Optimization of Traffic Signal Plans with Transit Priority

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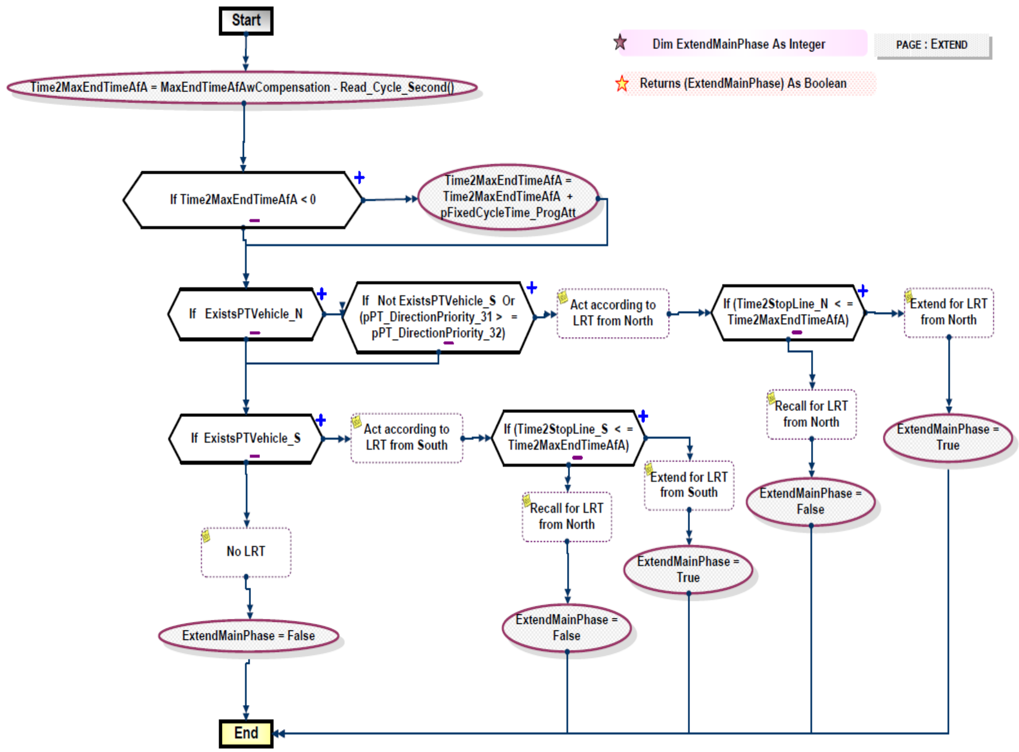
Outline

- Background
- MESCOP
- Case study
- Summary

Background

- Increasingly complex signal plans
  - Detector presence and queue states
- Transit priority functions
  - Early start
  - Extension
  - Insertion
  - Compensation



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Design parameters

- Large number
- Effect may be unintuitive

Group	Parameters included
Cycle Length & Split	• Cycle length • Minimum & maximum green • Phase start & end time
Waiting time	• Maximum pedestrians Red • Maximum Vehicle Red
Transit priority & compensation	• Early green • Maximum extension • Minimum accumulated green • Number of cycles
Queue detection	• Detector location • Queue period of time
Phase extension	• Gap Time • Minimum Gap • Gap Reduction

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Performance measures

Delays
Number of stops
Queue Lengths
Bandwidth
Fuel Consumption

Delay for pedestrians
Continuous Crossing

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Modeling needs

- Tools to evaluate designs
  - Analytical solutions intractable
- Parameter setting and optimization
- Few studies on actuated plans
  - Park and Yun (2006), Branke et al. (2007), Stevanovic et al. (2008, 2011) , Park & Lee (2009), Yun & park (2012)
  - Use micro-simulation traffic models
    - Computationally expensive
    - Limits number of parameters
    - Sequential optimization

