OPTIMIZATION OF CARGO TRUCK LOADING

LAMPA Martin[1], SAMOLEJOVÁ Andrea[1], SIKOROVÁ Andrea[1]

[1]*VSB - Technical University of Ostrava, Ostrava, Czech Republic, EU*

Abstract:

People are met with waiting in queues every day. They wait in queues in shops, at gas stations, elevators etc. It does not have to be only people, it can also be planes circling around an airport waiting to land, machines waiting to be repaired, cargo trucks waiting to be loaded etc. The problem of queue management tends to be complicated, because the scope of provision of services of various types grows quickly. The goal of these problems is establishment of an appropriate level of services. The method that enables solving these types of problems is called queueing theory.

The goal of the article will be to implement optimization of cargo truck loading and to identify how much money a company can save by the eventual acceleration of loading.

Keywords: Optimization, queueing theory, truck loading

1. INTRODUCTION

Distribution of goods by cargo trucks is a typical situation during which provision of services occurs. On the one hand, demand for services is not constant, fluctuation in certain periods occurs (e.g. queue of cars at the beginning and at the end of a shift). In addition, unpredictable changes of demand also occur. On the other hand, the time of service may change due to special requests of those who request the service [1]. As a result, it is difficult to satisfy a request immediately after its emergence, especially during peak hours.

The only way to satisfy requests immediately at all times is to build a service capacity so high that it always satisfies the peak demand. It is typically very expensive to build, operate and maintain service facilities so that they always satisfy all requests as soon as they emerge. It is very costly to keep changing and adapting the service capacity to emerging requests [2]. Service systems are designed so that their capacity is lower than the peak demand. Whenever the demand exceeds the capacity, a queue is created. This means that customers will not receive the service immediately after requesting it and they will have to wait. In other cases, service units will have idle time. With a high service capacity, customers will not wait long, but the service units will often be unused and their costs will be high. With a lower and less costly service capacity, idle time will be lower but customers will have to wait longer [3].

Management of services is a truly complicated process. If the management wants to satisfy the customer, it is very expensive and sometimes not even possible to satisfy everyone immediately at all times [4]. The management strives to find the appropriate level of services [5]. The theory for these problems is called queueing theory.

2. INDICATORS OF PERFORMANCE IN MODELS WITH QUEUES

When evaluating variants of service, indicators of performance are used especially if we are monitoring costs. These indicators are calculated from three input variables:

λ - average rate of arrivals,

μ - average rate of service,

K - number of service units.

Indicators of performance:

Average time W - time spent by the customer in the system - waiting for service:

$$W = \frac{1}{\mu - \lambda} = \frac{1}{\mu\,(1-\varphi)} \tag{1}$$

Average duration of waiting in queue W_q - the average duration the customer spends waiting in queue before they start being served:

$$W_q = \frac{\lambda}{\mu(\mu-\lambda)} = \frac{\varphi}{\mu(1-\varphi)} \tag{2}$$

Probability of inactivity of service facility *P(0)* - the probability that there will be no customer in the system (facility will be inactive):

$$P\,(0) = 1 - \frac{\lambda}{\mu} = 1 - \varphi \tag{3}$$

Probability of activity of the system P_w - this probability is identical to the probability that the system will not be inactive, that is:

$$P_w = 1 - P(0) = \frac{\lambda}{\mu} = \varphi \tag{4}$$

There are many more indicators of performance of queues, these are sufficient for solving the given problem.

3. CALCULATING COSTS OF SYSTEMS WITH QUEUES

In certain situations, it is possible to evaluate costs of waiting in monetary units. This is done on the basis of total costs *TC*, which consist of two components: costs of service facility C_F and total costs of waiting customers C_W.

$$TC = C_F + C_W \tag{5}$$

Costs are established in one of two ways. Either as “costs per unit of time” or “costs per served customer”.

$$C_w = W\,\lambda C = LC \tag{6}$$

W - average time per customer in the system

C - costs of waiting per customer per unit of time

L - average number of customers in the system

C_F - these are made up of both fixed and variable costs. Annual fixed costs (taxes, depreciations and insurance) and variable (hourly) costs must be converted to the same units of time that are used in the equation (6) so that both cost components can be added together. Costs of service facility can be evaluated per hour (50 CZK per hour), per served customer (500 CZK per customer) or per unit of service capacity (300 CZK per every customer that can be served).

