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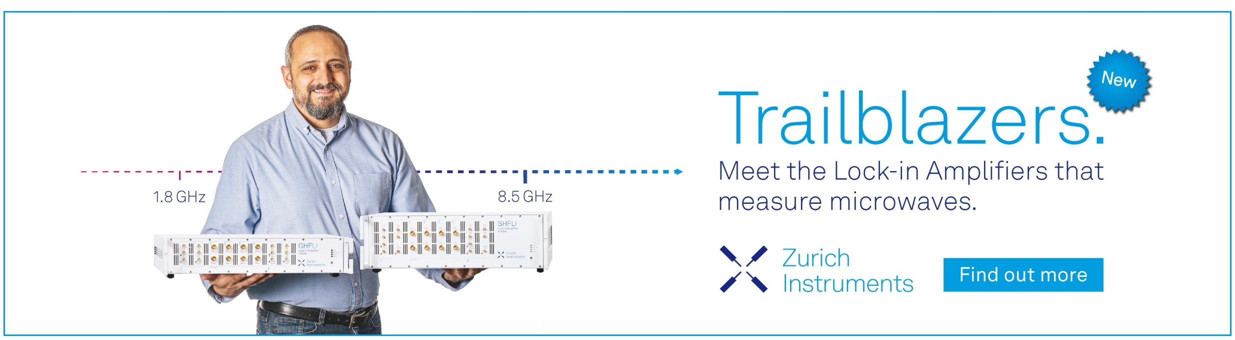

# Application of Methods of Applied Mathematics in the Gateway of Information Exchange for Business Applications Queuing Systems

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**Abstract.** The article deals with the general problem of the functioning of business systems that implement the service order model. The role and relevance of the use of economic methods of strategic planning is considered, their unsatisfactory performance in dynamic queuing systems is indicated. The design goal is indicated (development of an optimal model for servicing applications for a large business system: a network of car washes with a multichannel mode of service provision).The authors apply complex methods from applied mathematics, particular generalizations from game theory and graph theory. Using simulation modelling, the above scenarios of using the apparatus of the queuing theory in the path for exchanging information about the status of requests are considered and calculations are given. The role of the conducted research and computational and graphic work is emphasized.

## INTRODUCTION

The functioning of modern business systems is mediated by various stakeholders. One of the most common dilemmas in analysing the functioning of modern digital systems and related information systems and technologies is that they have the property of a "bottleneck" at the level of direct interaction with the recorded data. Somewhere it is throughput, somewhere it is a limited set of registered values. This aspect is considered even more difficult in software, where it is often built on the rigid principles of event handlers (both from the user side and from the system side).

### Problem Statement

Many researchers [1,2,3,4] have been involved in the development of new management and organizational decisions in the design of decision support systems, management systems, quality control systems, software products in the corporate sector of the economy.

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In a number of studies [5,6] an a posteriori judgement was expressed. This judgement expresses the features of thematic modelling from the standpoint of convergence control of real processes occurring in the contour of business systems.

## Research Questions

The nature of the manifestation of conjugation in a priori distributions prompts the identified problems. Indeed, if the system is considered as a set of events registered by it, arising only with a priori probability, in other words there is the probability of an event occurrence before additional data are received, then an extremely ideal model but not a real control system is obtained.

The solution to the forecasting problem based on the posterior approach also raises several questions. Firstly, for many processes occurring in technological processes or service processes, the human factor and total entropy play a role. This is especially pronounced in systems where the reference point plays an important role - i.e. in most complex systems, where a complex space-time dependence is observed, and only then, in the background, the event-processed line of behaviour of the considered components in the system, the interaction path, experimental convergence (empirical experience) plays a role.

## MATERIALS AND METHODS

Traditional methods of strategic planning for business management, associated with time costs caused by random values of queues and time for processing events, taken as the main function of a business system, also do not express a high efficiency factor [7].

Therefore, when a discrete model of an event processing system for an ERP service of a business company specializing in organizing the management of a network of car services and car washes has been developed, the existing approaches from management, including methods of managing complex technical systems have been considered [8,9].

The purpose of this study is to develop a means of optimization of the information exchange path in the context of using the queuing line in multi-threaded service of applications from the side of a proprietary business application.

The role of information exchange is the activation function of the transition from one final state of the service system to another.