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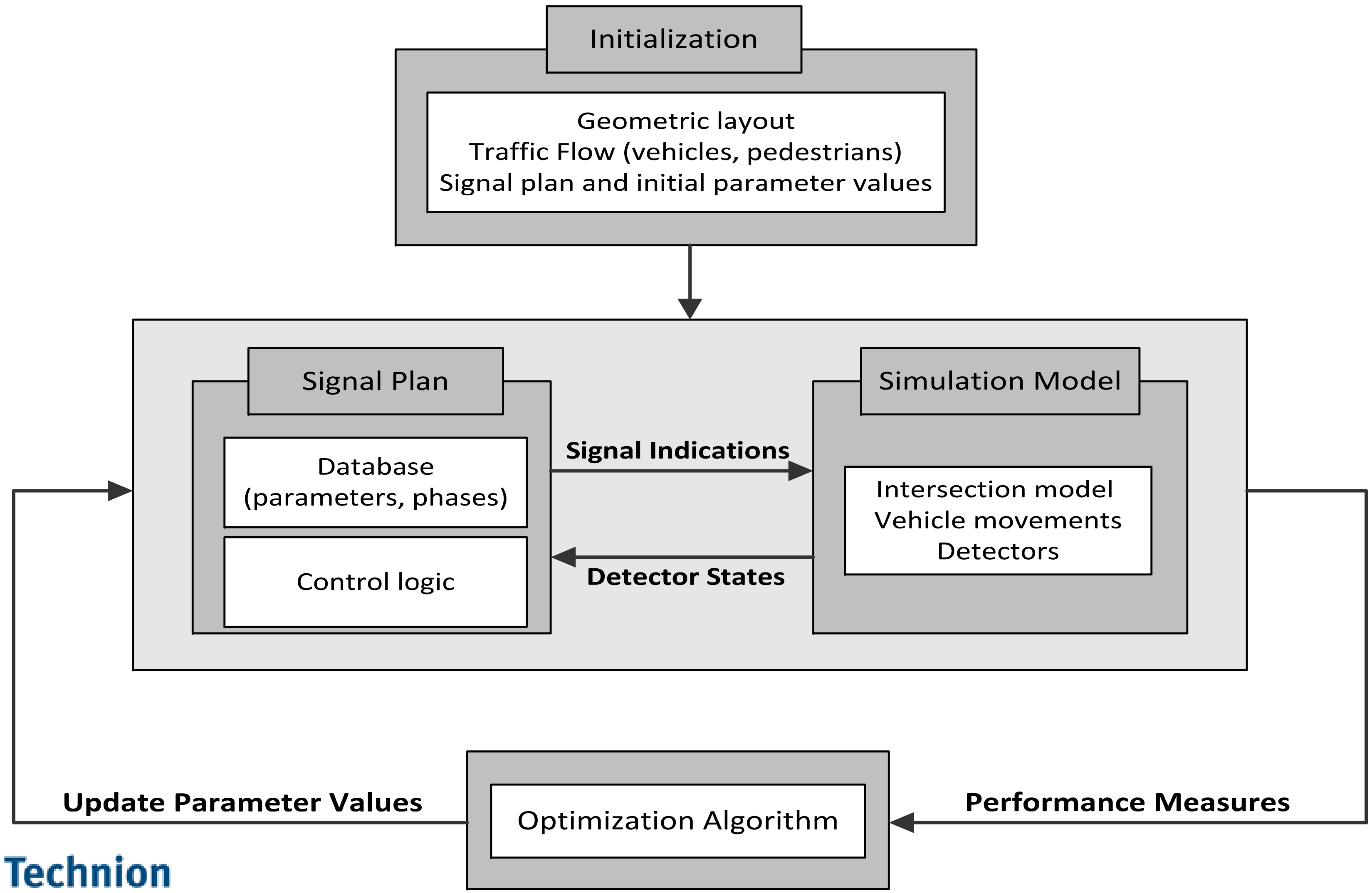
MESCOP

- Mescoscopic Evaluation of Signal COntrol Plans
  - Evaluate impact of signal plan parameters on intersection performance
  - Mesoscopic traffic simulation model
  - Computationally feasible
  - Supports evaluation of plan details
  - Support simultaneous optimization
  - Allows variety of performance measures

Overall structure



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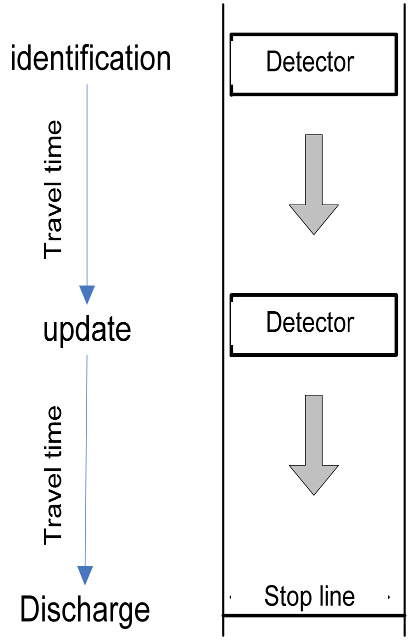
Simulation model

