SATURN 101: Part 1 – Understanding Simulation Capacities

2018 User Group Meeting

Dirck Van Vliet

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Final 03/12/18 - UGM2018 SAT101 Part 1 Understanding Simulation Capacities

Part 1 – SATURN 101:
Simulation Junction Capacities

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SATURN 101 Series

Background Essentials

- Building Blocks
- Path Building

Assignment with Buffer Networks

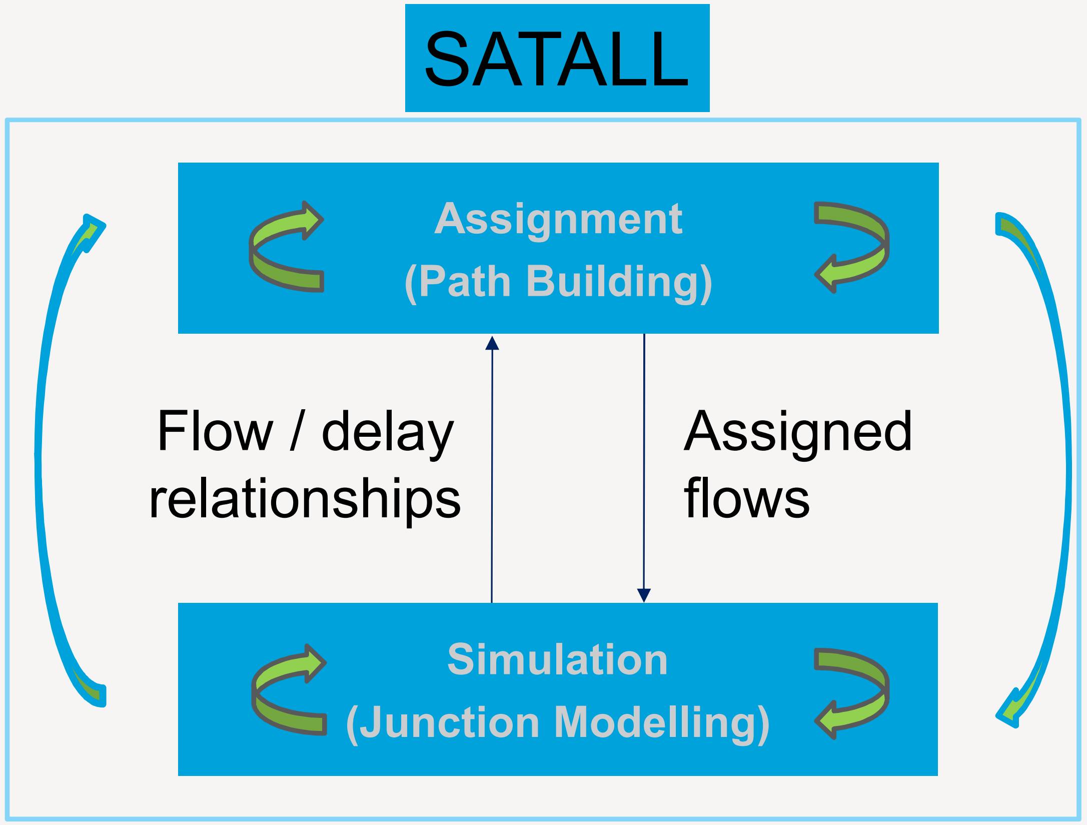
- Town v Country

Simulation

- Cyclic Flow Profiles
- Calculating junction capacities, queues & delays

Assignment with Simulation Networks

- Town v Country Mk2



Background Essentials (i)

Assignment Trees & Forests

› "Tree" = set of shortest routes from one origin to one (or all) nodes/zones in a network

› "Forest" = collection of trees from a single origin over all assignment iterations

Capacity constraint

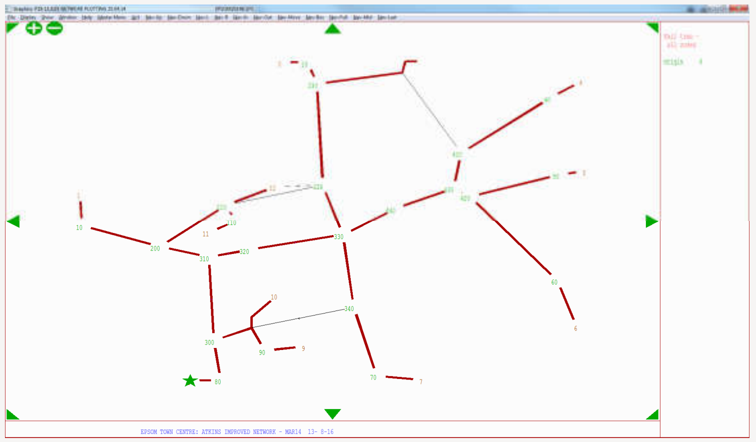
› Relationship between vehicle flow and travel time

