Co-ordinated Operation of Queues at Congested Arterial Signalised Intersections

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Overview

1. Introduction
2. Control and Models
3. Model for Co-ordination of Queues
4. Final Remarks

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1. Introduction
   - Motivation
   - Traffic Signals at Intersections
   - Co-ordination and Arterial Roads
   - Requirements
   - Challenges
2. Control and Models
3. Model for Co-ordination of Queues
4. Final Remarks

Motivation

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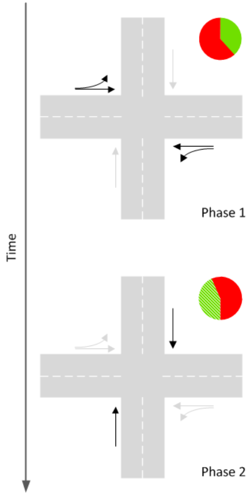
- Efficient **traffic signal** operation is a cost-effective method to deal with congestion
- During congested conditions, **queue management** is a decisive consideration
  - preventing further deterioration of traffic conditions,
  - improving total vehicular throughput
  - and relieving existing congestion hotspots

Traffic Signals at Intersections

a 2-phase signal controller



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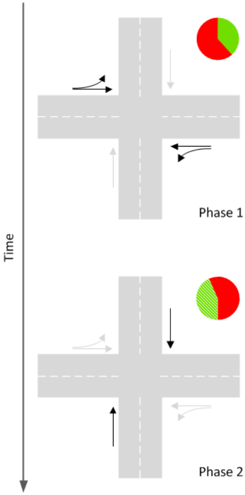

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A set containing one or multiple simultaneous conflict-free movements.

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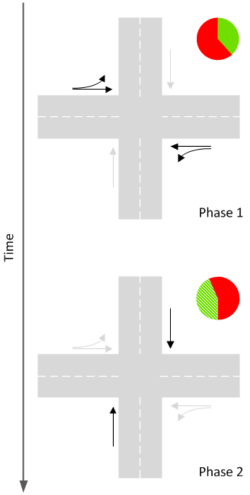

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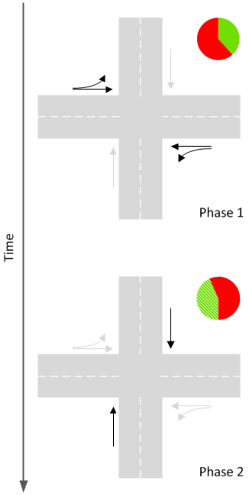

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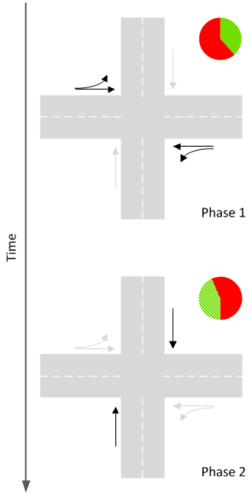

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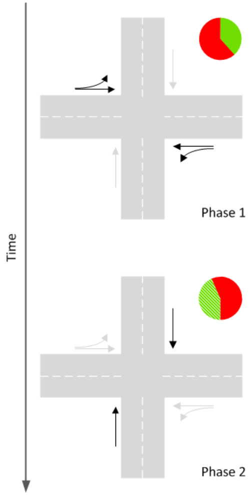

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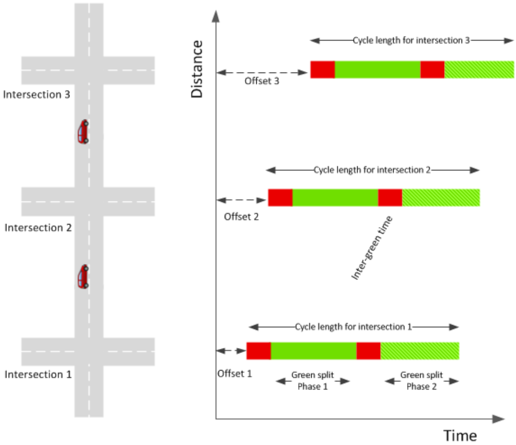
* and **Offsets** ...

Co-ordination and Offsets

in a 3-intersection arterial road



Definition (Offset)

Time between the start of co-ordinated phases and a master clock.

