Optimizing Traffic Signal Timings to Reduce Fuel Consumption

Florida Energy Systems Consortium

Aleksandar Stevanovic, PhD, PE

Tampa, FL
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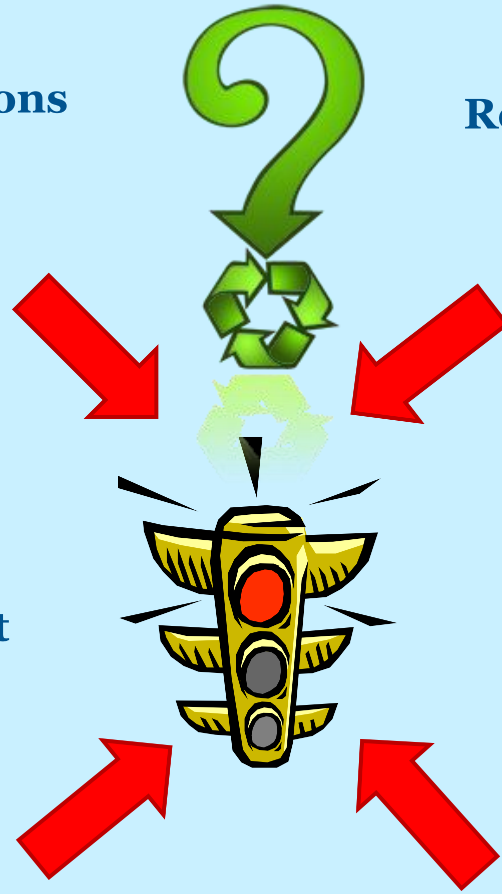
Sustainable Transportation

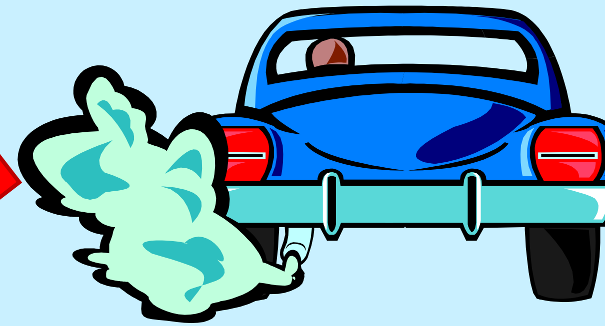
- Moves people, goods and information in ways that reduce its impact on the environment, the economy, and society.
- Promotes non-traditional ways of transport such as public transport, cycling and walking facilities.
- Advocates reduction in fuel consumption and use of cleaner fuels and technologies.

