TURUN RAITIOTIEN YS:N TARKISTUS
OPENTRACK-SIMULOINNIT

RAMBØLL

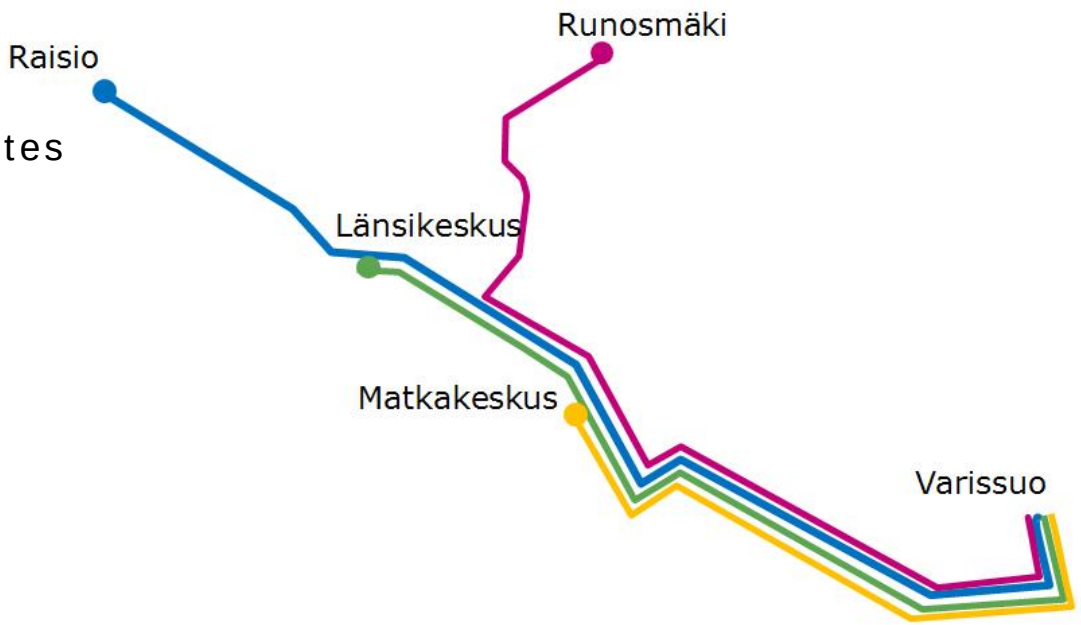
8.6.2017

CONTENTS

- Traffic concept and line alternatives
- Assumptions for the OpenTrack model and the rolling stock
- Detailed simulation results
- Conclusions

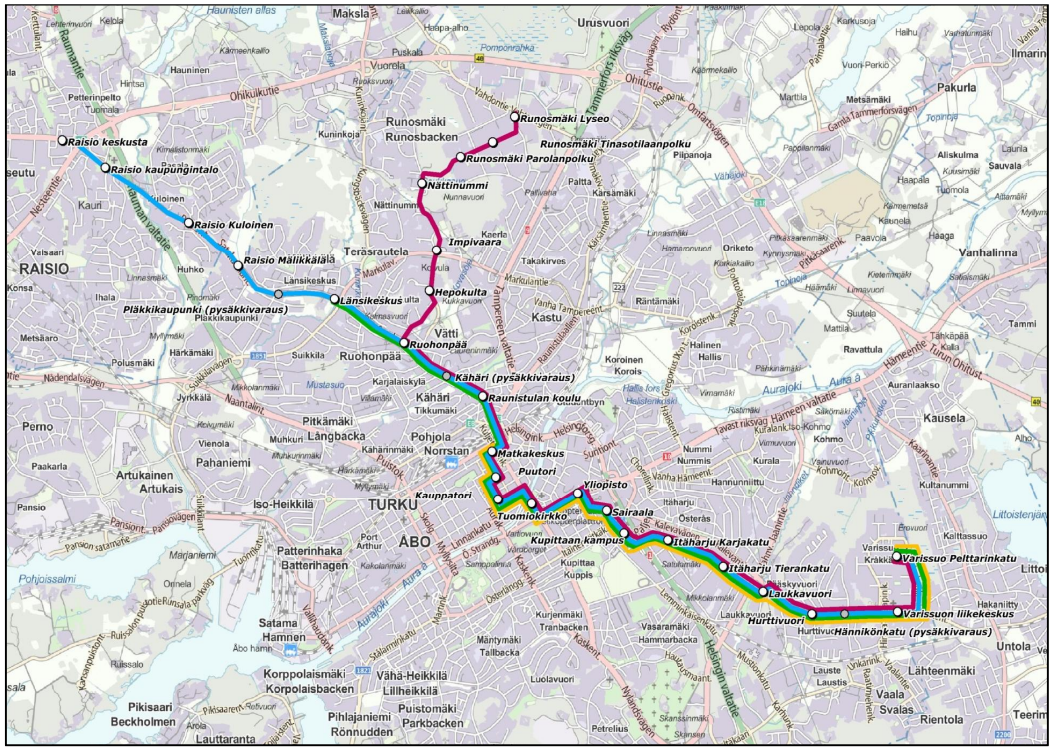
TRAFFIC CONCEPT AND LINE ALTERNATIVES

- Four line alternatives
  - All lines running Varissuo – City Center
  - Shortest planned headway is 7.5 minutes for every alternative (8 departures per hour)
  - During off-peak traffic (mornings and evenings), intervals are prolonged to 15 minutes on normal work day (4 departures per hour)
  - Operation from 4:30 – 00:00



ASSUMPTIONS FOR THE OPENTRACK MODEL AND VEHICLES
STATIONS AND BASIC NETWORK

- 26 stations with 47m long platforms each, and two extra stations as sensitivity analysis
- Approximately 21 km modelled network
- Same corridor for both Superbus and Tramway
- Full Superbus/Tramway priority at junctions, no delay from car traffic
- Turnaround stations are modelled for the tramway; the Superbus always needs a loop.



