Ports Organization and Management

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Queuing Theory Problems

Master Degree in Naval Architecture and Marine Engineering
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Problems:

1. (M/M/1) A ferry terminal is able to service 12 ships per day in a single quay. Calculate the average time of queueing and the average system time when the traffic intensity is 0.3 and 0.9. Calculate in each situation the average number of ships in the system and the average length of queue?

2. (M/M/1) An iron ore import terminal is required to handle 2000000 tons per year. There are two options for supplying the terminal:

a) Bulk carriers of 25000dwt, which can be unloaded at a rate of 400 tons/hour.

b) Bulk carriers of 2000000dwt, which can be unloaded at a rate of 800 tons/hour.

There is only one berth to service the ships and the terminal operates 360 days per year. Calculate the total queuing time for each type of ship per year.

3. (M/M/1) The container freight station (CFS) of a container terminal receives general cargo delivered by trucks. Trucks are unloaded by fork-lift trucks. Experience shows that trucks arrive at a rate of 16 trucks per day, following a Poisson process. The times taken to discharge trucks are variable, with negative exponencial distribution:

Number of fork-lift trucks	Average time of unloading (min)
1	50
2	20
3	15
4	12
5	10

The operation of the fork-lift trucks costs 15 euros/hour. The truck immobilization costs 30 euros/hour. What is the optimum number of fork-lift trucks so that costs of the system are minimum. The CFS works 8 hours per day.

4. (M/M/1) A liquid bulk terminal with one berth receives an average of 1 ship every 2 days. The average tanker is an aframax with 100000 tons of cargo deadweight, which will unload at a rate of 2500 tons/h.

a) Represent the terminal using a queuing model.
b) Calculate the following parameters:
    i. Average waiting time.
    ii. Probability of waiting more than 24 hours.
c) If an equivalent additional berth is provided and the one queue system is kept, how will these parameters change?

5. (M/M/1) Three Rivers Company operates a docking facility on the Ohio River. An average of 5 ships arrives to unload their cargos each shift. Idle ships are expensive. More staff can be hired to unload the ships, but that is expensive as well. Three Rivers Company wants to determine the optimal number of teams of stevedores (1 team up to 4 teams) to employ each shift to obtain the

minimum total expected cost. The estimated cost per hour of idle ship time is $1,000. The stevedore team salary or service cost is $6,000 per shift.

6. (5xM/M/1) A container terminal has 5 berths along the quay. A ship arrives at the terminal every 2 hours on average. The average service time is 8 hours. Each berth has a separate queue.

a) Represent the terminal using a queuing model.
b) Calculate the following parameters:
    i. Probability of a ship having to queue before berthing.
    ii. Probability of a ship arriving at the terminal and being berthed immediately.
    iii. Average waiting time and average time in system.
    iv. Average number of ships queuing.
    v. Probability of a ship having to wait more than 8 hours.
c) Solve again the problem assuming that only one queue is formed. Compare the results with the previous organization model.

7. (M/M/S) A general cargo terminal has 3 berths with identical conditions and with average service time of 2 days. On average, one ship arrives per day and the mooring space is unlimited if waiting is needed. Service follows the order of arrival.

a) Calculate the average time the ships spend in the port and the average time the ships spend waiting.

b) Calculate the probability of existing a queue and the average length of the queue.

Assume that the arrivals obey a Poisson distribution and the service time obeys a negative exponential distribution.

8. (M/M/S/K) A coal terminal has one mobile gantry crane capable of unloading 5 ships per day. The quay allows 2 ships to be berthed simultaneously and additional ships are deviated to a nearby terminal. The cost for each deviated ship is 20000 euros. Immobilization of ships in port costs 12000 euros per day per ship.

Arrivals may be considered as given by a Poisson distribution with an arrival rate of 3 ships per day. Service times follow a negative exponencial distribution.

Determine the economic feasibility of lengthening the quay in order to receive 3 ships, taking in consideration that the additional cost is 1000 euros per day.

9. (M/M/1/7) A dry bulk terminal consists of one berth for loading iron ore. The sheltered space in the port for mooring ships is limited to a maximum of 6 ships. When the mooring space is entirely taken, the ships will opt for another port located nearby. The average revenue per ship is 50000 USD. Ships arrive at the port for loading in this terminal at an average rate of 1 every 36 hours. The ships are on average capsizes with cargo capacity for 96000 tons. The terminal has two 2 loading gantries capable of delivering on average 1000 tons per hour each.

a) Represent the terminal using a queuing model.
b) Calculate the following parameters:

i. The average waiting time.
ii. Average number of ships in the system.
iii. Average revenue lost per month by the terminal.

c) If the terminal opens an additional berth, how much will decrease the average revenue lost per month?

d) If the terminal increases the mooring space allowing for 10 ships to be waiting, how much will decrease the average revenue lost per month?

10. (M/M/1/2) A repair shipyard has one dock and one quay for mooring ships while waiting for the dock to be made available. If both are occupied the ships sail for a neighboring port where there is another shipyard. The arrival rate is 36 ships per year and the service rate is 60 ships per year.

a) Calculate how many ships are lost per year, on average.

b) Calculate the average time spent by the ships in the shipyard and the average number of ships in the shipyard.

c) If an additional quay is built, how many more ships may be repaired per year? What is the average time spent by the ships in the shipyard and the average number of ships in the shipyard in this new situation.