Challenges of Sustainable Traffic Control

Improve Pedestrian Operations

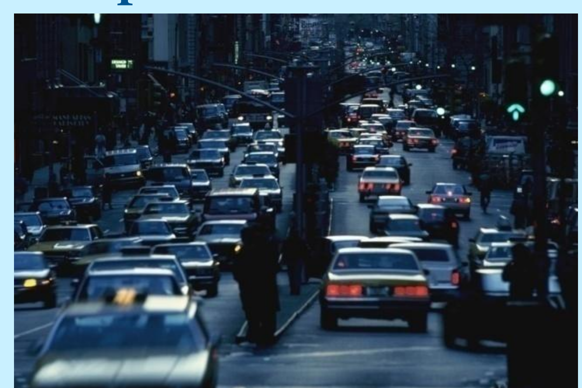


Reduce Vehicular Emissions

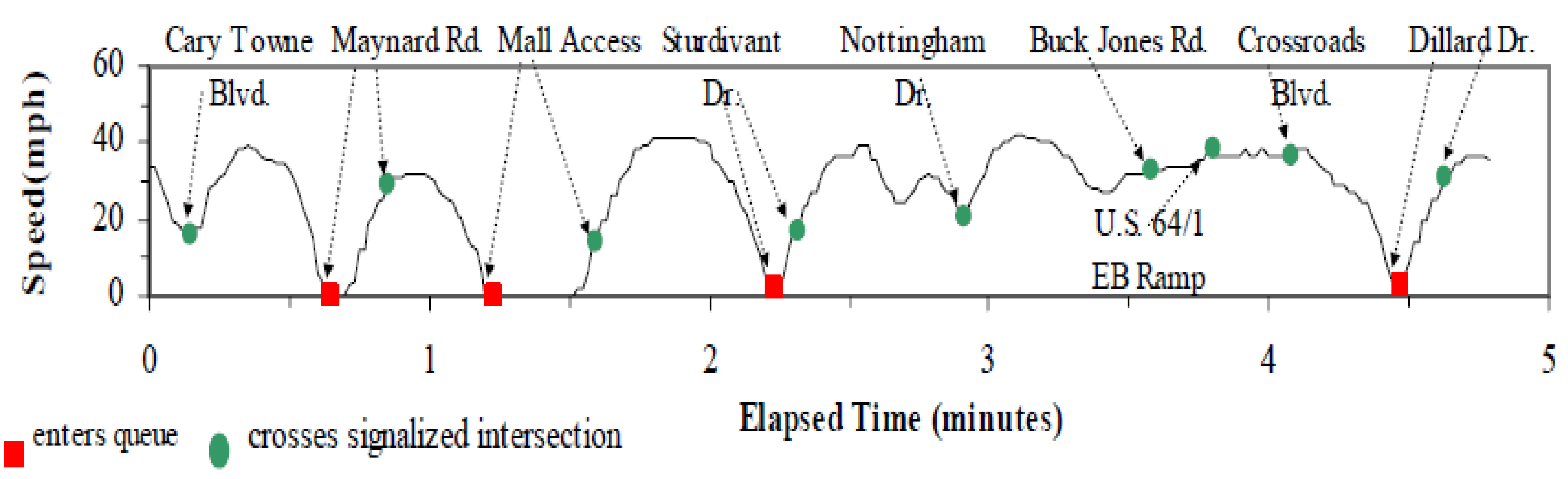


Provide Priority for Transit

