Modeling the arrival process at dry bulk terminals

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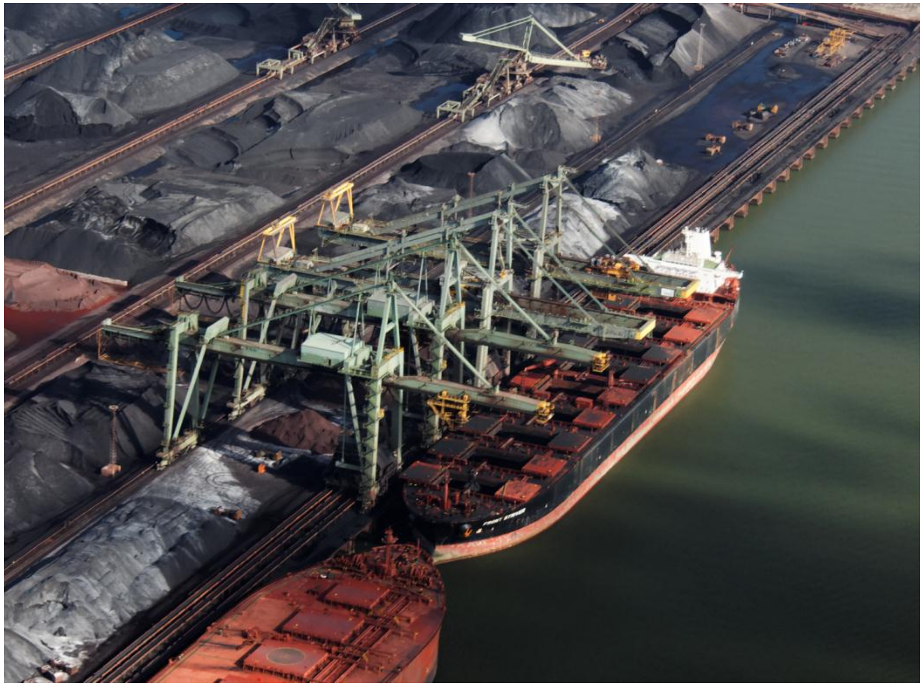
Arrival process

- Typical performance indicator is the average ships' waiting time
- Agreements between terminal operators and ship-owners are made about the maximum ships' port time
- Demurrage costs have to be paid if ships stay longer in the port
- How much capacity must be installed at the quay side?

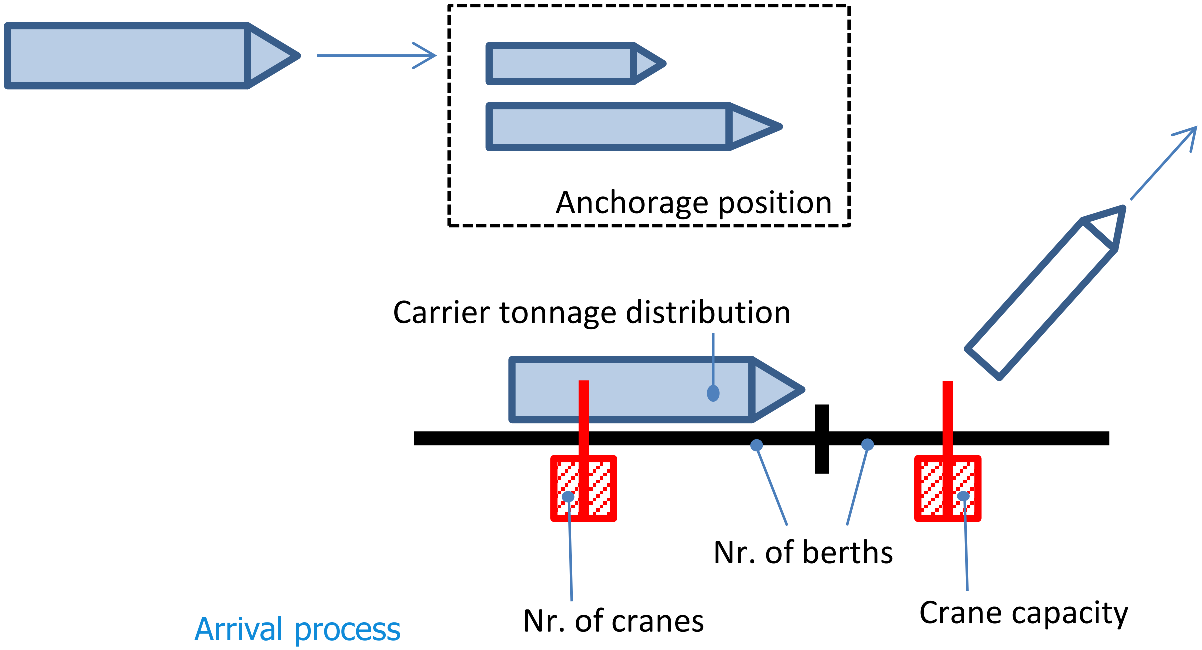
Ship loading (Courtesy of Richards Bay Coal Terminal)