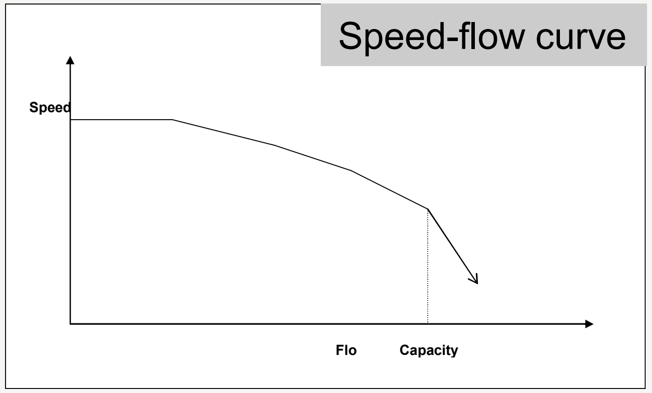
  › Usually non-linear

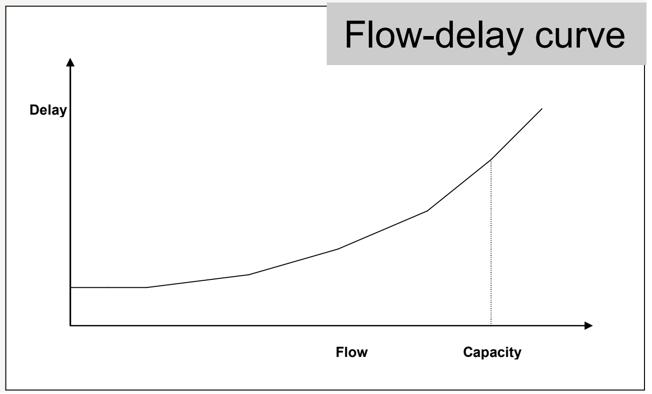
  › For example:

    › *COBA-based 'speed-flow' curves in Buffer network*

    › *Or more usefully a 'flow-delay' curve*







Background Essentials (ii)

Assignment:

› Single All-or-Nothing (AON) - allocates all the OD-demand to a single route (or ‘path’)

Equilibrium Assignment

› Series of AON assignments with paths costs varying through capacity constraint, leading to:

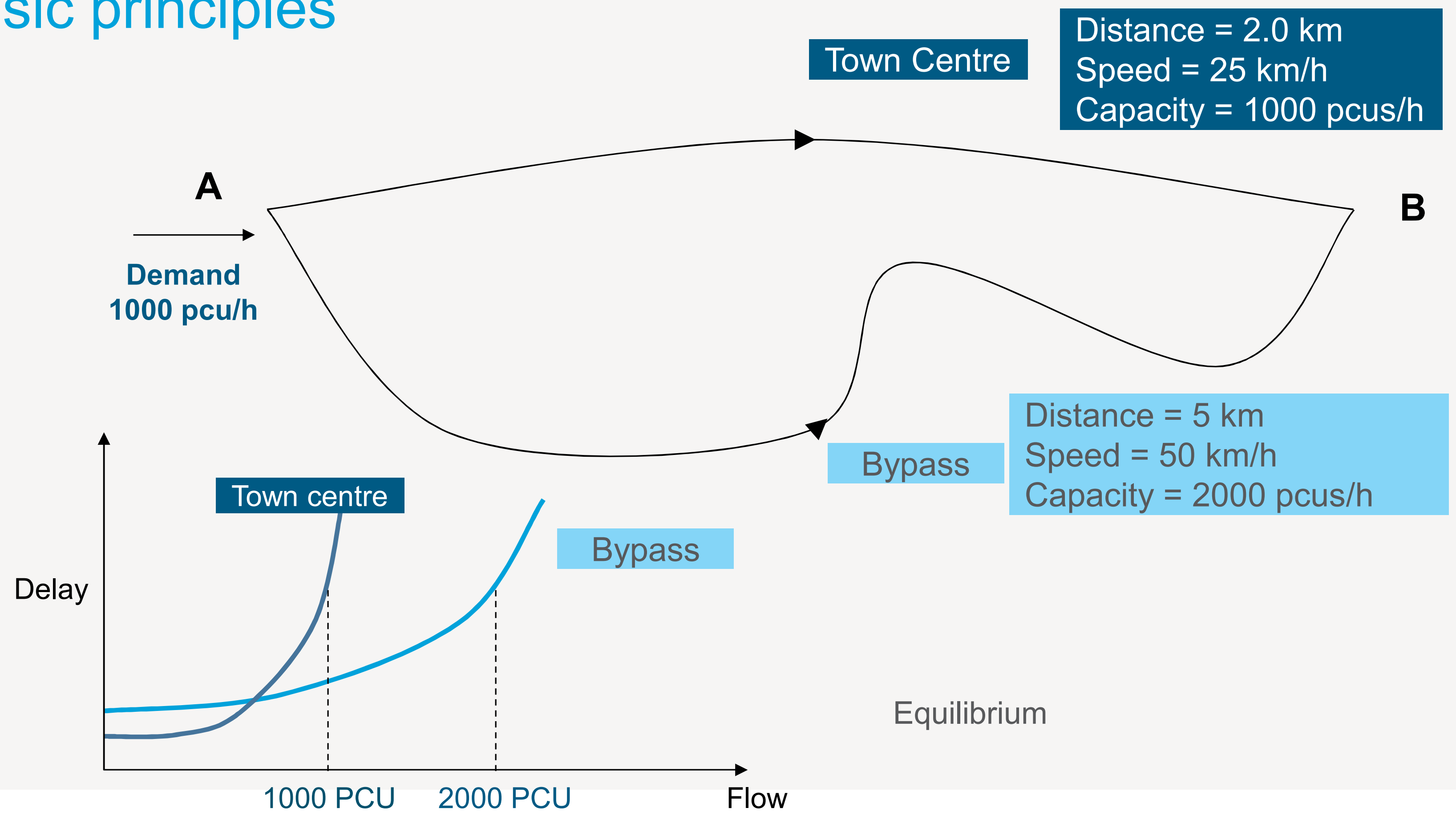
Wardrop Equilibrium

› “Traffic arranges itself on networks such that the cost of travel on all routes used between OD pair is equal to the minimum cost of travel and all unused routes have equal or greater cost” (TAG Unit M3.1)

In SATURN, this mathematical process is undertaken by:

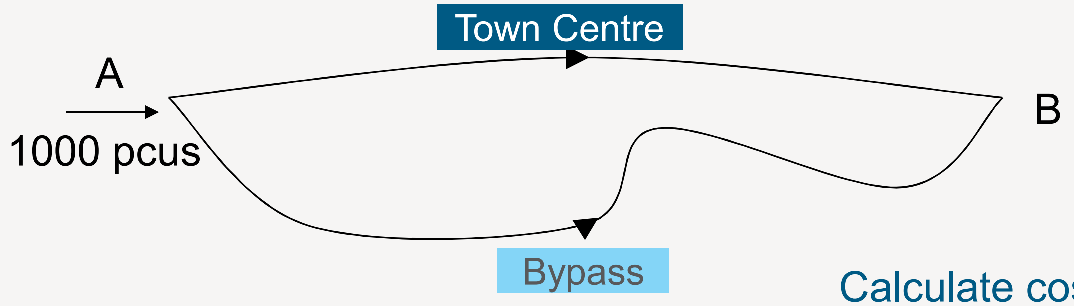
› ‘minimising’ an objective function
› using the Frank-Wolfe algorithm
› to determine the optimum combination (lambda) of the available AoN assignments.

Assignment for a Buffer Network (i) - Basic principles



Equilibrium

Assignment for a Buffer Network (ii) - Combining AoN solutions for Equilibrium



Path-building: Successive All-or-Nothings

… allocate 1000 pcus to either Town Centre or Bypass

Path Build	Town Centre	Bypass
1	1000	0
2	0	1000
3	0	1000
4	1000	0

Calculate costs based on flows of …

Iteration	Town Centre	Bypass
1	1000	0
Combine (e.g. 0:100)	(1000)	(0)
2	0	1000
Combine (e.g. 50:50)	(500)	(500)
3	0	1000
Combine (e.g. 66:33)	(333)	(666)
4	1000	0

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SATURN Simulation – Key Building Block