Improve Traffic Flow

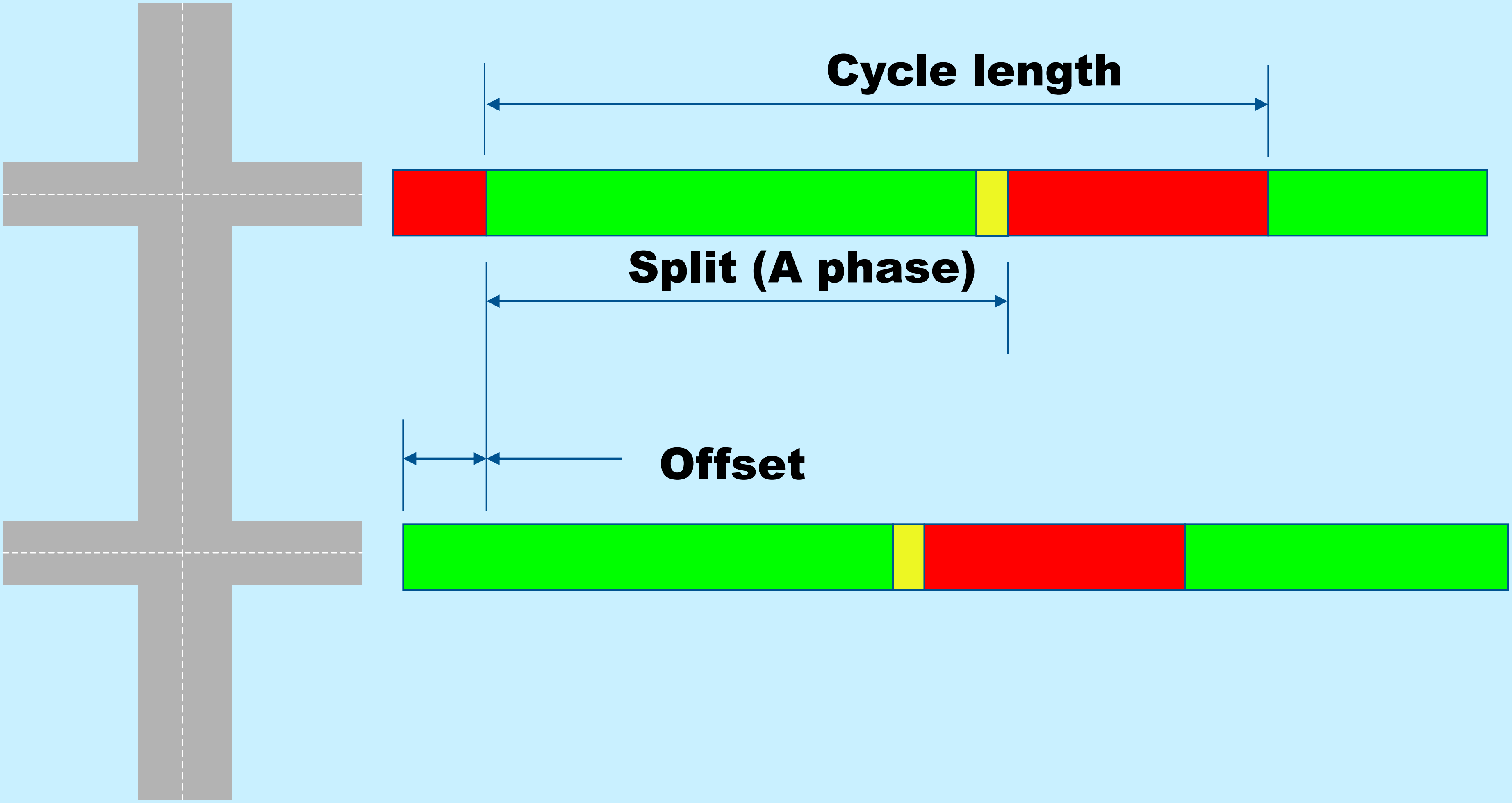


Arterial Speed Profile & Fuel Consumption



- Objectives for Minimal Fuel Consumption
  - Minimal delay (waiting time)
  - No stops
  - Uniform speed ~ 35-45 mph