## RESULTS AND DISCUSSION

### Results

The diagram shown in Figure 1 is used as a general model for servicing a car wash service. Accounting and auditing is carried out by means of predictive and direct analytics

Service A is the direct functioning of the decision support system to determine the car wash service.

Service B is data aggregating into the BI platform.

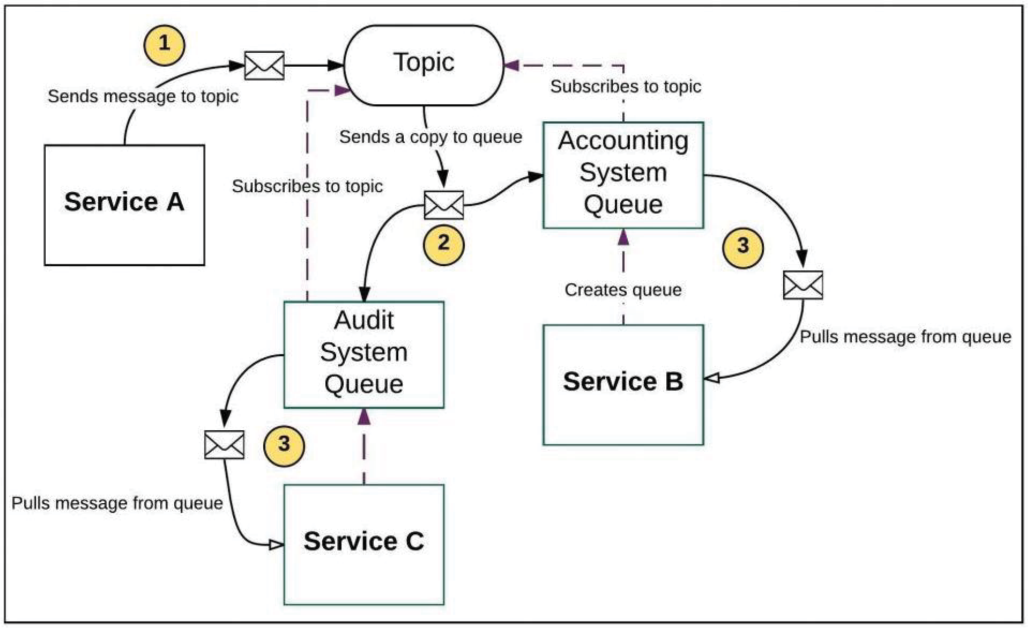


**FIGURE 1.** Schematic diagram of the functioning of the considered business system.

Modelling of the modes of operation of the systems with reduction to the model of the service system shall be considered from the point of structural analysis - in particular, from the consideration of the system in the form of interconnected graphs (their networks).

To describe the structural properties of the network, we will use a directed weighted graph G (V, E), the set of vertices of which V models the set of all nodes (stations) of the mesh network, including MSS and MBS, and the set of arcs E reflects the set of channels between them, where the presence of a channel (i, j) means the possibility of direct transmission of the user stream from the i-th node to the j-th.

A slot is a single link layer resource; in order to control the process of their distribution, a variable is introduced.

The task of self-organization is reduced to minimizing the function of energy efficiency of data transmission.

The solution to this problem is carried out in two stages: network initialization and self-organization.

To solve the problem, it is necessary to maintain a constraint condition:

– the network must be connected (there was one cluster for all nodes);

The resulting optimization problem belongs to a nonlinear programming problem. Since we do not know the region of minimum values of the function, to solve the problem, imitation modelling of the service system will be used. It will be considered as an interpretation of the operation of systems A and B in a single service link.

To solve this problem, the contour analysis method can be used.

A contour network is such an orthogonal network that does not contain open circuits. Any network can be represented as a contour network, having closed the source with its receivers, this closure is due to the fact that the flow must be circulated. The concept of circulation was introduced while describing the defect algorithm. According to this concept the sum of node inlet flows shall be equal to the sum of node outlet flows [10].

To meet this requirement, it is necessary to close the drain with its sources.Thus, all the nodal intensities (the weights of the activation function - the predicate of the transition to the layer of the contour network) are equal to zero, and, therefore, the connection between the basic intensities and the intensities in the network branches is determined only by the relation.

