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POWER UNIT – CARGO SPACE LINK IN TRANSPORT

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Abstract: This paper deals with transportation technology regarding links between power unit and cargo space. These links can be divided into two groups: rigid and flexible. Rigid link, established between power unit and cargo space, is dominant in maritime and road transport (sea ships and trucks), and occasionally in transport on inland waterways (self – propelled barges). Flexible link is used in the railroad transport (systems with trailers and semi trailers), and in inland waterway transport (push – towing and pulling systems, and combinations of the systems).
The main goal of this research is determination of possible link types and organization of the means of transportation.

Keywords: Means of transportation operations, power unit – cargo space link in transport.

1. INTRODUCTION

Rigid link power unit has less exploitation time, since it has to wait along with ship cargo space at loading and unloading points, depending on technology used, transportation process geography, and other operations (customs controls, change in transport conditions, etc.). In the use of flexible link between power unit and cargo space, possibilities for higher exploitation time of power unit exist. This is true for time periods during the cargo space operations only. For example, the motorboat and locomotive do not have to wait on tow or railcar units for cargo loading and unloading.

The power unit – cargo space link can be considered as queuing systems with bulk arrivals, single service and unlimited queue.

In this paper, bulk arrivals are presented by cargo space units without power units. The basic objective of the application of multi-channel bulk queue systems is determination of steady-state probabilities and adequate efficiency measures. The steady-state probabilities refer to the probability that the power unit is idle and the probability that the time spent in queue by a random cargo space unit arrived in bulk is greater than zero depending upon the utilization factor, power unit occupancy; number of cargo space units and number of power units.

2. DETERMINATION OF PROBABILITY THAT POWER UNIT IS IDLE AND PROBABILITY THAT TIME SPENT IN QUEUE BY RANDOM CARGO SPACE UNIT ARRIVED IN BULK IS GREATER THAN ZERO

Using mathematical derivations shown in Chaudhry *et al*, (1983), Radmilović, (1992) and Radmilović *et al*, (2003), the following equation can be derived:

$$\sum_{n=0}^{c-1}(c-n)\cdot P_n = c(1-\rho) \qquad (1)$$

where:
n - number of units in the cargo space in the operative transportation system;
c - number of power units;
P_n - steady-state probability that n cargo space units are in the operative transportation system;
ρ - utilization factor in queuing theory or power units occupancy defined as:

$$\rho = \frac{\lambda \cdot \overline{a}}{c \cdot \mu}$$

where:

λ - average arrival rate of cargo space units in bulk;
μ - average service rate;
$\overline{a}$ - average number of cargo space units in bulk.

From Eq.1, probability P_O can be easily determined by using the boundary condition and mathematical derivations shown in Radmilovic, (1992) and Radmilović *et al*, (2003).

For example, in the case that operative transportation system has four power units, the probability P_O can be obtained as:

$$P_o = \frac{3\overline{a}^3(1-\rho)}{8\rho^3 + 6\rho^2\overline{a}(3-a_1) + \rho\,\overline{a}^2(13-4a_1-a_2) + 3\overline{a}^3} \qquad (2)$$

where
a_1, a_2 - probabilities of one or two cargo space units present in the operative transportation system.

These probabilities are presented in Fig. 1, as a function of power unit occupancy, number of power units, and number of cargo space units in bulk, in the case when waiting time (V_q) of a random cargo space unit in an arriving bulk is greater than zero.

Using mathematical derivations shown in Chaudhry *et al*, (1983) and Radmilovic *et al*, (2003), the probability that cargo space unit in the bulk will be in the queue is:

$$P(V_q > 0) = 1 - \frac{1}{\bar{a}} \sum_{n=0}^{c-1} \left[c - n - \sum_{m=1}^{c-n} (c-n-m) \cdot a_m \right] P_n \tag{3}$$

where:
n - number of cargo space units in bulk;
a_m - probability that the bulk of m cargo space units is presented in operative transportation system.

