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INTRODUCTION

The Technical Faculty "Mihajlo Pupin", Zrenjanin, of the University of Novi Sad, the Republic of Serbia organizes VIIIth International Scientific Professional Conference "Information Technologies and Development of Education 2017" (ITRO 2017). The Conference will be held on 22nd June 2017 at the Technical Faculty "Mihajlo Pupin" in Zrenjanin, Serbia.

The Conference "Information Technologies and Development of Education 2017" (ITRO 2017) is organized due to the needs to connect science, profession and education through topics and content concept, first of all concerning the teaching process as base of information society. The tendencies of developed countries are in accordance with the efforts of UNESCO to improve this area related to the needs of life and work in the XXIst century. It is necessary to assess the state, detect the problems and perspectives of the development of education by competent professionals and teachers as well as the influence of the development of education on the development of the society as a whole.

The central topic of the meeting is the model of dual education as base for creating good base for the development of industry. Thus, our aim is to gather the representative entities who are able constructively contribute to establishing link between the educational system and industry as follows: Chamber of Commerce of Serbia – Centre for Dual Education, Ministry of Education, Science and Technological Development, Union of Employers of Serbia, ZREPOK – Business Organization of Zrenjanin and Companies that run their business in the region, directors of grammar schools and secondary vocational school, members of the academic communities and other participants who are interested in the topics.

The main topics of the scientific professional conference are:

- Model of dual education
- Teaching based on the concept of entrepreneurship

Other thematic areas of the Conference:

- Theoretical and methodological questions of contemporary Pedagogy
- Digital didactics media
- Contemporary communication in teaching
- Curriculum of contemporary teaching
- Developing teaching
- E-learning
- Management in Education
- Teaching methods of natural and technical subjects
- Information-communication technologies

The Chairman of the Organizing Committee of the ITRO 2017 Prof. Dragana Glušac opened the Conference. The participants were addressed by the vice dean of the Technical Faculty »Mihajlo Pupin«, Prof. Dijana Karuović; provincial secretary for science, higher education and scientific Research prof. Zoran Milošević, and the vice-major of Zrenjanin Mr. Dusko Radisic.

There were total of 143 authors that took part at the Conference from 12 countries, 2 continents: 82 from the Republic of Serbia and 61 from foreign countries such as: Macedonia, Bulgaria, Slovakia, Austria, Cyprus, Albania, Hungary, Spain, Bosnia and Herzegovina, USA, Portugal.

The Proceedings of papers contains 60 papers and it has been published in the English language.

President of the Organizing Committee
Prof. dr Dragana Glusac

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Simulation of Queuing System based on Anylogic

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Abstract - In this paper, we use the operations research's queuing theory to analyze the service process in queueing system and use AnyLogic simulation software to do modeling. We consider queuing system with Poisson input flow, exponential service time and infinite capacity of system. (There are an *M*/*M*/1and *M*/*M*/*n* systems). The accuracy of the experiment data is verified by doing comparisons with theoretical values.

I. INTRODUCTION

Queuing is the most common phenomenon in everyday life. It is common to see a large number of persons waiting in a bank, market, railway station or in a theatre to have some service carried out.

Computer simulations is a useful tool for the mathematical modeling of many natural systems. Computer simulations build on, and are a useful adjunct to mathematical models in Computer Science, Computing Science, Probability Statistics , Operations Research and so on. Through establishing mathematical models and simulating by computer, the original issue can be solved by using simulation result as approximatively solution.

Simulation can be used as a tool for predicting the effect of changes to existing systems and as design tool to predict the performance of new systems. Simulation techniques have advantages and disadvantages, so that make it impossible to receive a clear answer at the question when to use simulation.

Computer simulation is used often in the analysis of queueing system.

Queueing system are systems which have need of system resources. When resources are not available, those who need that resources, will wait for them to be available. Examples of these kind of systems include clients who requires bank teller services, customers who pays on supermarket, computer system processes that are waiting on a central processing unit, etc.

Queuing systems was studied by mathematical methods. But, with development of computer simulation techniques, queuing systems can be studied by simulation.

Authors in [3] attempts to investigate and suggest the best possible configuration for a bank in Malaysia through constructing computer–based simulation models. As the result of their study, the final suggested configuration shows improvement in terms of average utilization rate of counters and average waiting time that customers have to spend in the queue.

