The Effect of Uncertainties on the Makespan of Deterministically Constructed Ship-to-Shore Schedules

A Simulation Study

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The Ship-to-Shore Problem

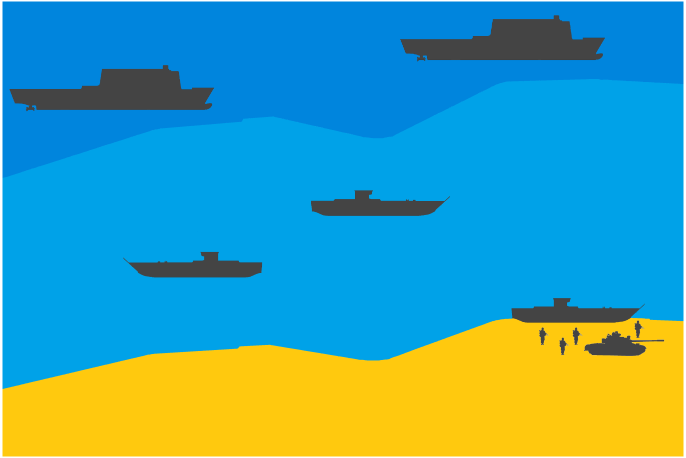

Figure 1: Schematic overview of the ship-to-shore problem

The Ship-to-Shore Problem

Constraints to the Problem:

- (Un)Loading capacity
- Fuel capacity of connectors
- Space and weight capacity of connectors
- Priority ordering of resources
- Delivery waves for resources

The Time-Space Network

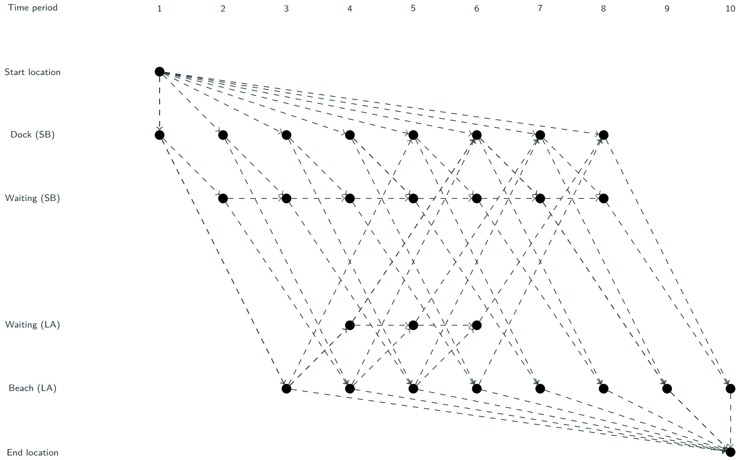

Figure 2: Example of a time-space network for one connector with one SB containing one dock and one LA containing one beach

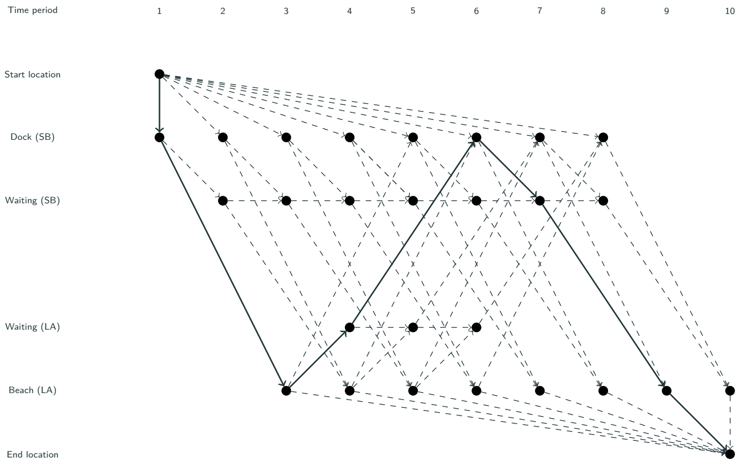

Figure 2: Example of a time-space network for one connector with one SB containing one dock and one LA containing one beach

The Time-Space Network

- Greedy Heuristic
  - Upper bound for TSN
  - Iteratively add trips
- Branch-and-Price Algorithm
  - Columns are routes
  - Branching on arcs and deliveries

For more details see Wagenvoort et al. (2022).