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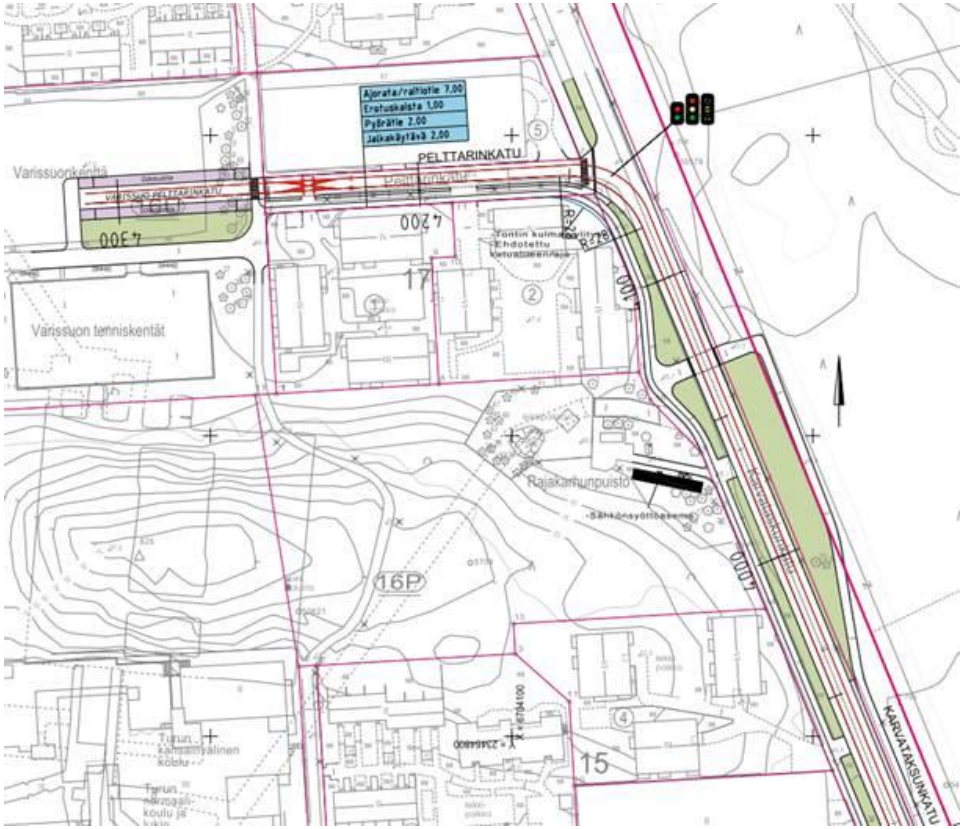
ASSUMPTIONS FOR THE OPENTRACK MODEL AND VEHICLES TRACK INFRASTRUCTURE



- Gradient based on the alignment
- Speed based on documentation & BOStrab recommendations
- Switches & switch speeds, are implemented accurately, release times and switch actioning times are based on switches for tramways from other projects (Helsinki & Stockholm)

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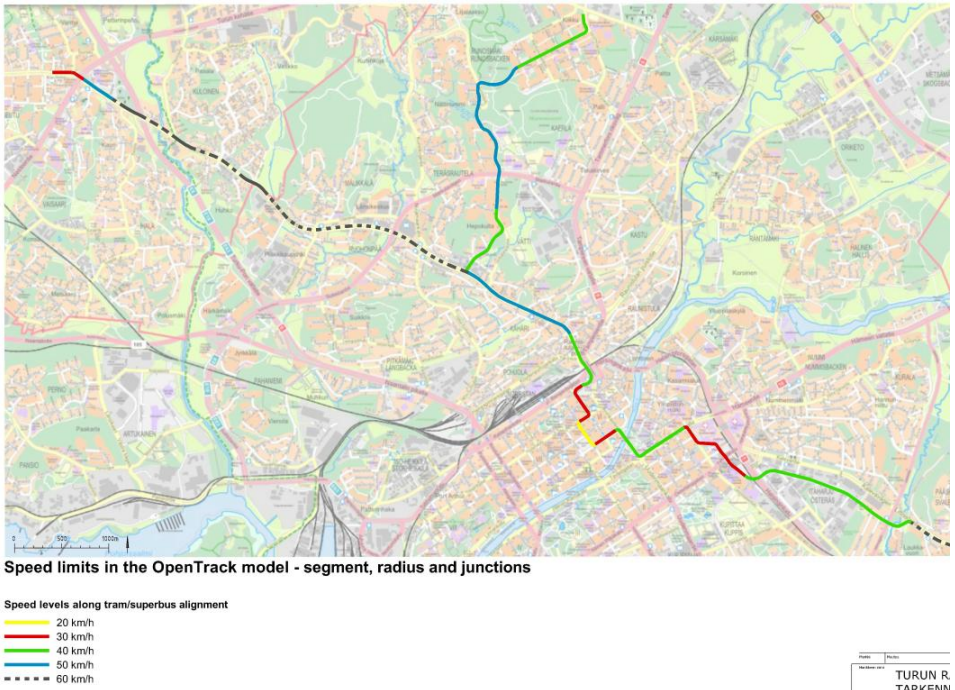
ASSUMPTIONS FOR THE OPENTRACK MODEL AND VEHICLES SPEED LIMITS

- Speed reduction in curves, determined by radius
  -> calculated according to the German BOStrab, use of rounded values

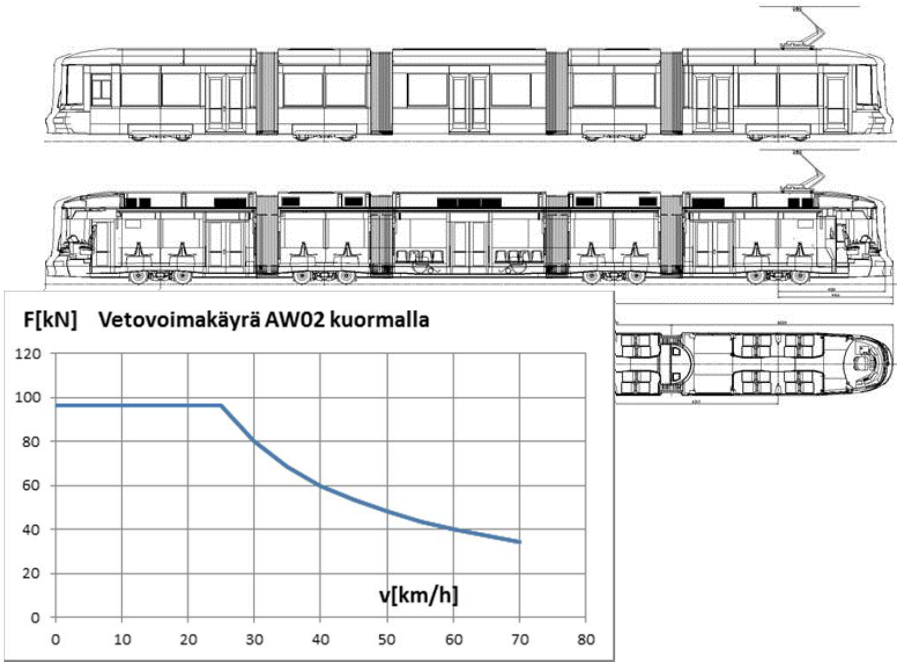
- Maximum speed on stretches are depending on the sharing with other traffic
  (20 km/h in the city center,
  60 km/h on the outer sections