Modelling vehicular movements

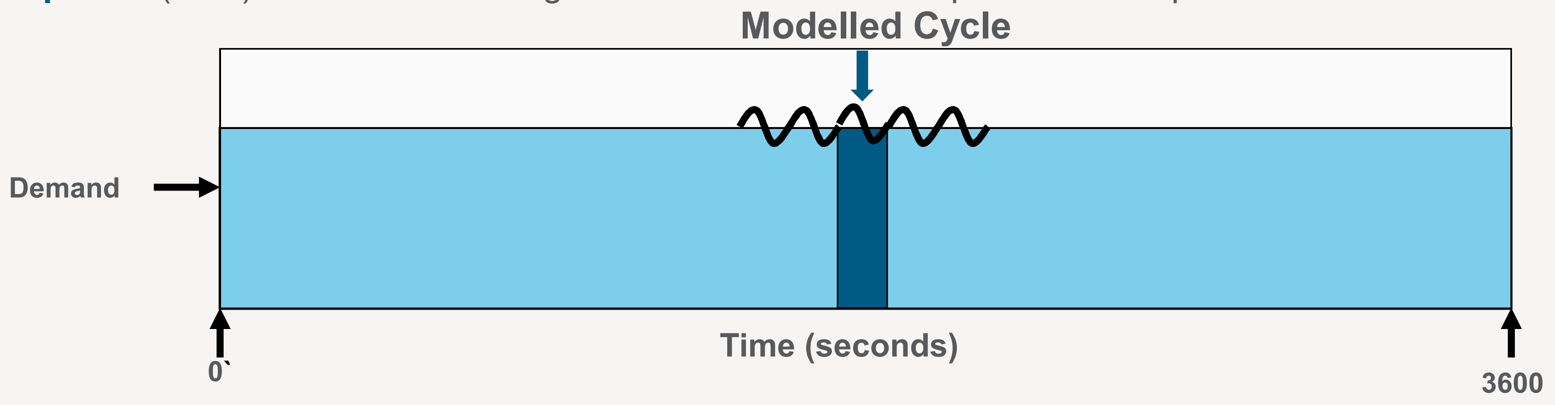
› Compromise between level of detail (eg individual vehicle level) and runtime

Two basic assumptions:

› That traffic flows are approximately constant over time periods of the order of 60 minutes (LTP);

› That traffic signals operating with fixed cycle times of the order of, say, 75 seconds, impose a pattern of "cyclic flow profiles" within the longer time frame (LCY).

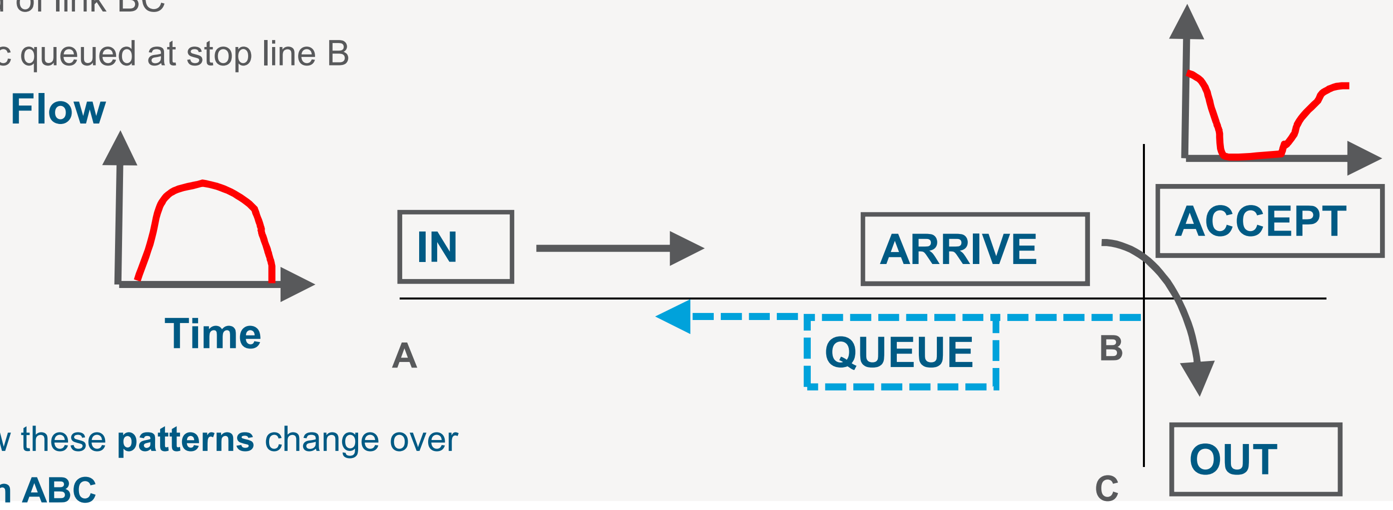
Cyclic flow profile (CFP) is the main building block - the flow of traffic past a certain point as a function of time.



