Research and Analysis of the Functioning Quality of Hardware and Software Complexes Automotive Service Systems with Using Logistic Approach

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***Abstract*—The analysis of the advantages using the architectural concept logistics system for the construction highly efficient hardware and software systems automotive services, supporting a wide range information services. As a result of the research, a mathematical model of the quality of functioning systems automobile services using logistics system, as a queuing system (QS), is proposed. On the basis of the model, the characteristics multichannel queuing systems with waiting and limited queue length, as well as the total number hardware and software systems, were analyzed. For the criterion of the quality functioning systems automobile services using the logistic approach, complex indicators of the productivity and reliability of the functioning complex systems have been selected. Based on the study model, analytical expressions were obtained that make it possible to estimate the indicators peak throughput, stationary and limiting probabilities states, as well as the probability failure-free operation of the system when providing information services. The considered characteristics make it possible to assess the state of the system, indicators probability failure, and also allow to optimize their parameters. On the basis of the model, a numerical analysis was carried out and a graphical dependence of the maximum value peak throughput on the total number hardware and software systems was carried out at an admissible system load factor and at a given average speed. It has been established that an increase in the total number hardware and software systems leads to an increase in the maximum value of the peak throughput, which meets the requirements for the performance and reliability of the system.**

Keywords*—performance, logistic system, service, reliability, mathematical model, system automobile service, logistic process.

I. Introduction

Currently, the intensive development network infrastructures of the digital economy and the creation strategic plans "Roadmap for digitalization" requires the optimal organization and management limited information resources transport and technological complexes that ensure the high-quality functioning automotive service systems in the provision information services and in the processing various message flows.

However, the development and implementation information and computer technologies in the systems automobile services for processing information flows various traffic, make it possible to research the operation algorithms and analyze the architectures complex transport and technological complexes at a qualitatively new level, built in accordance with the concept logistics systems.

Logistics is the science planning, organizing, managing and controlling the movement and time material and information flows in a system from the primary source to the final recipient. The term "logistics" comes from the Greek word "logistike" - as the art of calculating, reasoning, as well as distributing and managing all available resources for the provision various information services, taking into account numerous parameters [1, 2, 3].

In this case, the essence of the logistic approach to managing information flows is to integrate individual sections telecommunication and logistics processes into a single system automotive services for service, technical and mass maintenance.

The management and distribution information resources is based on the efficiency processing information flows circulating in the logistics system. In this regard, one of the key characteristics logistics are indicators information flow. Here we assume that the information flow can exist in the form of paper and electronic documents, which are useful and service traffic [2, 4].

For the criterion of the quality of functioning indicators transport and technological complexes, using the concept logistics systems automobile services, the performance of the information flow processing system was selected, which is characterized by the following complex indicators [2 - 5]:

- performance automotive service systems when processing various information flows based on a logistic approach;
- single and complex reliability functioning of a complex transport and technological complex in the logistics system.

Considering the above, it can be said that the tasks research and analysis of the above-mentioned indicators quality of functioning systems automobile services using advanced computer technologies and new logistic approaches are the most urgent task.

Performance and reliability are characterized by numerous complex indicators such as throughput, probabilistic-temporal characteristics, system cost, as well as the efficiency use and distribution information and network resources.

It should be noted that a significant number works are devoted to the study of a mathematical model optimization of the planning solution of a gas station [3, 4] and theoretical studies transport and technological complexes with a probabilistic nature of the quality of functioning systems automobile services [5-7].

In this paper, we propose a solution to the problem formulated above - the development of a mathematical model for optimizing the quality of functioning automotive service systems based on the architectural concept logistics systems in the provision information services.

II. GENERAL PROBLEM STATEMENT

Note that the system for transmitting and processing information flows automobile services are sources electronic documents, paths hardware and software complexes and communication channels, as well as specialized units using logistics systems for resources management.

To calculate the indicators of the paths hardware and software complexes, it is necessary to create a scheme for the functioning of the mathematical model system automobile services using logistics systems, which will most accurately take into account the telecommunication processes and management resources flowing in the system under consideration when providing service maintenance. The mathematical model systems automobile services is as a network model of the quality of functioning hardware-software systems based on the logistic approach.

