Dynamic Intersection Signal Control Optimization (DISCO)

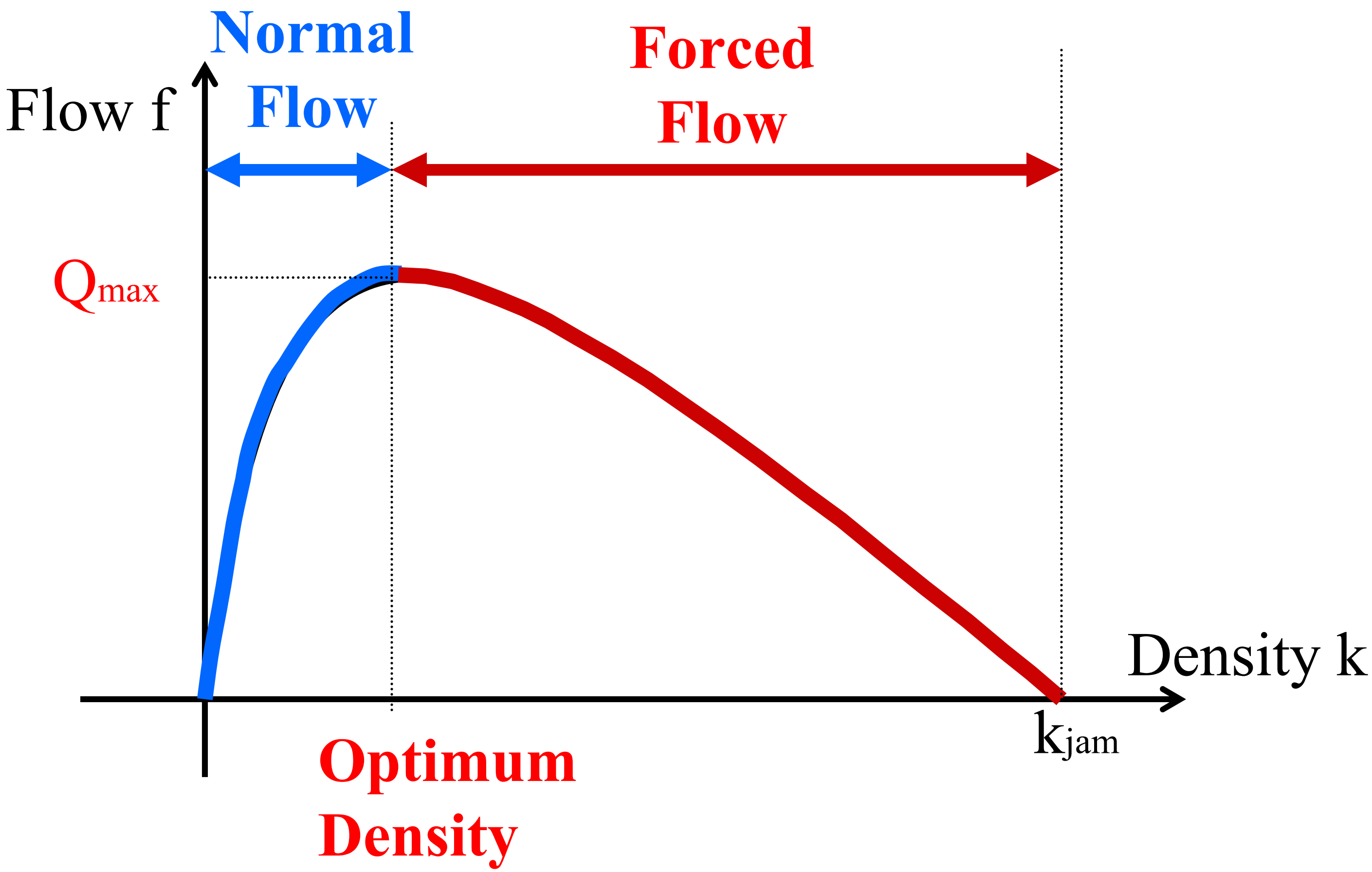
Hong K LO 羅 康 錦
cehklo@ust.hk

Civil Engineering
Hong Kong University of Science and Technology

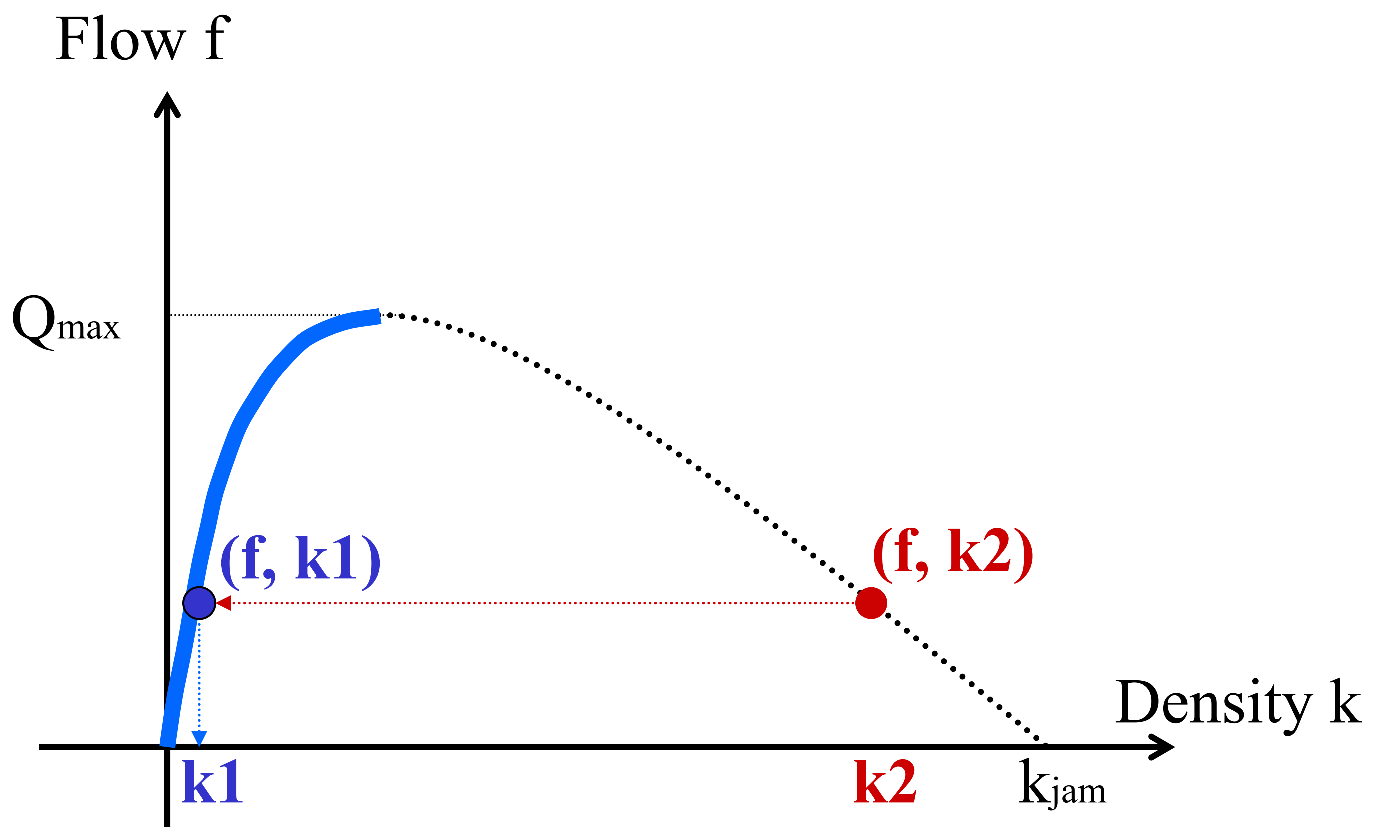
Existing Traffic Signal Control Approaches

