The probability determination of the queuing system state of the motor transport enterprise

S V Bulatov

Orenburg State University, 149, Victory Ave., Orenburg, 460048, Russia

E-mail: bul.sergey2015@yandex.ru

Abstract. The article describes the queuing system by the example of one-passenger motor transport enterprises for the purpose of carrying out the analysis of the applications flow for spare parts, the conditions identifications of the formation of the waiting list. All this including the determination of the optimum number of the service stations for units and sets will allow serving in due time the rolling stock without idle times.

1. Introduction
The queuing systems intended for the mass flow service of the requirements (applications) of accidental character have "input" and "output" and an internal state [1-5], which is characterized by the timely order, the existence of necessary spare parts and also the speed and the quality of the unit or set installation. In practice the applications flow for the units and sets service is stochastic [6-9], this circumstance forces to have additional stations for the service, therefore there is a need for the determination of the optimum number for the service stations.

2. Method of forecasting
The queuing theory, as a rule, researches and determines the quantitative parameters of the material flow (units and sets). The applications flow has such signs as stationarity (the coming probability of a number of applications during a certain period of time \( t \) depends only on the length of this period) and ordinariness (only one application comes to the system at each timepoint). In our case all applications come to the system independently of each other.

3. Experimental research
The considered flow is called "Poisson" (without after-effect) as the number of \( m \) applications, falling on an interval of time \( t \), is distributed according to the Poisson's law:

\[
P_m(t) = \frac{(\lambda t)^m}{m!}e^{-\lambda t},
\]

where \( \lambda \) – density of the applications flow that is the quantity of applications per unit of time.

The general scheme of the queuing system of the passenger motor transport enterprise (PMTE) is presented in figure 1.
The density of the entrance flow (the number of units and sets in a unit of time) is a constant:

\[ \lambda = \frac{N}{T} = \text{const} \]  

(2)

where \( N \) – the quantity of units and sets received in the system during \( T \).

The density of the output flow \( \mu \) is a variable that is reverse to the average time of service for one unit or set \( \bar{t} \):

\[ \mu = \frac{1}{\bar{t}}. \]

The state of the service system with refusals is described by the Erlang’s formula [10]:

\[
P_k = \frac{1}{1 + \frac{\alpha}{\mu} + \frac{\alpha^2}{2! \mu} + \ldots + \frac{\alpha^n}{n! \mu}},
\]

(3)

where \( P_k \) - probability of the system state \( 0 \leq k \leq n \); \( P_0 \) - probability that all service stations of units and sets are free; \( P_1 \) - probability that 1 service station of units and sets is occupied; \( P_2 \) - probability that 2 service stations of units and sets are occupied; \( P_k \) - probability that \( k \) service stations of units and sets are occupied; \( P_n \) - probability that all service stations \( n \) are occupied or probability of refusal in the service of units and sets.

We carry out the analysis of the applications of the flow character for the conditions of identifications of the formation of waiting in the queuing systems of PMTE. It has become clear that waiting lists are formed because of the insufficient number of the serving stations, the high intensity of the applications flow, the insufficient number of spare parts, the slow service of the applications. All these reasons work separately and all together. Thus, the rate and the probability of the waiting list formation determine two parameters [11-13]:

- \( n \) – the quantity of the service stations;
- \( \alpha = \lambda / \mu \) - the specified density of the applications flow.

As units and sets are not removed from the waiting list until they are not served, then at:

- \( \lambda / \mu < n \) - each unit or set will wait for the service sooner or later;
\[ \frac{\lambda}{\mu} > n \] - the quantity of the units or the sets being in the waiting list will increase beyond all bounds over time.

It follows from this that in the management of the material flow the ratio of entrance and output flows with the orientation to the quantity of the service stations is monitored. The service process becomes established at \( \frac{\lambda}{\mu} < n \).

At one of the passenger motor transport enterprises the units and sets service is made in 4 stations. 16 units (sets) are served a day; the average time of service is 35-40 minutes (figure 2).

The applications flow is accepted by Poisson.

The calculation results according to the Poisson's formula are presented in table 1.

| The quantity of the units (sets) | 0    | 1    | 2    | 3    | 4    | 5    | 6    | ... |
|----------------------------------|------|------|------|------|------|------|------|-----|
| Probabilities                    | 0.135| 0.270| 0.270| 0.132| 0.092| 0.036| 0.012|     |

According to table 1, the service of 1 and 2 units (sets) within one hour will be the most probable option, the probability of the 3 units (sets) service is high, and the probability of service within one hour of 4 and more units (sets) is very low. It often happens that there are no applications for service within one hour at all.

Further, the probabilities of the system state are determined by the Erlang’s formula (2). The calculation results are presented in table 2.

| The quantity of the stations | 0   | 1   | 2   | 3   | 4   |
|-----------------------------|-----|-----|-----|-----|-----|
| Probabilities of the system state | 0.369| 0.369| 0.184| 0.062| 0.016|

According to table 2, the probability that all stations are free is rather high – 37%, the occupation of one stations has the same probability, the occupation probability of two stations is 18%. The occupation probability of three stations is already relatively small – 6% and, about 1% is the probability of the waiting list formation, therefore of idle time for the rolling stock.

4. Conclusion

The costs of the maintenance of the reserve service stations (they will grow) and the losses from idle times of the rolling stock (they will decrease) are compared for the solution of this problem.

The results of the study of this work are implemented at the passenger motor transport enterprise “CJSC Avtokołonna No. 1825”, Orenburg.

References

[1] Kubarev A I 1989 Reliability in mechanical engineering (M: Izd-vo standards)
[2] Kuznetsov E S 2004 Technical operation of cars (M.: Transport)
[3] Fastovtsev G V 1989 Organization of maintenance and repair of cars (M.: Transport)
[4] Kubarev A I 1989 Reliability in mechanical engineering (M: Izd-vo standards)
[5] Karagodin V I, Mitrokhin N N 2001 Repair of motor vehicles and engines (M: Skill. ouch. school)
[6] Fomina E V, Kozhukhova N I, Sverguzova S V, Fomin A E 2018 Application of mathematical model methods for optimization tasks in construction materials technology Journal of Physics: Conference Series 1015 052015
[7] Glushchenko V V 2018 Modeling methods of technical services for transport operation Journal of Physics: Conference Series 1118 012016
[8] Bulatov S V 2018 Expense management of transmission spare parts taking into account their quality for rolling stock Journal of Physics: Conference Series 1118 012011
[9] Gise R 1991 Modern concept of complex management of circulating material resources Motor transport enterprise 3 105-107
[10] Boutellier R 2006 Strategy and organization of supply (M: KIA center)
[11] Schonberger R 1988 Japanese methods of management of production (M: Economics)
[12] Bulatov S V 2018 Requirement definition of passenger motor transport enterprises for spare parts by method of short-term combined forecasting Journal of Physics: Conference Series 1015 052004
[13] Kruglov M G, Sergeev S K and Taktashov V A 1997 Management of quality systems (M: IPK Publishing house of standards)