Requirements

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- ∗ Co-ordinate phases along arterials roads
- ∗ Have reasonable waiting times in minor phases (cross-traffic)
- ∗ Maintain adequate queue lengths
- ∗ Dissipate queues and promote progression

Challenges

* Size of the networks to co-ordinate.
* Uncertainty in traffic (unknown demands), reductions in capacity.
* Detection and estimation of indicators and decision variables.
* Oversaturated control is intrinsically different from undersaturated
* Real-time traffic adaptive control

Overview

1. Introduction
2. Control and Models
   - Classification
   - The Bandwidth Maximisation Problem
   - Queue Management Strategies
3. Model for Co-ordination of Queues
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Classification

Control: Strategy

- Offline: Fixed-time, Actuated
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Models: Objective Function

- Min Disutility:
  Delay, Stops, Travel time
- Max MoE:
  Throughput, *Bandwidth*, No. of arrivals on green

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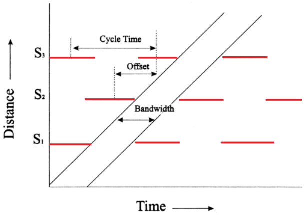
Models: Approach

- Mathematical programming
- Simulation-based

The Bandwidth Maximisation Problem

* The BMP model finds offline settings for co-ordinated arterial roads based on directional bands.



source: Pillai et al. (1998)

1 Little, J.D.C., 1966. The synchronization of traffic signals by mixed-integer linear programming

The Bandwidth Maximisation Problem

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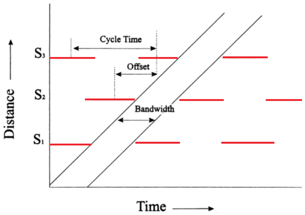
BMP: Little's [1] MILP formulation

Given	cycle time, splits,
	travel times $t_i(\bar{t}_i)$ (or speeds),
	queue clearances $\tau_i(\bar{\tau}_i)$
Find	bandwidth $b, \bar{b}$
	interferences w_i, $\bar{w}_i$
	offsets ϕ_i, $\bar{\phi}_i$, Δ_i, Δ_{i+1}, m_i
to maximise	$b = \bar{b}$
subject to	interference constraints
	loop-integer constraints
	$b, w_i, \bar{w}_i \geq 0 \qquad i = 1, ..., n$
	m_i = integer



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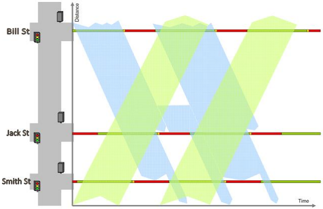

source: http://www.tmr.qld.gov.au/

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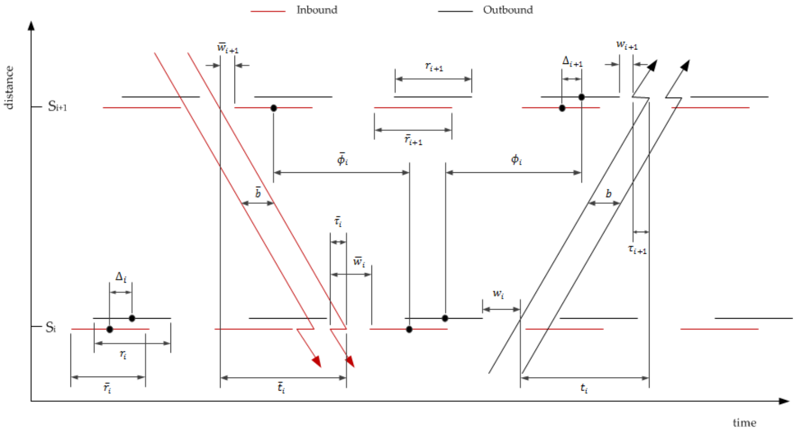
The Bandwidth Maximisation Problem
Geometry



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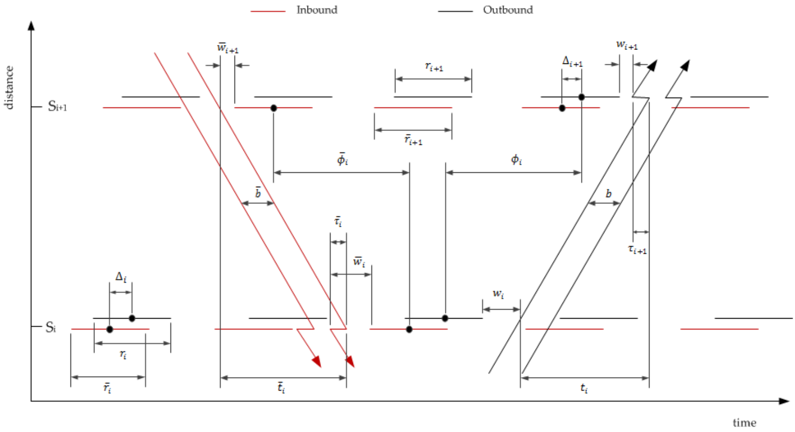