- Static Models
  - don't work well for congested traffic
  - e.g. TRANSYT, MAXBAND, PASSER
- Dynamic Models
  - don't work for light traffic
  - ignore the fundamental diagram

Fundamental Diagram



Flow-density Relationship



Potential Problems

- No operational model for over-saturated traffic
- Traffic conditions fluctuate from light to saturated daily
- Frequent manual overrides are common

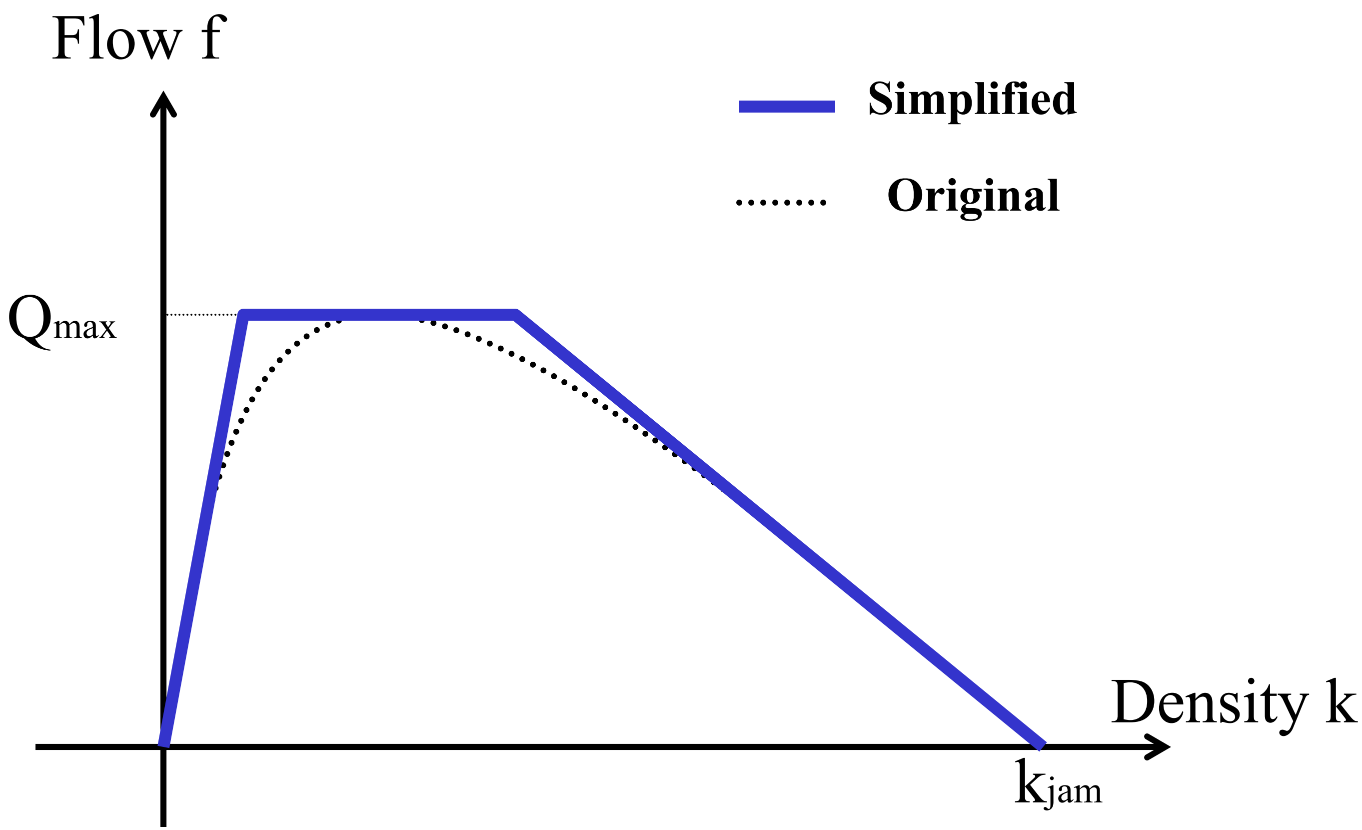
Features of This New Formulation

- Models dynamic traffic
- Captures queue dissipation and formation dynamics, kinematic waves.
- Covers the entire range of traffic conditions
- Modify traffic density to the optimum flow level in over-saturated traffic

Dynamic Intersection Signal Control Optimization (DISCO)

- Minimize total dynamic delay, subject to
  - Cell-Transmission Model (Daganzo, 1994, 1995) (CTM) to model traffic dynamics
  - Timing plan constraints, max green, cycle time, etc.