The Simulation

The Simulation

- Event
- Uncertainty sets
- "Rules"

Events

- Arrival SB/LA
- Finish loading at SB/LA
- Departure SB/LA

Uncertainty Sets

- Current and/or wind

Uncertainty Sets

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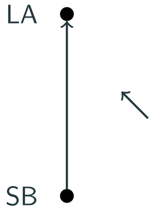
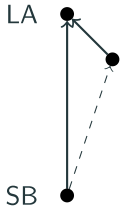


Uncertainty Sets

- Current and/or wind



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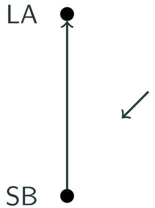

Uncertainty Sets

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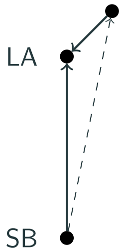
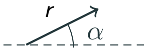


Uncertainty Sets

- Current and/or wind
  - $\alpha \sim UNIF(0, 360)$ degrees
  - $r \sim UNIF(0, 1)$ nautical miles



Uncertainty Sets

- Current and/or wind
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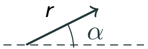
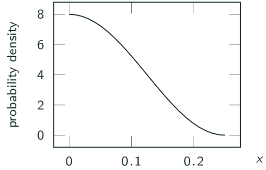
- Speed (% reduction)
  PDF: $4\cos\{4\pi x\} + 4$





Uncertainty Sets

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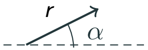
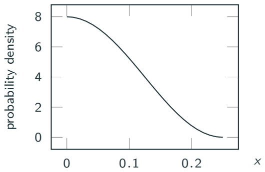
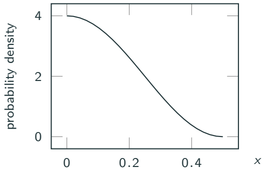
  - $\alpha \sim UNIF(0, 360)$ degrees
  - $r \sim UNIF(0, 1)$ nautical miles
- Speed (% reduction)
  PDF: $4\cos\{4\pi x\} + 4$
- (Un)loading time (% addition)
  PDF: $2\cos\{2\pi x\} + 2$







“Rules”

- Constraints
- Adhere to ordering
- Limit the time ahead of schedule

Results

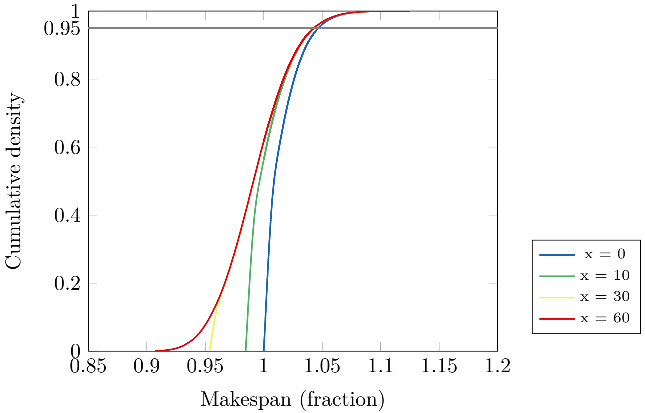


Figure 3: The effect on the distribution of the makespan when you are allowed to be x minutes ahead of schedule.

Results

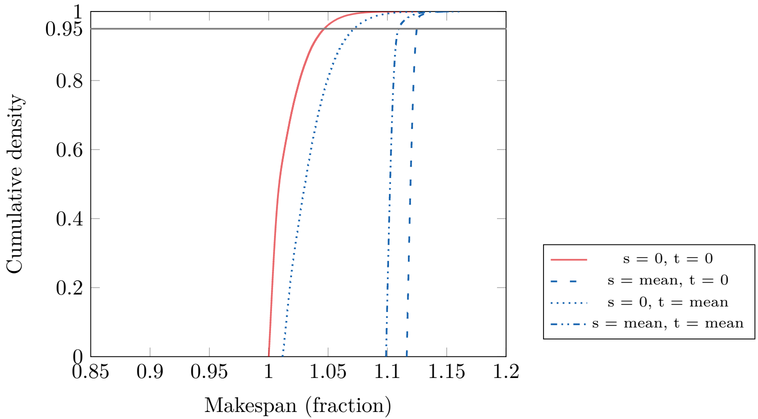


Figure 4: The effect on the distribution of the makespan of schedules constructed with different parameters. Here s corresponds to the % reduction in speed and t corresponds to the % addition to the (un)loading time.