The analysis shows [1, 2, 8] that the systems automobile services in the provision information services is a large real-time information system, which is in accordance with the accepted logistic approaches and resources. This ensures the provision of the various services requested by the user, subject to the availability of the necessary resources.

Thus, the quality of functioning automobile services using the logistic approach can be considered as an open queuing system, as a network model of the system.

The development of a mathematical model quality of the functioning systems involves a quantitative assessment of the quality adopted technical solutions and can be formulated as a search for the vector optimal parameters hardware and software systems and elements of the logistics system [2]:

$$Q(\lambda) \rightarrow extr\,,\ \lambda \subseteq \lambda_{all.}\,,\ G(\lambda) \subseteq G_{all.}(\lambda)\,,$$
$$P_r(\lambda) \subseteq P_{r.\,all.}(\lambda) \qquad , \qquad (1)$$

where $\lambda -$ the vector of parameters of hardware and software systems system automobile services based on the concept of logistics systems in the provision information services and is equal to $\lambda = \sum_{i=1}^{n} \lambda_i$, $i = \overline{1,n}$; $\lambda_{all.} -$ the set valid values for these parameters; $Q(\lambda) -$ a criterion for the quality of functioning of the network model systems automobile services of the decisions made, the extremum which must be ensured by choosing the appropriate vector parameters of the network model λ; $G_{all.}(\lambda) -$ the set of acceptable values for these criteria; $P_r(\lambda) -$ the vector of reliability of a single and complex functioning complex hardware and software complexes that determine the quality of functioning of the network model systems automobile services in the logistics system; $P_{r.\,all.}(\lambda) -$ a set admissible values indicators reliability functioning complex hardware and software systems.

Expression (1) characterizes the essence of the considered logistic approach to the management of information services and defines a set of criteria for the mathematical model of the quality of functioning of the paths of hardware and software complexes of systems of automobile services with minimal economic costs.

In addition, (1) performs the optimization problem of the quality of functioning systems automobile services based on a logistic approach to the problems managing network and information resources, which allows obtaining analytical expressions for assessing their main characteristics.

III. CONSTRUCTION OF A STRUCTURAL DIAGRAM AND DESCRIPTION ALGORITHMS FOR THE OPERATION OF THE PATHS HARDWARE AND SOFTWARE COMPLEXES

To perform the objective function (1), fig. 1 shows a block diagram of the mathematical model paths hardware-software complexes of the systems automobile services. The structure under consideration is a scheme for the functioning of the model of a link automobile services and consists of the following functional, block-modular systems such as a source and a load consumer, controlling an element of a logistics system and a transmission system, as well as an information processing system and a server buffer storage .

The algorithm operation and the presented scheme of the model's functioning is described in detail in [2, 9], where it is noted that the data flows generated by various load sources are analyzed at the channel level, which make it possible to determine the characteristics of the network model paths hardware and software complexes automotive service systems.

The investigated diagram of the mathematical model of the paths of the hardware and software complexes of the systems automobile services demonstrates the essence of the logistic approach for the management information services. Mathematical models are based on the integration individual control elements logistics with the links performing the telecommunication and logistics process to create a unified system automotive services [2, 3, 10].

Taking into account expression (1), the algorithms of the presented scheme show [2, 3, 11] that the considered system automobile services is a queuing system (QS, Queueing Systems) with a servicing hardware and software complex (server, router) and a buffer storage (BS) final capacity N_{BS}.

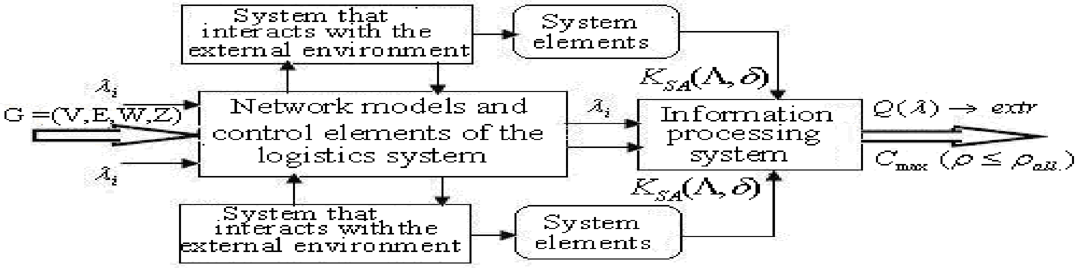

Figure 1. Block diagram of the model paths hardware and software complexes systems automobile services using the logistic approach

We represent the mathematical model automobile services based on a logistics system in the form of an undirected weighted connected graph:

$$G = (V, E, W, Z)\,,\ \ |V| = N\,,\quad |E| = M$$

where $V -$ set of peaks; $E -$ many edges (hardware and software systems or channels); $W -$ set of edge weights; $Z -$ a lot of traffic of information services (service data).