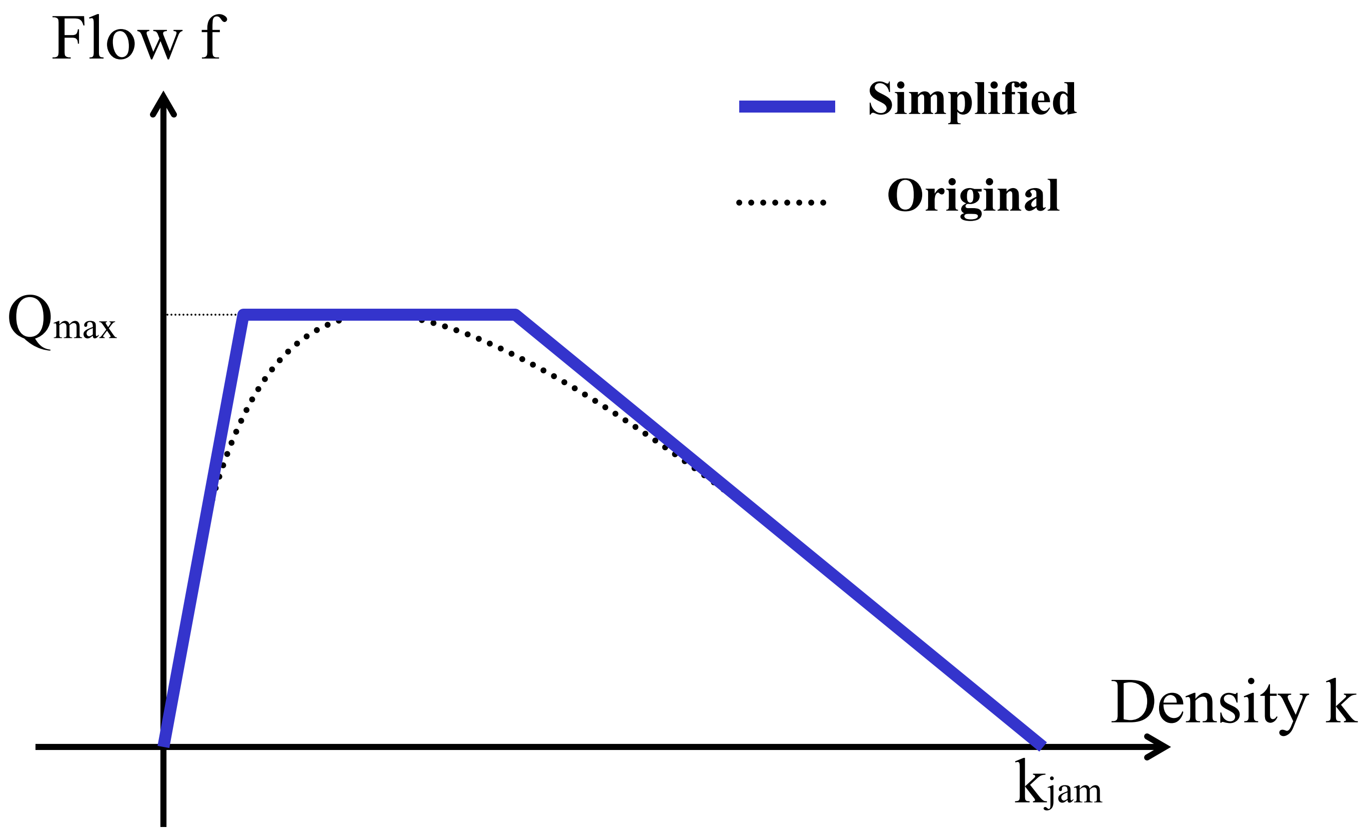
Simplified Flow-density Relationship



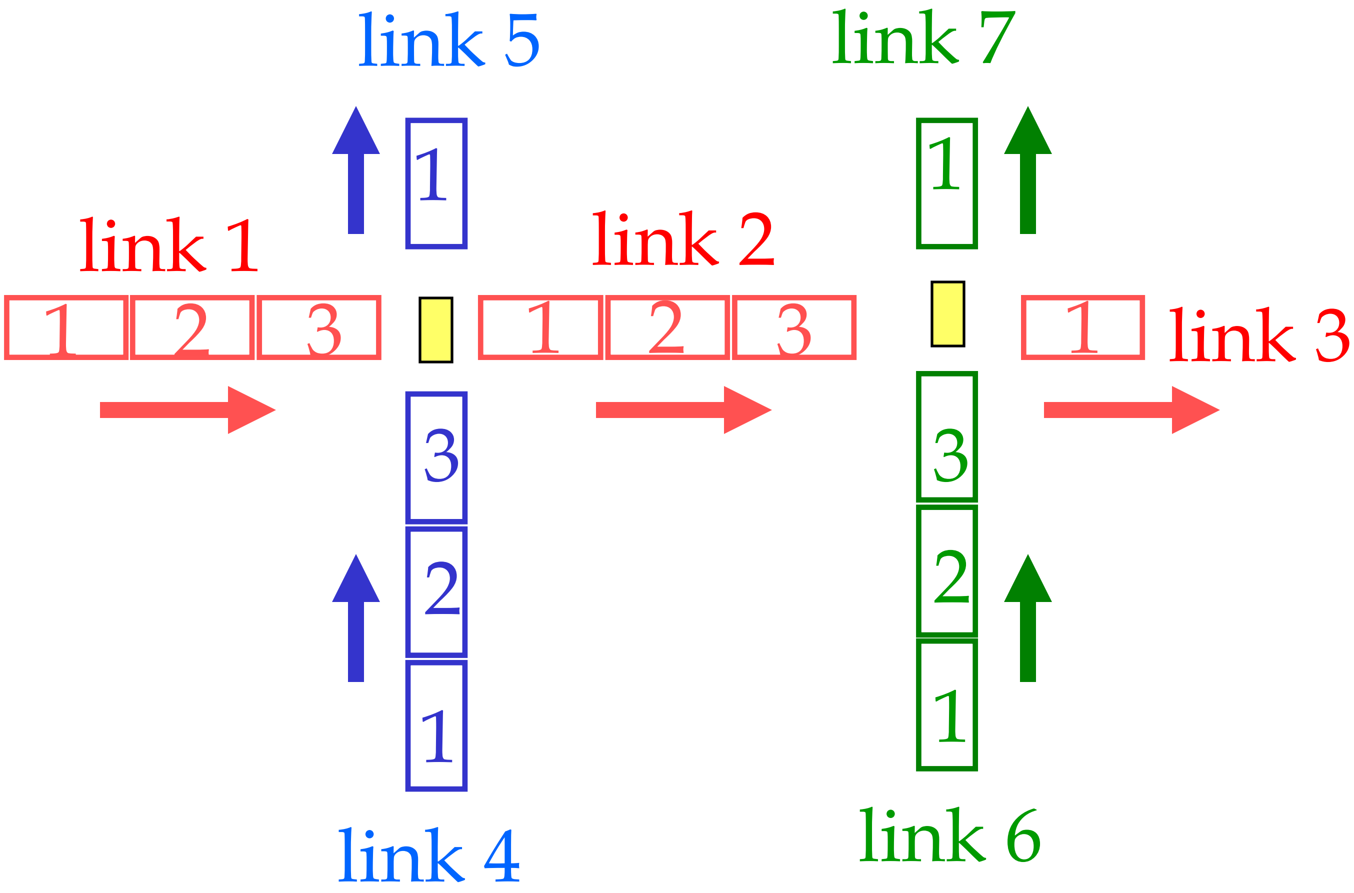
Model Components

- Cell-Transmission Model (Daganzo, 1994, 1995) (CTM) to model traffic dynamics
  - a convergent approximation to the Lighthill and Whitham (1955) and Richards (1956) (LWR) model
- Mixed-integer programming technique to incorporate CTM into a mathematical program

Simplified Flow-density Relationship



Network Example



Cell-Transmission Model: Basic conditions

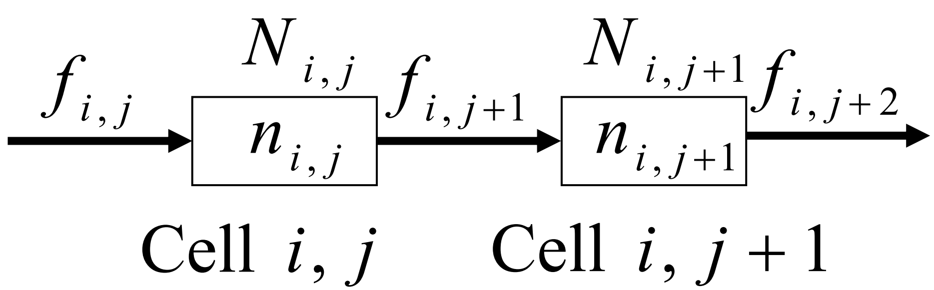
- Cell inflow equation:

$$f_{i,j+1}(t) = \min\left\{Q_{i,j+1}(t), n_{i,j}(t), \frac{W}{V}\left[N_{i,j+1}(t) - n_{i,j+1}(t)\right]\right\}$$

Inflow Capacity **Flow waiting** **Available space**

- Conservation condition for normal cell:

$$n_{i,j}(t+1) = n_{i,j}(t) + f_{ij}(t) - f_{i,j+1}(t)$$