- Individual road users
  - Transit & non-transit vehicles
  - Pedestrians
- Time-based
  - To fit with control step
- Limited details of vehicle movements
  - Arrival at detector locations and stop lines

Vehicle movements

- Stochastic arrivals
  - At upstream detectors
- Travel time
  - Between detectors/stop line
  - Arrival distribution at downstream intersection
- Lane assignment
  - Turning movements and critical lane flows
  - No lane changing
- Queues
  - FIFO, vertical
  - Detector activation
  - Saturation rate discharge



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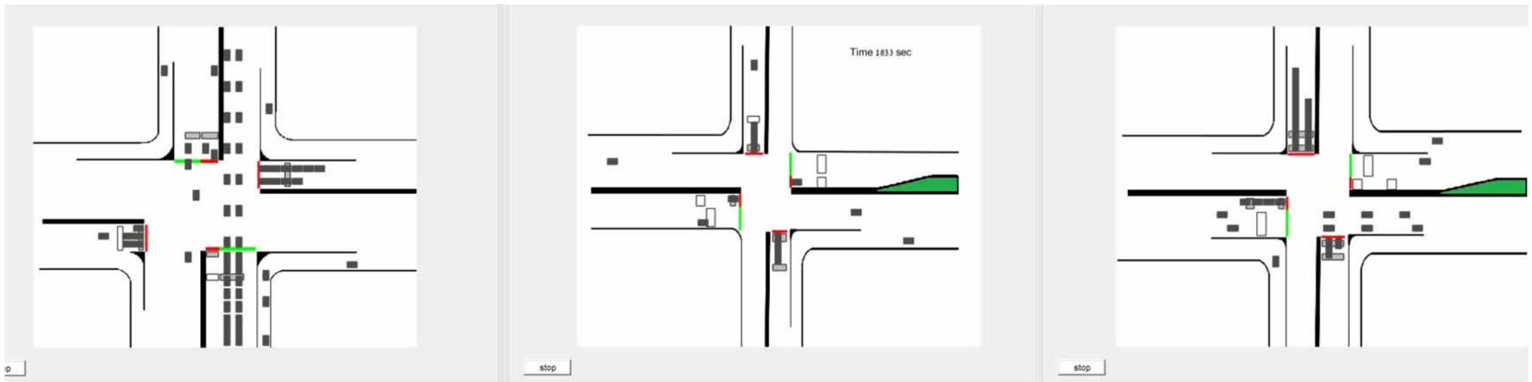
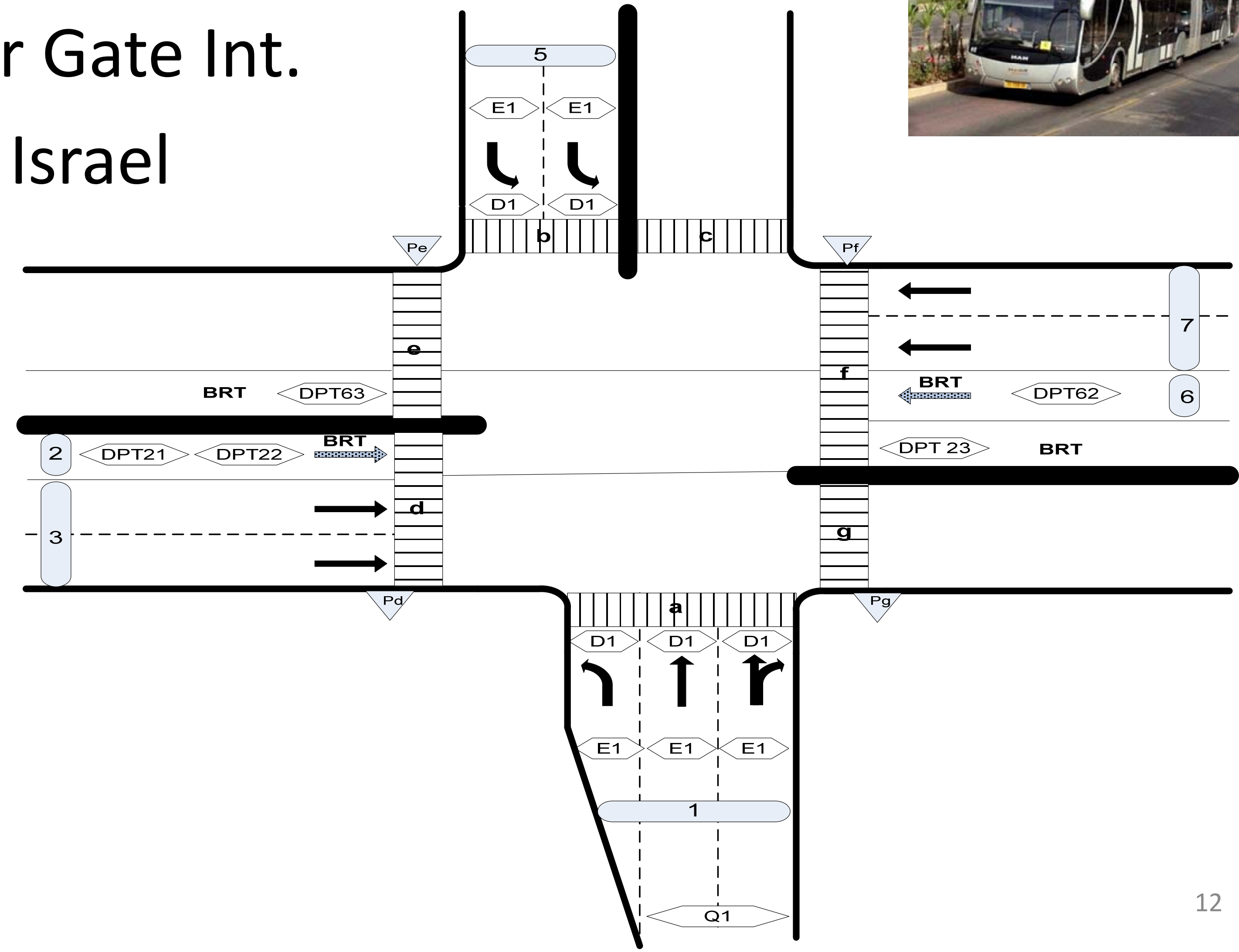
Pedestrians

