# Possibilities of Simulation Tools for Describing Queuing Theory and Operations Service Lines in Railway Passenger Transport

Jan Ponický
Faculty of Operation and Economics of Transport and Communications, University of Zilina
Zilina, Slovakia
jan.ponicky@fpedas.uniza.sk

Juraj Camaj
Faculty of Operation and Economics of Transport and Communications, University of Zilina
Zilina, Slovakia
juraj.camaj@fpedas.uniza.sk

Martin Kendra
Faculty of Operation and Economics of Transport and Communications, University of Zilina
Zilina, Slovakia
martin.kendra@fpedas.uniza.sk

***Abstract*— The subject of queuing theory is a mathematical analysis system (equipment), which are providing queuing. Queuing system (equipment) are providing the service with a specific type. This system can consist of one or more service points. A typical example of queuing theory in rail transport is a sale of travel ticket for passengers in railway stations. The input flow of passengers in the system is stochastic and the intensity of the input current is different during a day. During peak hours, the input flow of customers is so high that for each service line are forming the queues. The waiting time in each service line is different of depend on the services which is providing for passengers. If at railway station are located several offices (equipment) passengers can choose treasures relatively shortest queues, but this does not guarantee it for the shortest time operation.**

**The paper deals quantification of the percentage of the production lines service (personal cash) in the railway using simulation tools.**

***Keywords—Queuing theory; service line; railway passenger transport***

## I. Introduction

The railways stations are places, where passengers can buy a travel ticket. These places are the typical example of the queueing systems. The input flow of passengers in the system has a different intensity during the day. The input flow of customers in the system reaches highest values during the morning and afternoon peaks. Waiting time in each queue is different because of different services that customers demand. Waiting time also depends on technical equipment of lines and speed of operator´s experiences.

The queuing theory is based on the principles of Markov´s chain. [1, 3, 6, 7]

## II. The characteristics of Markov´s chains

The characteristic feature of random processes is that the processes do not retain the memory. This means that only the current state of the process can influence where they go further i.e. how they will evolve. Such a process is called Markov´s processes. The processes which can only be finite or countable state is called a Markov´s chain. [2]

Markov´s chain is model different phenomena because they lack the ability to preservation of memory, allowing you to predict how it will evolve and allow the calculation of probabilities and expected values, which quantify their subsequent behavior. [1, 4]

*X(t)* is random variable and is depends by the parameter *t*. This parameter has a value $T = R, R^+, Z, Z^+$ or his subsets. Stochastic process we will consider by the composite of probabilities.

$$P(X(t_1) \in A_1, \dots, X(t_n) \in A_n) \quad t_1, \dots, t_n \in T \tag{1}$$

The homogeneous random process is called, when valid:

$$P(X(t_1) \in A_1, X(t_2) \in A_2, \dots, X(t_n) \in A_n) = (X(t_1+\tau) \in A_1, X(t_2+\tau) \in A_2, \dots, X(t_n+\tau) \in A_n \tag{2}$$

for any τ such that $t_1, t_1+\tau, \dots, t_n, t_n+\tau \in T$.

In the theory of queueing are the random variables presenting of a passengers. This states will become final or countable set. [7] Random process of their development in time will be describe by the composite of probabilities

$$\begin{Bmatrix} P(X(t_1)) = j_1, \dots, X(t_n) = j_n): n \in Z^+, \\ t_1, \dots, t_n \in T, j_1, \dots, j_n \in Z^+ \end{Bmatrix} \tag{3}$$

The probability that the interval of "t", at least one event occurs is determined by the relationship:

$$1 - p_0(t) = 1 - e^{-\lambda t} \tag{4}$$

The assumptions about the sequence of events say that in disjoint intervals the number of their occurrence are independent of each other and in intervals of equal length their numbers don't depend on the position of these intervals on the real axis [5]. And we can define a random chain X (t) with the countable set of values for the number of events that occur in the interval of length t. Based on $1 - p_0(t) = 1 - e^{-\lambda t}$ it can be argued that for $t_1 \geq t_2 \geq ... \geq t_n$ valid [5]:

$$P\big(X(t) - X(t_1)\big) = i_1\big(X(t_1) - X(t_2)\big) = i_2, ..., X(t_{n-1}) - X(t_n) = i_n = P\big(X(t) - X(t_1)\big) = i \quad (5)$$