Signal Timing Parameters



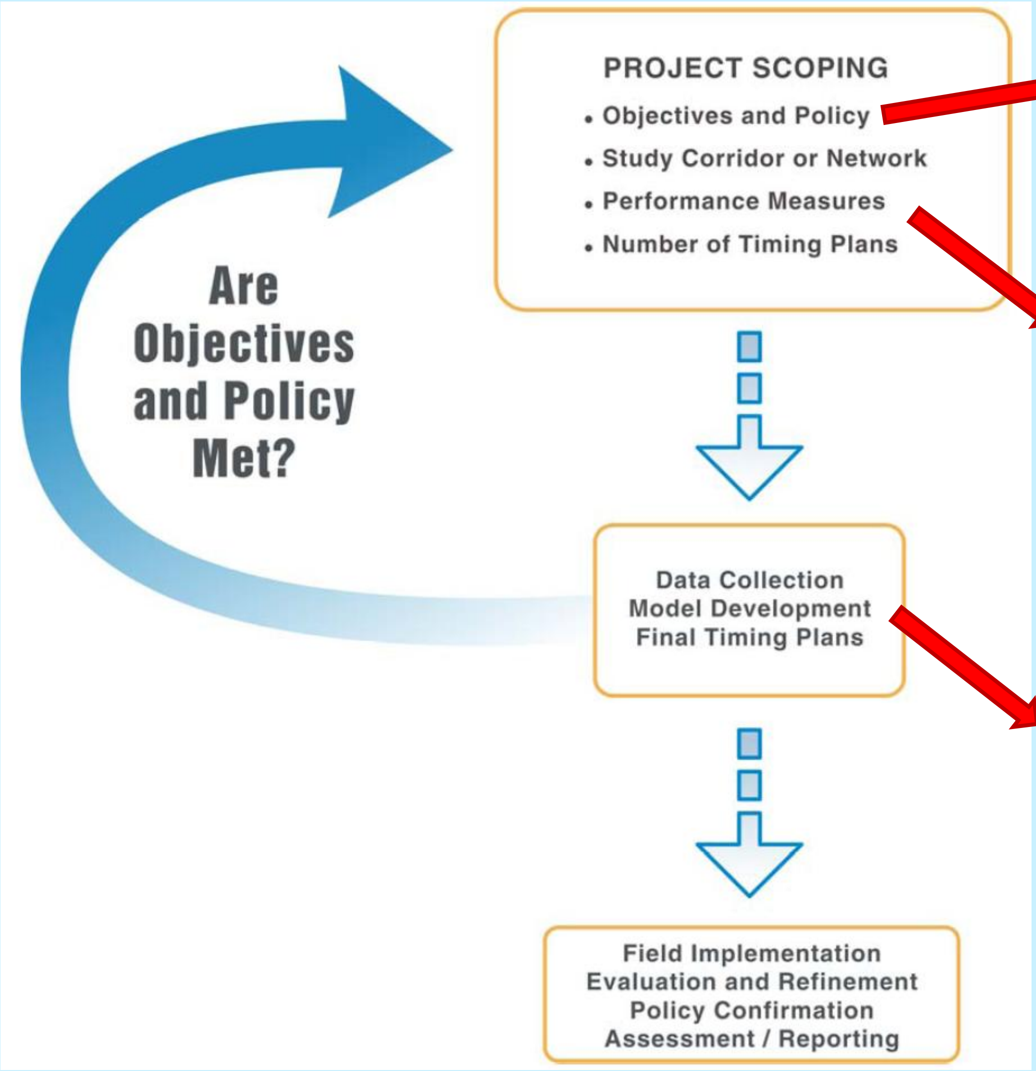
Fuel Consumption & Traffic Signals

- Cycle Lengths
  - Higher CL provide more capacity but cause more delays per each vehicle in the network (+ FC)
  - Very low CL cause extreme delays (++ FC)
- Splits

  Should be equivalent to the demand for each movement (phase) – if inappropriate cause cycle failure – a vehicle needs to wait for one more cycle (+ FC)
- Offsets

  Impact progression (# of stops) of the major traffic movements between intersections – the most important parameter to reduce FC

Scoping of a Signal Timing Project



Do we have right objectives and policies?
No, sustainable policies to consider – transit, emissions, person-based costs, etc.

Do we (always) know what performance measures to use?
No, we use surrogate performance measures (in lieu of emission-related metrics)

Can current models support our goals?
No, we need better models and better interface between models and field operations