Results

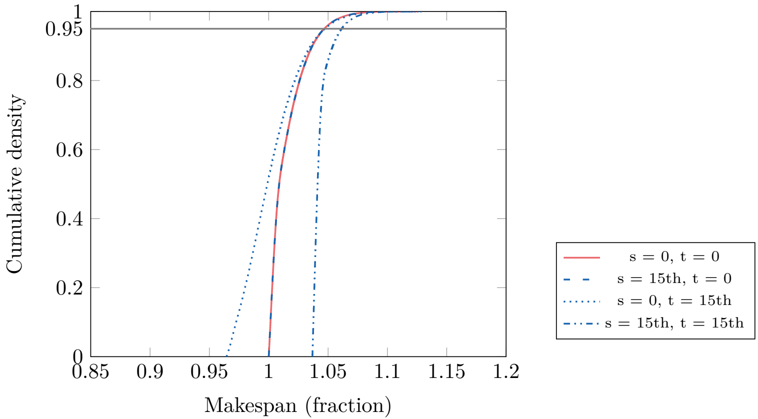


Figure 5: The effect on the distribution of the makespan of schedules constructed with different parameters. Here s corresponds to the % reduction in speed and t corresponds to the % addition to the (un)loading time.

Results

Table 1: P-values for the t-test with the basic schedule in which the maximum speed and minimum (un)loading time are used.

		Max. min. ahead of schedule			
s	t	0	10	30	60
0	5th	**0.00***	**0.00***	**0.00***	1
0	10th	**0.00***	**0.00***	1	1
0	15th	**0.00***	**0.00***	1	1
0	25th	**0.00***	1	1	1
0	mean	1	1	1	1
5th	0	-	-	-	-
10th	0	-	-	-	-
15th	0	-	-	-	-
25th	0	-	-	-	-
mean	0	1	1	1	1
5th	5th	1	1	1	1
10th	10th	**0.00***	**0.00***	1	1
15th	15th	1	1	1	1
25th	25th	**0.00***	1	1	1
mean	mean	1	1	1	1

*: < 0.0001
-: all replications the same

Results

Table 2: P-values for the quantile comparison with the basic schedule in which the maximum speed and minimum (un)loading time are used.

		Max. min. ahead of schedule			
s	t	0	10	30	60
0	5th	**0**	0.9995	1	1
0	10th	**0.001**	1	1	1
0	15th	0.983	1	1	1
0	25th	1	1	1	1
0	mean	1	1	1	1
5th	0	0.498	0.500	0.501	0.507
10th	0	0.498	0.500	0.501	0.507
15th	0	0.498	0.500	0.501	0.507
25th	0	0.498	0.500	0.501	0.507
mean	0	1	1	1	0.370
5th	5th	1	1	1	1
10th	10th	**0.001**	1	1	1
15th	15th	1	1	1	1
25th	25th	1	1	1	1
mean	mean	1	1	1	1

Conclusion

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- TSN already partially captures delays
- Adding (limited) additional slack can be beneficial
- Next: sensitivity to the used distribution parameters

Conclusion

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References

References

Wagenvoort, M., Bouman, P., van Ee, M., Lamballais Tessensohn, T., & Postek, K. (2022). An exact and heuristic approach for the ship-to-shore problem. *Econometric Institute Research Papers*(EI 2022-05).

Additional Slides

Quantile Comparison

Algorithm 1 Quantile Comparison

Input: X_i, Y_i for $i = 1, \ldots, n$ the samples that we wish to compare

Output: p, the p-value

```
for j = 1:B do
    for k = 1:n do
        Let U_1 ~ UNIF(1, n) and U_2 ~ UNIF(1, n).
        Set X'_k = X_{U_1} and Y'_k = Y_{U_2}.
    end for
    Let θ*_X and θ*_Y be the 95th quantiles of X' and Y'.
    Let d_j = θ*_Y − θ*_X.
end for
Let A = Σ_{j=1}^{B} I_{(−∞,0)}(d_j) and C = Σ_{j=1}^{B} I_{[0]}(d_j).
Let p = (A + 0.5C) / B.
```