Process with independent increments has Markov´s characteristic when for each $t \geq t_1 \geq t_2 \geq ... \geq t_n$ and $i, j_1, ... , j_n$ valid:

$$P(X(t) = i(X(t_1) = j_1, ..., X(t_n)) = j_n = P(X(t)) = i(X(t_1)) = j_1 \quad (6)$$

## III. The Application of Queuing Theory in Railway Transport

The basic mathematical model, which is shown in Figure 1 operates on the following principle [2, 4]:

- Customers who require the service come into the system in the sequence,
- After the arrival, each passenger must wait until the line is free.
- The time between arrivals is a random variable equal distribution,
- Operation time of line is a random variable for any other division.

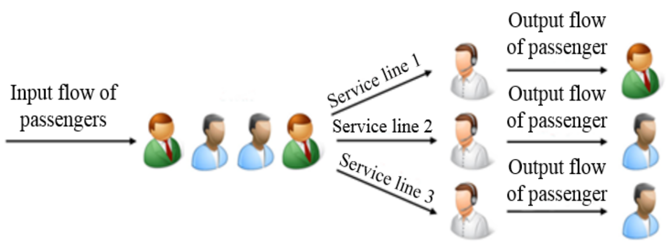


Fig. 1. Queueing system with one front and three service lines

The main variable is a random process "(Xt)", which records the number of passengers in system at time "t". It takes into account customers who are waiting for services, even those who are just serviced. In cases where the period between arrivals and service time has an exponential distribution are talking about Markov´s chain with continuous time. In this case, it is possible to analyze a given queue.

The main variable is a random process "*(Xt)*", which records the number of passengers in system at time "*t*". It takes into account customers who are waiting for services, even those who are just serviced. In cases where the period between arrivals and service time has an exponential distribution are talking about Markov´s chain with continuous time. In this case, it is possible to analyze a given queue.

If only the time between arrivals is exponential distribution analysis is still possible if we use that Poisson process does not retain memory customers coming.

## IV. Classification of Queueing System

For the classification of queuing systems used by Kendella symbolism. This classification is divided according to three aspects [3, 5, 6]:

- random process describing the influx of requests,
- probability distribution for the duration of the operation,
- The number of service lines.

The shape of queuing system is written in the form

*X / Y / N*. The exact meaning of the letters *X* and *Y* is shown in the table 1.

TABLE I. Meaning of letters *X* and *Y* by Kendall [1]

| word | X | Y |
|---|---|---|
| **M** | Poisson´s process of input | Exponential distribution of service time |
| **$E_k$** | Erlang´s input flow set "*k*" | Erlang distribution set "*k*" of service time |
| **D** | Deterministic input flow | The constant service time |
| **G** | Common example - no assumptions about the input process of the requirements | Common distribution of service time |

In this case, it is necessary to deliver information on the operating mode, a mode queue. It usually adds another symbol Kendell classification which describes the maximum number of requests in the queue. [6] The syntax will then look *X / Y / n / m*. While for the letter "n" will be populated with natural numbers and the letter "m" natural number or infinity. We appoint an infinity if the queue is unlimited.

The most commonly used entry in the queuing theory is writing *M / M /N / m*. [6]

## V. The Survey of Basic Values

The basics of the analysis of the fundamental values of QS, which is characterized by the input current passenger's service time lines and the number of working lines [2].

Analysis of the various input variables was carried out on the basis of data provided by rail operator. Input variables relating to the railway station Trnava [4].

### A. Total input flow of passengers to QS

Total input flow of passengers is divided by hours (Fig. 2). The influx of customers during the day varies. The largest increase in passengers recorded at the time of about 5:00 during the morning rush hour. The situation is similar in the afternoon when the tip begins around 12:00.