Ship unloading (Courtesy of J.Hiltermann)

Average port time (1)

- Average port time is the average waiting time plus the average service time
- Ships' interarrival time predominately determines the average waiting time
- Quay crane capacity and carriers' tonnage determines the average service time

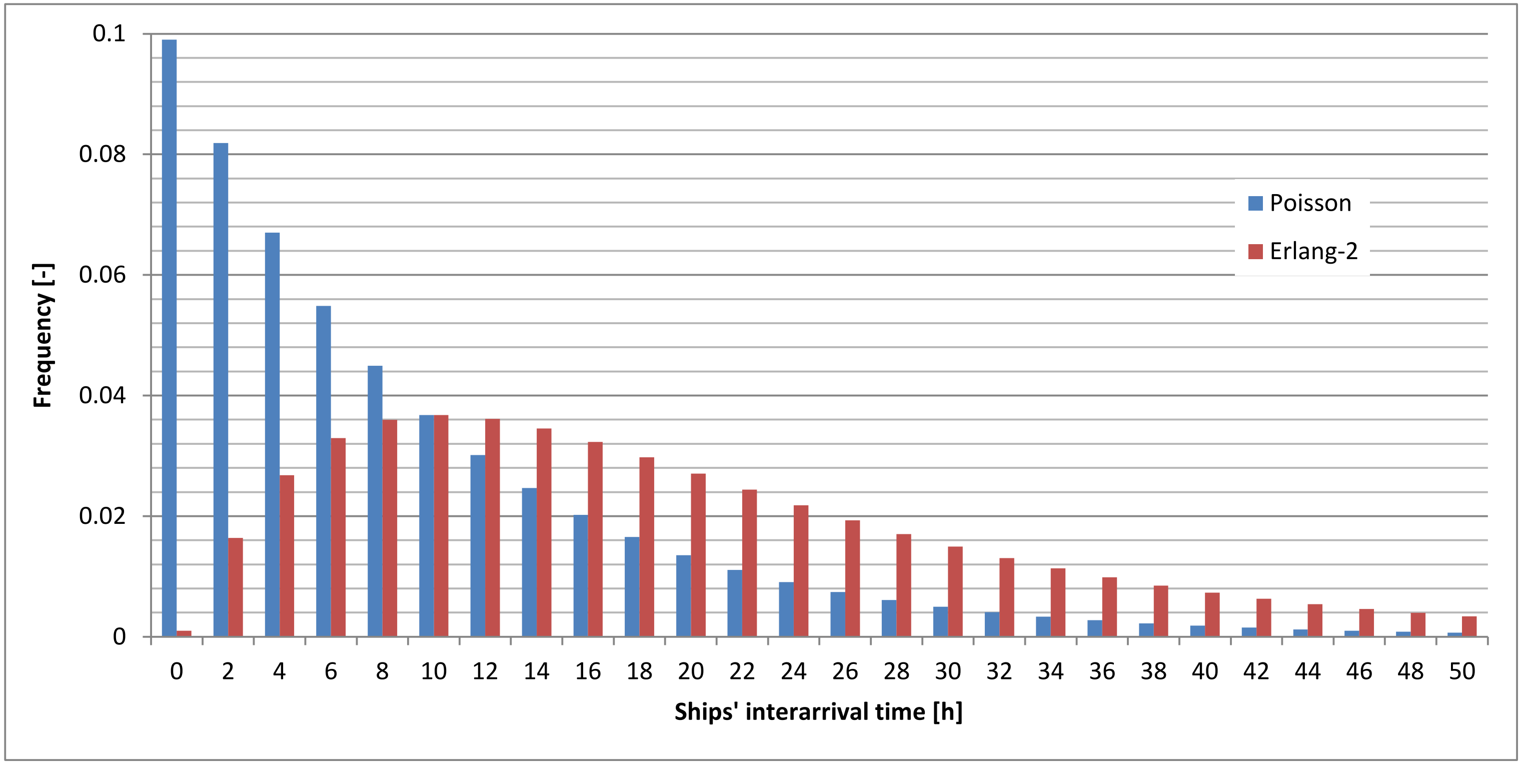


Average port time (2)

- Existing literature about ships' arrivals:
  - Ships do not generally arrive at their scheduled times because of bad weather conditions, swells and other natural phenomena during the sea journey as well as unexpected failures or stoppages (Jagerman and Altiok, 2003)