From the description of the weighted connected graph, it can be seen that the considered model of automotive services is a VANET (Vehicular Ad Hoc Networks) road transport network for the provision any type of service, technical and information services.

In the system, the incoming flows messages (requests) information services are random and have the properties of the simplest Poisson flow to obtain indicators characterizing the process functioning automobile services based on a logistics system. To implement and describe this problem, it is advisable to apply the mathematical apparatus Markov random processes [2, 3, 9-11].

To quantify the performance of the system paths based on the network model, it is necessary to pay special attention to the required transmission rate $V_{i.k}$, $i = \overline{1,n}$ at a given rate of arrival of the input stream λ_i, under critical system load $\rho_i = (\lambda_i \cdot b_i) \le 1$, $i = \overline{1,n}$, route matrix $\Lambda_i = [\lambda_i, \eta_i]$, displacement probability matrices $P = [p_{ij} \,|\, i, j = 0,1,...,n]$, where the number waiting places in the system is limited N_{BS}. Here, $b_i -$ duration service of the $i-$th traffic flow; $\eta_i -$ coefficients effective use information and network resources logistics systems.

III. RESEARCH AND EVALUATION OF THE CHARACTERISTICS PATHS SYSTEMS HARDWARE AND SOFTWARE COMPLEXES

Taking into account the peculiarities of the proposed mathematical model, a necessary and sufficient condition for the existence of a stationary mode of the system is the following condition:

$$\rho = \sum_{i=1}^{n} [(\lambda_i \cdot L_m)/(N \cdot V_{i.k})] < 1, \qquad (2)$$

where $L_m -$ average message length; $V_{i.k} -$ average router speed, $V_{i.k} \ge (2.048,...,32.0)$ Mpbs.

Thus, the system-technical analysis shows [9, 10] that the system under study is a multichannel QS with expectations and a queue length limitation.

In this case, the multichannel QS $N > 1$ with waiting will be when the message request does not leave the system unserved, when all hardware and software complexes (channels) are busy, the request enters the queue and waits for service. Let the maximum number places in the queue be $N_{BS} \ge 1$, then in the queue they can wait for their service no more than $m = N_{BS}$.

An information flow (requests) that has arrived at the entrance to QS at the moment when there are already requests in the queue is rejected and leaves the system. This filling of QS with applications from the input information flow occurs in two stages: service servers (channels) are loaded first i, then the queue is full r. In this case, $i + r < N$, where $i \ge r$, $i = 1, 2, ..., n$.

Now we will consider the analysis algorithms for the operation filling stations based on the proposed network model using the resources logistics systems that provide a significant increase in system performance and economic the efficiency of the object.

Suppose that at filling stations there are a certain number of similar groups of fuel dispensers with th filling positions , and the flow $i-$th rate of cars arriving for filling is λ.

Let us denote the maximum number of places in the queue for refueling through m. In this case, the total number of cars at the gas station and at the waiting area will be

$$i + m \le N_o\,, \qquad i = 1, 2, ..., n \quad , \qquad (3)$$

where $N_o -$ the total number cars (request) at which the next request (cars) leaves the system unserved. If at the moment there is a petrol station $i+r$ cars and at the same time $i \geq r$, where i refuel, and r are queuing up for a gas station, then $i+r<N_o$.

In this case, the numbering of the states of the system will be as follows [2, 3, 6, 10]:

- from state S_0 (there are no orders in QS and all hardware and software systems (channels) are free) to state S_N (there are applications in QS $i-$th and all channels N are busy) there is no queue
- from the state S_{N+1} (in QS $N+1$ applications, where all channels are busy and one request is in the queue) to the state S_{N+m} (all channels N are busy and all $m=N_{бн}$ places in the queue are occupied by applications) the queue is filled.

