SIMULATION ASSIGNMENT THE UITHOFLIJN

ORESTIS MELKONIAN

CHRIS ARONIS

PROBLEM DESCRIPTION

- A new tram-line connecting Utrecht with the Utrecht University

- Nine stops from Central station to P+R De Uithof

- The line operates from 06:00 to 21:30

- Two different timetables one for each end station

- All trams have a fixed capacity of 420 passengers

PROBLEM DESCRIPTION

Questions to be answered:

- Feasible frequencies of the tram

- Maximum amount of passengers that line can handle

- Possible measures to improve the operational performance
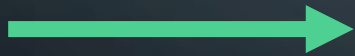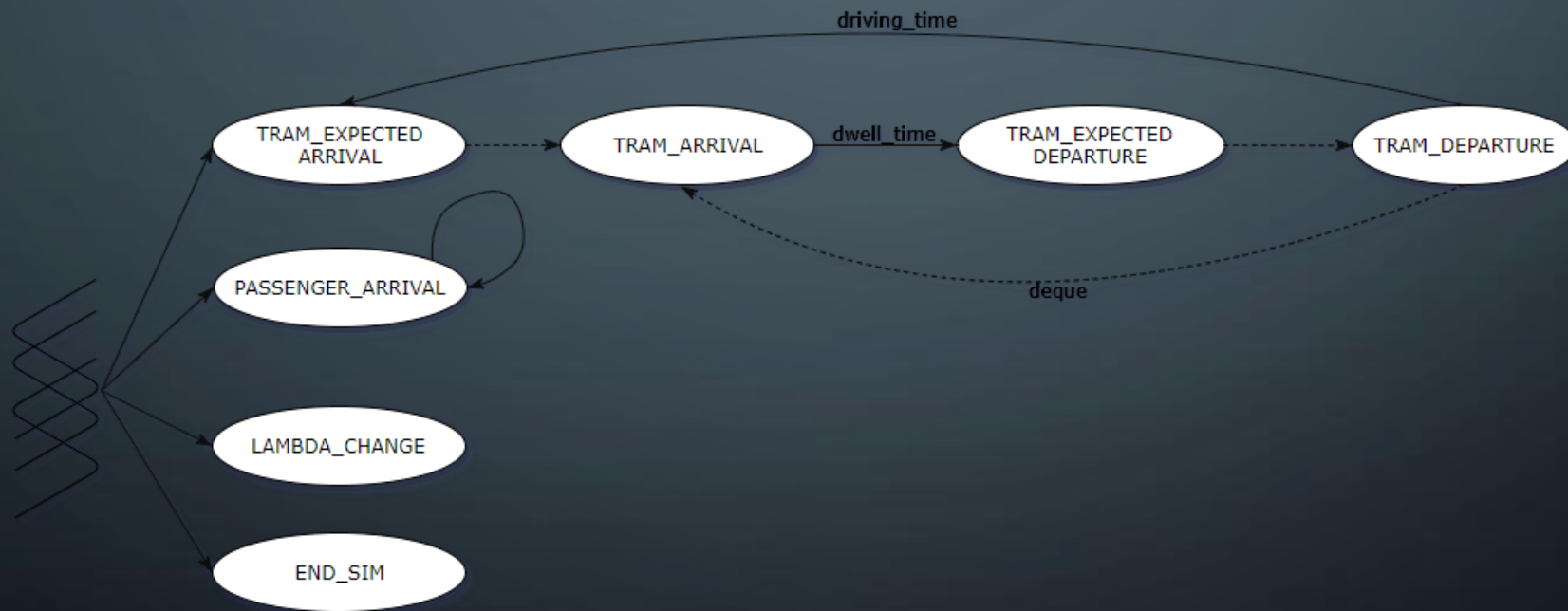
→   SIMULATION

PROBLEM DESCRIPTION

Simulation model:

- Events

- Initialization

- State

- Event handlers

- Performance Measures

PROBLEM DESCRIPTION

Event graph:

Performance Measures

- Punctuality:

  - $departure\ delay = t_{actual} - t_{timetable}$

- Passenger Waiting Times:

  - $waiting\ time = t_{boarding} - t_{arrival}$

- Stop Congestion:

  - $congestion_{avg}(stop) = \frac{\sum_{t \in T} stop.capacity(t)}{T}$

INPUT ANALYSIS

Data derived from the bus 12 route ————————→ Fitting

- Entering passengers
  - Poisson process, varies (λ) every 15 min.
  - Exponential distribution to model interarrival times.