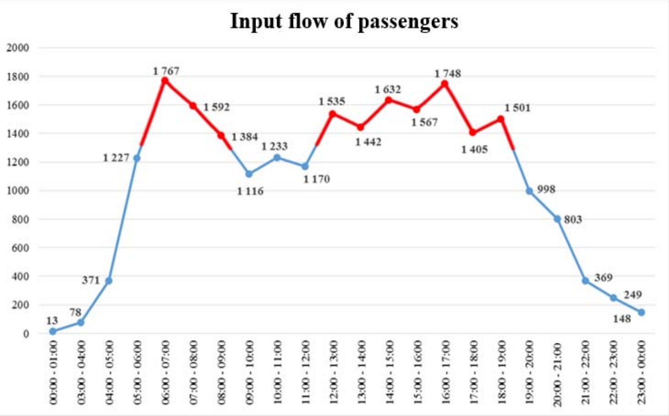


Fig. 2. Input flow of client during one day

### *B. Service lines*

Individual service lines represent personal cash desks (PCD 1, PCD 2) and Client Centres (CC 1, CC 2) in railway station Trnava.

The personal cash desks are providing of sale domestic and international travel documents, couchettes and tickets and their reservation. The personal cash desks have information system KVC (complete clearance of passengers). [4, 8]

For service lines was determined by the average service time of customers on the basis of observation (direct measurement) in railway station Trnava. The observation was performed at the afternoon time 14:00 to 16:00.

The mean time of operation is [2]:

- Passengers arrival time at the cash desks,
- The time of purchase the necessary travel documents,
- Time-out customers.

TABLE II. AVERAGE TIME OF THE PASSENGER SERVICE [4]

| | ***The number of passengers*** | ***Average service time*** |
|---|---|---|
| ***Domestic transport*** | 244 | 0,39 min. |
| ***International transport*** | 31 | 1,46 min. |

## VI. THE USE OF SIMULATION TO QUANTIFY TIME INDICATORS

For the quantification of the service lines was used simulation software AnyLogic Personal Learning Education (PLE). AnyLogic program is a simulation modeling tool that supports agents based on discrete event simulation and system dynamics.

AnyLogic allows the user to combine different approaches within the same model. Programming language is directly applicable to a variety of complex modeling problems in economics, operations research, logistics and so on. [8]

### *A. Input requirements (total input stream)*

Total input flow of passengers entering the system is divided by hour. The simulation program provides users with the "Schedule", which is a special feature allowing to define changing values over time.

### *B. Routing input requirements*

Input requirements, respectively routes of individual passengers are routed to multiple outputs depending on their condition, which can be deterministic or stochastic. Input requirements for routing (routes) passengers in railway station Trnava was used function "Select output".

### *C. Service lines*

Individual service lines (personal cash desks) provide for the sale of travel documents.
The "Service" to define: [8]

- The number of service lines (number of units)
- Average service time (delay time)
- The maximum capacity of the queue (queue maximum capacity).

### *D. The final model in the AnyLogic program*

By linking individual functions in the simulation program was created model (Fig. 3) for the quantification of the time exploitation for service lines.

 