Considering the above states of the system, the probability of a multichannel QS downtime with waiting (for all servicing hardware and software systems) is calculated using the formula under the following conditions:

1.The coefficient of effective use of hardware and software complexes in the system, $\rho \neq 1$:

$$P_0 = 1/\sum_{i=0}^{N}\frac{N^i}{i!}\cdot\rho^i + \frac{N^N}{N!}\cdot\frac{\rho^{N+1}\cdot(1-\rho^{N_{BSн}})}{1-\rho}, \quad (4)$$

2. The coefficient of effective use of hardware and software complexes in the system , $\rho = 1$:

$$P_0 = 1/\sum_{i=0}^{N}\frac{N^i}{i!} + \frac{N^N}{N!}\cdot N_{бн}, \quad (5)$$

where $\rho-$ also, is an indicator of the incoming load on one channel and is expressed as follows:

$$\rho = [\lambda/(N\cdot\mu)] < 1,$$

where $\mu-$ service speed information flows, $\mu = 1/t_o$, t_o- average time of service of a request in the system.

Expressions (4) and (5) determine the probabilistic characteristics of the system automobile services based on the logistic approach with expectation. In addition, expressions (4) and (5) characterize the stationary states QS.

Taking into account the numbering states of the system, on the basis model it is possible to determine the remaining limiting probabilities of the states QS, which are calculated by the formulas:

$$P_i = P_0\cdot\frac{N^i}{i!}\cdot[\lambda/(N\cdot\mu)]^i, i=1,2,...,n, \quad (6)$$

Suppose that the system from the state S_{N+1} enters the state S_{N+m}. More over, QS has $N+1$ applications where all N channels are busy and all N_{BS} places in the queue are also occupied by applications, i.e. the queue is filling up in the system. Then, the limiting probabilities states for $i=N+1,\ N+2,...,N+N_{BS}$ expressed as follows:

$$P_i = P_0\cdot\frac{N^N}{N!}\cdot[\lambda/(N\cdot\mu)]^i,$$

$$i=N+1,\ N+2,...,N+N_{BS}, \quad (7)$$

Expressions (6) and (7) estimate the limiting probabilistic states of a system based on a logistic system with an expectation for various state enumerations.

On the basis of the model, the obtained analytical expressions for the probability P_i value make it possible to calculate the main characteristics of the quality of functioning systems automobile services such as QS.

IV. ANALYSIS AND EVALUATION OF SYSTEM PERFORMANCE CHARACTERISTICS

It is known [1, 2, 6, 11] that the system performance according to the I.350 recommendation is defined in terms parameters that are important for automotive services based on the concept logistics systems, which are widely used for the design, configuration, operation and maintenance of the system.

One of the key characteristics for assessing system performance is the maximum value the peak throughput (Peak-raite throughput), which characterizes the maximum number information streams that the system can transmit per unit time. The maximum value of the peak throughput under the conditions allowable loading hardware and software systems $\rho_{all.}$ is determined by the following expression:

$$C_{\max}(\rho \leq \rho_{all.}) = N\cdot\sum_{i=1}^{n}V_{i.k}, \ i=\overline{1,n}, \quad (8)$$

Under critical system load $\rho \leq \rho_{all.} \leq 1$, that is, when everyone is busy N hardware and software systems and all places $m=N_{BS}$ in the queue, the probability of a denial of service is found as follows:

$$P_{омк.}(\rho_{доп.} \leq 1) = \frac{N^N}{N}\cdot P_0\cdot\rho_{all.}^{N+N_{BS}}, \quad (9)$$

Taking into account the state of the system in (4) and (5), expression (9) characterizes the blocking of the system with probability P_B. In a system with a blockage with probability P_B, the pure intensity income can be interpreted as

$$\Lambda_{pi}(\lambda) = N\cdot[1-P_{pof.}(\rho_{all.} \leq 1)]\cdot\rho\cdot\mu$$

$$\text{at} \quad P_B = P_{pof.}(\rho_{all.} \leq 1). \quad (10)$$

Expression (10) determines the maximum value of the throughput hardware and software systems with a heavy load system. In addition, blocking probability means the probability that messages cannot be received by the system because the buffer storage is full.

If the system $N >> 1$ и $\rho \le \rho_{all.} < 1$, then $\rho^{N+1} << 1$ и $P_B = (1 - \rho_{all.}) \cdot \rho_{all.}^{N}$. This means the probability that the system is in a state $i = N$.