Simulation in More Detail (ii) – Cyclic Flow Profiles

Five Basic CFPs

- the **In** pattern – flow profile upstream at end of link AB
- the **Arrive** pattern – profile at end of link AB
- the **Accept** pattern – pattern of traffic which actually makes the turn
- the **Out** pattern – flow upstream end of link BC
- the **Queue** pattern – pattern of traffic queued at stop line B



The simulation process calculates how these **patterns** change over the **cycle time** for each simulated **turn ABC**

Simulation in More Detail (iii) - Junction Capacities

Junction Capacities based on the Accept profile

Simply the summation of the final Accept profiles

Start with the coded saturation flow by turn then reduce it based on:

More information in section 8.2 onwards

Turn Saturation Flow

- 8.5 Exit Link Blocking Back
- Traffic Signal Red Phase
- 8.2.2 Give-way GAP Acceptance
- 8.8 Lane Choice Allocation
- 8.2.4 (+) Signal X-Turn TAX
- 8.2.6 (+) Extra capacity with Flares
- Mid-link capacity constraints

Turn Capacity

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Simulation in More Detail (iv) – Delays, Flows & Curves

Flow-Delay Curves

Once five CFPs determined, now using Queue profile to calculate average delay per vehicle

In addition to calculating the "actual" delay, simulation also needs to calculate a "flow-delay" curve for each turning movement

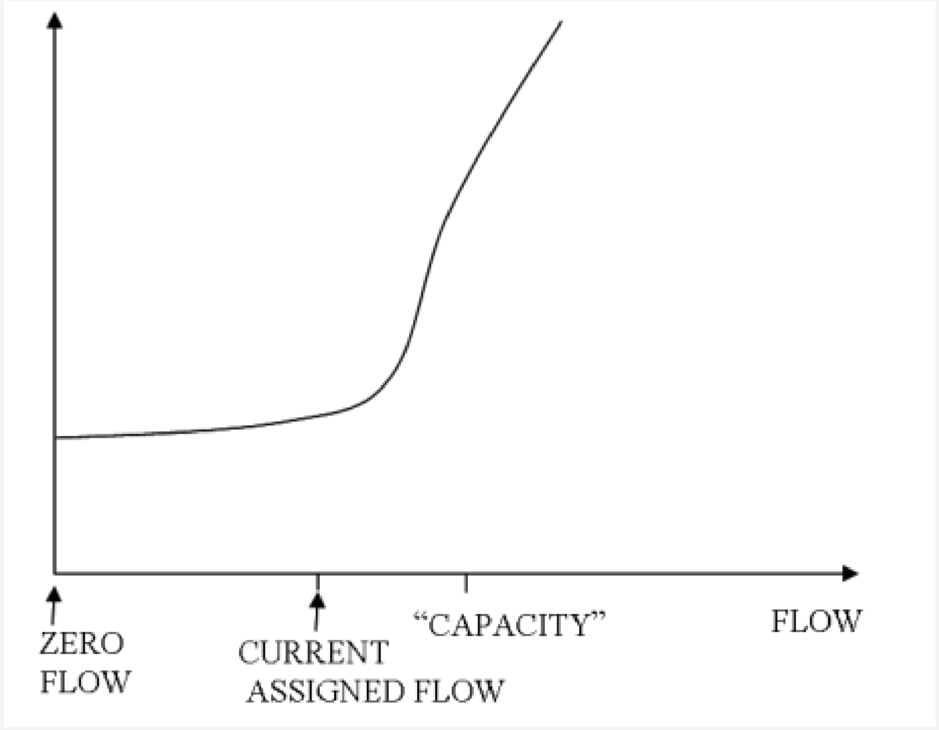
› See section 8.4

Additional Random Delays and Queues (LRTP)

Assumption that same 75 second cyclic flow profile pattern repeated across whole modelled period is unrealistic

› Random element introduced particularly when junction operating near to capacity
› See section 8.6

Simulation Flow Delay Curve



Simulation – Internal Structure

A neat ‘coding’ trick … internally expand the junctions into a set of individual one-way links for each turn

› Called the ‘Assignment network’

For example, four arm junction gives:

Assignment nodes

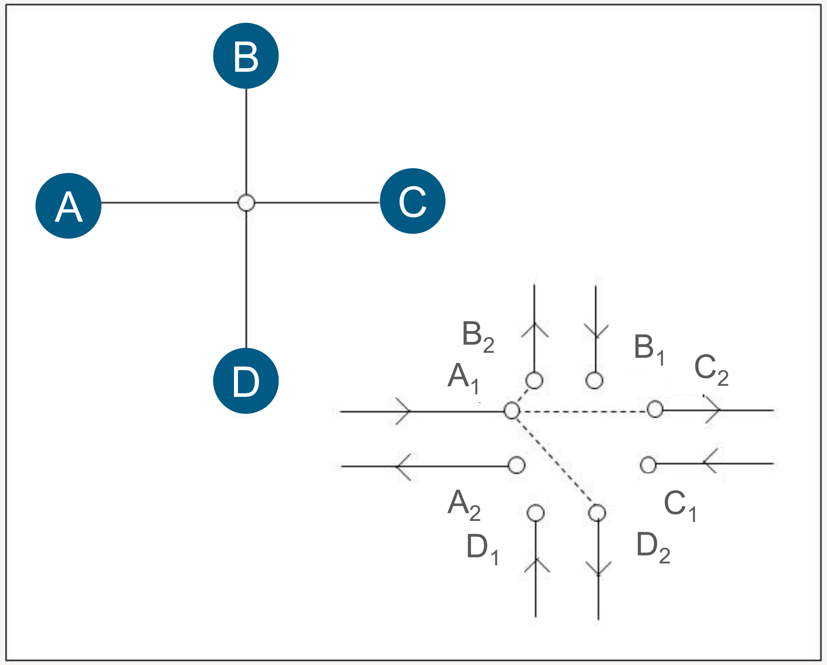
› 4 inbound (A_1, B_1 …)

› 4 outbound (B_2, C_2 …)