4. OPTIMIZATION OF CARGO TRUCK LOADING

A company distributes its production by cargo trucks. An average duration of loading is 20 minutes per truck. Cargo trucks come in at an average rate of 2 trucks per hour. The management feels that the existing loading facility is more than satisfactory. However, drivers complain that they have to spend more than 50% of their time by waiting. The goal is to identify how much money the company can save by accelerating loading, when the truck waiting costs are 30 euros per hour. The working time is 8 hours.

$\lambda = 2$

$\mu = 3$ (20-minute service means 3 per hour)

After substitution into the formula (4), the probability of waiting in queue is:

$$P_w = 1 - P(0) = \frac{\lambda}{\mu} = \frac{2}{3} = 0.667 * 100 = 66.7\%$$

complaints of drivers are therefore justified. According to the formula (2), the average waiting time of drivers in queue is:

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{2}{3 * (3 - 2)} = \frac{2}{3} hr. = 40\ minutes$$

there are 16 loading operations (2*8) per day

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{2 * 16}{3 * (3 - 2)} = 10.67\ hrs. per\ day$$

The total costs according to the formula (5) are:

*TC = 10.67*30 = 320 euros*

Hence the company should consider suitable variants that would reduce costs. For example, implementation of an automated facility that is able to serve 10 trucks per hour for 200 euros per day of operation compared with the existing facility.

then

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{2}{10 * (10 - 2)} = 0.025\ hrs. = 1.5\ minutes$$

there are 16 loading operations (2*8) per day

$$W_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{2 * 16}{10 * (10 - 2)} = 0.40\ hrs. per\ day$$

The total costs according to the formula (5) are:

*TC = 0.40*30 = 12 euros*

The total daily savings are:

320 - (200 + 12) = 108 euros

For clarity, all is shown in the following table:

Table 1 Comparison of costs of truck loading

System	Costs of service facility C_F (euros)	Costs of waiting				Total costs (euros/hr.)	Total costs (euros/day)
		λ	W_q	C (euros)	C_W (euros)		
Current	-	2	0.667	30	40	40	320
Automated	200 per day (25 per hr.)	2	0.025	30	1.50	26.50	**212**

The **Table 1** clearly illustrates that implementing the given automated system of service will result in saving of costs and reduction of waiting times spent in queue.

5. CONCLUSION

The queueing theory is a tool that is used mainly to calculate indicators of a service system. The management uses this information to design a system of service and to improve its functioning. The main cause of occurrence of queues even in cases, when the average rate of service is greater than the average rate of arrival, is that both rates fluctuate in an unpredictable manner. This results in temporary changes in both the rate of arrival and the rate of service. This leads to unutilized capacity in certain periods of time and waiting in other periods of time.

ACKNOWLEDGEMENTS

The work was supported by the specific university research of the Ministry of Education, Youth and Sports of the Czech Republic No. SP2017/67.

REFERENCES

[1] GROS, I.; DYNTAR, J. *Matematické modely pro manažerské rozhodování*, Praha: Vysoká škola chemicko-technologická, 2015. 303 p.

[2] TURBAN, E; MEREDITH, J. R. Fundamentals of management science, USA: R. R. Donnelye & Sons, 1991. 1010 p.

[3] SAKÁL, P.; JERZ, V. *Operačná analýza v praxi manažéra*. Trnava: SP SYNERGIA, 2003. 335 p.

[4] BESTA, P., SAMOLEJOVÁ, A., LENORT, R., ZAPLETAL, F.*: INNOVATIVE APPLICATION OF MATHEMATICAL METHODS IN EVALUATION OF ORE RAW MATERIALS FOR PRODUCTION OF IRON,* METALURGIJA, 2014, vol. 53, no. 1, pp. 93-96.

[5] ADAN, I.; RESING, J. *Queueing Systems* [online]. [cit. 22.5.2017]. Dostupné z: http://www.win.tue.nl/~iadan/queueing.pdf, Eindhoven: Eindhoven University of Technology, 2015.