- Curves with radii bigger than 300m on own infrastructure for the tramway are built with cant, so that less speed is lost



Speed limits in the OpenTrack model - segment, radius and junctions

ASSUMPTIONS FOR THE OPENTRACK MODEL AND VEHICLES TRAMWAY



TRANSTECH Artic vehicles

Length: 32.6 m

Weight (loaded): 66 t

Passenger capacity: 212 (4 pers/m^2)

Max. speed: 70 km/h

Max. acceleration: 1,2 m/s^2

Max. deceleration: 1,3 m/s^2

Rolling resistance factor: 3,2

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ASSUMPTIONS FOR THE OPENTRACK MODEL AND VEHICLES SUPERBUS - VANHOOL

VanHool AGG 300

Length: 25 m

Weight (loaded): 35 t

Passenger capacity: 153 (4 pers/m^2)

Max. speed: 70 km/h

Max. acceleration: 1,1 m/s^2

Max. deceleration: 1,3 m/s^2

Rolling resistance factor: 30 (on asphalt)

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ASSUMPTIONS FOR THE OPENTRACK MODEL AND VEHICLES SUPERBUS - HESS

Hess LighTram (Trolley)

Length: 25 m

Weight (loaded): 35 t

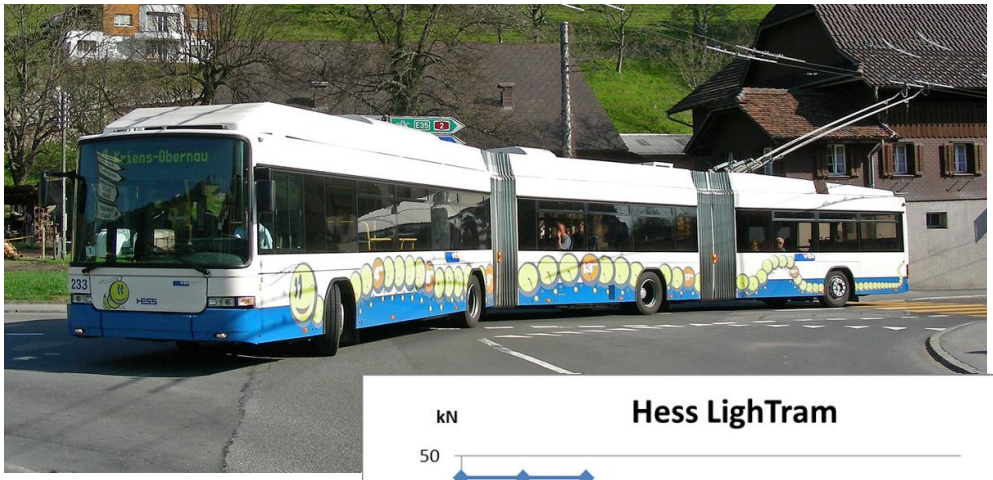
Passenger capacity: 143 (4 pers/m^2)

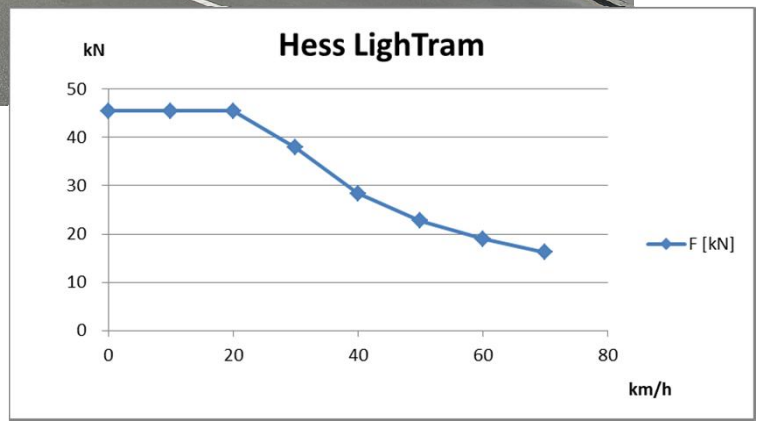
Max. speed: 70 km/h

Max. acceleration: 1,3 m/s^2

Max. deceleration: 1,3 m/s^2

Rolling resistance factor: 30 (on asphalt)





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ASSUMPTIONS FOR THE OPENTRACK MODEL AND VEHICLES STATION DWELL TIME

- Three dwell time categories depending on the amount of passengers boarding & alighting

A: <20 passengers, 15 s

B: 20-40 passengers, 20 s

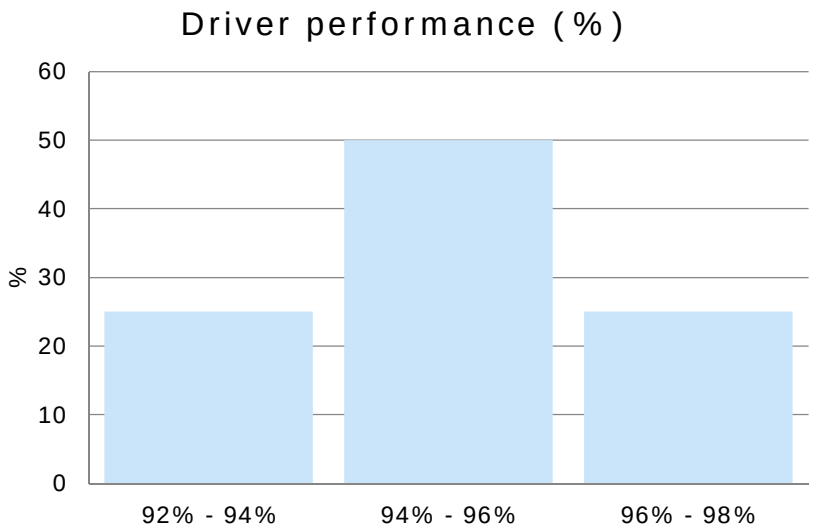
C: >40 passengers, 25 s

Dwell times are symmetrical, and there is no difference between Superbus and Tramway