In [7], based on Anylogic6.0 simulation software, some simulation models of queuing systems with different queuing disciplines are established, including First Come First Service, Last Come First Service and Random Service. Compared with the theoretical values, the accuracy of the experiment data is verified. Also, with Comparative Analysis of experiment data, in [7] is showed that under a special condition, the difference of the performance of the queuing systems with different queuing disciplines is limited.

In [6] is analyzed the queuing system with finite capacity *M*/*M*/*n*/*m*. Additionally demonstration of simulation of the market as example of $M / M / n / m$ queuing system is given.

In [5] is given *M*/*M*/*m* queue and is compare *M*/*M*/1 queue with a fast server operating at $m\mu$ with an *M*/*M*/*m* system. Also is given $M/M/\infty$ queueing system.

The two queuing system's analytical solutions are compared and analyzed, then two queuing system's simulation results are analyzed. After that each kind of queuing system's analytical solution and the simulation results are compared and analyzed. This is done in paper [4]. Also, in the same paper, it is pointed out that the analytic results and the simulation results are significantly different, and the defects which may exist in analytical solution and the simulation solution also were analyzed.

Document [1] gives an overview of the standard methods used to model and analyze the performance of queuing systems. Includes both analytical techniques and simulation methodology. Attention is restricted to single-queue systems and the *M*/*M*/1 queue is used as an illustrative example regarding analytical work. Simulation is discussed in the setting of the *G*/*G*/1 queue and various sampling-strategies are central to the discussion.

In paper [2] authors use the operations research's queuing theory to analyze the container terminal's service process; and simultaneously use the AnyLogic-based simulation to do modeling. Through the calculation of key indicators, they analyze advantages and disadvantages of the simulation modeling in container terminal logistics application. By changing the ratio of the number of critical facilities, they come up with an effective method to enhance the utilization of port equipment's.

AnyLogic is a very flexible, dynamic simulation tool developed by The AnyLogic Company, suitable for all fields and business areas where simulation methods are commonly applied. This means that AnyLogic supports system dynamics as well as process-oriented (discrete event) and agent-based methodologies.

In order to study on operation efficiency of queuing systems of type M/M/1 and M/M/K with different queuing disciplines, this paper use computer simulation technology to establish some simulation models based on Anylogic6.0 simulation.

II. QUEUEING SYSTEMS

The basic queueing model is shown in Fig 1. (Queueing Systems Ivo Adan and Jacques Resing)

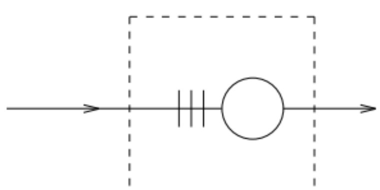

Figure 1. Basic queuing system

Key elements of the queueing systems are the clients and the servers.

Queueing model is characterized by:

- The arrival process of customers.

Usually we assume that the interarrival times are independent and have a common distribution.

- The behavior of customers.

Clients may be patient and willing to wait or clients may be impatient and leave after a while.

- The service times.

Usually we assume that the service times are independent and identically distributed, and that they are independent of the interarrival times.

- The service discipline.

Queuing disciplines have many forms, including First Come First Service, Last Come First Service and Random Service and so on.

- The service capacity.

There may be a single server or a group of servers helping the customers.

The Kendall classification of queuing systems exists in several modifications. The most used classification uses 6 symbols:

$$A/B/s/q/c/p$$

These symbols represent the following characteristics of the system:

A - the distribution of the length of the intervals between two successive arrivals.
B - distribution of service time.
s - is the number of servers.
q - is the queuing discipline (FIFO, LIFO,…)
c - is the system capacity.
p - is the population size (number of possible customers).
In this paper we will regard the following queuing system:

System 1. *M/M/*1 system. For this system, we have Poisson input flow i.e. exponential interarrival times with mean $1/\lambda$, exponential service times with mean $1/\mu$ and a single server.

System 2. *M/M/K* system. For this system, we have Poisson input flow i.e. exponential interarrival times with mean $1/\lambda$, exponential service times with mean $1/\mu$ and *n* servers.

III. *M/M/*1 SYSTEM AND *M/M/K* SYSTEM

A. *M/M/*1 System

M/*M*/1 system is queueing system where arrival distribution of client follows Poisson distribution (arrival rateλ), distribution of service time follows exponential distribution, [8]. The system is composed of 1 server (service rate μ) and unlimited FIFO queue. (Fig 2.).