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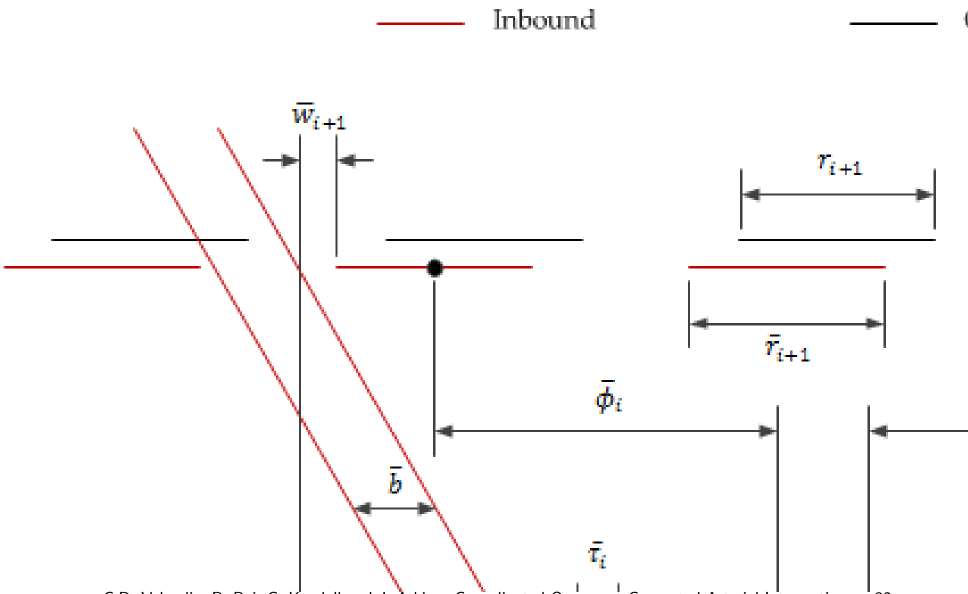

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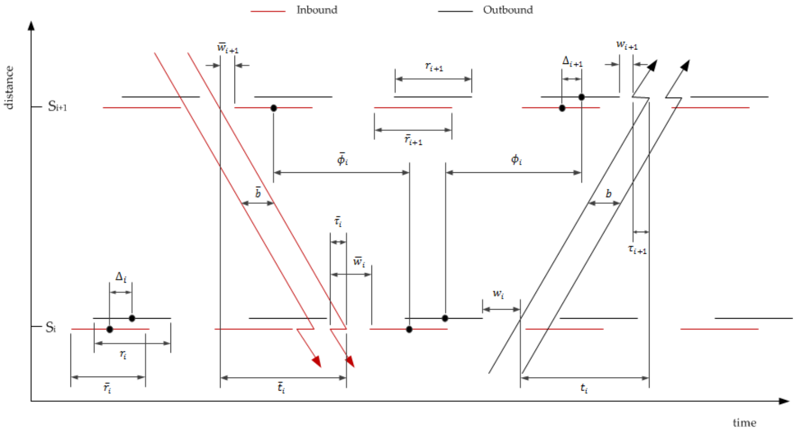