Taking into account the last assumption and expression (10), the actual intensity of servicing information flows is defined as

$$\gamma_{ai}(\mu) = (1 - P_0) \cdot \mu \quad . \tag{11}$$

Based on the network model and formulas (9), ..., (11), the absolute throughput automotive service systems will be expressed as follows:

$$C_{\max}^{an}(\rho \le \rho_{all.}) = \lambda \cdot [1 - P_B] = \Lambda_{pi}(\lambda), \tag{12}$$

As a result of the research, the obtained analytical expressions (8), ..., (12) determine the performance indicators of the system in the provision information services.

On the basis of a model systems automobile services using the concept logistics systems, analytical expressions were obtained, with the help which numerical calculations were carried out using MATLAB 7.5 and its Signal Processing Communications packages [12].

Taking into account the obtained numerical results, in figure 2, a family graphical dependence of the maximum value peak throughput on the total number hardware and software systems is built at an admissible systems load $\rho_{all.}$ factor and at a given value of the average speed V_{ik}.

Analysis of the family graphical dependencies shows that an increase in the total number of hardware and software systems leads to an increase in peak throughput $C_{\max}(\rho \le \rho_{all.})$, a system that meets the requirements for the reliability of the functioning information security. Its noticeable change begins with the meaning $N \ge (250,...,300)$ at $V_{ik} \ge 20.0$ Mbps. In this case, the gain in throughput is manifested along with the gain in system reliability.

V. ANALYSIS RELIABILITY INDICATORS COMPLEX HARDWARE AND SOFTWARE SYSTEMS

The reliability of the system operation is a characteristic that determines the ability hardware and software systems over the VANET network in the event technical failures and operational errors without a noticeable deterioration in the probabilistic-time characteristics of the quality of service information services messages.

Let us assume that the system has many states operability hardware and software systems Q_{pc}. On the basis figure 1, the set failure states of system elements is equal to:

$$Q_{oc} = 1 - Q_{pc} \quad , \tag{13}$$

One of the main characteristics assessing the reliability complex hardware and software systems is the probability failure-free operation of the system:

$$P_{ВБР}(t) = K_{AS}(\Lambda, \delta) \cdot \exp(-t_{nb} / T_{cb}) \quad , \tag{14}$$

where $K_{SA}(\Lambda, \delta) -$ system availability taking into account the failure rate Λ and restoration δ of the working state hardware and software systems; t_{nb} – continuous mean time between failures system elements; T_{cb} – mean time between failures systems elements.

