a technical and economic system
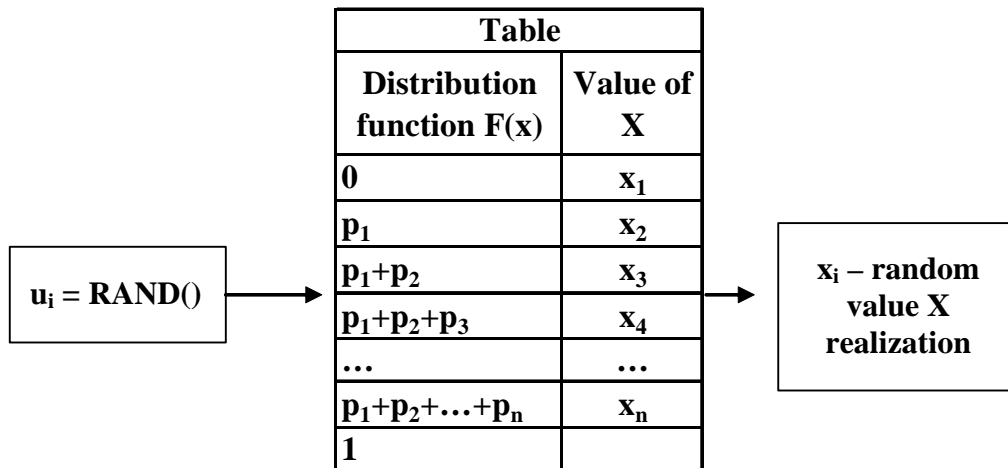
Table	
Distribution function F(x)	Value of X
0	x_1
p_1	x_2
p_1+p_2	x_3
$p_1+p_2+p_3$	x_4
…	…
$p_1+p_2+…+p_n$	x_n
1	

$u_i = RAND()$

x_i – random value X realization

Figure 7. Realization of the method of inverse function using MS Excel function VLOOKUP
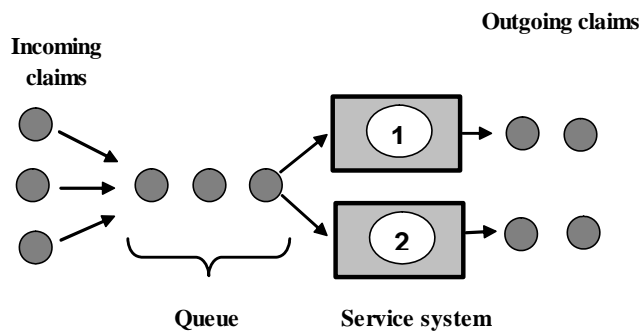

Figure 8. The circuit of service of requirements in technical systems with two devices of service

in more detail.

The purposes of modeling (Figure 9 Stage 3) are to model the process of receipt and service of requirements in a system of mass service with two serving devices (automatic devices);

Investigation of the modeling system (modeling process) (Figure 9 Stage 5):

1. Using program MS Excel for modeling k service cycles of requirements in a system with two serving devices.

2. To process files of the received information and to create a solid chronological file of occurrence and the system incoming events in the system modeled.

3. To calculate parameters of the technical and economic system:

a. Q(t) - number of the requirements in turn at the moment of time t;

b. B(t) - number of the requirements which are taking place in service, at the moment of time t;

c. Z(t) - number of the requirements which are taking place in a system (both in service and in turn), at the moment of time t.

d. $\hat{d}(n)$ - an expected average delay in turn for each of n requirements for individual realization of

process of modeling;

e. $\hat{q}(n)$ - average on time number of requirements in turn for individual realization of process of modeling;

f. $\hat{u}(n)$ - parameter of employment of the serving device for each individual process of modeling.