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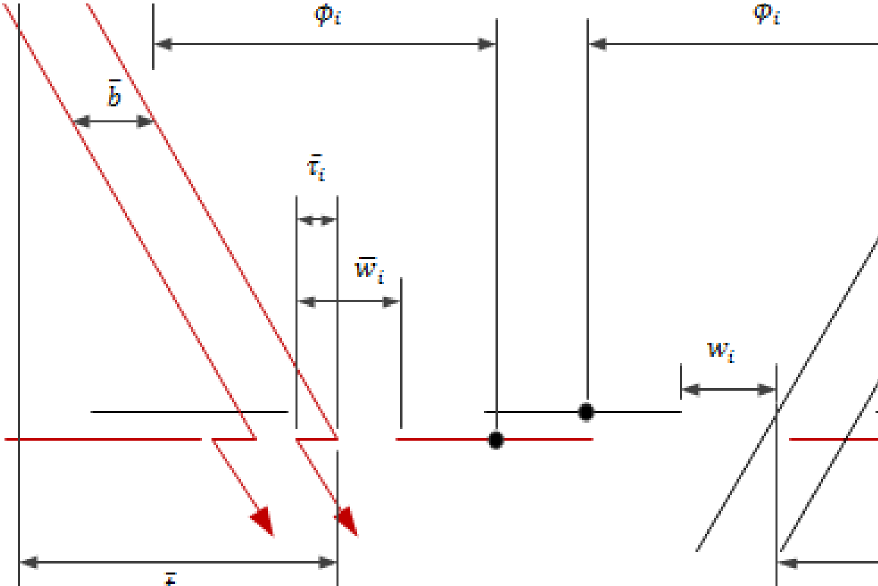

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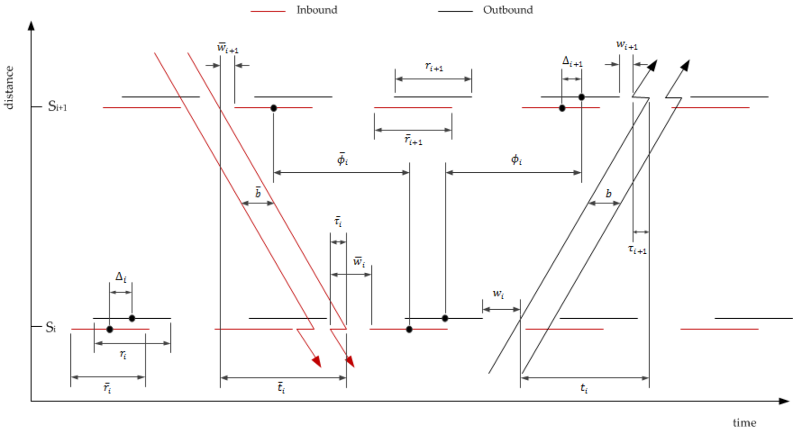

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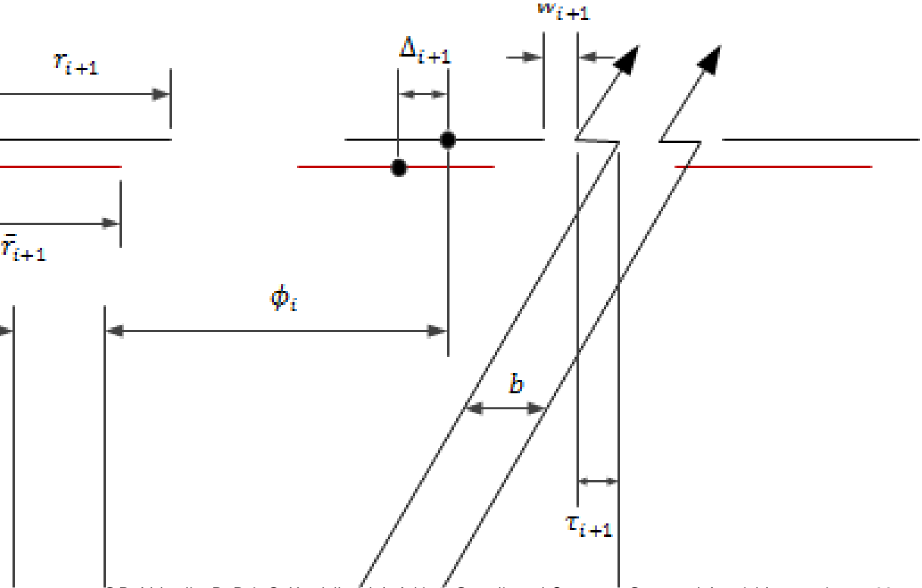
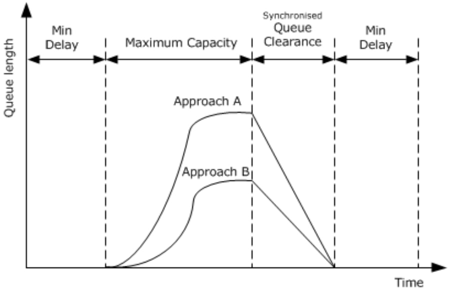
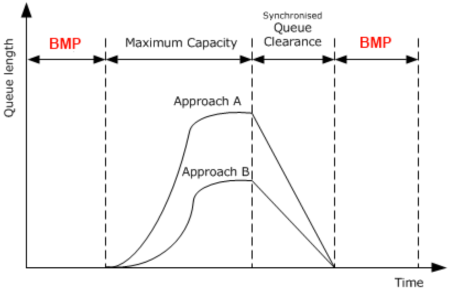