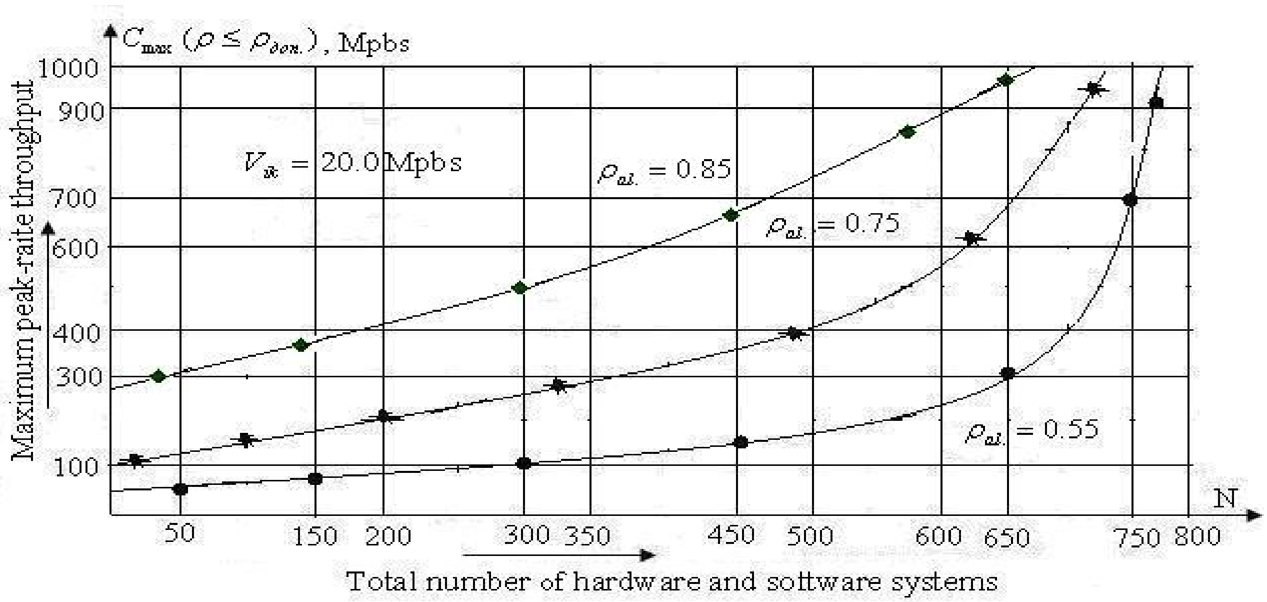

Fig. 1. Graphical dependence of the maximum value peak system throughput on the total number hardware and software systems

Based on the model, the non-stationary system availability factor is expressed as follows:

$$K_{SA}(\Lambda, \delta) = \frac{\rho}{1 + \rho} \cdot \exp[-(\Lambda + \delta) \cdot t] + (1 + \rho)^{-1} . \tag{15}$$

Expressions (13), (14) and (15) show that the reliability of the functioning hardware-software complexes is determined by the reliability of the system elements included in it. In addition, expressions (13), (14) and (15) are a single and complex indicator of the reliability functioning of a complex transport and technological complex in the logistics system.

Thus, on the basis of the proposed model, analytical expressions have been obtained that allow one to assess the quality indicators of the functioning of the automobile services system using the logistic approach.

CONCLUSIONS

As a result of the study, a network model was proposed for optimizing the quality of the functioning automobile services using the concept logistics systems, taking into account the performance indicators of the system, single and complex indicators reliability of the functioning hardware and software systems.

On the basis of the model, analytical expressions are obtained for assessing the indicators of the maximum value peak throughput, stationary and limiting probabilities states, as well as the probability failure-free operation and the availability factor of the system in the provision information services.

REFERENCES

[1] D.G.Evseev, M.Yu.Kulikov, A.S.Kuzyutin. Network model of service maintenance freight cars // Bulletin of the Bryansk State Technical University, No. 5 (66), 2018. – pp. 24 - 32.

[2] B.G.Ibrahimov, A.M.Talibov. Researches efficiency functioning systems processings information flows automobile services. *T-Comm*, vol. 13, No.5. 2019. - pp. 56-60.

[3] V.S.Lubentsova Mathematical models and methods in logistics. Samara State Technical University. Samara, 2008. – 157 p.

[4] D.G. Evseev, M.Yu. Kulikov, A.S. Kuzyutin Evseev. Methodological concept of technology for fright car Servicing // Fundamental and Applied Problems of Mechanical Engineering: Proceedings of the VI-th Inter. Conf. "Design-Technological Informatics".M.: Spectrum, 2017. – pp. 90-97.

[5] M.A.Masuev. Designing of automobile transport enterprises: textbook. manual for university students. - M .: Publishing House "Academy", 2007. – 224 p.

[6] R. Yu. Levin, V. A. Maslennikov. Mathematical model optimization of the planning solution of a gas station // *Journal of automotive engineers*. No. 1 (96), 2016.-p. 34-35.

[7] A.V. Gasnikov, S.L. Klenov, E.A. Nurminsky. Introduction to mathematical modeling of traffic flows. Textbook. Moscow: MIPT, 2010. – 362 p.

[8] G.G. Levkin, Commercial logistics. Tutorial. St. Petersburg: SPbUEF, 2018. – 145s

[9] Aliev, T.I. Fundamentals of System Modeling / T.I. Aliev. – S-Pb.: U ITMO, 2015. – pp. 120.

10] V.G. Kartashevsky. Foundations of the theory of queuing. - M .: Hotline - Telecom. 2013. – 130 p.

[11] G.Bianchi. Performance Analysis of the IEEE 802.11 Distributed Coordination Function» // *IEEE Journal on Selected Areas in Communications*. Vol.18, No.3, 2000. – p.535-547.

12. O.I.Shelukhin. Information systems modeling. Textbook for universities.-M .: Hotline - Telecom, 2018. – 516 p.