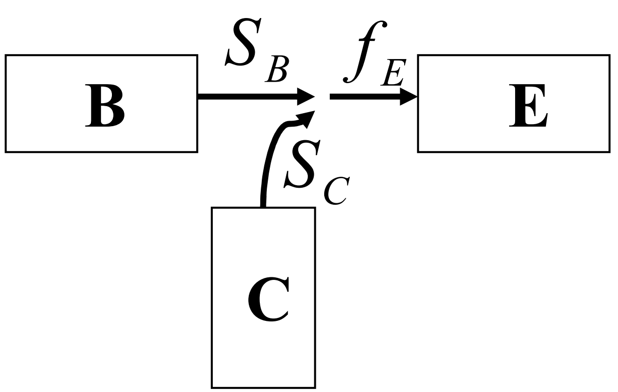
Cell-Transmission Model: Merges

- Conservation condition for merges:

$$S_C(t) = \min\{n_C(t), Q_C(t), \delta[N_E(t) - n_E(t)]\}$$

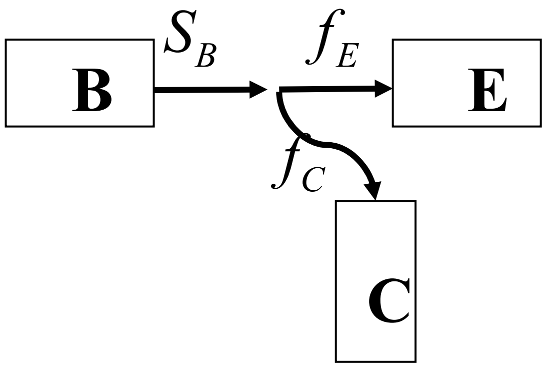
$$S_B(t) = \min\{n_B(t), Q_B(t), \delta[N_E(t) - n_E(t)]\}$$

$$f_E(t) = S_C(t) + S_B(t)$$



Cell-Transmission Model: Diverges

- Conservation condition for diverges:



$$S_B(t) = \min\left\{\begin{matrix} n_B(t) \\ Q_B(t) \\ \min\{Q_E(t), \delta[N_E(t) - n_E(t)] / \beta_E\} \\ \min\{Q_C(t), \delta[N_C(t) - n_C(t)] / \beta_C\} \end{matrix}\right\}$$

$$f_C(t) = \beta_C \cdot S_B(t)$$

$$f_E(t) = \beta_E \cdot S_B(t)$$

Signal Control Formulation (1)

- Objective function: minimize delay

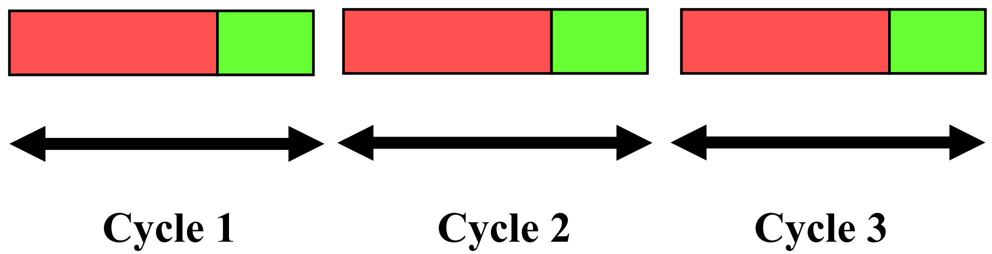
$$J = \min_{g,\,r} \sum_{t} \sum_{i \notin \mathrm{E}} \sum_{j} n_{ij}(t) - f_{ij}(t)$$

- Dynamic Demand:

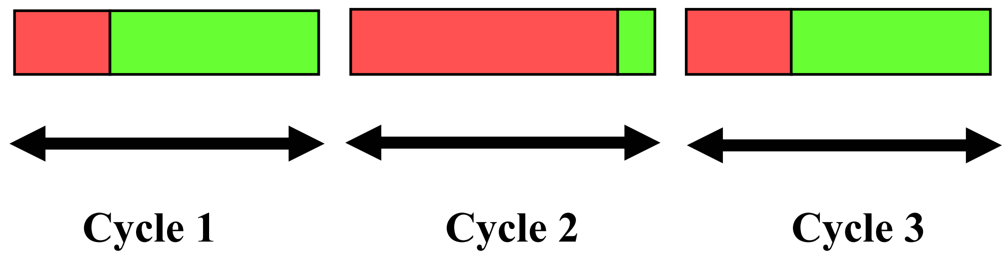
$$Q_{i2}(t) = D_i(t) \quad i \in \Omega$$

Signal control methods

Fixed Green
Fixed Cycle (FGFC)

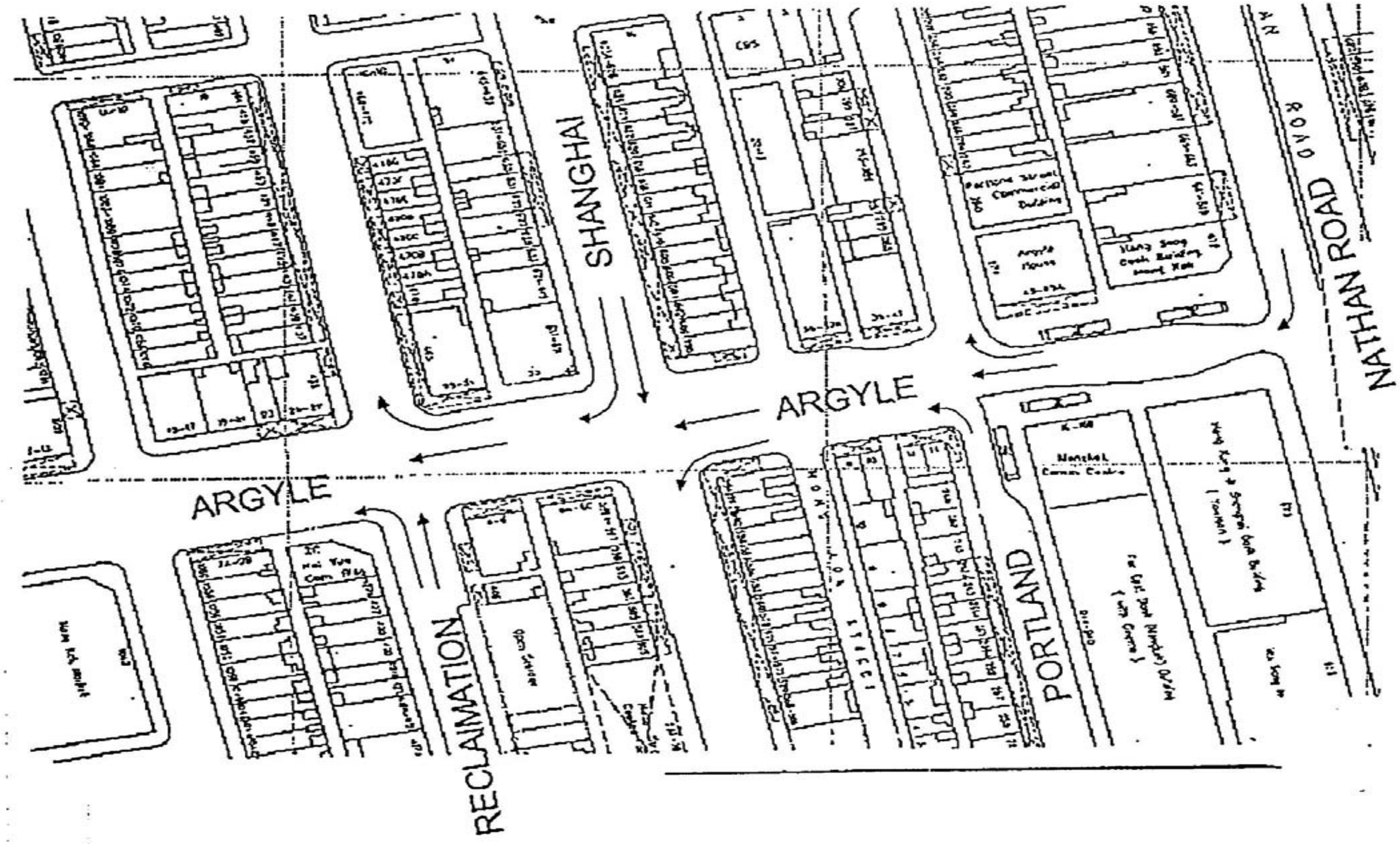


Variable Green
Fixed Cycle (VGFC)