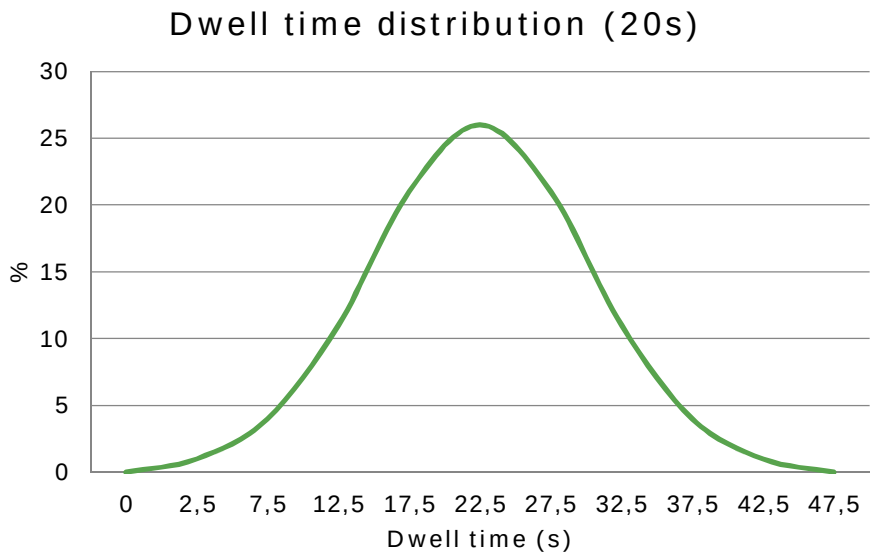
Pysäkki	Pysäkkiaika
Runosmäki Lyseo	15
Runosmäki Tinasotilaanpolku	15
Runosmäki Parolanpolku	15
Nättinummi	15
Impivaara	15
Hepokulta	15
Ruohonpää	20
Raunistulan koulu	15
Matkakeskus	25
Puutori	20
Kauppatori	25
Tuomiokirkko	20
Yliopisto	20
Sairaala	20
Kupittaan kampus	25
Itäharju Karjakatu	15
Itäharju Tierankatu	15
Laukkavuori	15
Hurttivuori	15
Varissuon liikekeskus	15
Varissuo Pelttarinkatu	15

DRIVER BEHAVIOUR AND DWELL TIME VARIATION

- Driver behaviour has been taken into account as an overall performance distribution:

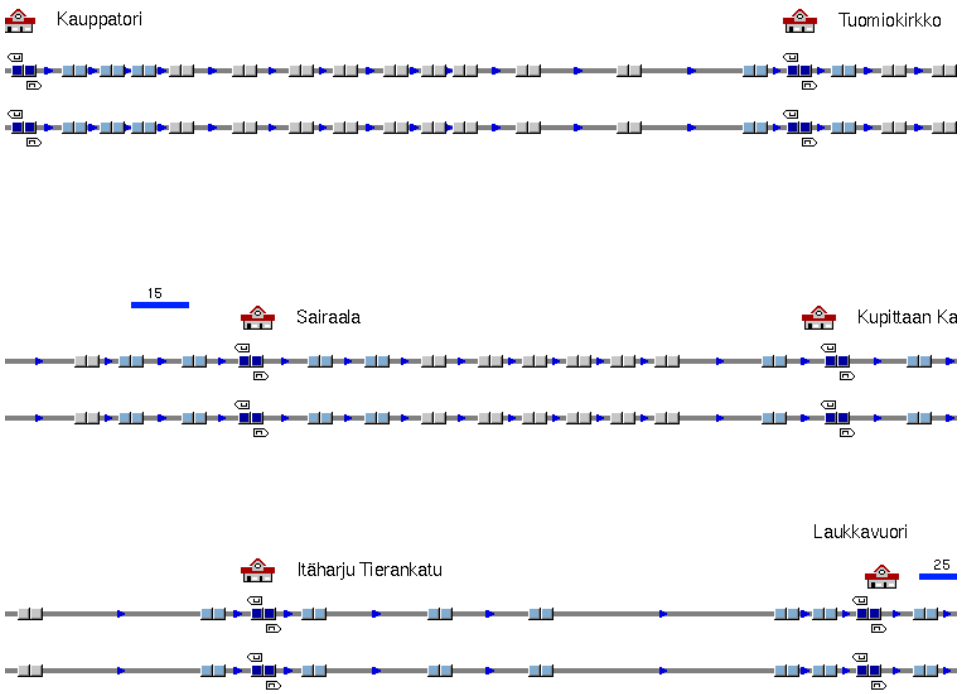


Delay distributions are used with normal distributions around those average value for the delay simulations



ASSUMPTIONS FOR THE OPENTRACK MODEL AND VEHICLES SIMULATIONS & MODELLING

- Simulation of the driving times during rush hour (07-09)
- No influence of car traffic taken into account
- 15 iterations for estimating the average driving times



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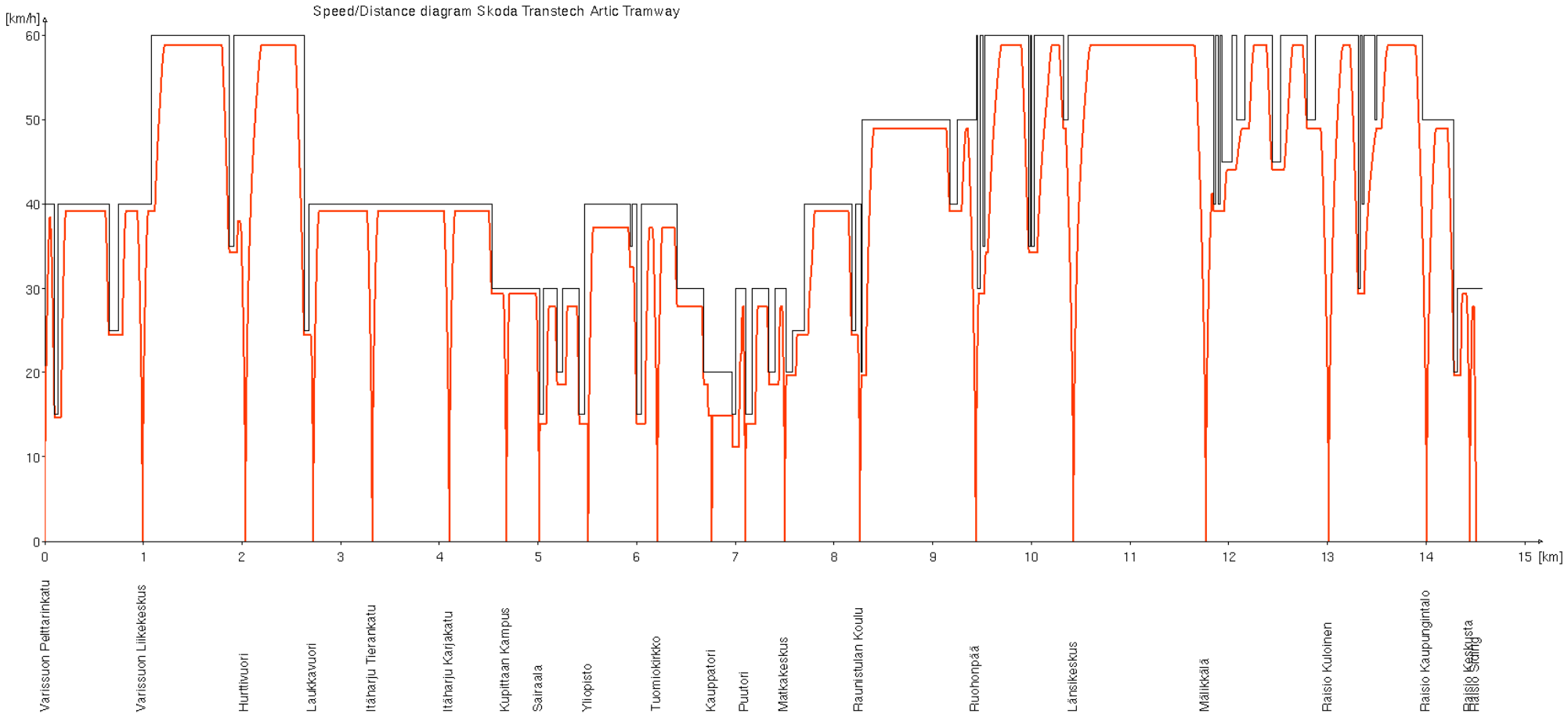
SPEED / DISTANCE DIAGRAMS – TRAMWAY (ARTIC)