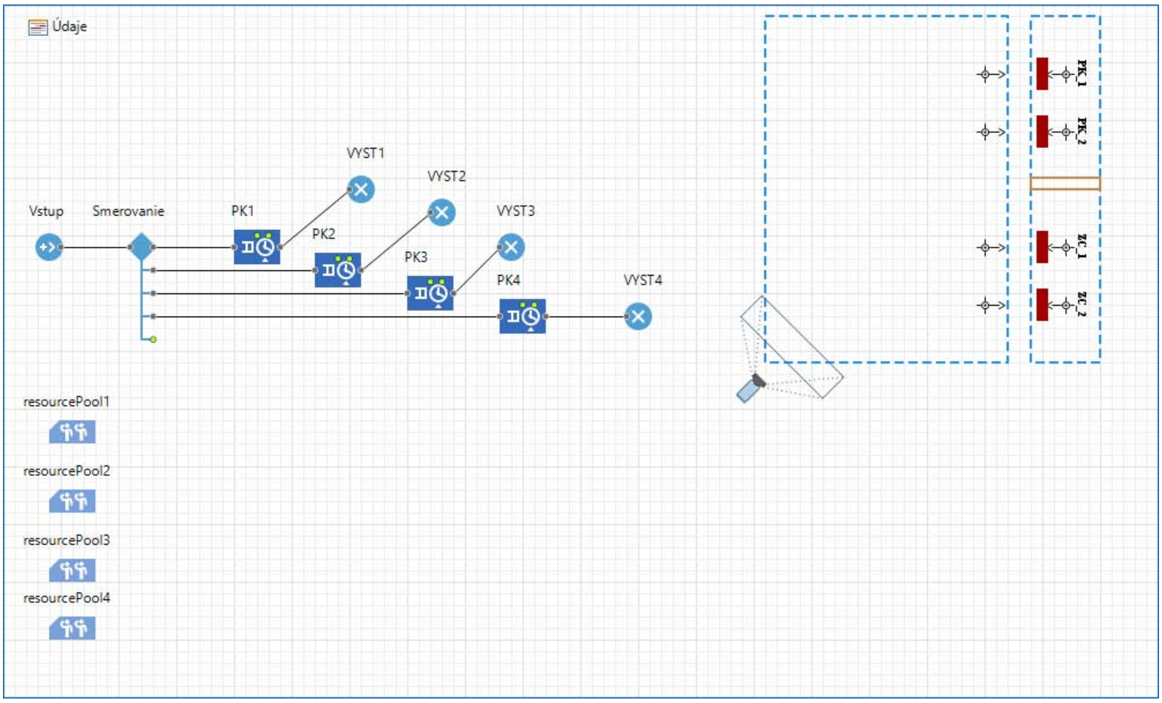


Fig. 3. The resulting model for quantify temporal indicators

## VII. Simulation Results

After implementation of the simulation results we get use of individual service lines (Fig. 4). These data represent the percentage usage of individual lines (personal cash desks).

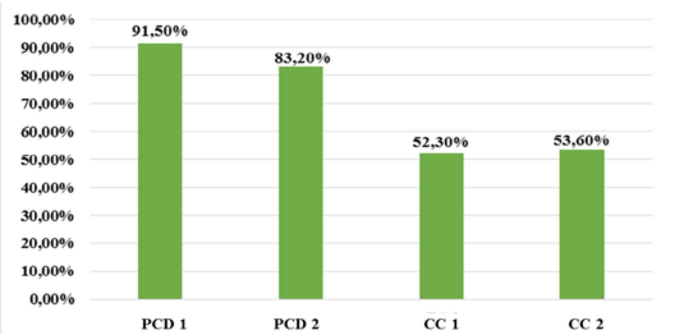


Fig. 4. The percentage usage of individual service lines

## VIII. Conclusion

From realized research we can say this results:

- The most used line service is personal cash PCD 1 and 2. This is because they are in operation throughout the day (00:00 - 24:00) with the exception of the award of the railway station to the public (1:00 to 03:00).
- Fewer lines used by operators as customer centers CC 1 and CC 2 reason is the limited operating time (05:00 -21: 00) compared to a personal cash register PCD 1 and PCD 2.
- The opening of other treasures to the information system KVC would enable faster expedition passenger railway station in Trnava.

## Acknowledgment

This paper was created within the framework of the following projects:

Project VEGA 1/0095/16 "Assessment of the quality of connections on the transport network as a tool to enhance the competitiveness of public passenger transport system."

## References

[1] Achimská, V. 2011 Modelovanie systémov, 1st edition, Žilina: EDIS, ISBN 978-80-554-0450-9.

[2] Čamaj, J., Mašek, J., Kendra, M. 2015 Possibility of applying the common queue of waiting for servicing railway passenger. In: Transport means 2015: proceedings of the 19th international scientific conference: October 22-23, 2015, Kaunas University of Technology, pages 147-151. ISSN 1822-296X.

[3] G. Eason, B. Noble, and I.N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529-551, April 1955.

[4] Hudek, M., 2015 Návrh zavedenia spoločnej fronty čakania vybavenia cestujúcich pri osobných pokladniciach v ŽST Trnava (diploma thesis)

[5] Janková, K. a kol. 2015 Markovove reťazce a ich aplikácie Žilina: EDIS, ISBN 978-80-562-0075-9.

[6] Meyn, S., Tweedie, R. L., 2009 Markov Chains and Stochastic Stability. Cambridge University Press, 569 pages., ISBN 978-0-521-73182-9.

[7] Norris, J.R. 1997 Markov Chians. Cambridge University Press. 251p., ISBN 0-521-48181-3.

[8] Ponický, J., Kendra, M., Čamaj, J.: Kvantifikácia časových faktorov v prepravnom reťazci osobnej dopravy. In: Železničná doprava a logistika. Railway transport and logistics : scientific and technical on-line journal. ISSN 1336-7943. P. 19-24.

 