Assignment links

› 12 links (A_1B_2, A_1C_1, $A_1D_{1.}$

Provides an assignment structure compatible with the buffer network



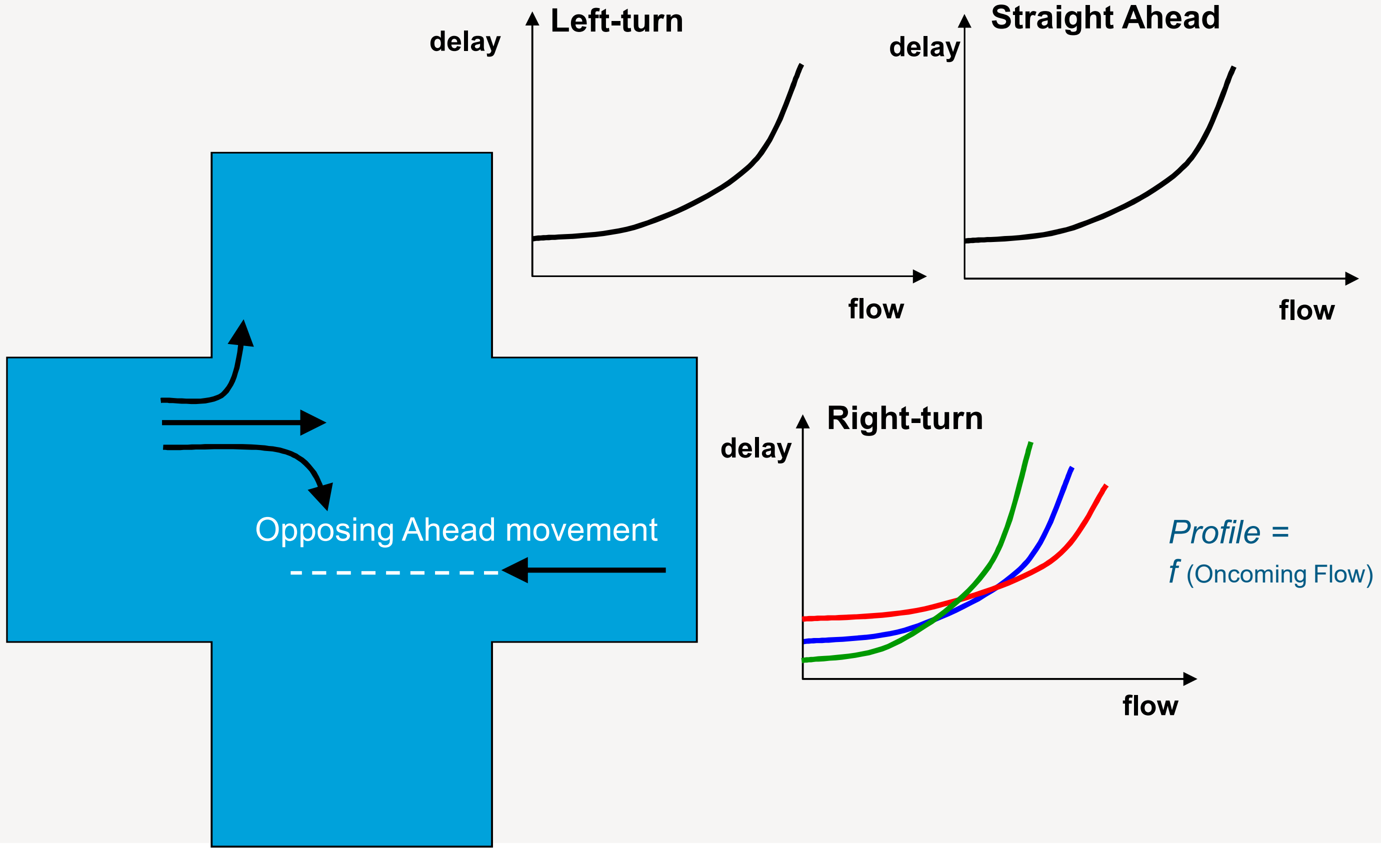
Simulation – Outputs: Flow-delay curves

Internal simulation calculations undertaken

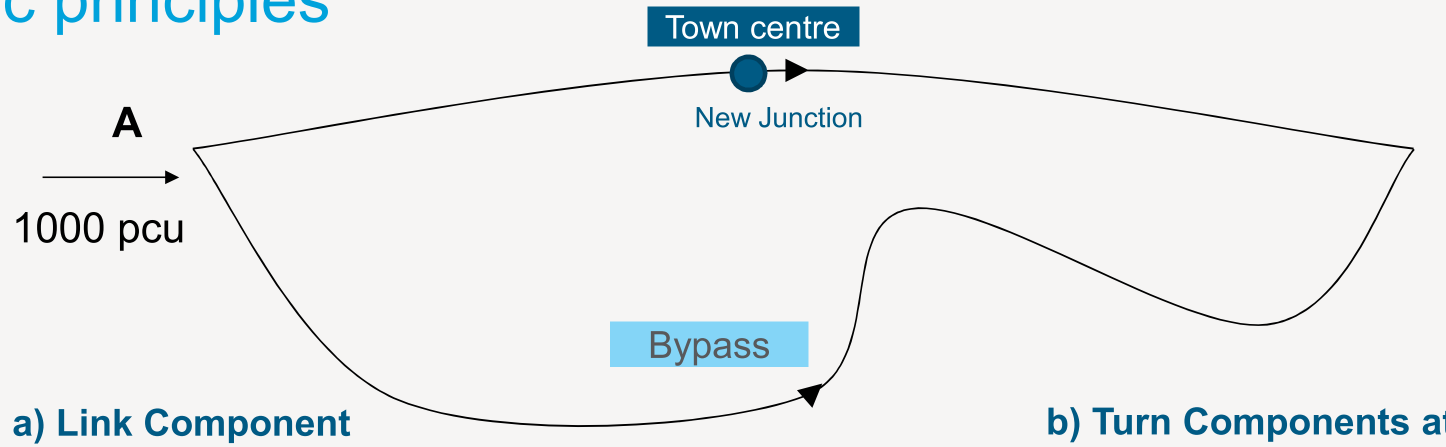
- See before

Outputs are set of unique flow-delay curves for each simulated turn

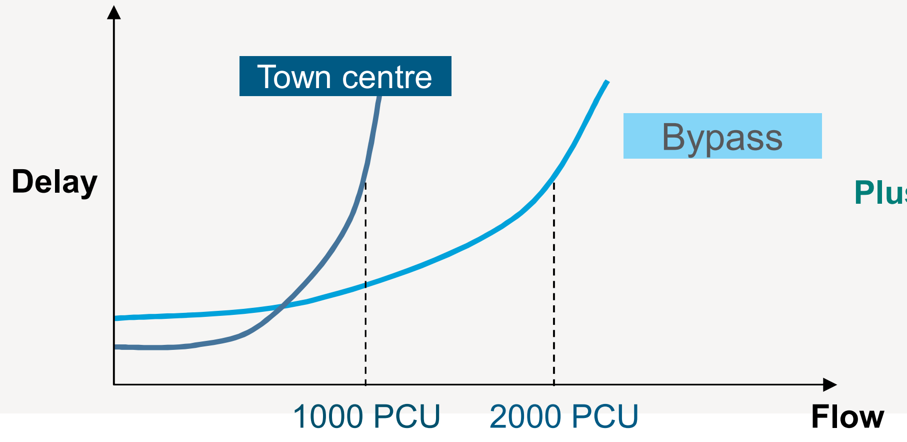
- Right-turns more variable as greater level of level of interactions
- Revised flow-delay curves fed back to the assignment