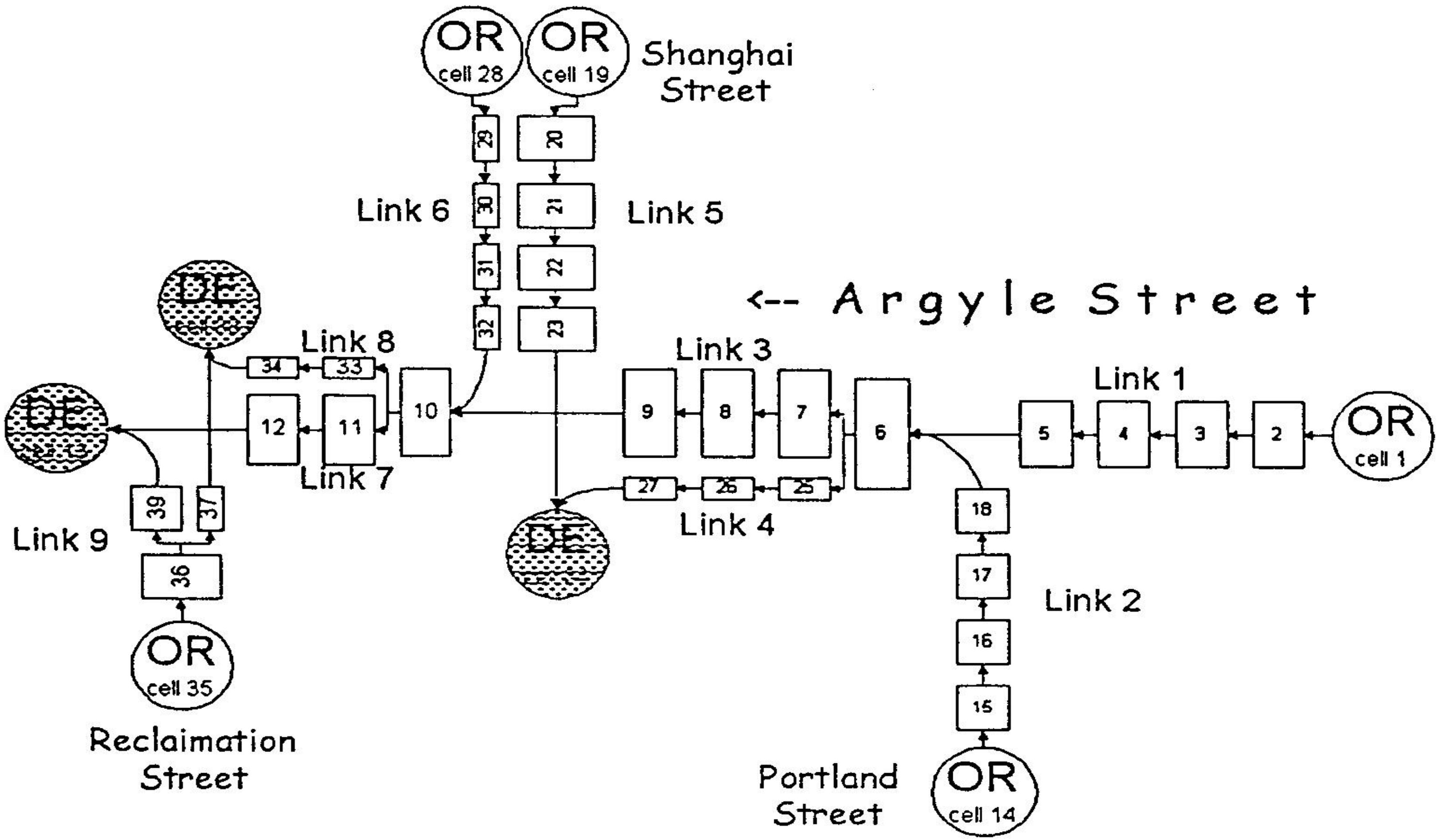


Variable Green
Variable Cycle (VGVC)