- Arrival process
  - Activate push buttons on arrival
- Cross at constant speed
- Multiple crosswalks



Case study

- Palmer Gate Int.
  Haifa, Israel



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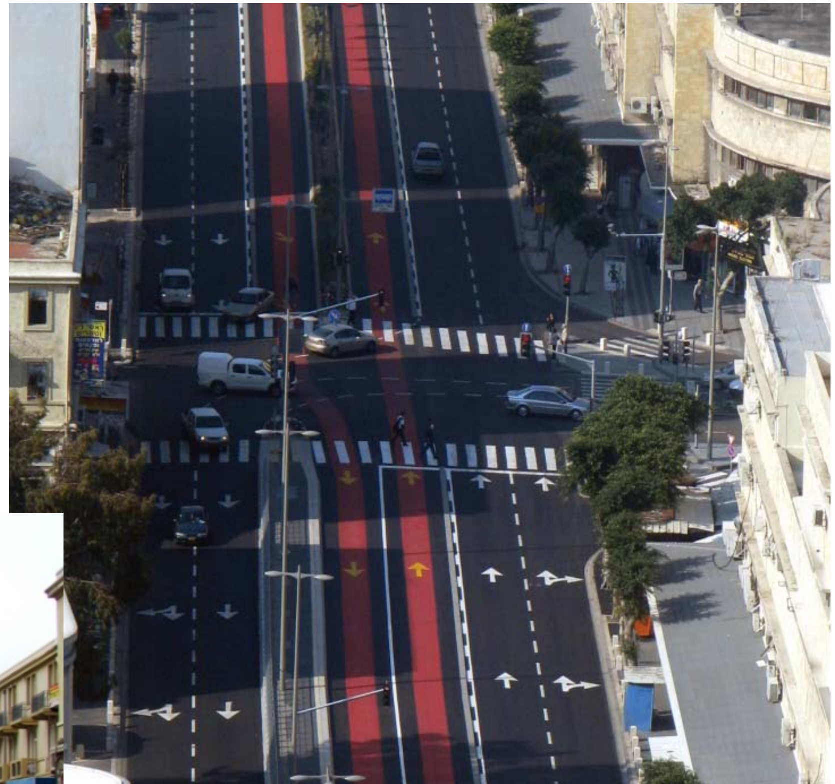
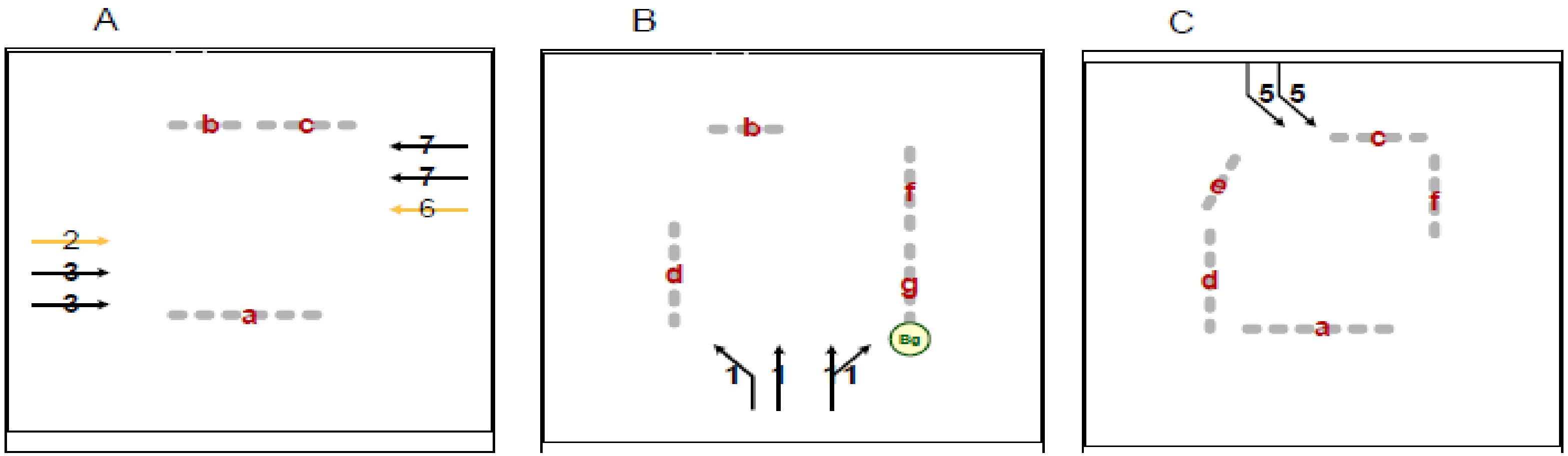
Case study (2)