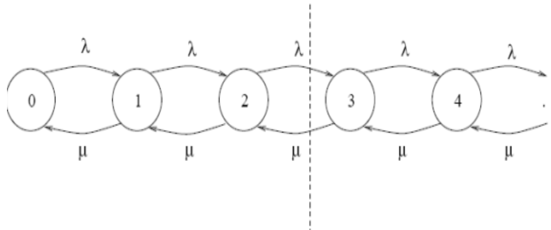

Figure 2. *M*/*M*/1 system

We require that

$$\rho = \frac{\lambda}{\mu} < 1, \quad (1)$$

since, otherwise, the queue length will explode. The quantity is the fraction of time when the server is working. The probability that there are n client in the system is

$$p_n = \rho^n (1-\rho). \quad (2)$$

The probability that there are no clients in the system:

$$p_0 = 1 - \rho. \quad (3)$$

The expected number of client in the system is:

$$L = \frac{\lambda}{\mu - \lambda}. \quad (4)$$

The expected number of jobs in the queue is

$$L_q = \frac{\lambda^2}{\mu(\mu - \lambda)}. \quad (5)$$

From the Little's formula, the average time spent waiting in the queue is:

$$W_q = \frac{L_q}{\lambda}, \quad (6)$$

and the average time spent in the system:

$$W = \frac{L}{\lambda}, \quad (7)$$

Applying Little's Formula,

$$W = \frac{1}{\mu - \lambda}, \quad (8)$$

and

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)}. \quad (9)$$

B. *M/M/K* System

M/*M*/*K* system is queueing system where arrival distribution of client follows Poisson distribution (arrival rateλ), distribution of service time follows exponential distribution, [9]. The system is composed of *K* servers (service rate μ) and unlimited FIFO queue. (Fig 3.)

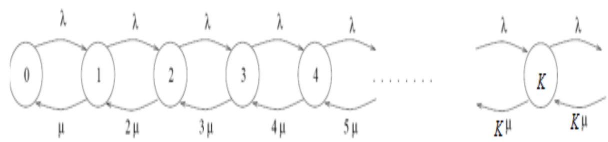

Figure 3. *M*/*M*/*K* system

This system, for any values of λ and μ for which $\rho = \frac{\lambda}{\mu} \neq 1$ may be observed in a stationary regime of work:

$$t \to \infty,\ p_k^{'}(t) = 0,$$
$$p_k(t) = p_k. \quad (10)$$

For this system we apply following formulas:

The server utilization can be obtain with following formula:

$$\rho = \frac{\lambda}{K\mu}. \quad (11)$$

The probability that there are no clients in the system:

$$p_0 = \left[\sum_{i=0}^{K-1} \frac{(K\rho)^K}{K!} + \frac{(K\rho)^K}{K!} \frac{1}{1-\rho} \right]^{-1}.$$

(12)

The probability that there are *n* clients in the system

$$p_n = \begin{cases} p_0 \rho \dfrac{1}{n!}, & n < K \\ p_0 \rho \dfrac{1}{K! K^{n-K}}, & n \geq K \end{cases}. \qquad (13)$$

Probability of an arriving client finding that all servers are busy is called Erlang - C formula and is given by

$$P_q = P(queueing) = \frac{(K\rho)^K}{K!} \frac{p_0}{1-\rho}. \qquad (14)$$

The average number of client in the queue is:

$$L_q = P_q \frac{\rho}{1-\rho}. \qquad (15)$$

Average waiting time of clients, in the queue is:

$$W_q = \frac{L_q}{\lambda}, \qquad (16)$$

or

$$W_q = P_q \frac{\rho}{\lambda(1-\rho)} = P_q \frac{1}{K\mu(1-\rho)}.$$

Average waiting time of clients, in the system is:

$$W = W_q + \frac{1}{\mu}. \qquad (17)$$

Average number of clients in the system is:

$$L = \lambda W. \qquad (18)$$

IV. Simulation Model

In this paper, the queuing systems $M/M/1$ and $M/M/K$ with FIFO unlimited queuing disciplines are studied. The simulation model of queueing systems based on Anylogic 7.3.6. is established. It is shown in Fig.4 below:

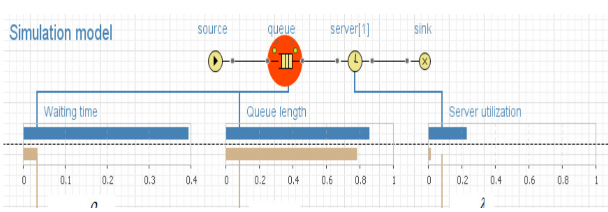

Figure 4. Simulation model of queuing system based on Anylogic 7.3.6

This model contains four objects: source, queue, server and sink. Source Object generates entities according to the need. Queue Object simulates customers queue. Server Object simulates service desk. Sink Object means that the end of the service and the customer leave off. We can shown different number of the servers. (from 1 to 5),