## Findings

Let us bring the considered service system to the contour analysis method in the Simulink environment, check the calculations of the optimal options for organizing service proposed by the system (three options).

The developed closed-loop system has been used in the modelling, and the simulation took into account the possibility of a service node failure.

The claims source subsystem is modelled using the orders generator.

In the first case of use, a simple service model that takes into account transition probabilities and time costs based on the empirical nature of the car's transition from the waiting area to the service area has been used (Figure 2).

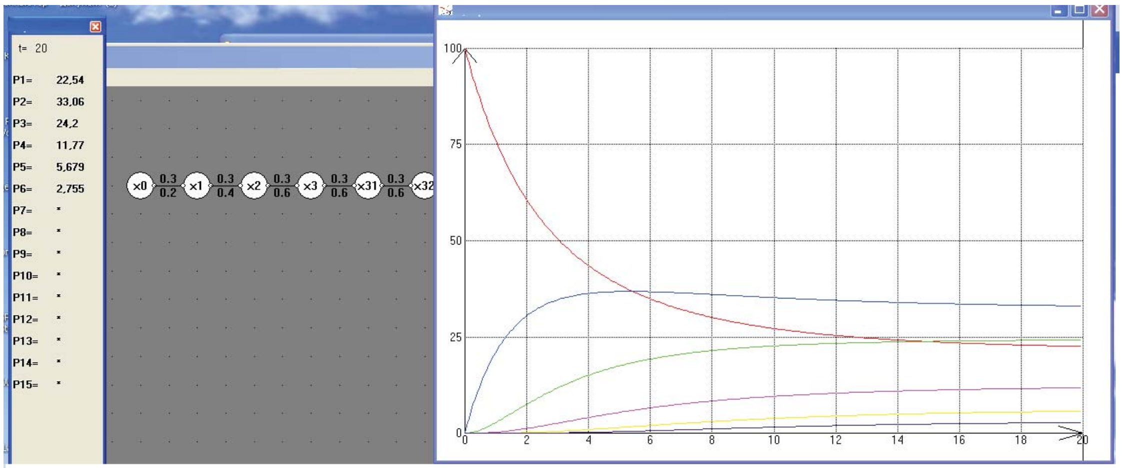


**FIGURE 2.** The first version of the model of the business service maintenance system.

The values of the steady state probabilities of the system:
P0 = 22.54;
P1 = 33.06;
P2 = 24.2;
P3 = 11.77;
P4 = 5.679;
P5 = 2.755.

The calculation of the characteristics of the queuing system of a business system (based on the results of simulation modelling) is presented for comparison with other options for modelling and finding the optimal times for the considered business system.

Probability of failure (calculated in the program):

Pfail.= 0.02755.

Relative bandwidth (calculated in the program):

q = 0.97245.

Absolute bandwidth (calculated in the program):

A = 0.277842857.

Average number of busy channels: (formula 1)

$$\bar{k} = 0 \cdot p_0 + 1 \cdot p_1 + 2 \cdot p_2 + 3 \cdot p_3 + 3 \cdot p_4 + 3 \cdot p_5, \tag{1}$$

$$\bar{k} = 0 \cdot 22{,}54 + 1 \cdot 33{,}06 + 2 \cdot 24{,}2 + 3 \cdot 11{,}77 + 3 \cdot 5{,}679 + 3 \cdot 2{,}755 = \frac{142{,}07}{100} = 1{,}42.$$

Average number of applications in the queue (calculated in the program):

$$\bar{r} = 0{,}11189.$$

Average waiting time for an application in the system (calculated in the program):

$$\bar{t_c} = 5{,}253865.$$

The values of the steady state probabilities of the system (Fig. 3, Fig.4, Fig. 5):
P0 = 0.0333
P1 = 0.1973
P2 = 0.3886