  - Uncontrolled ship arrivals results in ship delays (Asperen, 2004)
  - Ships interarrival times best approximated by a Poisson or Erlang-2 distribution (UNCTAD, 1985)
  - Erlang-2 distribution can be used to represent the service time distribution (UNCTAD, 1985 and Jagerman and Altiok, 2003)

Average port time (3)

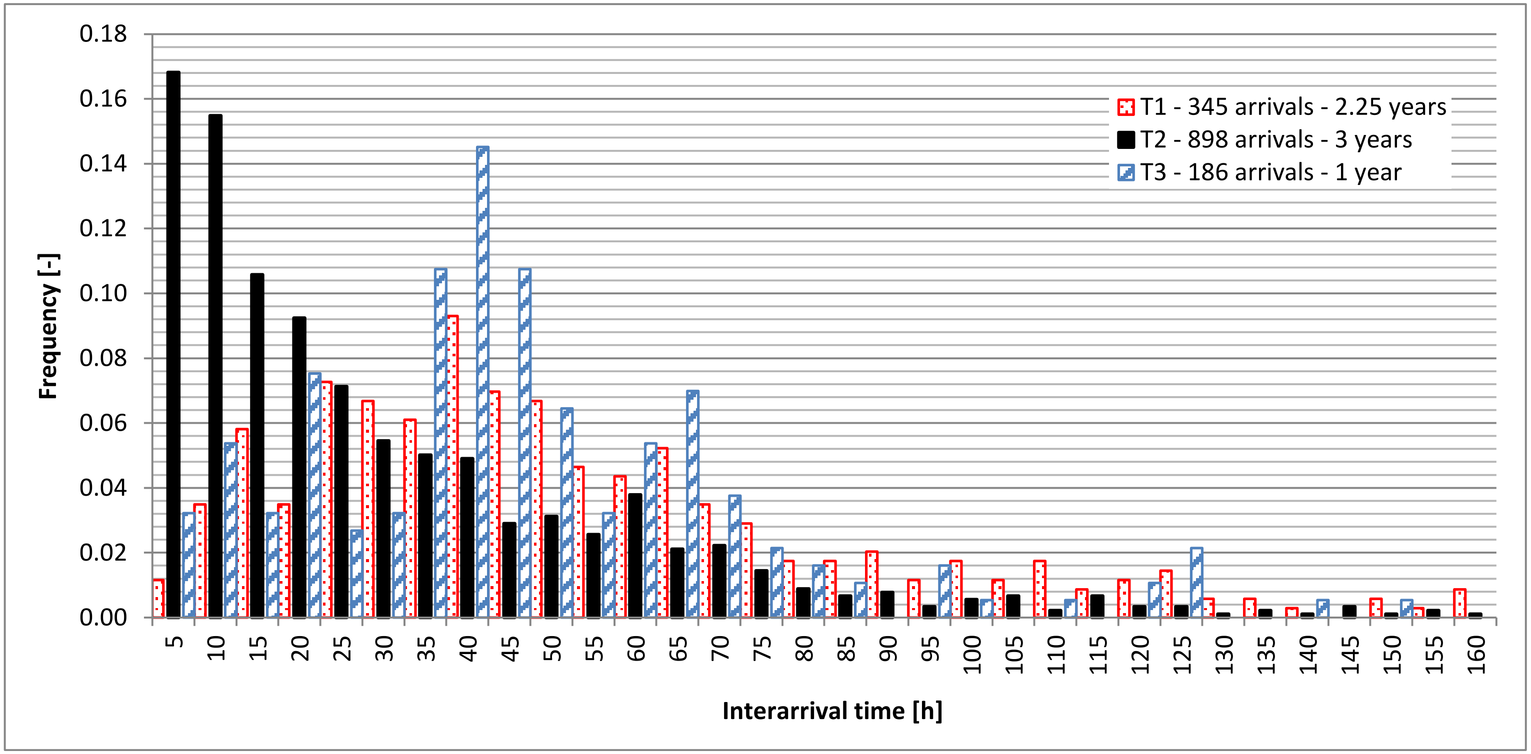
- But what is meant with Poisson or Erlang-2 distributed interarrival times?
  - Poisson and Erlang-2 distributions are probability distributions which express the probability of a ship arrival in a fixed interval of time