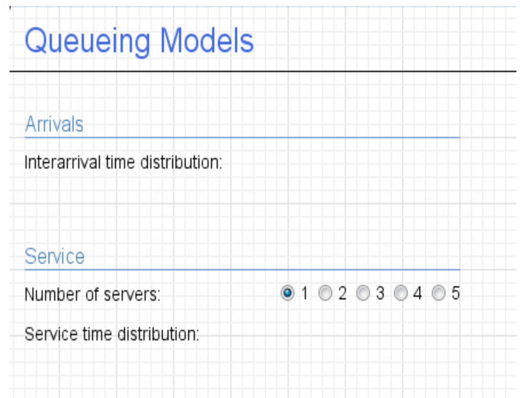

Figure 5. Queueing model

If we choose 1 server then we will consider $M/M/1$ queueing system, otherwise we will consired $M/M/K$ queueing system.

With this simulation model we will compute average waiting time of clients in the queue, average number of clients in the system and server utila.

A. $M/M/1$ System

Arrival rate λ represent the number of clients who arrive in one minute. Average service time is the mean time needed to service a client. We assume that the input process is Poisson flow with arrival rate λ = 0.6667 and the service time is an exponential distribution with service rate μ = 1. We can obtain the average interarrival time as a reciprocal value of the parameter λ ($1/\lambda$ = 1.5). Also, we can obtain average service time as a reciprocal value of the parameter μ ($1/\mu$ = 1), Fig.6.

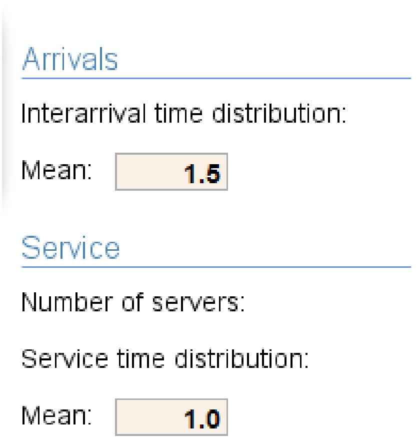

Figure 6. Input parameters

In Fig 7. the result of the simulation are shown:

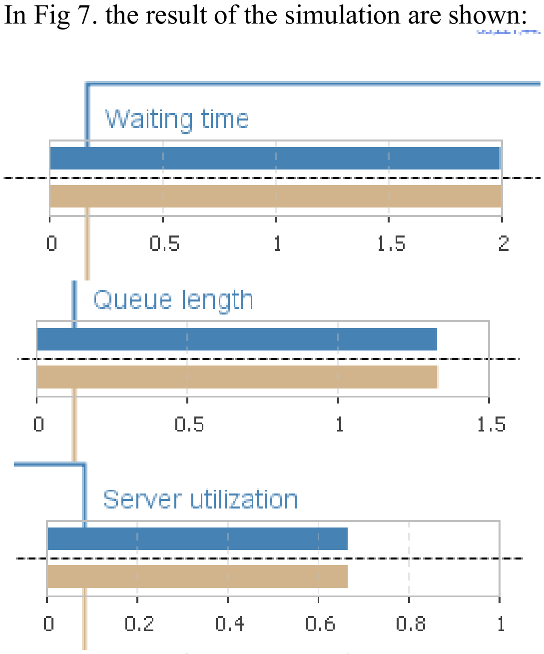

Figure 7. Output results

From Fig 7. we can see that average waiting time in the system is $\overline{W}_q \approx 2$, average number of client in the queue is $\overline{L}_q \approx 1.3$ and server utilization is $\overline{\rho} \approx 0.7$.

B. *M/M/K* System

We assume that the input process is Possion flow with arrival rate $\lambda = 3$ and the service time is a exponential distribution with service rate $\mu = 4$. Average interarrival time is $1/\lambda$ = 0.333 and average service time is $1/\mu$. We choose 2 servers.

In Fig. 8, input parametars for *M/M/K* system are given.