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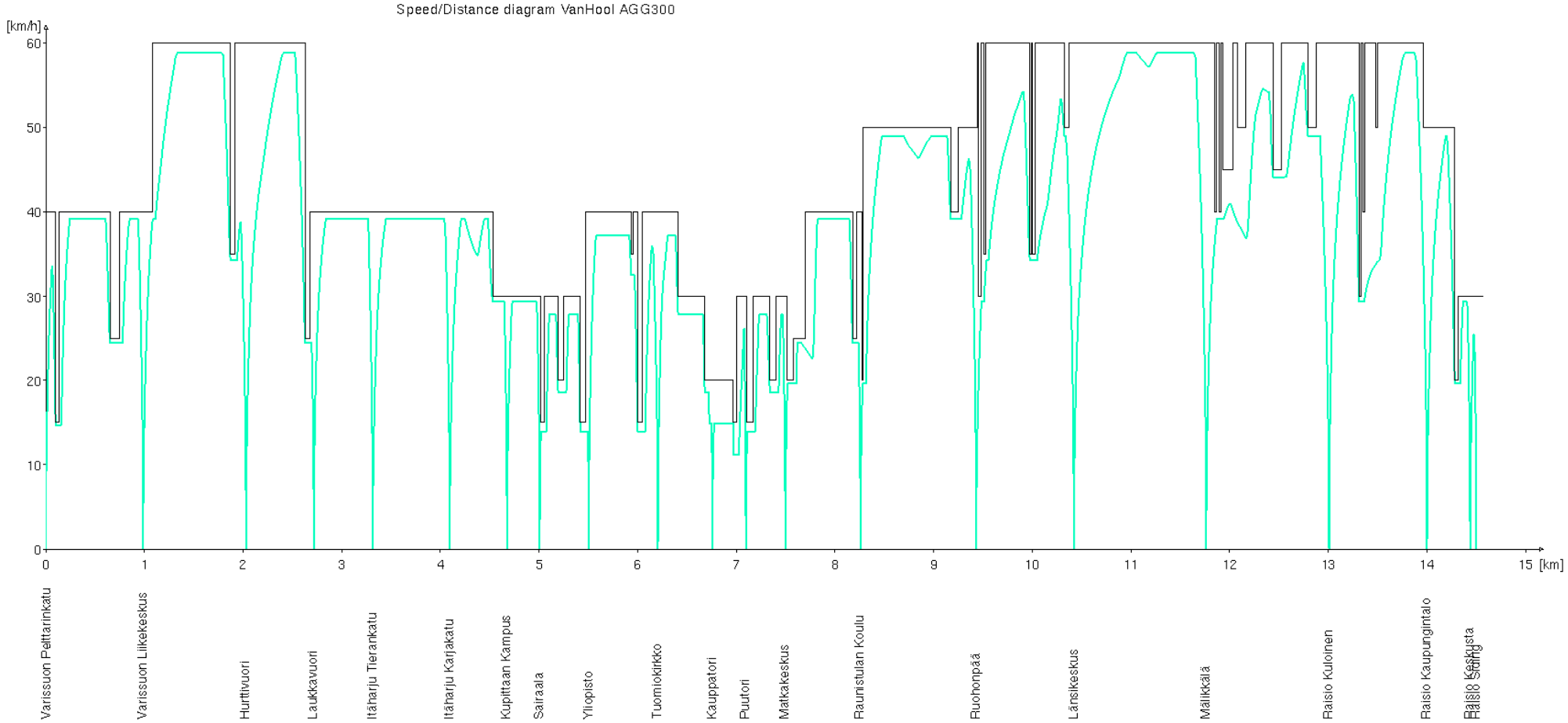
SPEED / DISTANCE DIAGRAMS – SUPERBUS (AGG300)