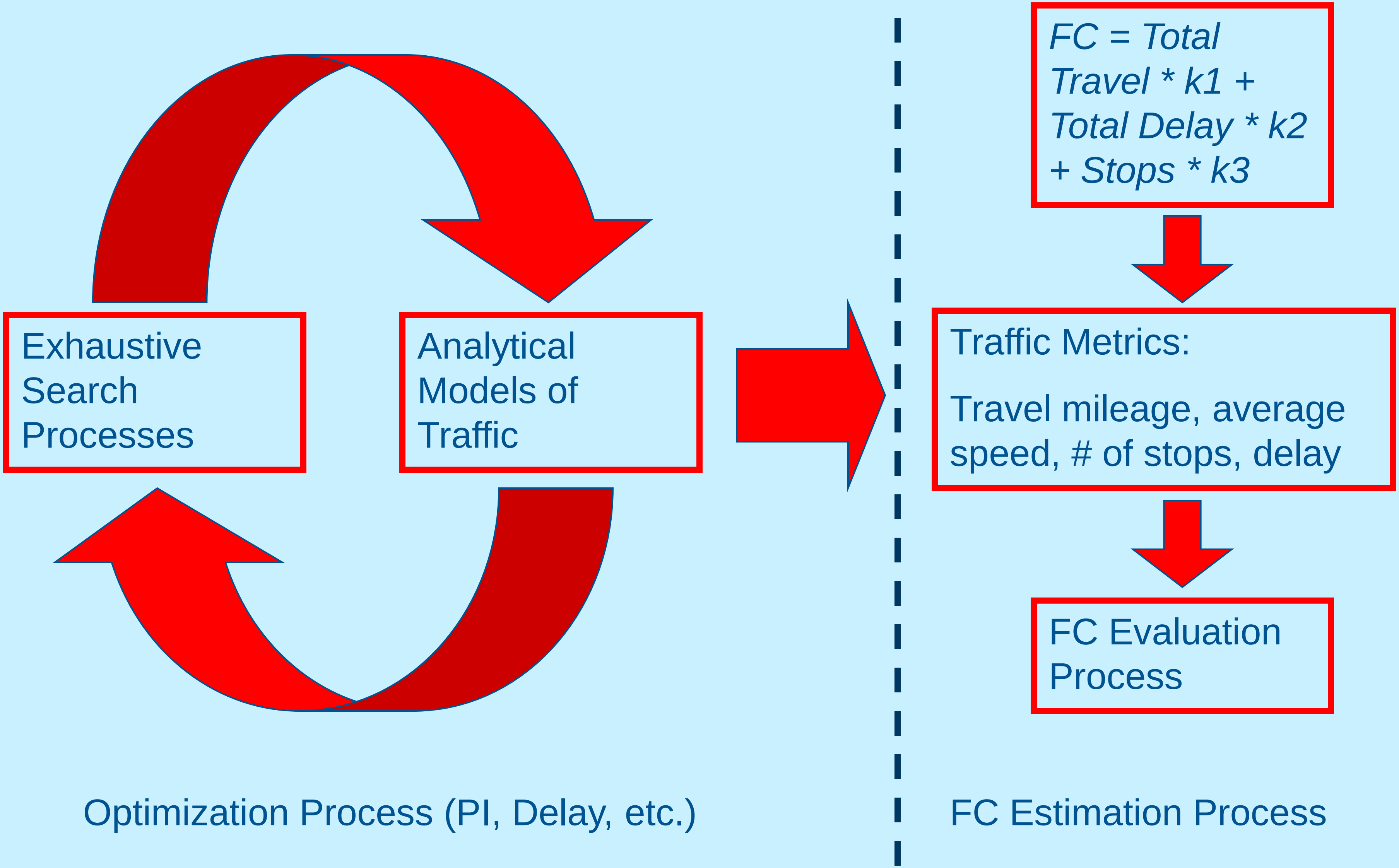
Source: Signal Timing Manual, FHWA 2008

Early Research on Minimizing FC

Robertson, D.I., Lucas, C.F., Baker, R.T. (1980). "Coordinating traffic signals to reduce fuel consumption." Transport Research Laboratory (TRL) Report – LR934

- Concept of Performance Index – PI = Delay + W* Stops
- Lowest FC achieved when a stop is worth 40 seconds of waiting time (delay) (Robertson et al.)
- Signal timings optimized (in TRANSYT 8) to minimize fuel consumption
- Benefits of such signal timings may decrease fuel consumption by up to 3%
- FC estimated from its linear relationship with delay, stops, and average speed

FC Estimation in Current Tools



Current Practice

- Tools: SYNCHRO & TRANSYT-7F (and similar)
- Macroscopic and analytical tools (no individual driving behavior)
- FC not used as an objective function in optimization
- Very simplistic relationships between overall traffic activity in the area and fuel consumption
- FC not based on cyclical engine loads
- No ability to account for various vehicular technologies (new vs old) and different vehicle types (heavy, diesel, …)
- …