Poisson and Erlang-2 distributions for ships' interarrival times with an average of 10 hours

Average port time (4)

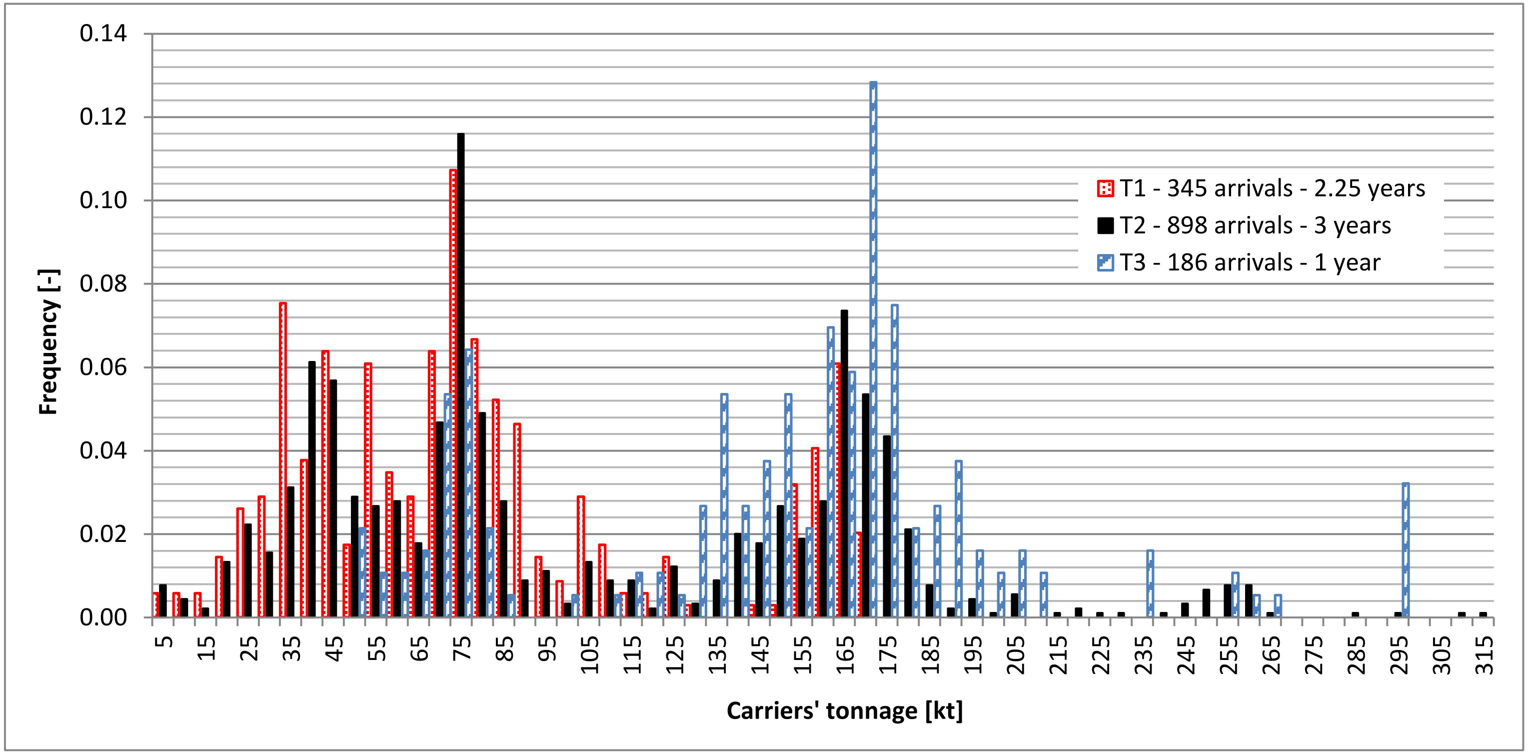
- From 3 terminals, the arrival process was investigated to check real-world data with existing literature
  - T1: single-user, import terminal
  - T2: stevedore, import terminal
  - T3: single-user, export terminal