Control logic

- BRT Priority
  - Extend phase A
  - Early terminate phases B and C
  - Compensation minimum green over numner of cycles
  - Override if queue in detector Q1
  - Pedestrian maximum waiting time
  - Fixed cycle length



Design parameters

- 14 parameters optimized
  - Cycle length
  - Minimum & maximum green times
  - Early green to BRT
  - Maximum pedestrian red time
  - Compensation
    - Minimum green & number of cycles
  - Queue detection
    - Length & period of continuous detection
  - Gap time

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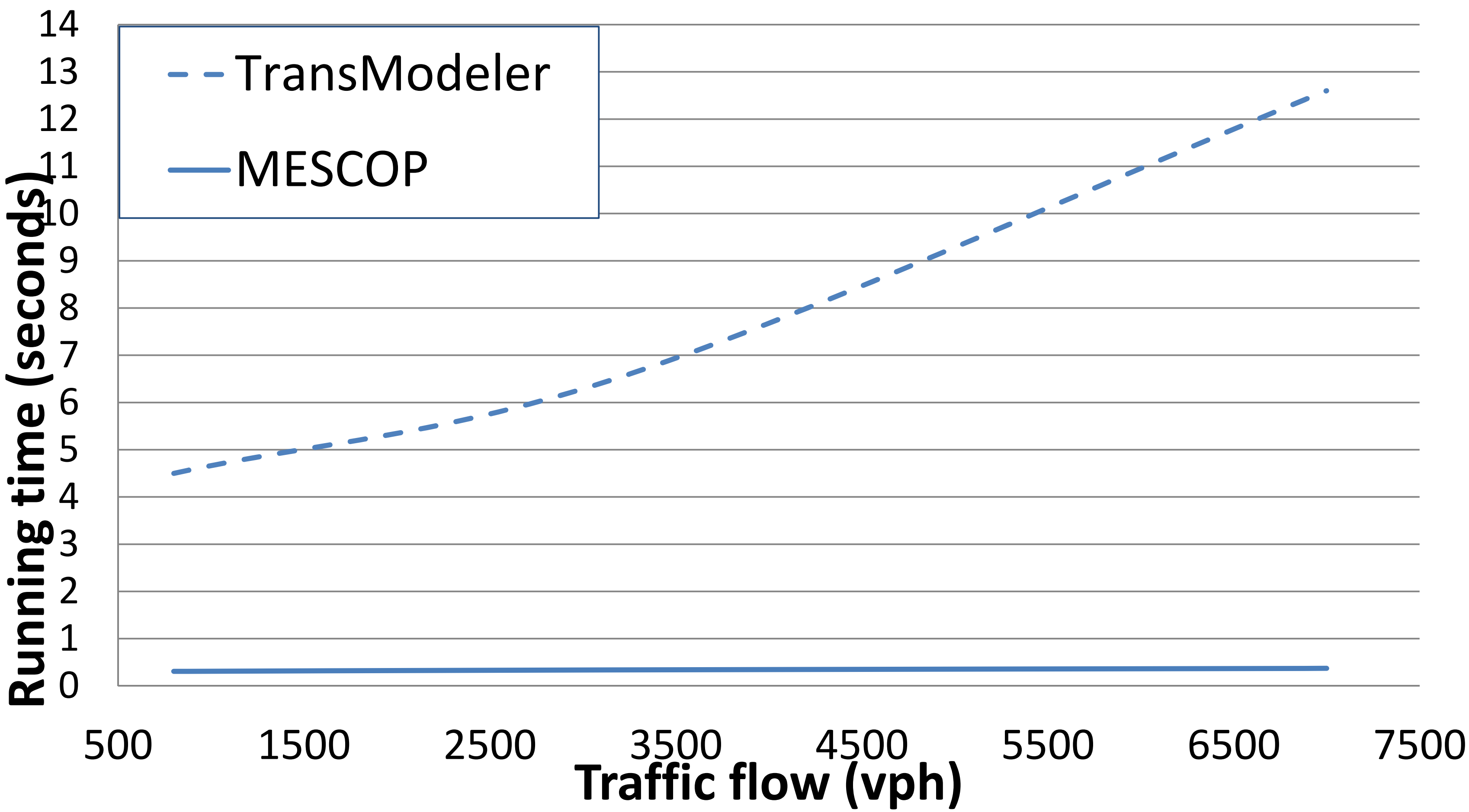
Computational performance



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Optimization objective

- Minimize person delay

$$d = \frac{1}{R}\sum_r \frac{\sum_i \sum_n d_{nr} N_i \delta_{ni}}{\sum_i \sum_n N_i \delta_{ni}}$$

d - average person delay

d_{nr} - delay for vehicle or pedestrian *n* in simulation run *r*

N_i - number of travelers in vehicle *i* (1 for pedestrians)