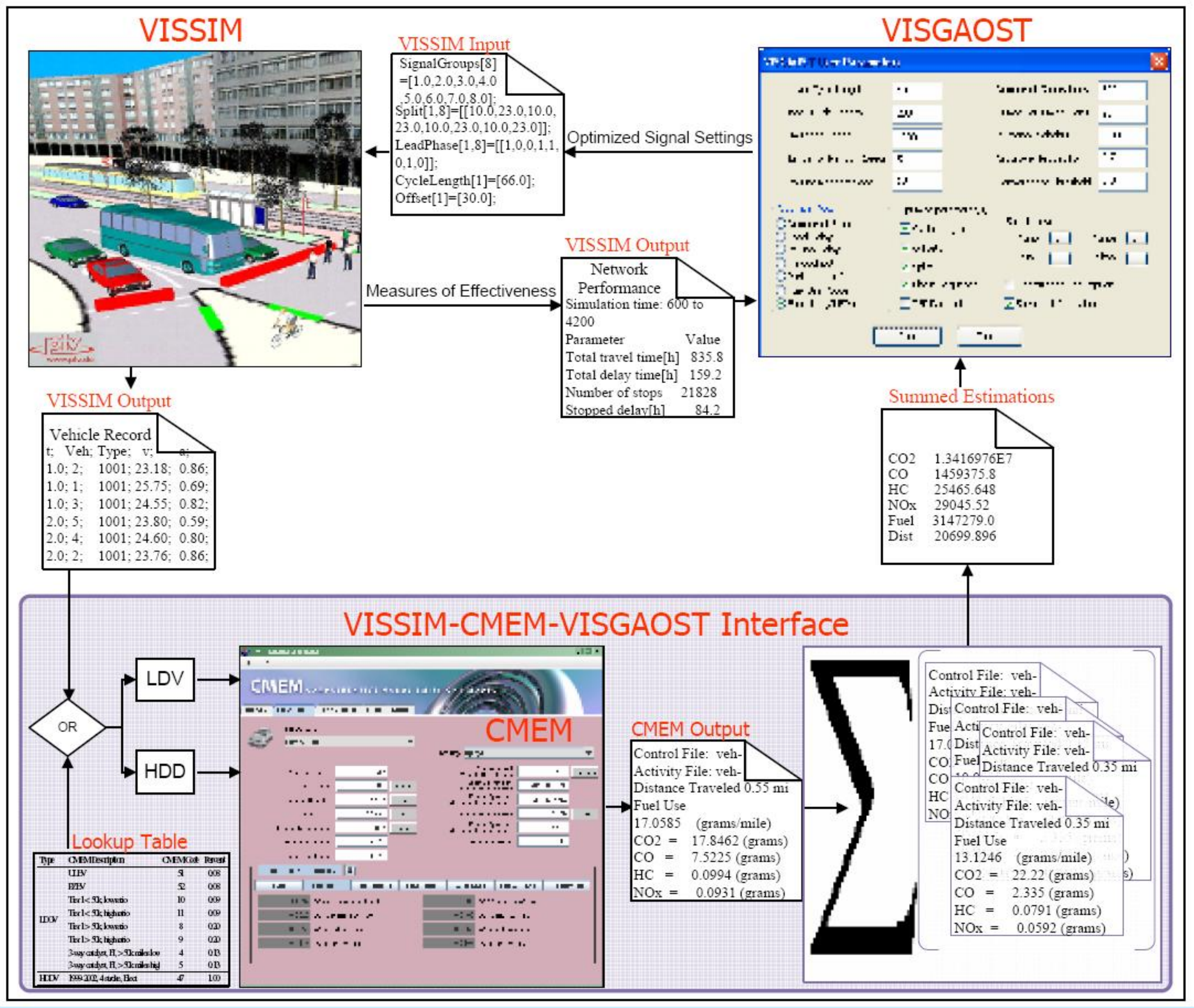
Current Practice – Fuel Consumption

- *FC = Total Travel * k1 + Total Delay * k2 + Stops * k3*