Interarrival time distributions

Average port time (5)

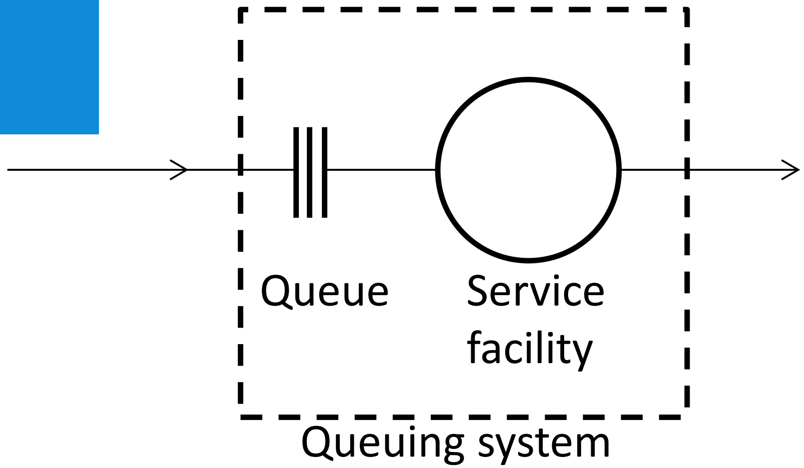
- Service time relates directly to the carriers' tonnage



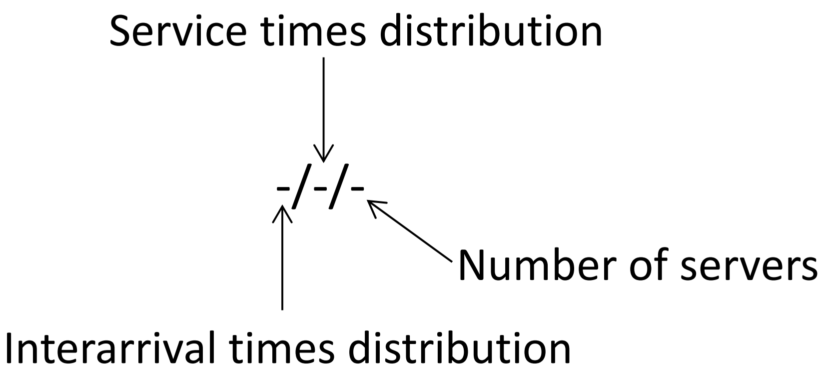
Carriers' tonnage distributions

Modeling arrival process (1)