δ_{ni} - indicator variable that take 1 if vehicle *n* is of type *i*

R - number of replication

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Results

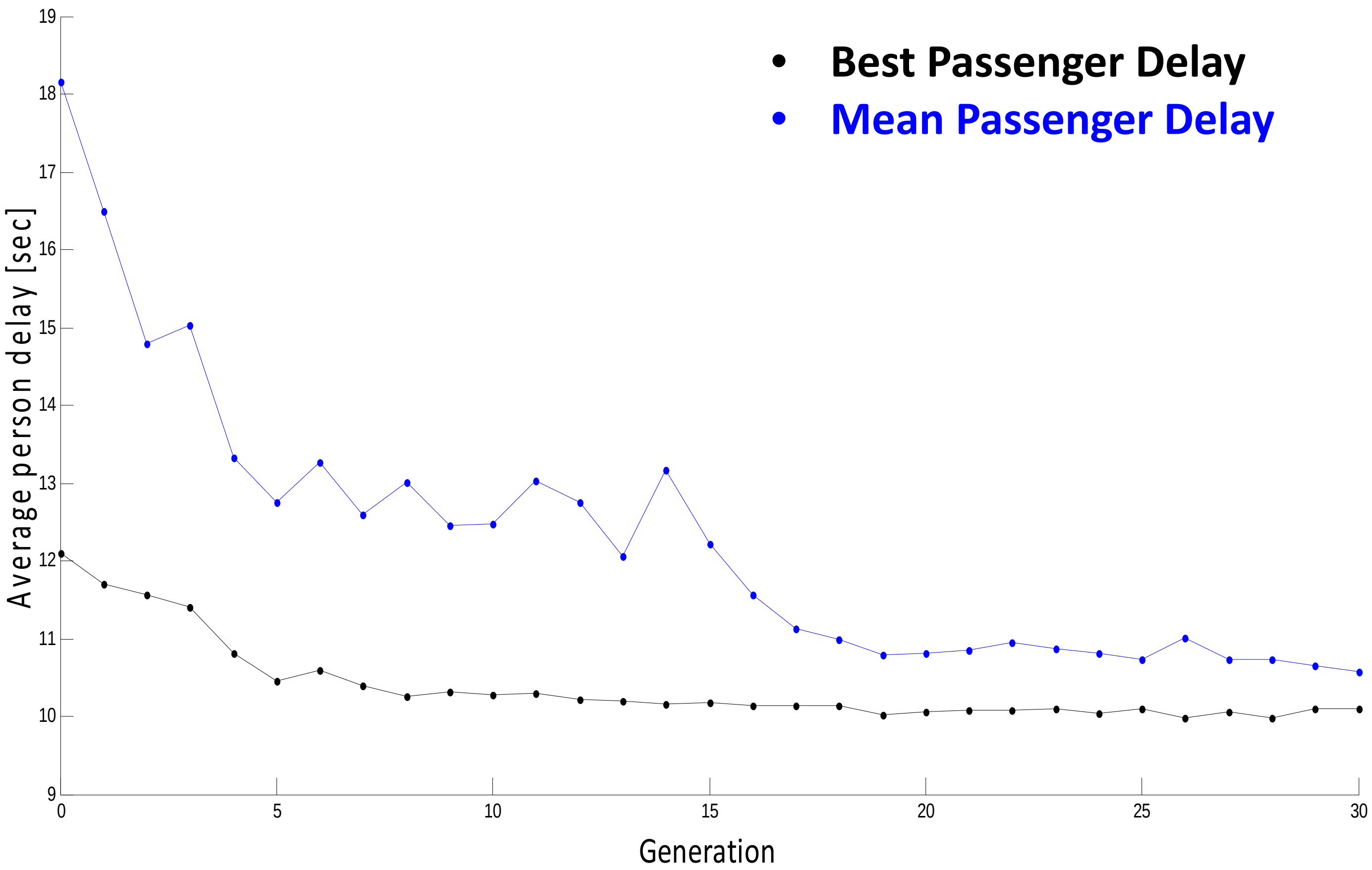
Road users	Average person delays (seconds)		Change (%)
	Initial parameters	Optimal parameters	
BRT	**1.54**	**1.53**	**0**
Non-transit vehicles	**18.48**	**14.17**	**-23**
Pedestrians	**24.31**	**15.95**	**-34**
All	**14.41**	**10.40**	**-28**

Results (2)

Design Parameter	Original Value	Optimal Value
Cycle Length [sec]	110	72
Minimum Green Phase A [sec]	11	19
Maximum Green Phase A [sec]	50	37
Minimum Green Phase B [sec]	10	5
Maximum Green Phase B [sec]	10	13
Minimum Green Phase C [sec]	10	5
Maximum Green Phase C [sec]	10	12
Maximum Pedestrians Red [sec]	138	110
Early Green [sec]	0	5
Accumulated Minimum Green [sec]	18	12
Compensation Period of Time [cycles]	2	4
Queue Length [vehicles]	30	27
Queue Time [sec]	5	15
Gap Time [sec]	3	3

Results (3)