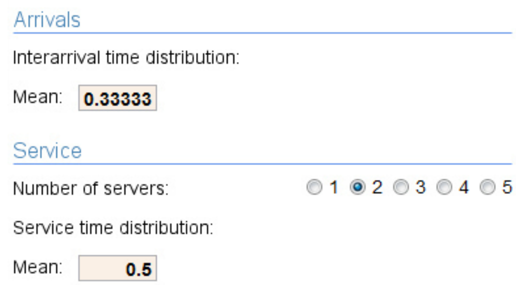

Figure 8. Input parameters

In Fig 9. the result of the simulation are shown:

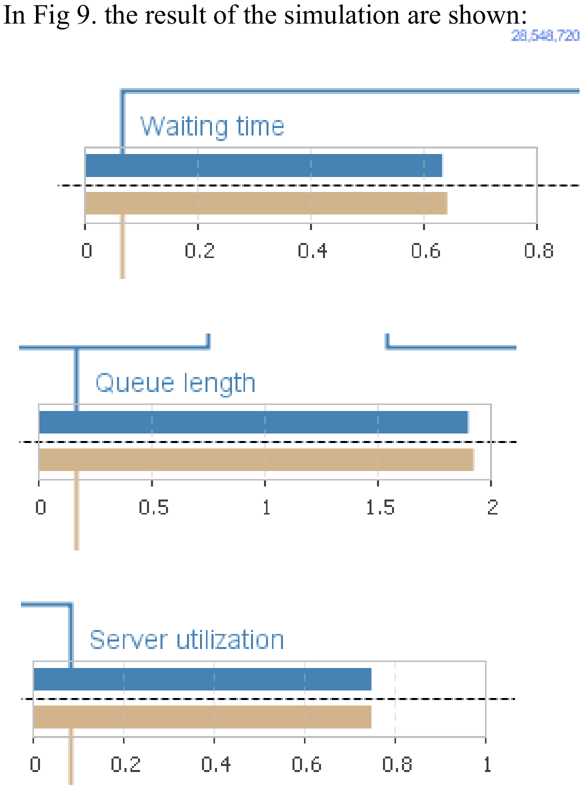

Figure 9. Output results

From Fig 9. we can see that average waiting time in the queue is $\overline{W}_q \approx 0.625$, average number of client in the queue is $\overline{L}_q \approx 1.9$ and server utilization is $\overline{\rho} \approx 0.7$.

V. THE ANALYSIS OF THE SIMULATION RESULTS AND CONLUSION

In this part we will make comparison between results given from simulation and analytical results.

First, we consider, the *M/M/*1 queueing system, with arrival rate λ = 0. 6667 and service rate μ = 1.

From the formula (9), for average waiting time in the queue we obtain:

$$W_q = \frac{\lambda}{\mu(\mu-\lambda)} = \frac{0.6667}{0.3333} = 2{,}0003 .$$

We can conclude that simulation results $\overline{W_q} \approx 2$ and results which are obtained by analytical model are approximately equal.

For the average number of client in the queue, analytical result is:

$$L_q = \frac{\lambda^2}{\mu(\mu-\lambda)} = \frac{0{,}6667^2}{0{,}3333} = 1{,}3336.$$

We can see that $\overline{L_q} \approx L_q$.

For the system, *M*/*M*/*K* inputs parameter for the simulation are $\lambda = 3$ and $\mu = 2$. Server utilization is

$$\rho = \frac{\lambda}{K\mu} = \frac{3}{4} = 0.75.$$

First, we will compute, the probability that there are no clients in the system:

$$p_0 = \left[\sum_{i=0}^{K-1} \frac{(K\rho)^i}{i!} + \frac{(K\rho)^K}{K!}\frac{1}{1-\rho}\right]^{-1}.$$

$$= \left[\sum_{i=0}^{1} \frac{(2\cdot 0.75)^2}{2!} + \frac{(2\cdot 0.75)^2}{2!}\frac{1}{1-0.75}\right]^{-1}$$

$$= \frac{1}{7} = 0{,}143.$$

Probability of an arriving client finding that all servers are busy is

$$P_q = \frac{(K\rho)^K}{K!}\frac{p_0}{1-\rho} = \frac{(2\cdot 0.75)^2}{2!}\frac{0.143}{0.25} = 0.6428.$$

Finally, for W_q we will obtain

$$W_q = P_q \frac{1}{K\mu(1-\rho)} = \frac{0.6428}{2\cdot 2\cdot 0.25} = 0.6428.$$

Average number of client in the queue, we will compute by Little's formula:

$$L_q = \lambda W_q = 3\cdot 0.6428 = 1.9284.$$

We can conclude that simulation results and results which are obtained by analytical model are approximately equal.

$$\overline{W_q} \approx 0.625 \approx 0.6428 = W_q$$

and

$$\overline{L_q} \approx 1.9 \approx 1.9284 = L_q .$$

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