- Modeling of the arrival process based on Queuing Theory



Basic of a queuing system

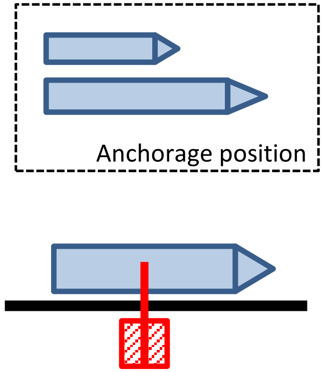


Labeling of queuing models

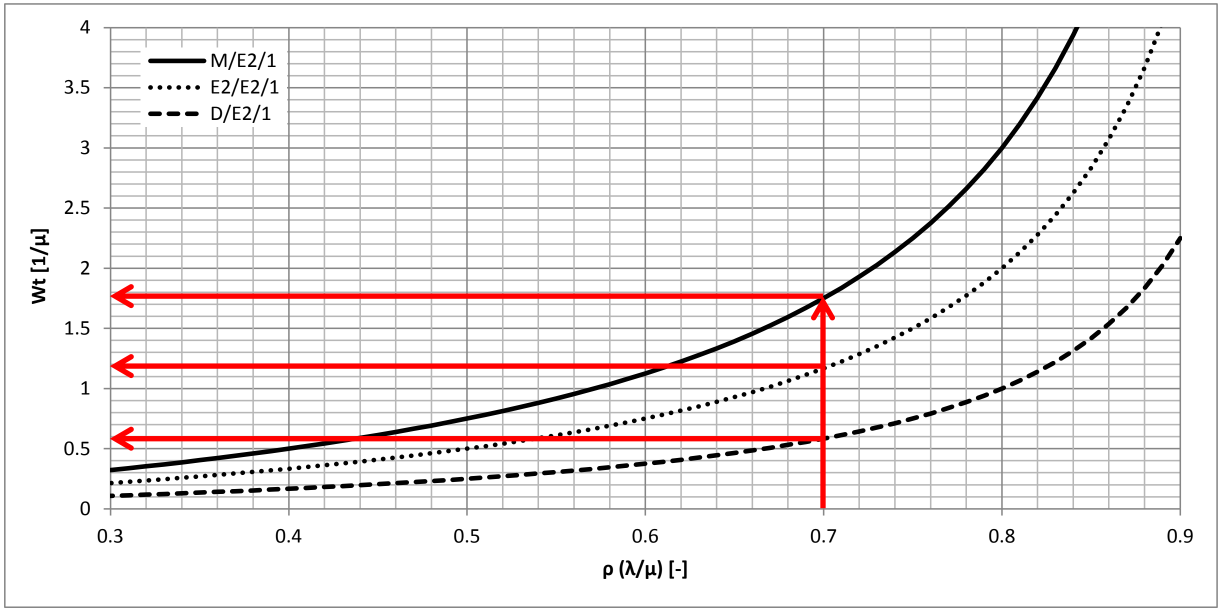
- M/E2/2:
  - Interarrival times distributed according a Poisson (Markovian) distribution
  - Service times distributed according Erlang-2 distribution
  - 2 servers → 2 berths where each berth is equipped with 1 quay crane

Modeling arrival process (2)

- For single berth queuing systems, the impact of the several interarrival times distribution was investigated