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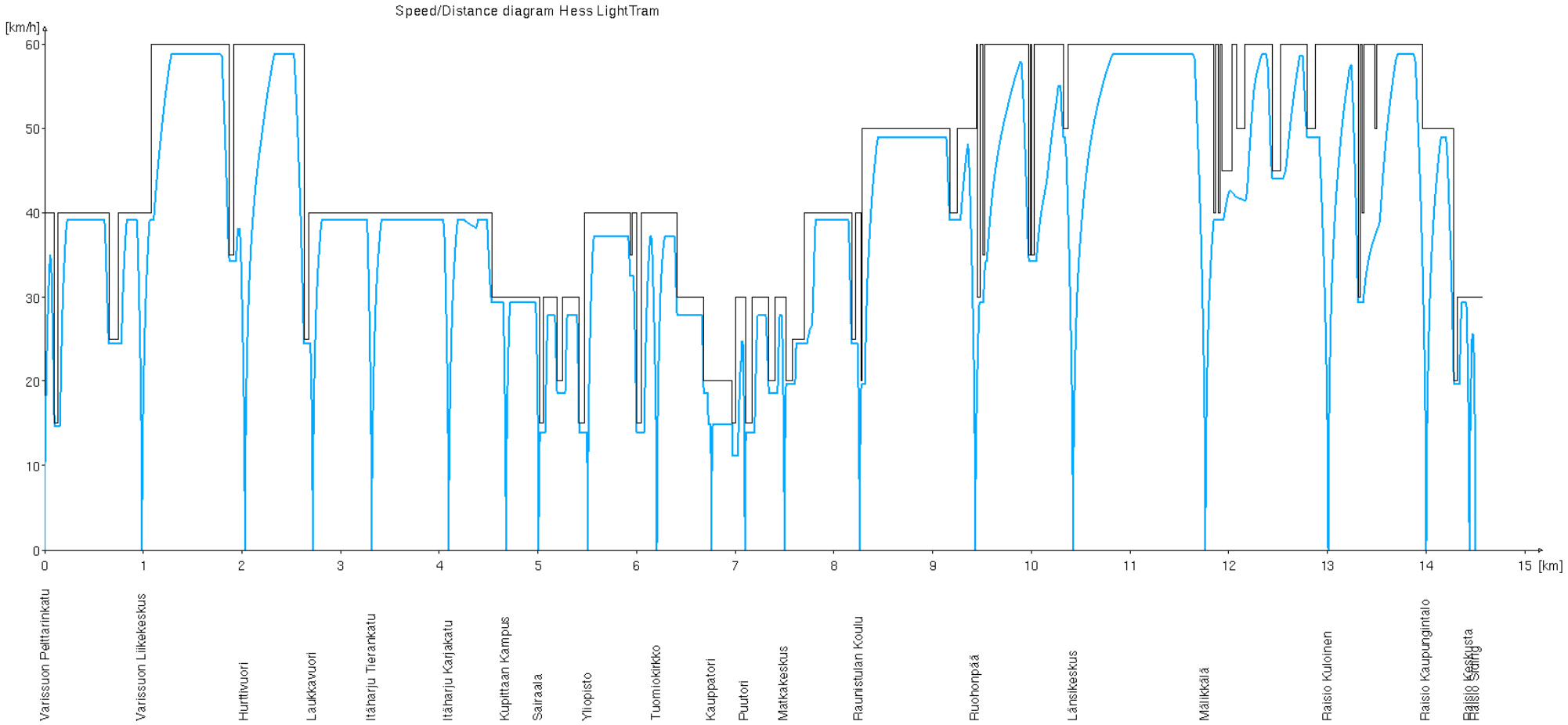
SPEED / DISTANCE DIAGRAMS – SUPERBUS (LIGHTRAM)



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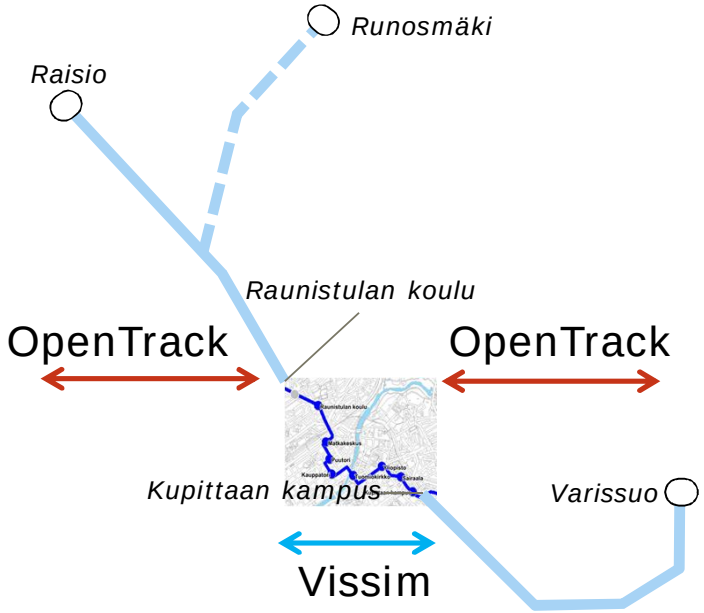
COMBINED TRAFFIC SIMULATIONS

Combined simulations with delays from the car and bus traffic in the city center

Delays in the city center are calculated with Vissim

Dwell time delays and driving times are simulated in OpenTrack



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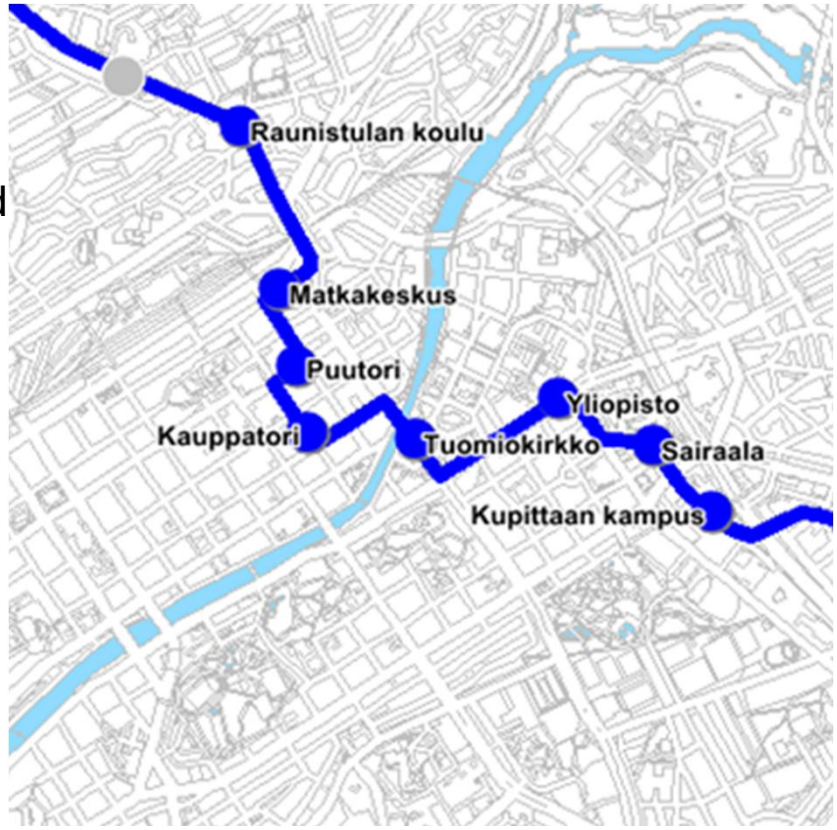
VISSIM SIMULATIONS