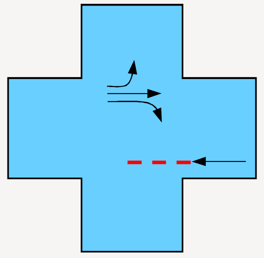
Assignment for a Simulation Network (i) - Basic principles



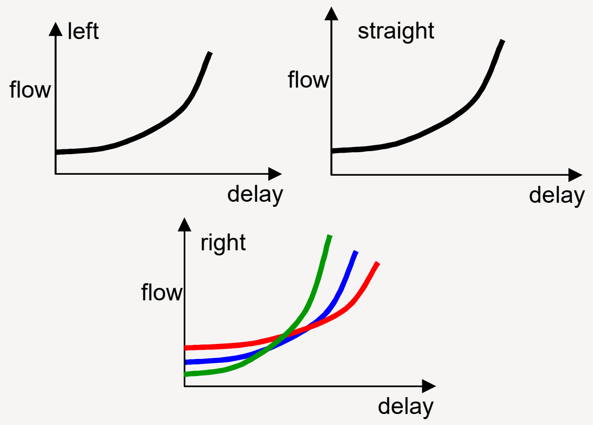
a) Link Component



Plus



b) Turn Components at New Junction



SATURN Assignment & Simulation

Assignment sub-model (SATASS)

- uses the ‘assignment’ network =

  Buffer Network + Exploded Simulation Network

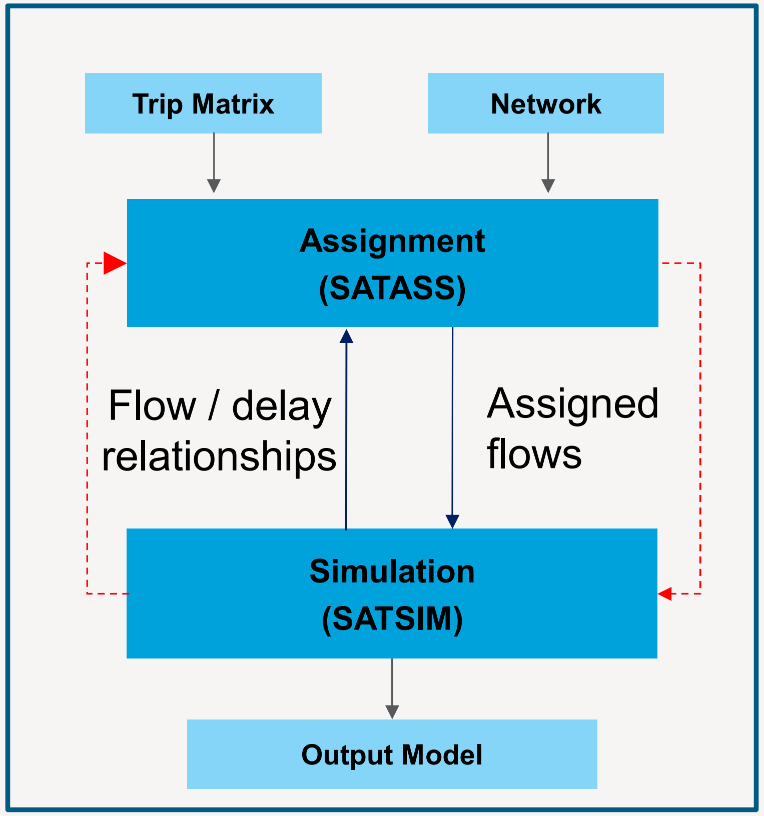
In terms of the assignment, there is no distinction between the two – each has its own flow-delay curve

But … their flow-delay curves have been generated by two different processes:

- Buffer = explicitly defined by the users
- Simulation = generated by the **SATURN Simulation (SATSIM)**

Iterative process until convergence achieved

- Both within SATASS & SATSIM
- AND also between successive ASS-SIM loops


Trip Matrix
Network
Assignment (SATASS)
Flow / delay relationships
Assigned flows
Simulation (SATSIM)
Output Model