- Leaving passengers
  - Transformation into percentages
  - Beta distribution (a,b)

Data derived from Nieuwegein-tramline

- Run-times
  - Gamma distribution

OUTPUT ANALYSIS

Questions answered by the experiments:

- Feasible frequencies of the tram

f	$\overline{wt}$	$\overline{dd_{PR}}$	$\overline{dd_{CS}}$	$\overline{cong}$
4	1m 18s	51s	9s	8.86
5	1m 48s	0s	0s	11.04
6	2m 04s	0s	0s	13.55
7	2m 33s	0s	0s	16.10
8	2m 56s	0s	0s	19.37
9	3m 22s	0s	0s	19.76
10	3m 55s	0s	0s	23.75
11	4m 17s	0s	0s	24.55

OUTPUT ANALYSIS

Questions answered by the experiments:

- Measures to improve operational performance

f	$\overline{dd_{PR}}$	$\overline{dd_{CS}}$
1	4h 15m 22s	4h 17m 09s
2	2h 38m 56s	2h 39m 04s
3	47m 56s	45m 20s
4	51s	7s
5	0s	0s

OUTPUT ANALYSIS

Scenarios:

• Extra tram, 14 trams instead of 13

• Better technology

Scenario	nt	db	q	f
A	14	10%	q_{base}	f_{base}
B	13	1%	$q_{base} - 2$	f_{base}

OUTPUT ANALYSIS

Scenarios Results:

- During peak hours

q_{base}	f_{base}	$\overline{wt_A}$	$\overline{wt_B}$	$\overline{cong_A}$	$\overline{cong_B}$
5	3	51.8	60.12	11.89	12.6
5	4	73.3	69.38	15.66	16.67
5	5	98.17	37.35	21.67	9.1
5	6	75.08	55.54	19.12	10.85
6	3	62.11	35.9	14.04	7.89
6	4	54.77	78.86	12.43	15.9
6	5	101.48	90.0	19.56	21.0
6	6	112.92	47.69	9.67	9.67
7	3	55.0	49.28	12.24	11.17
7	4	59.28	51.72	14.62	11.02
7	5	75.76	112.38	15.42	20.98
7	6	114.44	103.62	24.56	24.9

OUTPUT ANALYSIS

Scenarios Results:
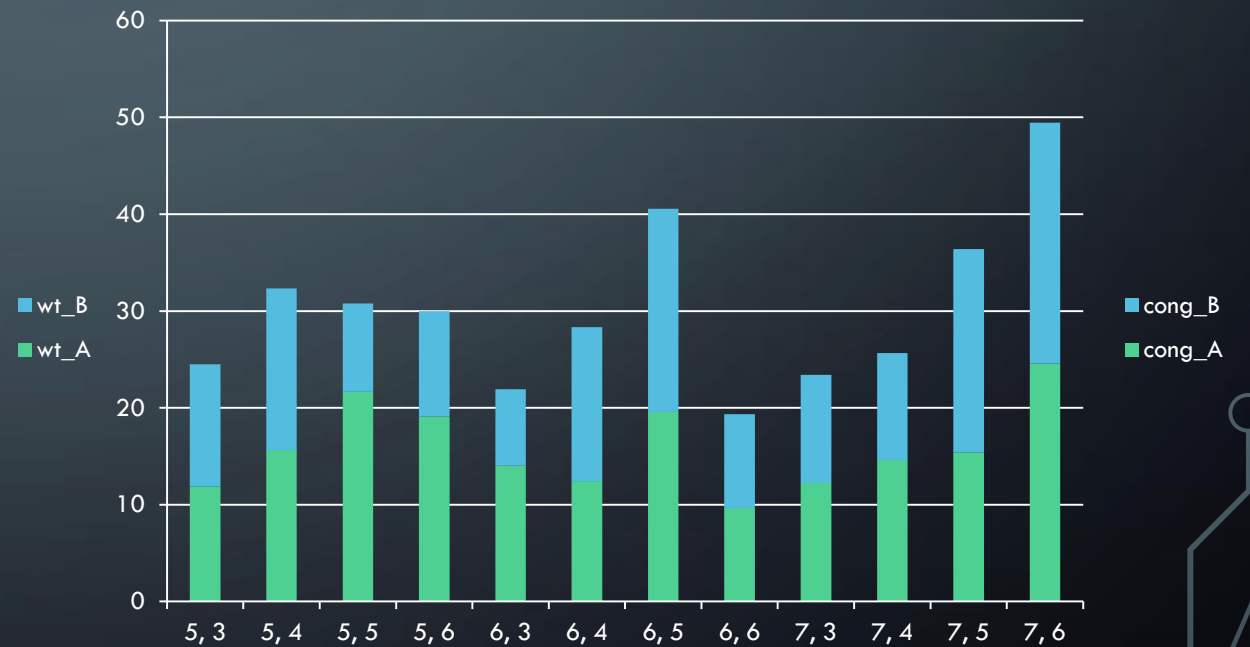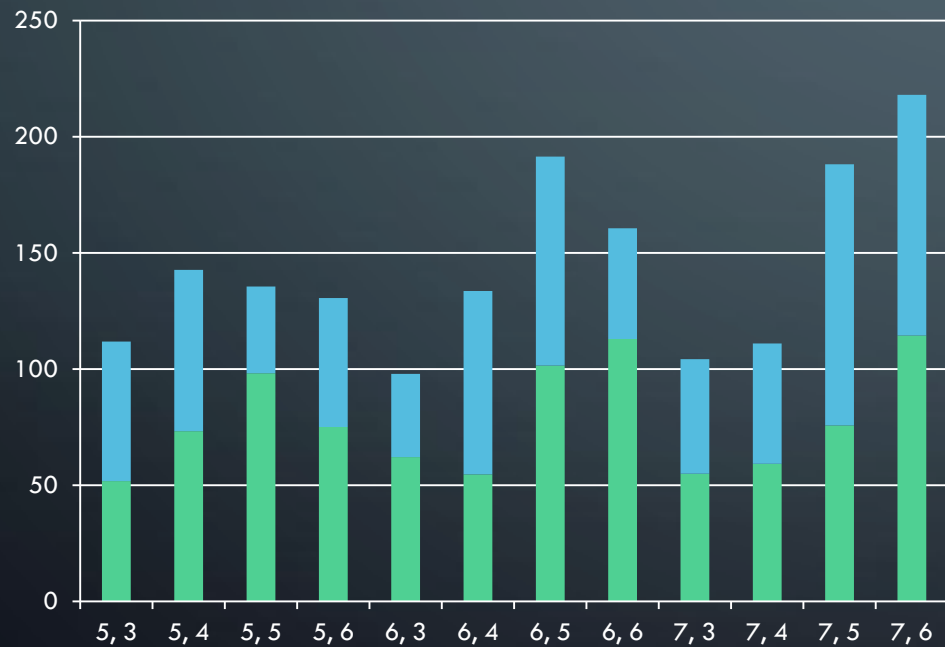
OUTPUT ANALYSIS