Single berth queuing system

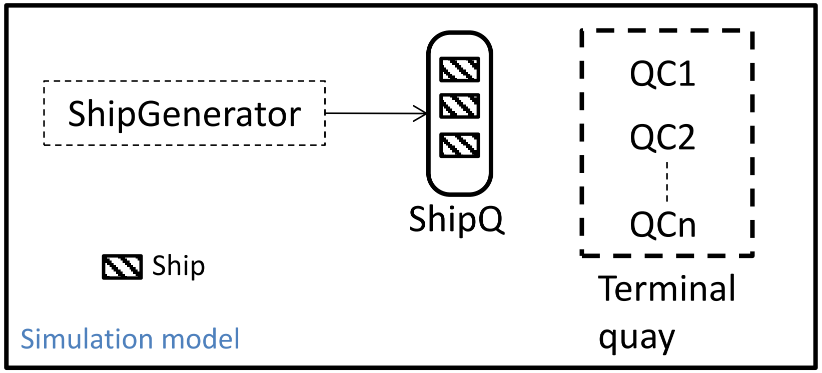


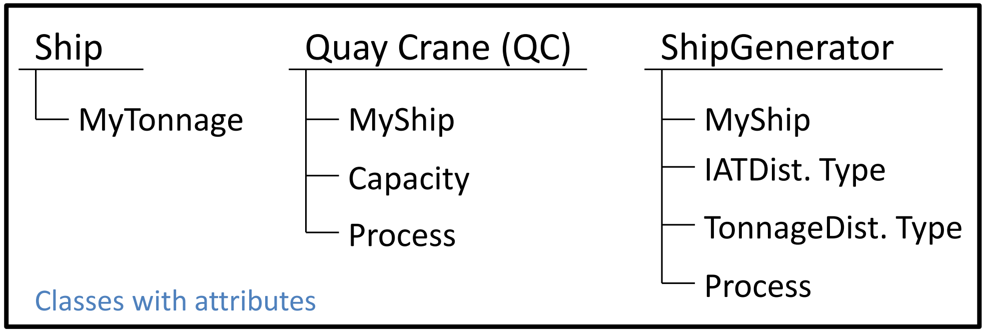
Average waiting time, expressed in average service time, versus quay occupancy for single berths

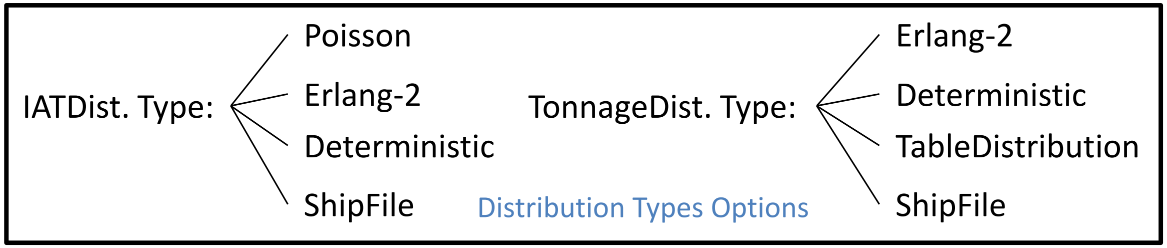
(M/E2/1: 1.75, E2/E2/1: 1.17, D/E2/1: 0.58)

Modeling arrival process (3)

- For multiple berths queuing systems, there are hardly analytical solutions, and that's why a discrete-event simulation model was developed