4. To construct schedules:

- $\int_0^{T(n)} B(t)dt$ - the area under function of employment in (t) during the period of time of modeling T(n);

- $\int_0^{T(n)} Q(t)dt$ The area under function Q (t) during the period of time of modeling T (n);

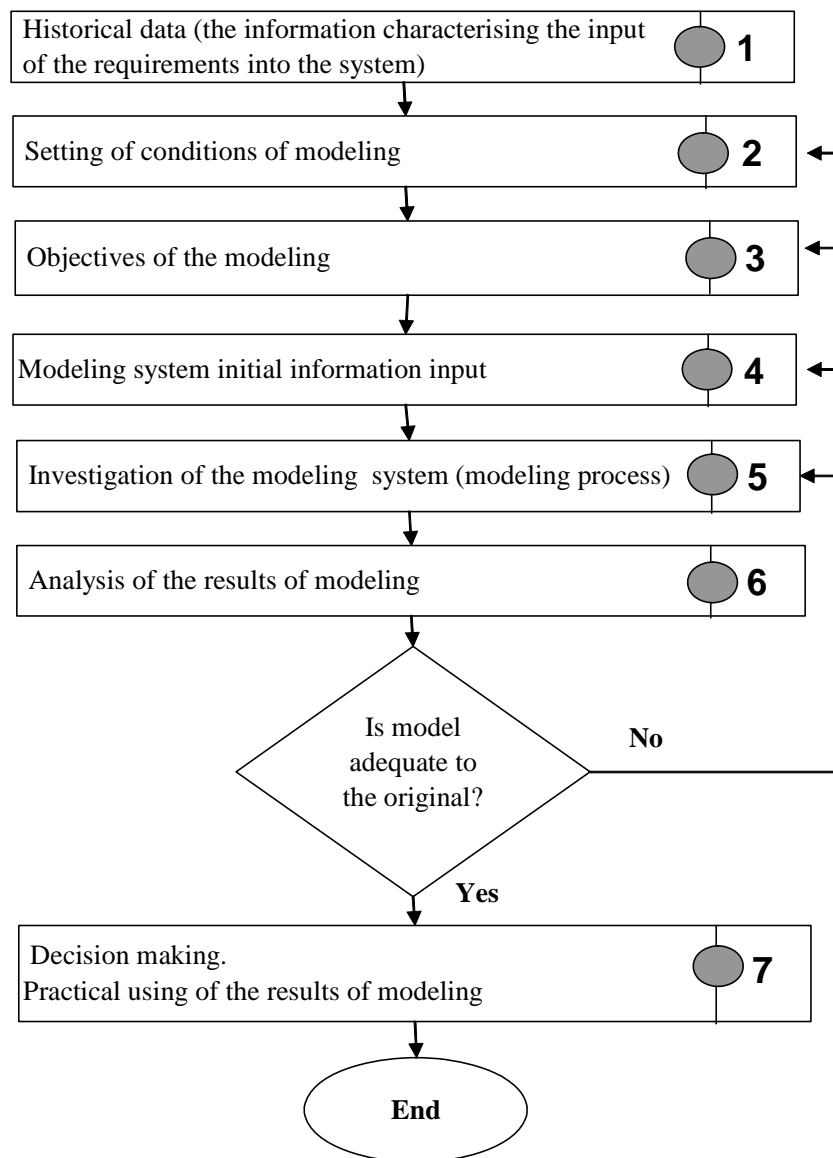- $\int_0^{T(n)} Z(t)dt$ - the area under function Z (t) during the period of time of modeling

Figure 9. Stages of modeling

T(n).

A distinguishing feature of the decision of the given problem will be:

- generating the statistical information describing the process of receipt in the system of requirements of service, using the program MS Excel;

- distribution of a stream of requirements between two serving devices of the system;

- graphically display differences in the system during modeling.

The basic characteristic of the automatic serving device which will be used in the model is service time t_s.

During the time interval t_s the number of the requirements acting in the system and probability of their occurrence are presented in the table (See Table 1).

As a result of generating we receive the file of information describing the process of receipt and service of requirements in a technical system. Results of modeling are submitted as schedules (Figures 10, 11, 12) and are summarized in Table 2.

Analysis of the results of modeling, (Figure 9 Stage 6).