Scenarios Comparison:

- Paired t-confidence intervals
  - α=0.05

q_{base}	f_{base}	$\overline{Z_{wt}}$	$S^2_{z_{wt}}$	$\overline{Z_{cong}}$	$S^2_{z_{cong}}$
5	3	-12.22	50.33	-1.91	5.06
5	4	10.7	0.66	0.92	1
5	5	43.38	207.9	6.08	0.02
5	6	8.97	125.8	2.585	29.46
6	3	27.78	2.343	6.24	0
6	4	-15.05	71.18	-1.48	10.68
6	5	19.12	534.2	-0.27	6.82
6	6	70.55	11.84	15.58	0.93
7	3	5.93	267.1	2.39	6.17
7	4	5.30	148.13	4.44	6.82
7	5	-28.1	293.8	-3.36	5.96
7	6	25.51	124.6	6.11	46.03

OUTPUT ANALYSIS

Scenarios Comparison:

- Computed confidence intervals

q_{base}	f_{base}	$Z_{wt}^{95\%}$	$Z_{cong}^{95\%}$
5	3	[-13.6, -10.8] < 0	[-2.3, -1.4] < 0
5	4	[10.5, 10.8] > 0	[0.7, 1.1] > 0
5	5	[40.5, 46.2] > 0	[6, 6.1] > 0
5	6	[6.7, 11.1] > 0	[1.5, 3.6] > 0
6	3	[27.4, 28] > 0	[6.2, 6.2] > 0
6	4	[-16.7, -13.3] < 0	[-2.1, -0.8] < 0
6	5	[14.5, 23.7] > 0	[-0.7, 0.2] = 0
6	6	[69.8, 71.2] > 0	[15.3, 15.7] > 0
7	3	[2.6, 9.1] > 0	[1.8, 2.8] > 0
7	4	[2.8, 7.7] > 0	[3.9, 4.9] > 0
7	5	[-31.5, -24.6] < 0	[-3.8, -2.8] < 0
7	6	[23.2, 27.7] > 0	[4.76, 7.4] > 0

VALIDATION

Artificial dataset results:

f	$\overline{wt}$	$\overline{dd_{PR}}$	$\overline{dd_{CS}}$	$\overline{cong}$
4	1m 41.81s	0s	0s	39.13
5	1m 48.99s	0s	3.59s	46.37
6	2m 1.5 s	1.4s	0s	46.7
7	3m 22.79s	0s	0s	78.8
8	8m 29.15s	0s	0s	200.29
9	12m 16.7s	0s	0s	308.72
10	12m 56.1s	0s	0s	356.47
11	12m 47.6s	0s	0s	440.33