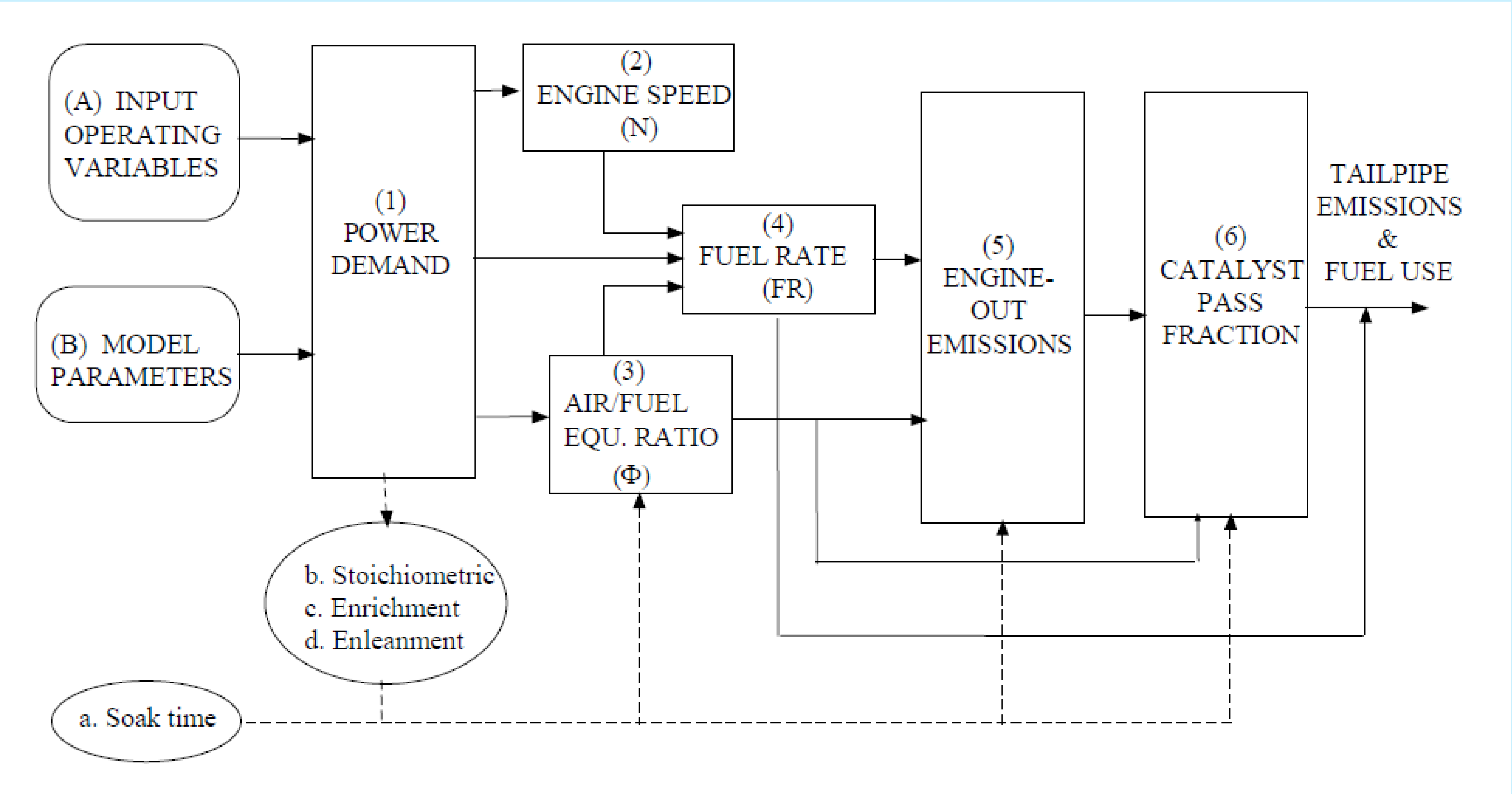
- k1 = 0.075283 - 0.0015892 * Speed + 0.000015066 * Speed^2
- k2 = 0.7329
- k3 = 0.0000061411 * Speed ^ 2