Analyzing the received information (Table 2), we can more precisely describe the behavior of technical and economic systems researched at various values of parameters of its functioning. Imitating modeling is very important in the cases when extreme values of parameters of these systems are investigated. In practice it enables the company heads

Table 1. Historical data (the information characterizing the input of the requirements into the system)

Number of requirements X	Distribution function F(x)
x_1	0
x_2	p_1
x_3	p_1+p_2
x_4	$p_1+p_2+p_3$
…	…
x_n	1
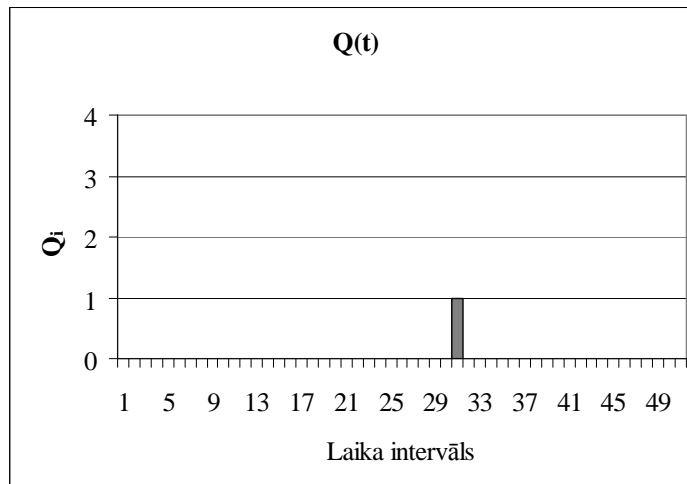
Figure 10. Change of the area under Q(t) in a system with two serving devices during the time of modeling
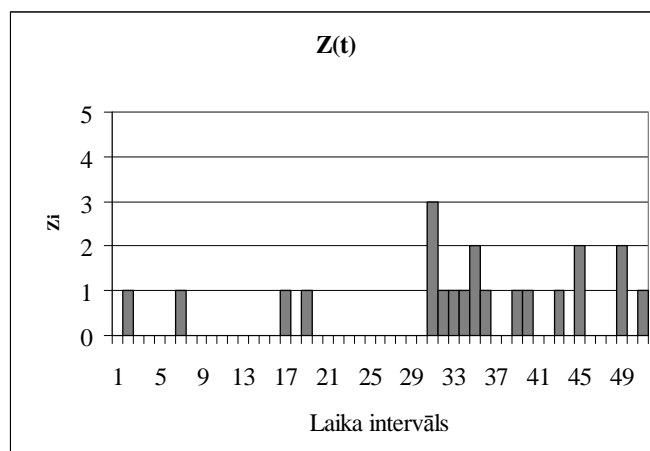
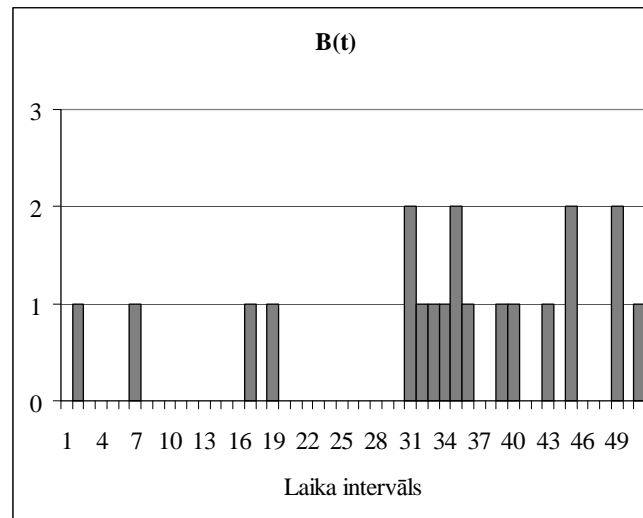**Figure 11. Change of the area under Z(t) in a system with two serving devices during the time of modeling**

Figure 12. Change of the area under B(t) in a system with two serving devices during the time of modeling

Table 2. Final information of the modeling of the system

$\hat{d}(n) =$	**0,10**
$\hat{q}(n) =$	**0,02**
$\hat{u}(n) =$	**0,40**

and managers make adequate decisions in critical situations, thereby raising the effectiveness of the performance of enterprises.

The algorithm shown above can be used for modeling similar technical and economic processes or service systems.

References

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