- To determine the delays caused by other traffic in the city center, Vissim model was simulated both with and without other traffic (passenger cars and buses)
- Average travel times between the stops were recorded in both simulated scenarios and their differences were calculated
- Delays of each station-to-station sections were then transferred into Opentrack accordingly



VISSIM SIMULATIONS - RESULTS

- Due to the separated infrastructure for tramway/superbus from the other traffic (except buses), the average delays on the stretch through the city are very small

- Those delays are added to the rest of the delays that are calculated with OpenTrack

	Average delays (sec)	Standard deviation
Kupittaan kampus - Sairaala	0,1	0,2
Sairaala - Yliopisto	0,1	0,8
Yliopisto - Tuomiokirkko	0,7	0,3
Tuomiokirkko - Kauppatori	0,4	0,3
Kauppatori - Puutori	16,0	0,4
Puutori - Matkakeskus	1,6	0,6
Matkakeskus - Raunistulan koulu	3,0	0,7

TIMETABLE CONSIDERATIONS

Average Delay considering all delays on the stretch
Sairaala – Matkakeskus,
considering 9 minutes timetabled time.

Average delay considering all delay types	Tramway	Superbus Van Hool AGG300	Superbus Hess LighTram
Sairaala – Matkakeskus	+21 seconds	+41 seconds	+30 seconds

If tramways will end in Matkakeskus, it is recommended to take those delays into account for the driving times (+1 minute driving times for both Superbuses)

Considering the timetabled relief time on the third part of the track, the delays do not affect the timetabled driving time for the lines to Raisio or Runosmäki

TIMETABLE BUILDING

- Sairaala and Matkakeskus are timing stations
  (= vehicles wait until timetabled time)
- Timetables are built up to the full minute
- The timetable has more relief time in the last third of the line,
  so that 80% of trains arrive at the end stop with max +30 seconds with normal delays
  (dwell times + traffic)

		Varissuo - Raisio	Varissuo - Runosmäki	Varissuo - Sairaala	Sairaala - Matkakeskus	Matkakeskus - Ruohonpää	Ruohonpää - Raisio	Ruohonpää - Runosmäki
Tram	Average driving time	0:33:17	0:34:01	0:11:08	0:09:16	0:04:06	0:08:32	0:09:01
	Timetabled time	0:34	0:35	0:12	0:09	0:04	0:09	0:10
Superbus Hess LighTram	Average driving time	0:33:54	0:34:08	0:11:33	0:09:18	0:04:10	0:08:52	0:09:14
	Timetabled time	0:35	0:36	0:12	0:10	0:04	0:09	0:10
Superbus VanHool AGG300	Average driving time	0:34:37	0:34:57	0:11:48	0:09:21	0:04:13	0:09:14	0:09:35
	Timetabled time	0:35	0:36	0:12	0:10	0:04	0:09	0:10

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TURNAROUND STRATEGY

- Turnarounds in the end stations have been timed according to the driving times
- Minimum turnaround time for tramways 4 minutes
- Turnarounds are longer in Varissuo than in the stops in the north
  (Driver exchange & break area)

- For 7,5 minutes interval, one of the turnarounds has to be longer than the headway
  (For increased robustness in the timetable)

- The total turnaround has to be at least 12 minutes for the lines ending in Länsikeskus and Matkakeskus

- Superbuses need turnaround loops, no capacity constraints (crossing paths)

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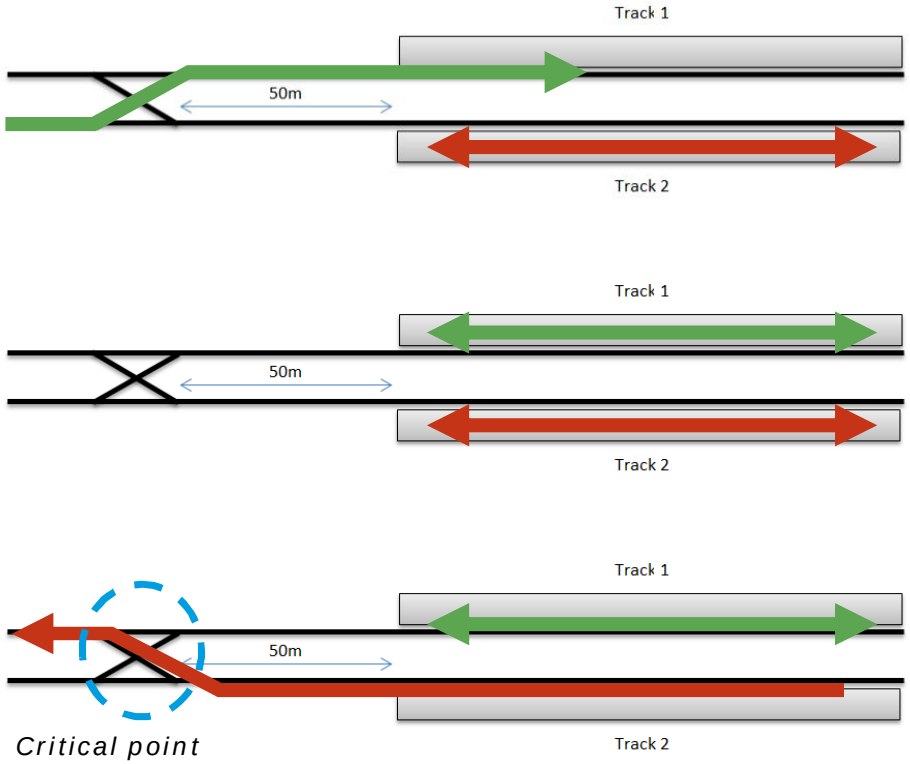
TURNAROUND IN A TRAMWAY TERMINAL STATION - METHOD

- The turnaround station has two turnaround tracks (assumed to be at the station)

- Because of conflicting paths the turnaround time should not be within 1 minute of a multiple of the interval
(crossover in front of the turnaround stations)

- In Varissuo one train has to stay in the station while another comes in
(for intervals less than 10 minutes)



Time between arrival and departure

must be at least 1 minute in the timetable

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SIMULATION RESULTS: VARISSUO - RAISIO

	Tramway			Superbus - VanHool			Superbus - Hess		
Driving time	34 min			35 min			35 min		
Interval	7,5 min	10 min	15 min	7,5 min	10 min	15 min	7,5 min	10 min	15 min
Turnaround Varissuo	9,5 min	14 min	12 min	14 min	14 min	12 min	14 min	14 min	12 min
Turnaround Raisio	5 min	8 min	10 min	6 min	6 min	8 min	6 min	6 min	8 min
Vehicles necessary	11	9	6	12	9	6	12	9	6