P3 = 0.3807

Calculation of the characteristics of the considered object


**FIGURE 3.** The second option - a system with less pronounced iterative differentiation.

Average number of technical devices (cars) in the queue for service (calculated by the program):

$$\overline{r} = P_3 = 0{,}38.$$

Average number of serviced technical devices (calculated by the program):

$$\overline{\mathrm{k}} = 1{,}74.$$

Average number of non-operated technical devices (formula 2):

$$\overline{l} = \overline{r} + \overline{k} = 2.12. \quad (2)$$

The probability that there will be a downtime of technical device (formula 3):

$$\beta = \frac{\overline{\mathrm{l}}}{\mathrm{n}} = 0.71. \quad (3)$$

The probability that the service system at a car wash will work in conjunction with an adjacent service line (gateway) (formula 4):

$$\gamma = 1 - \beta = 0.29\,. \quad (4)$$

The average number of car service channels (the total number is not considered in the considered analysis) occupied by the service (formula 5):

$$\overline{\mathrm{z}} = 0 \cdot \mathrm{p}_0 + 1 \cdot \mathrm{p}_1 + 2 \cdot \mathrm{p}_2 + 3 \cdot \mathrm{p}_3 + 2 * (\mathrm{p}_2 + \mathrm{p}_3) = 3{,}66. \quad (5)$$

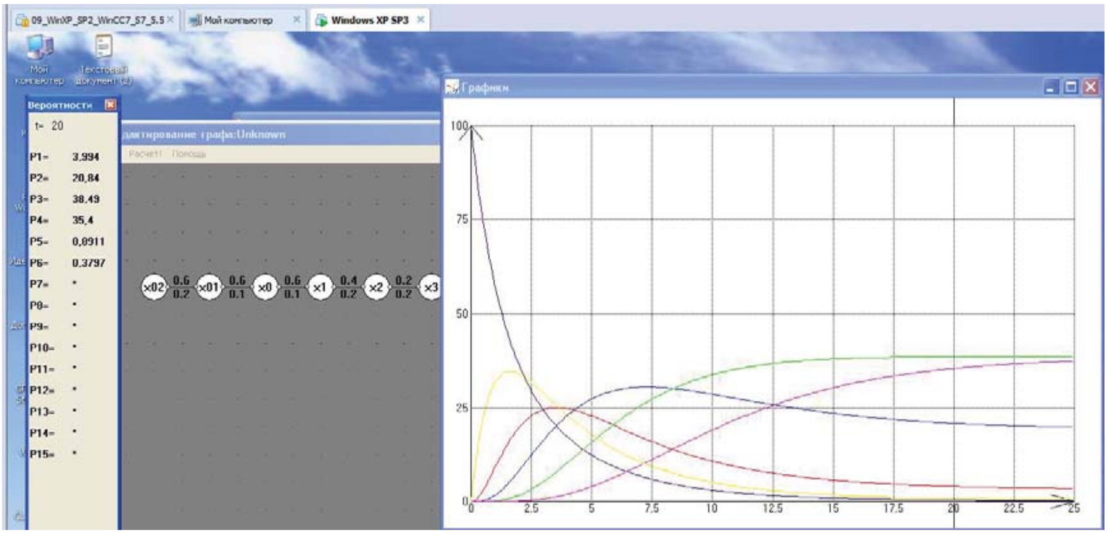


**FIGURE 4.** Service system model (option 3).

## Discussion

The values of the steady-state probabilities of the system states in options 3 and 4 are defined in Table 1.

After studying the principle of operation and creation of an algorithm of work, writing of the program for managing the business service system itself can be started.Since the program is written for the PR200 programmable relay, the OWEN Logic program serves as a program writing environment.Since many tasks will be implemented in the program, it is necessary to create function macro blocks.The creation of macros reduces the time for writing a program [11,12].

The project used such macros as:

1. time&Speed is a macro where the main objective of a program will be implemented.
2. rise_Fail is a macro of a linear change of a value over time, it is used to implement a smooth acceleration, as well as a smooth deceleration of the transition to the next state.
3. TIME U/D is a macro of time counting, serves to count time for indication of revolutions of the machine within a minute.
4. fSave is a macro for saving a floating point value. It allows to save the last value [13].

Optimization of the selected operating mode (modes - 1-4) of the service system (discrete operating mode) is indicated as a sample in Table 1.

