ECONOMIC DIMENSION OF THE PORT BERTHS QUANTITY OPTIMIZATION ISSUE

Lyubov V. Terentyeva

In this article the author considers the criterion function of the berths quantity optimization issue at the port, which can be solved by using the queuing theory. Also the author shows the structure of berth operating costs including the expenditures of the cargo front technological lines either busy with freight handling or idle waiting for a vessel.

Keywords: port, berth, berth quantity optimization, berth maintenance costs, service channel.

The issue of berths demands optimization for a sea port or a stevedore company can be solved by using methods of the queuing theory (QT), in other words - waiting-line theory. The queuing theory allows us to consider a port as an n-channel queuing system. For *n* the number of berths at a port or a stevedore company may be admitted. The input flow of equal processing requests is the flow of ships. The flow of ships arriving in a port is considered as a simple stream, for which the probability $P_k(t)$ of occurrence of *k*-number of events for the period of time t is determined by the Poisson law [1]:

$$P_k(t) = (\lambda t)^k / k!)\, e^{-\lambda t}, \qquad (1)$$

where λ is intensity of the ship traffic flow.

Using the queuing theory the results of requests (ships) processing in a port with a different number of processing channels i.e. berths can be calculated. For a specified value of freight turnover the berths number growth is followed by port production facilities outage increase. On the other hand, the growth of berths number in a port reduces the fleet

idle time while waiting for processing. The problem is to determine the number of berths for given characteristics of freight and vessel traffic, which reduces the total harbor costs C_{harbor} and fleet outlay C_{fleet} to minimum, i.e., as the objective function a complex estimator is used - a minimum of total harbor and fleet costs [2]:

$$C_{total} = C_{harbor} + C_{fleet} \rightarrow min. \quad (2)$$

These harbor costs take into account the cost of berths construction and maintenance when the ones are in use in ships processing $T_{berth\ proc}$ and idle waiting vessel approach for processing $T_{berth\ idle}$:

$$C_{harbor} = (K_{berth} \times E_n / T_{nav} + S_{proc}) \times T_{berth\ proc} + (K_{berth} \times E_n / T_{nav} + S_{idle}) \times T_{berthidle} \quad (3)$$

where K_{berth} - the cost of berth construction; E_n - standard coefficient of the investments economic efficiency; T_{nav} - the duration of the port navigation period measuring in days; S_{proc}, S_{idle} - daily maintenance cost of the berth during ship processing operations and the one being idle waiting for vessel approach respectively.

The fleet costs include vessel construction cost and vessel maintenance charge during its processing at a pier $T_{proc}(T_{proc} = T_{berth\ proc})$, and the time they are idle waiting for processing (or free place at a pier) T_{idle}:

$$C_{fleet} = (K_v \times E_n / T_E + S_{port}) \times (T_{proc} + T_{idle}), \quad (4)$$

where K_v - vessel construction cost; T_E - vessel working period (days); S_{port} – vessel operational costs for a day in a port.

The values of vessel processing time (berths being busy for vessel processing time) are calculated by the equation

$$T_{proc} = T_{berth\ proc} = (\lambda \times T_{nav})/v, \quad (5)$$

where v- is the inverse value of the average duration of vessel processing at the pier, measuring in days.

The duration of idle period of vessels waiting for free space at a berth for processing is calculated by the equation:

$$T_{idle} = \lambda \times T_{nav} \times \tau_{wait}, \quad (6)$$

where τ_{wait} is the average delay of a vessel waiting for free berth for processing (days).

The idle time for berths waiting the approach of vessels is determined by the equation:

$$T_{berth\ idle} = T_{nav} \times (n \times v - \lambda), \quad (7)$$

The values of τwait in the equation 6 are defined by the probability theory and vary depending on the number of berths i.e. the number of processing channels. To calculate the fleet costs, we can use the technical standards of daily operational costs, which are defined by the shipping company for each type of vessel and used to calculate the economic indicators of the voyage job, along with other indicators of the regulatory base. Determination of the economic components of the equation 3, in particular daily operating cost of the pier during cargo operations or during idle time waiting for a vessel requires additional methods of calculation, as these standards are not used in ports operational practices.

Berth as a port engineering construction includes moorage wall, an adjacent area, gantry rails, open storages and private warehouses, railways for cargo operations and maneuvering in border and rear administrative areas, production lines (PL) of cargo seafront and port utility services. The production lines include expensive cargo-handling equipment, i.e. rail mounted gantry cranes, quayside cranes and various types of loaders and carriers. The running cost of cargo-handling equipment highly affects the total berth cost.

For more accurate expenditures recognition it is necessary to single out the cost of a production line that performs vessel cargo operations and the cost of an idle one waiting for cargo-handling. Singling out the costs for one production line allows accounting from its total quantity the number of production lines involved in the vessel processing and being idle. These cost data may also be useful to solve the complex task of optimizing the processing standards for vessels in a seaport by simulation technique.

In general, the berth operating costs without the cost of production line include deductions for the berth depreciation and maintenance, the cost of electricity, the cost of salary for managerial and administrative personnel as well as portion of port general costs. For theoretical calculations the cost of managerial and administrative staff salary is considered in prescribed proportion of the port workers salary, which in turn, accounting during calculations of the cost of one production line. In alternate calculations when comparing choices, the portion of general port costs as well as the cost of electricity for illumination is usually ignored.

The operating costs of one cargo seafront production line used for cargo operations (in rubles per day) include the following:

- Deductions for depreciation and maintenance of mechanization appliances (main cargo-handling machine, e.g. crane or a transtainer, and loaders which is needed for the production line operation as technologically prescribed).
- Expenses of salary for dockers servicing cargo-handling equipment of one production line.
- Expenses of salary for docker-mechanics performing transshipment operations.
- Cost of electric power for the crane.
- Cost of electricity for battery fork-lift trucks or other electric loaders;
- Cost of fuel for oil engine vehicles.
- Cost of lubricants and cleaning materials.
- Cost of low-value or high-wear inventory.
- The cost of managerial and administrative staff.

The operating costs of one idle production line (in rubles per day) include the following:

- The cost of depreciation and maintenance of cargo-handling equipment.
- Expenses of salary for dockers servicing cargo-handling equipment of one production line.
- Expenses of payment to idle docker-mechanics per day, in cases when a stevedoring company has its own staff of docker-mechanics; does not use the services of employment company providing docker crews for cargo operations at the request of the stevedoring company;

and can't provide the docker-mechanics with specified dock-work.

- The cost of managerial and administrative staff.

The costs of the work of a production line in the rear part of cargo seafront may be calculated in a similar way, but it is necessary to take into account the fact that there are loaders and trucks and no cranes or transtainers in operation there. Number of production lines of the rear part of cargo seafront must provide daily volume of cargo-handling operations from a railcar to a warehouse or vice versa.

Thus, to determine the daily operating costs of the berth it is necessary to summarize the actual costs of the berth as the port facility without production lines and the daily costs of the production lines of the cargo seafront's fore- and rear parts performing cargo-handling operations and being idle.

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