Queue Management Strategies



Sequence of traffic signal algorithms for clearance of peak hour queues (source: Quinn, 1992) at isolated intersections

Queue Management Strategies



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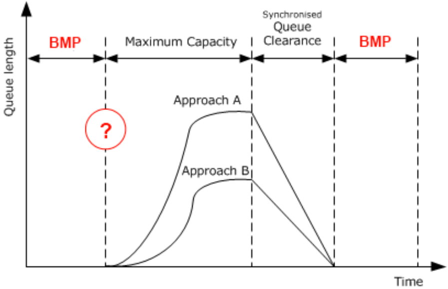

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Not so easy...

* What happens to the progression bands as queues build up at the downstream?

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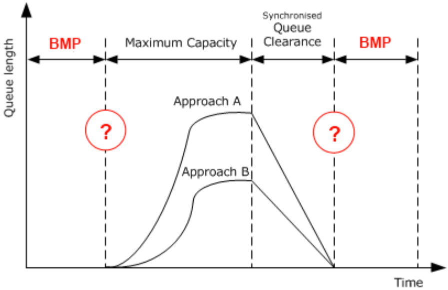

Sequence of traffic signal algorithms for clearance of peak hour queues (source: Quinn, 1992) along arterials

Not so easy...

* What happens to the progression bands as queues build up at the downstream?
* How to clear existing queues and produce bands simultaneously?

Revised Objectives

for Queue Management

Objective 1

* Avoid band disruptions due to downstream queues. In case this isn't possible see Objective 2.

Objective 2

* Dissipate queues and keep the vehicles moving (platooning).
* Use a reverse progression (neg. offset) if queue overflows to upstream intersections.

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And...

* Reduce stress at critical intersections (distributing queues, equity principle, traffic metering) by reducing incoming traffic and larger green times.
* Maintain cross-traffic queues at acceptable lengths, while considering turners contribution to the arterial traffic.

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   - Basic Model
   - Simulation-based Optimisation
   - Simulation of Traffic
   - Improved Model
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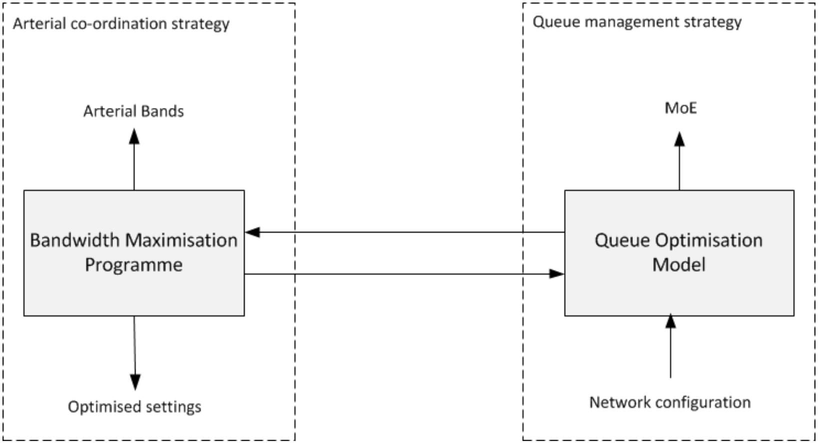
Basic Model

Combining co-ordination and queue control



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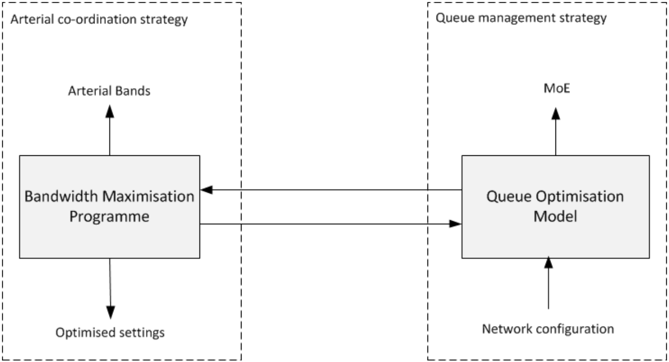
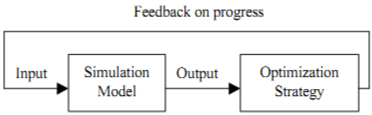


How to represent queue and intersection interactions with enough detail to achieve the revised objectives?