- Genetic algorithm



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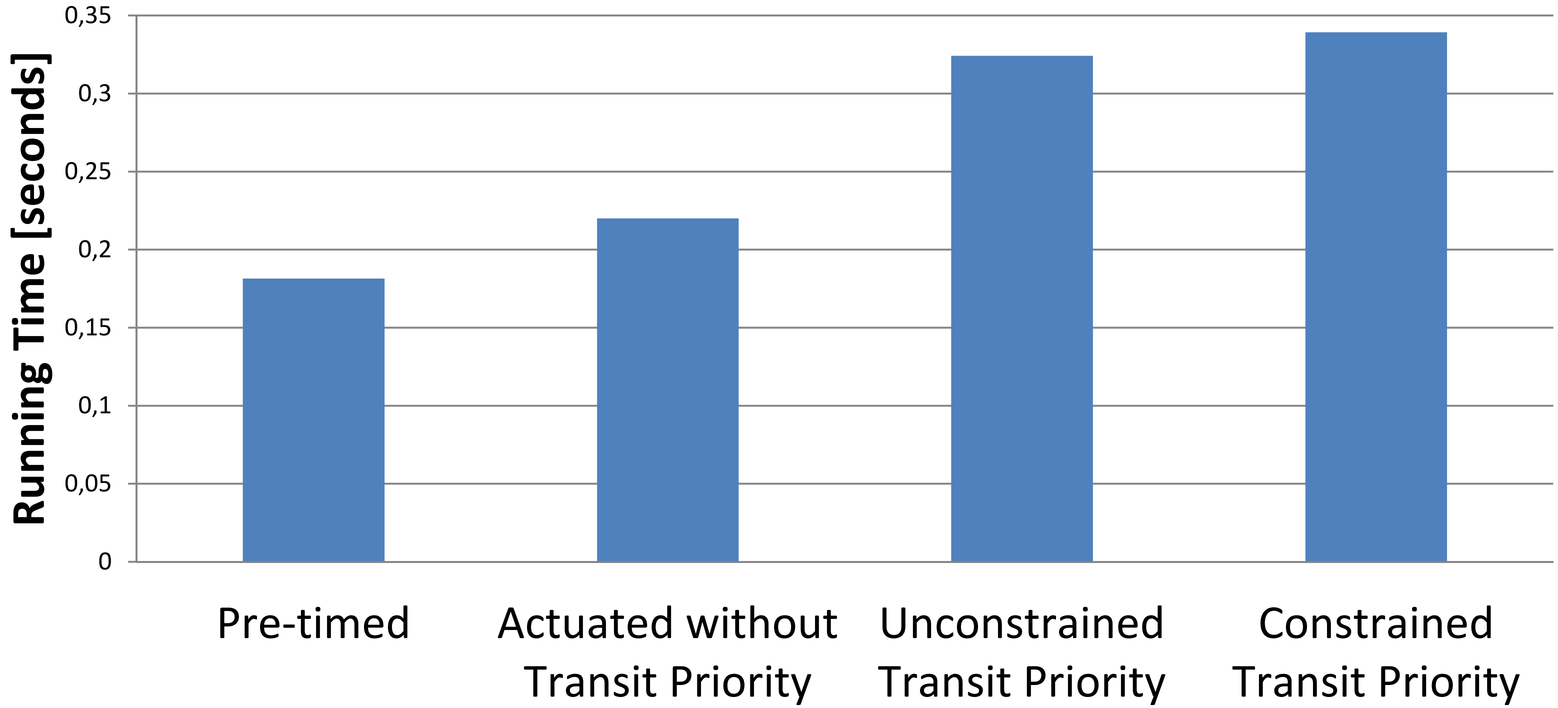
Computational effort



Model components	Running time [%]
Traffic dynamics	8.6
Control logic	81.1
Other (Input/Output)	10.3

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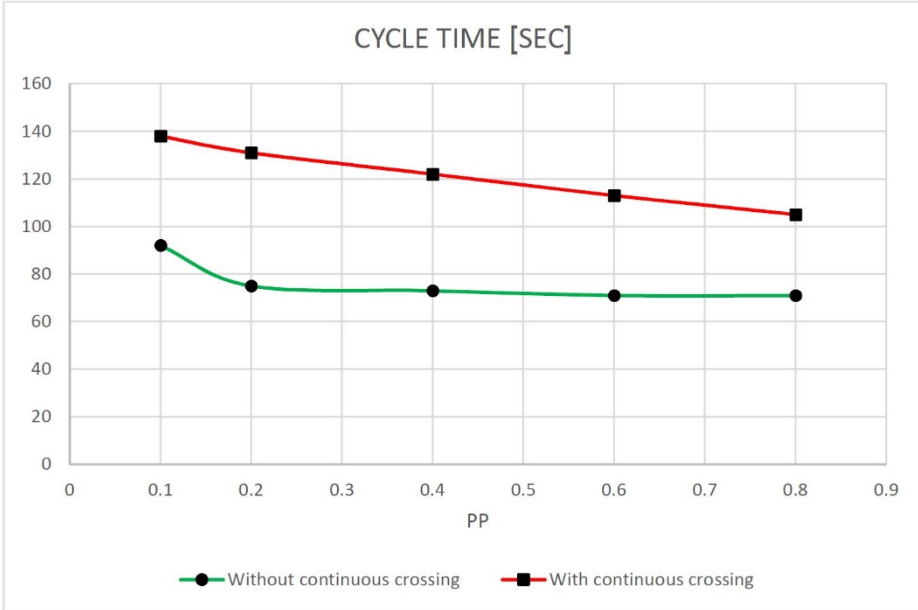
Continuous pedestrian crossing



Summary

- MESCOP
  - Mesoscopic simulation model for evaluation of traffic signal plans
- Optimization of parameters
  - Significant improvements in performance measure
  - Computational feasibility
  - Sensitivity analysis to reduce parameters dimensionality