The timetabled times from the timetabled driving times above have been taken for this calculation

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SIMULATION RESULTS: VARISSUO - LÄNSIKESKUS

Additional 1 minute timetabled time,
as relief time (from delays)

	Tramway			Superbus - VanHool			Superbus - Hess		
Driving time	27 min			28 min			28 min		
Interval	7,5 min	10 min	15 min	7,5 min	10 min	15 min	7,5 min	10 min	15 min
Turnaround Varissuo	9,5 min	8 min	11 min	13 min	8 min	13 min	8,5 min	7 min	10 min
Turnaround Länsikeskus	4 min	8 min	10 min	6 min	6 min	6 min	3 min	7 min	9 min
Vehicles necessary	9	7	5	10	7	5	9	7	5

Short turnaround time;

not recommended

(but reduced need by one vehicle)

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SIMULATION RESULTS: VARISSUO - RUNOSMÄKI

	Tramway			Superbus - VanHool			Superbus - Hess		
Driving time	35 min			36 min			36 min		
Interval	7,5 min	10 min	15 min	7,5 min	10 min	15 min	7,5 min	10 min	15 min
Turnaround Varissuo	8,5 min	12 min	12 min	12 min	13 min	12 min	12 min	13 min	12 min
Turnaround Runosmäki	4 min	8 min	8 min	6 min	5 min	6 min	6 min	5 min	6 min
Vehicles necessary	11	9	6	12	9	6	12	9	6

SIMULATION RESULTS: VARISSUO - MATKAKESKUS

Additional 1 minute timetabled time, as relief time (from delays)

	Tramway			Superbus - VanHool			Superbus - Hess		
Driving time	21 min			22 min			22 min		
Interval	7,5 min	10 min	15 min	7,5 min	10 min	15 min	7,5 min	10 min	15 min
Turnaround Varissuo	12 min	9 min	12 min	10 min	8 min	10 min	12 min	9 min	12 min
Turnaround Matkakeskus	6 min	9 min	6 min	6 min	8 min	6 min	6 min	9 min	6 min
Vehicles necessary	8	6	4	8	6	4	8	6	4

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CONCLUSIONS

- The Superbus and the Tramway do have competitive driving times if no car traffic is considered
- The Superbus is a little slower than the tramway (no cant in curves, less power, more friction)
- There is enough time for all the vehicles to turn around without problem, the robustness of the system is good
- The delays through the city centre with the current planned traffic system do not influence the needed vehicle amounts

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SCENARIO: ADDITIONAL STOPS

- Additional stops are planned in Hännikönkatu and Kähäri
- Both stops are of stop category A (15 s average dwell time at a station)

- The driving times are prolonged, and the timetable has changes – Generally +1 minute along the whole length of the line

		Varissuo - Raisio	Varissuo - Runosmäki	Varissuo - Sairaala	Sairaala - Matkakeskus	Matkakeskus - Ruohonpää	Ruohonpää - Raisio	Ruohonpää - Runosmäki
Tram	Average driving time	0:34:08	0:34:13	0:11:30	0:09:08	0:04:34	0:08:33	0:09:01
	Timetabled time	0:35	0:36	0:12	0:09	0:05	0:09	0:10
Superbus Hess LighTram	Average driving time	0:34:57	0:35:12	0:11:45	0:09:16	0:04:41	0:08:52	0:09:14
	Timetabled time	0:36	0:37	0:12	0:10	0:05	0:09	0:10
Superbus VanHool AGG300	Average driving time	0:35:55	0:35:51	0:12:01	0:09:22	0:04:52	0:09:14	0:09:35
	Timetabled time	0:36	0:37	0:12	0:10	0:05	0:09	0:10

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SIMULATION RESULTS: VARISSUO - RAISIO

	Tramway			Superbus - VanHool			Superbus - Hess		
Driving time	34 min			35 min			35 min		
Interval	7,5 min	10 min	15 min	7,5 min	10 min	15 min	7,5 min	10 min	15 min
Turnaround Varissuo	8,5 min	12 min	10 min	12 min	12 min	10 min	12 min	12 min	10 min
Turnaround Raisio	4 min	8 min	10 min	6 min	6 min	8 min	6 min	6 min	8 min
Vehicles necessary	11	9	6	12	9	6	12	9	6

The timetabled times from the timetabled driving times above have been taken for this calculation

SIMULATION RESULTS: VARISSUO - LÄNSIKESKUS

	Tramway			Superbus - VanHool			Superbus - Hess		
Driving time	27 min			28 min			28 min		
Interval	7,5 min	10 min	15 min	7,5 min	10 min	15 min	7,5 min	10 min	15 min
Turnaround Varissuo	7,5 min	7 min	10 min	11 min	6 min	11 min	11 min	6 min	11 min
Turnaround Länsikeskus	4 min	7 min	9 min	6 min	6 min	6 min	6 min	6 min	6 min
Vehicles necessary	9	7	5	10	7	5	10	7	5

Only one exception to vehicle fleet demand due extra stop

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SIMULATION RESULTS: VARISSUO - RUNOSMÄKI

	Tramway			Superbus - VanHool			Superbus - Hess		
Driving time	35 min			36 min			36 min		
Interval	7,5 min	10 min	15 min	7,5 min	10 min	15 min	7,5 min	10 min	15 min
Turnaround Varissuo	8,5 min	12 min	10 min	12 min	12 min	10 min	12 min	12 min	10 min
Turnaround Runosmäki	4 min	8 min	10 min	6 min	6 min	8 min	6 min	6 min	8 min
Vehicles necessary	11	9	6	12	9	6	12	9	6

SIMULATION RESULTS: VARISSUO - MATKAKESKUS

	Tramway			Superbus - VanHool			Superbus - Hess		
Driving time	21 min			22 min			22 min		
Interval	7,5 min	10 min	15 min	7,5 min	10 min	15 min	7,5 min	10 min	15 min
Turnaround Varissuo	10 min	8 min	10 min	8 min	7 min	8 min	8 min	7 min	8 min
Turnaround Matkakeskus	6 min	8 min	6 min	6 min	7 min	6 min	6 min	7 min	6 min
Vehicles necessary	8	6	4	8	6	4	8	6	4

SCENARIO: ADDITIONAL STOPS - CONCLUSIONS

- Two additional stops were included. The timetabled driving time for all vehicle types per direction is one minute longer than without the stops

- The additional driving time shortens the turnaround times, but those stay within the set strategy limits

- In practice, no additional vehicles are needed for the additional stops