Simulation-based Optimisation



source: Carson and Maria (1997)

Definition (Carson and Maria, ibid)

The process of finding the best input variable values without explicitly evaluating each possibility... Minimising resources spent while maximising the information obtained...

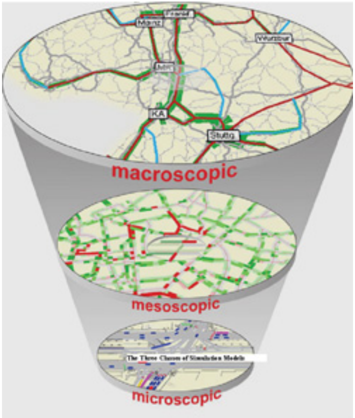
* Reproduces rare scenarios and occurrences
* Several techniques (including GAs and hyperheuristics have been adapted to SO)
* Provide high level of accuracy
* Computationally Expensive

in traffic

* Simulation is already used in traffic studies to evaluate solutions before deployment and to optimise.

Simulation of Traffic

Classification



http://www.its.dot.gov

* Macro: Based on formulae relating speed, density and flow
* Meso: Symplified flow dynamics (e.g, combining vehicles in platoons, flows and densities per road link)
* Micro: Interaction between vehicles, driver perceptions and lane interactions.

[1] Liu, Y. and Chang, G., 2011. An arterial signal optimization model for intersections experiencing queue spillback and lane blockage. Transportation Research Part C: Emerging Technologies, 19(1), pp.130 - 144.

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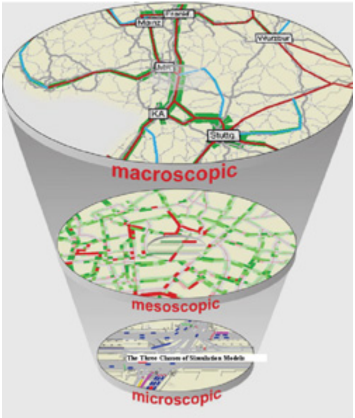

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* Meso: Symplified flow dynamics (e.g, combining vehicles in platoons, flows and densities per road link)
* Micro: Interaction between vehicles, driver perceptions and lane interactions.
  * Detailed representation of difficult queue dynamics and complex intersections, e.g, impact of turning traffic better than BMP [1]

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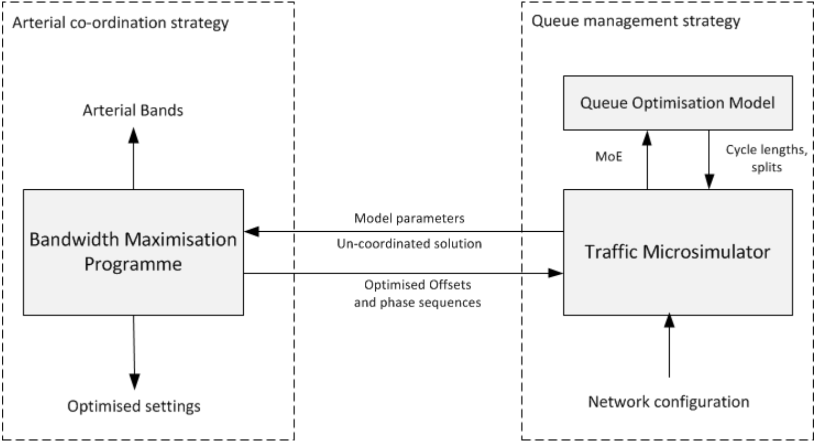
Improved Model

including microsimulation



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   Conclusions
   References

Conclusions

* Traffic signal timing optimisation is a hard problem that hasn't been solved satisfactorily for oversaturated networks.
* Combining methodologies (mathematical and simulation-based) different aspects of the problem could be solved.
* Traffic models can describe queues using microsimulation and in turn co-ordinate them at arterial roads.
* Queues haven't been addressed actively in the context of co-ordinated arterials. Managing queues is crucial for effective traffic control.
* Other co-ordination methods, such as the combination technique (Gazis, 2002) could be used instead of the BMP.

References

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