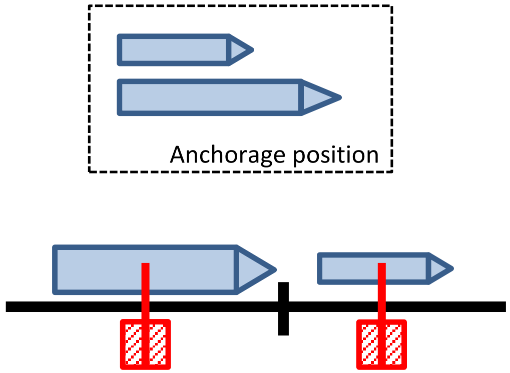




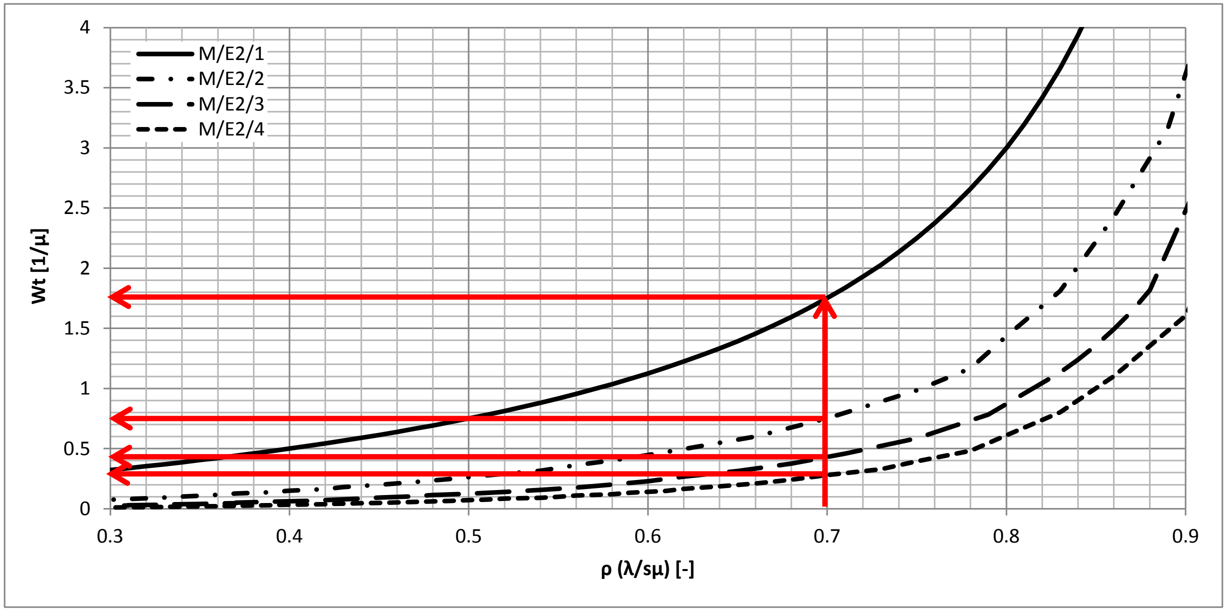


Modeling arrival process (4)

- For multiple berths queuing systems, the simulation model was used to determine the average ships' waiting time



Multiple berths queuing system



Average waiting time, expressed in average service time, versus quay occupancy for multiple berths

(M/E2/1: 1.75, M/E2/2: 0.75, M/E2/3: 0.58, M/E2/4: 0.28)

Modeling arrival process (5)

- Can analytical models be used for an accurate arrival process modeling?
- The simulation model was used to compare terminals' real-world arrival data with analytical models

Comparison real-world data with analytical models

Wt [1/μ]	Real-world data	Analytical models	Analytical models	Analytical model / Table distribution
T1	1	$E_2/E_2/3$: 0.49	$E_2/D/3$: 0.18	$E_2/G/3$: 1.05
T2	1	$M/E_2/4$: 1.57	M/D/4: 1.10	M/G/4: 0.96
T3	1	$D/E_2/2$: 1.90	D/D/2: 0	D/G/2: 0.95

Table distribution to represent carriers' tonnage for T2

Tonnage minimum [t]	Tonnage maximum [t]	[%]
0	25,000	5*
25,000	50,000	19.4
50,000	75,000	23.6
75,000	100,000	10.1
100,000	150,000	12.3
150,000	200,000	25.5
200,000	300,000	4.1

* 5% of all bulk carriers were generated with tonnages between 0 tons and 25,000 tons.

Conclusions

- Serving ships on time and at correct speed is crucial for terminal operators
- Modeling the ships' arrival process is required to design the terminal's quay side
- The interarrival time distribution predominately determines the average ships' waiting time
- The 'wilder' the arrival pattern, the greater the average waiting time
- Modeling the arrival process must be based on Queuing Theory
- However, for multiple berths there are hardly analytical solutions and a discrete-event simulation is proposed
- For an accurate modeling, it is proposed to use a table distribution which represents the carriers' tonnage instead of using analytical models

Thank you!