**TABLE 1.** Experimental data of the characteristics of the queuing business system and the values calculated from them.

| | | | | | | |
|---|---|---|---|---|---|---|
| $\lambda$ | 0.81 | 0.28 | 0.2 | 0.08 | 0.04 | 0.01 |
| P0 | 0.30 | 19 | 40.78 | 57.74 | 75.9 | 93.39 |
| P1 | 4.90 | 42 | 43.14 | 34.82 | 21.92 | 6.464 |
| P2 | 27.87 | 30.75 | 14.47 | 6.95 | 2.1 | 0.15 |
| P3 | 66.90 | 8.152 | 1.6 | 0.5 | 0.07 | 0 |
| $\lambda$ | 0.80 | 0.25 | 0.2 | 0.08 | 0.04 | 0.01 |
| $\mu$ | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| P0 | 0.003 | 0.19 | 0.4078 | 0.5774 | 0.759 | 0.9339 |
| P1 | 0.049 | 0.42 | 0.4314 | 0.3482 | 0.2192 | 0.06464 |
| P2 | 0.2787 | 0.3075 | 0.1447 | 0.0695 | 0.021 | 0.0015 |
| P3 | 0.669 | 0.08152 | 0.016 | 0.005 | 0.0007 | 0 |
| r | 0.669 | 0.08152 | 0.016 | 0.005 | 0.0007 | 0 |
| k | 1.9444 | 1.19804 | 0.7528 | 0.4972 | 0.2626 | 0.06764 |

**TABLE 1.** Continued

| | | | | | | |
|---|---|---|---|---|---|---|
| l | 2.6134 | 1.27956 | 0.7688 | 0.5022 | 0.2633 | 0.06764 |
| β | 0.871133333 | 0.42652 | 0.256267 | 0.1674 | 0.087767 | 0.022547 |
| 1-β | 0.128866667 | 0.57348 | 0.743733 | 0.8326 | 0.912233 | 0.977453 |
| z | 4.5088 | 2.0576 | 1.0902 | 0.6512 | 0.3067 | 0.07064 |
| λ | 0.45088 | 0.20576 | 0.10902 | 0.06512 | 0.03067 | 0.007064 |

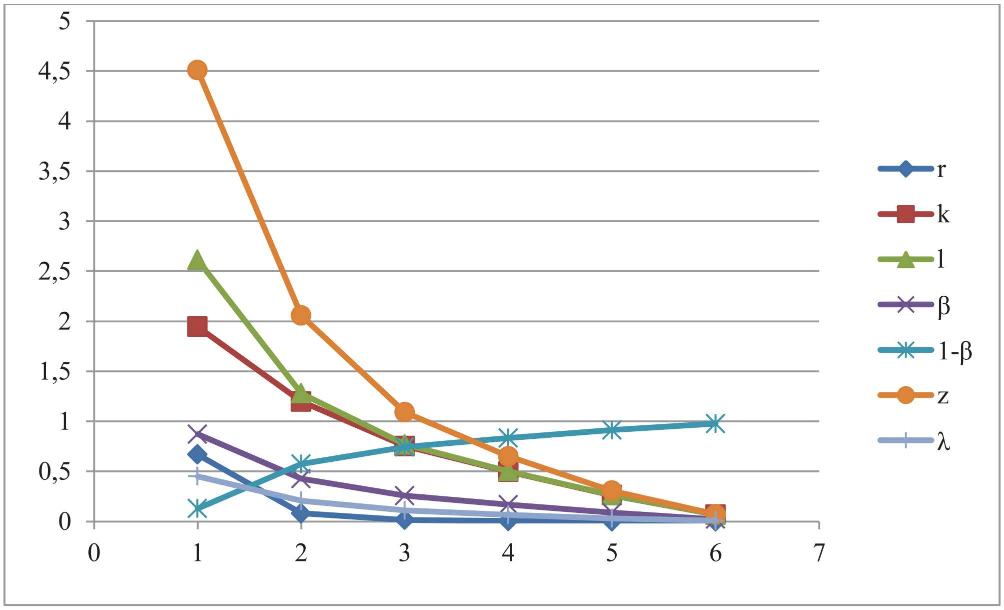


**FIGURE 5.** Diagram of indicators for four modelling options.

## CONCLUSION

According to the results of this study, the best characteristics have been shown by the mode of operation of the business system of service by the flow of the car wash system in the context of the queuing model (Fig. 5). As part of the reduction to the model of probabilistic analysis, option 4 has been chosen, where the functional indicator$\lambda$ is equal to 0.2.

Since it is in this invariance that the average number of devices in the queue will be minimal with sufficiently high other indicators. As a result of the modelling using the methods of applied mathematics of various modes of operation of queuing systems, the best performance has been shown by the proposed discrete mode of operation [14].

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