For example, in the case of the operative transportation system with four power units and by using Eq.3 the following expression can be shown:

$$\begin{aligned} P(V_q > 0) = 1 - \frac{1}{\bar{a}} \left[4 - \frac{3}{\bar{a}} - 2\frac{1-a_1}{\bar{a}} - \frac{(1-a_1)(1-a_2)}{\bar{a}} \right] P_o - \\ - \frac{1}{\bar{a}} \left[3 - \frac{2}{\bar{a}} - \frac{1-a_1}{\bar{a}} \right] \frac{4\rho}{\bar{a}} P_o - \frac{1}{\bar{a}} \left(2 - \frac{1}{\bar{a}} \right) \cdot \left[\frac{2\rho}{\bar{a}}(1-a_1) + \frac{8\rho^2}{\bar{a}^2} \right] P_o - \\ - \frac{1}{\bar{a}} \left[\frac{4\rho}{3\bar{a}}(1-a_1-a_2) + \frac{8\rho^2}{\bar{a}^2}(1-a_1) + \frac{32\rho^3}{3\bar{a}^3} \right] P_o \end{aligned} \tag{4}$$

Numerical results are given in the Fig. 1 and explained in the Appendix

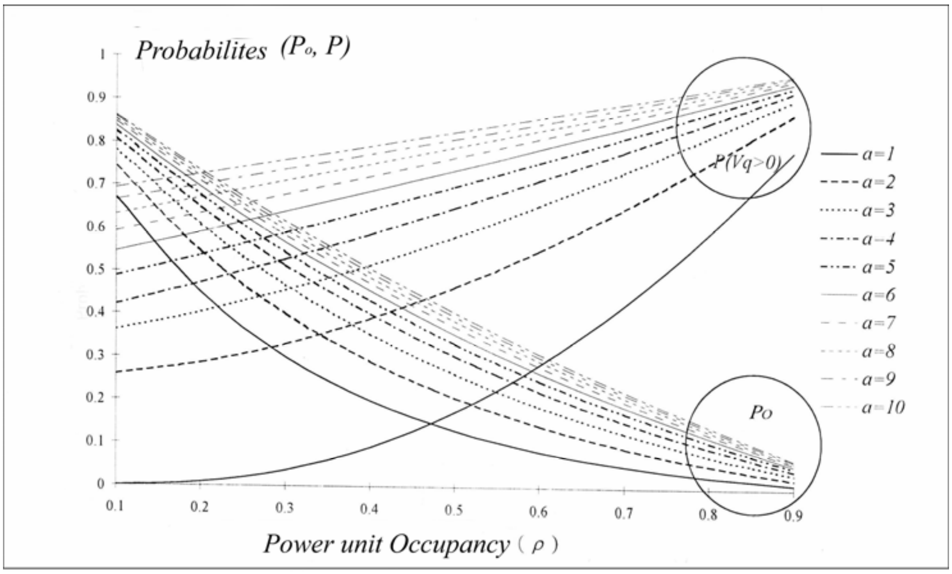

Figure 1: Queueing analysis solutions for probability that power unit is idle (P_o) and probability that time spent in queue by random cargo space unit arrived in bulk is greater then zero *($P(V_q>0)$) $M^x/M/4(\infty)$, $X=\bar{a}$* =1,2,3,4,5,6,7,8,9,10, delayed system

3. SUMMARY AND CONCLUSIONS

Presented models and results are convenient for different analyses, planning and development of operative transportation systems with flexible link between power units and cargo space units. Nevertheless, the conveniences of this methodology are the simple application and estimates of existing conditions. Also, the results obtained in this paper are restrictive because the assumptions about inter arrival and service time distributions, as well as the bulk size probability distribution must be verified before application in operative transportation systems.

4. APPENDIX

Fig. 1 shows the numerical results of queuing system with bulk arrivals, single service and waiting time. The service system can be presented as $M^{X=\overline{a}}/M/4$, where:
M – Poisson's distribution of cargo space units arrivals in bulk;
$X=\overline{a}=const=1,2,\ldots,10$ – constant number of cargo space units;
M – Exponentional distribution of service time for each units separately;
c – number of power units in operative transportation system.

This methodology is successfully applied in the monography Radmilović and Dragović, (2003), in the examples of the transportation proccess modeling on inland waterways and terminals.

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