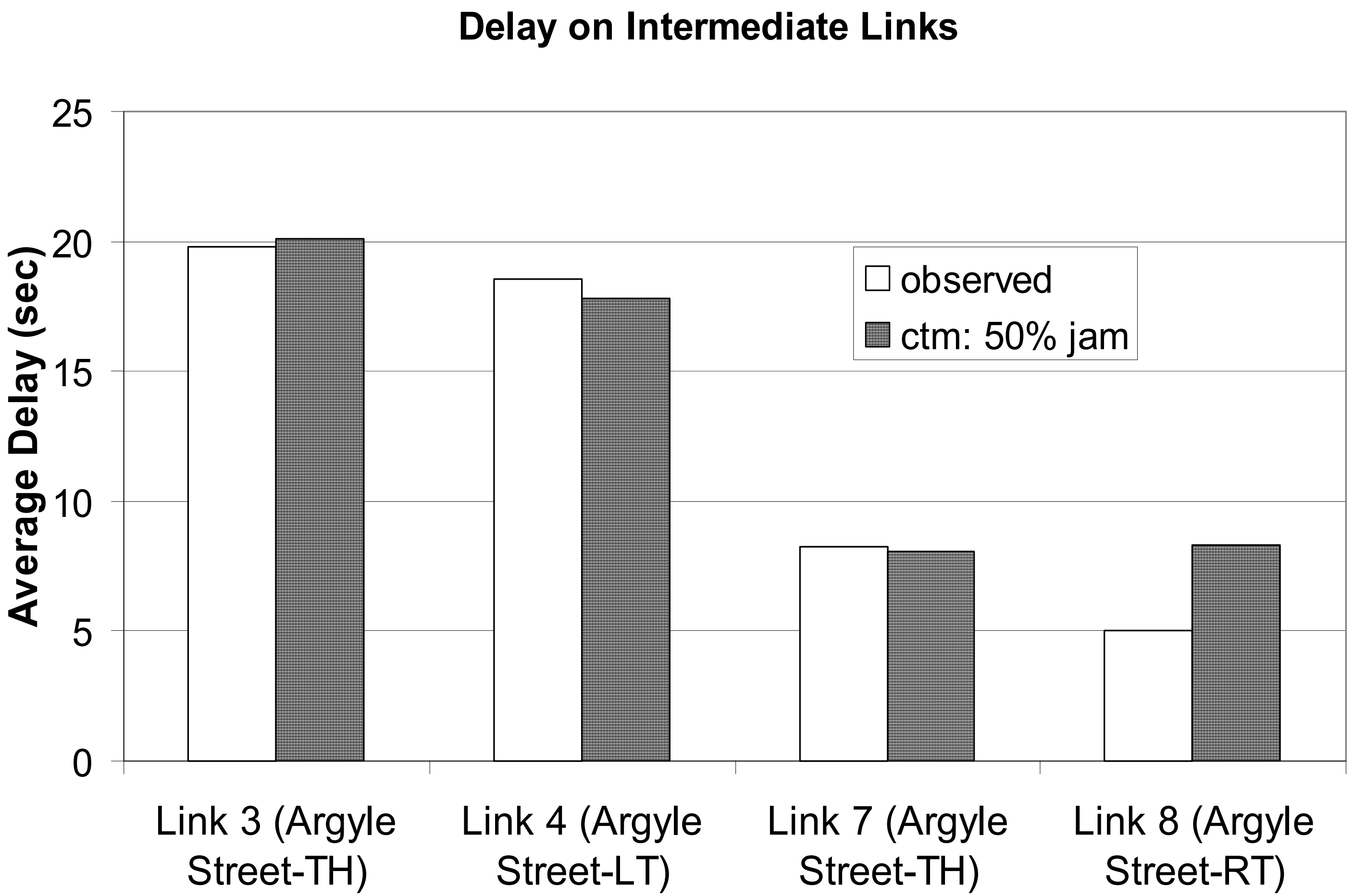
Test Site: Mong Kok



Model Construction

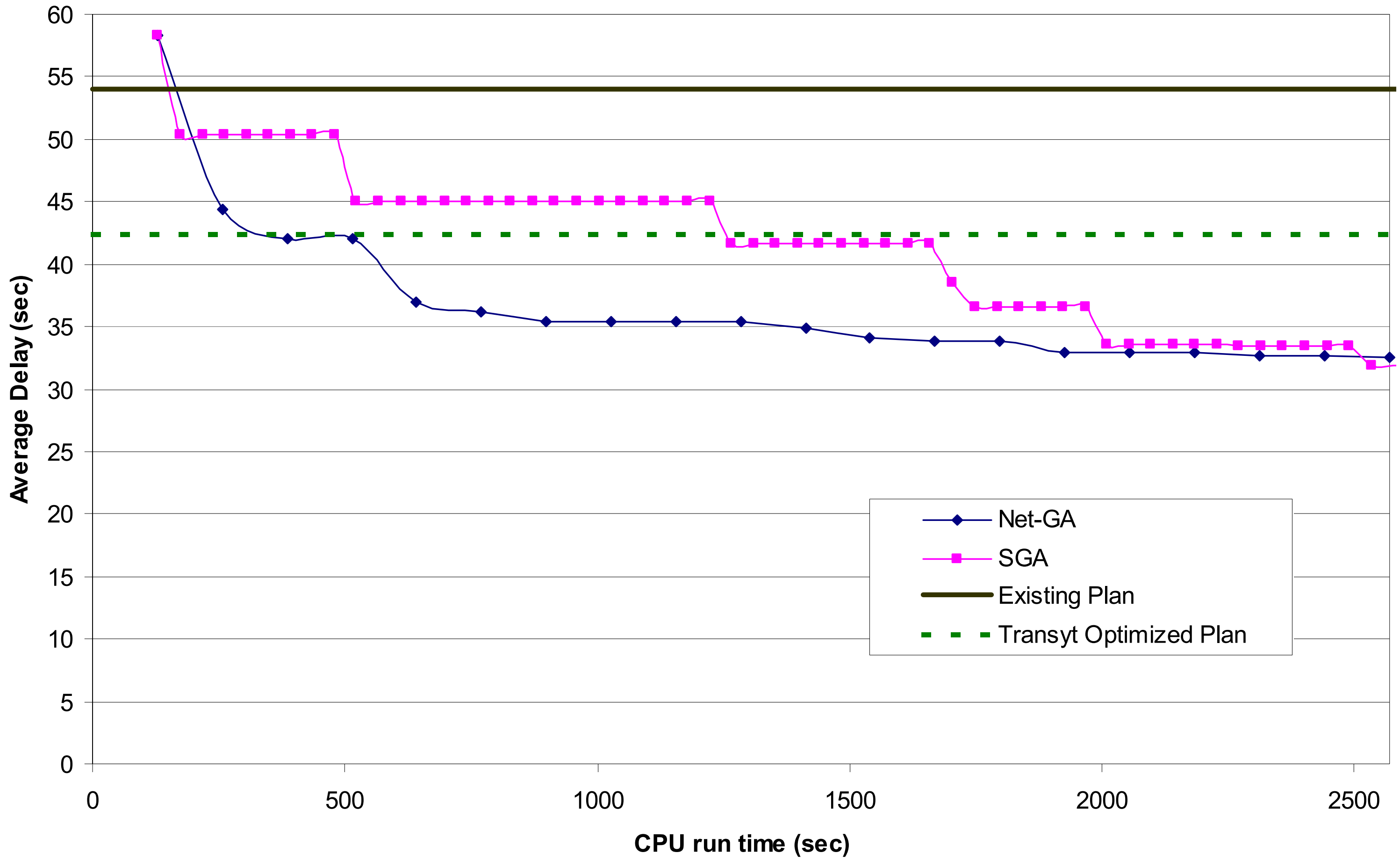


Model Validation



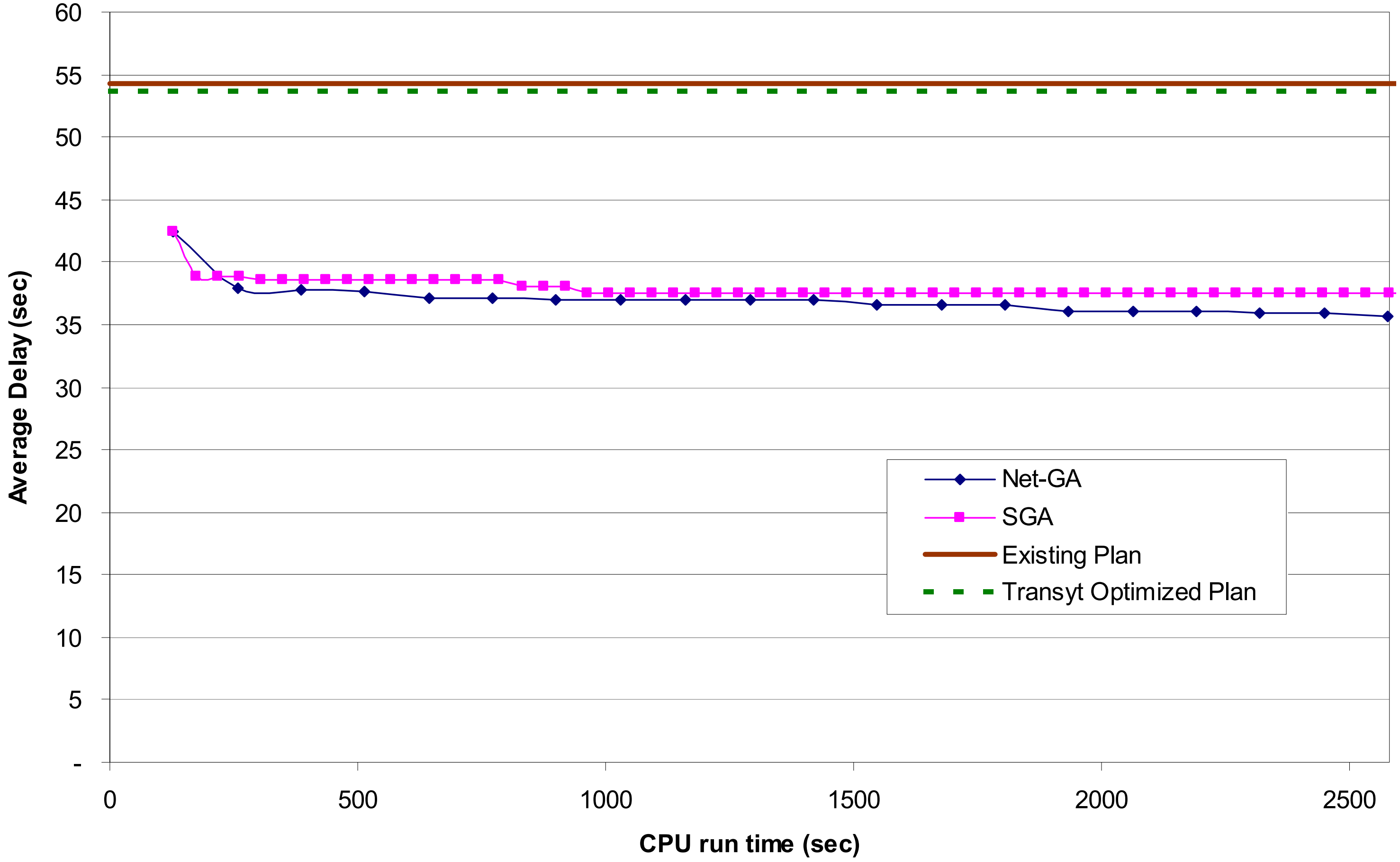
Results: Uncongested Case

Figure 5-6: Average Delay
Uncongested Flow, 50% initial cell occupancy (unc50)

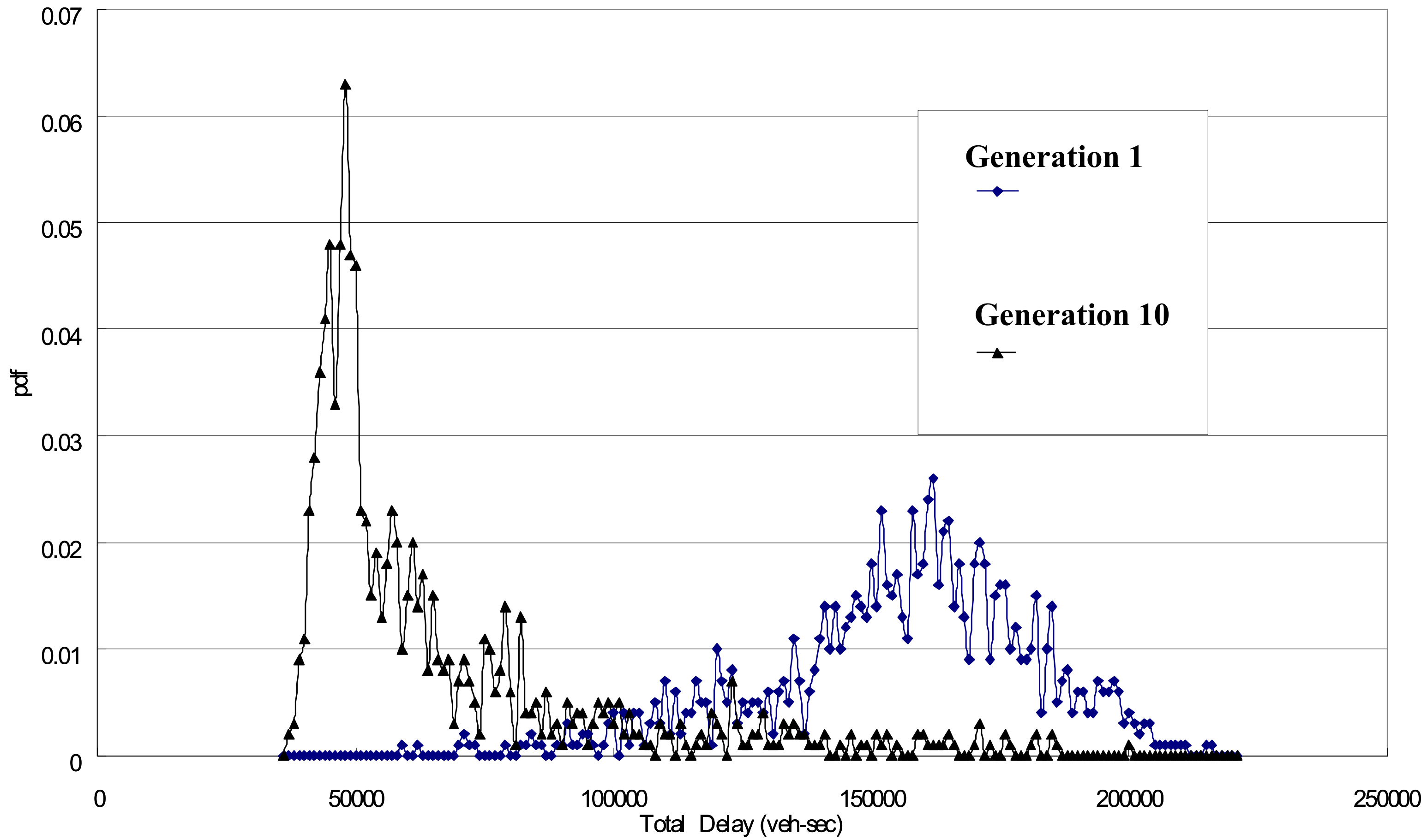


Results: Congested Case

Figure 5-3: Average Delay
Congested Flow, 100% initial cell occupancy (con100)



Performance of Genetic Algorithm



Results

Delay (veh-hr)	Existing	FGFC	VGFC	VGVC
Fixed Demand	12.0	7.5	7.4	7.4
Time-variant Demand	14.9	10.1	10.0	10.0
Halfly-preloaded	19.5	11.5	11.3	10.9
Fully-preloaded	50.5	34.6	34.3	33.8

% change	Existing	FGFC	VGFC	VGVC
Fixed Demand	0.0	37%	38%	38%
Time-variant Demand	0.0	32%	33%	33%
Halfly-preloaded	0.0	41%	42%	44%
Fully-preloaded	0.0	32%	32%	33%

Conclusions

- DISCO works for all traffic conditions
- DISCO has superb performance for congested traffic
- DISCO shows promise as a future dynamic traffic control system