- FC= Fuel Consumption [gal]
- Speed = Cruise speed [mph]
- Total Travel = Vehicle-miles traveled [veh-mil]
- Total Delay = Total signal delay [hours]
- Stops = Total stops [veh/hour]

VISSIM-CMEM-VISGAOST Integration



Comprehensive Modal Emission Model



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FC & Emission Scenarios in CMEM

- Stoichiometric Cruise Section
- Constant Power Section
- Constant Acceleration Section
- Air Conditioning Hill Section
- Repeat Hill Cruise Section

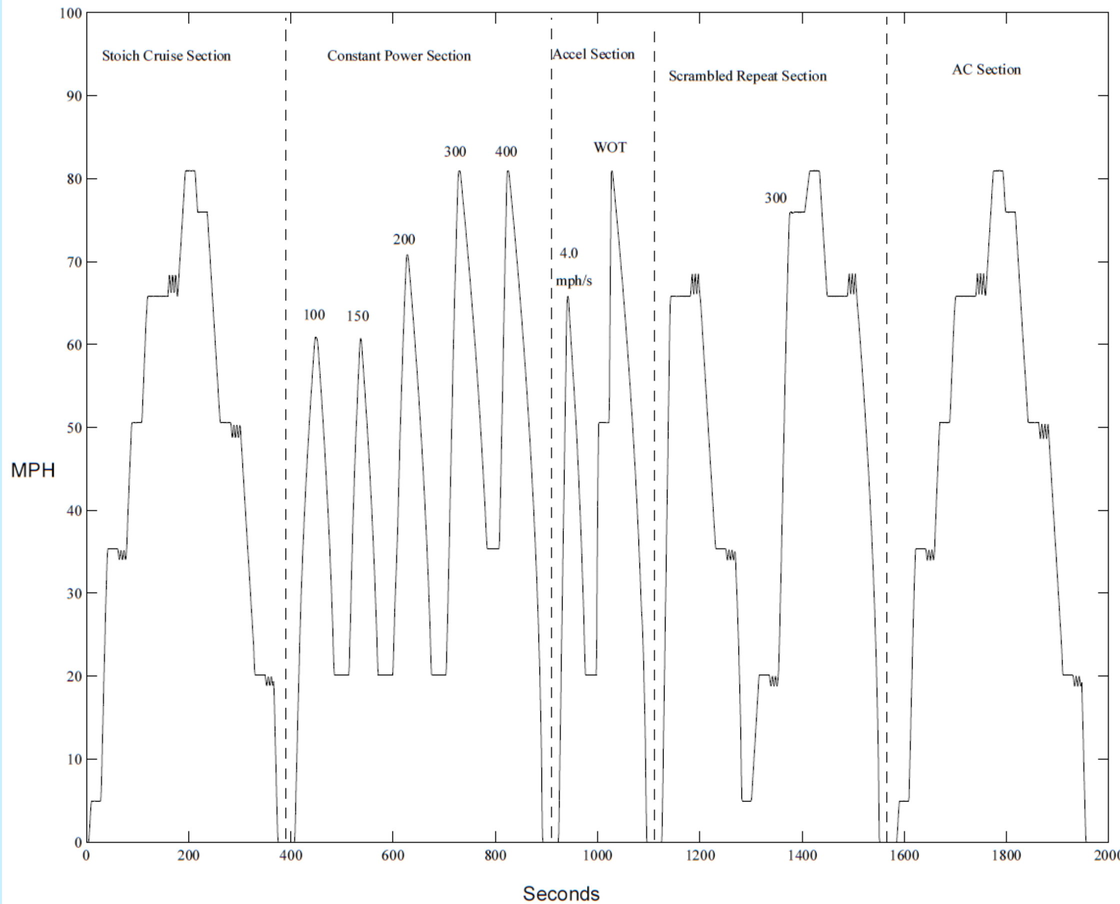
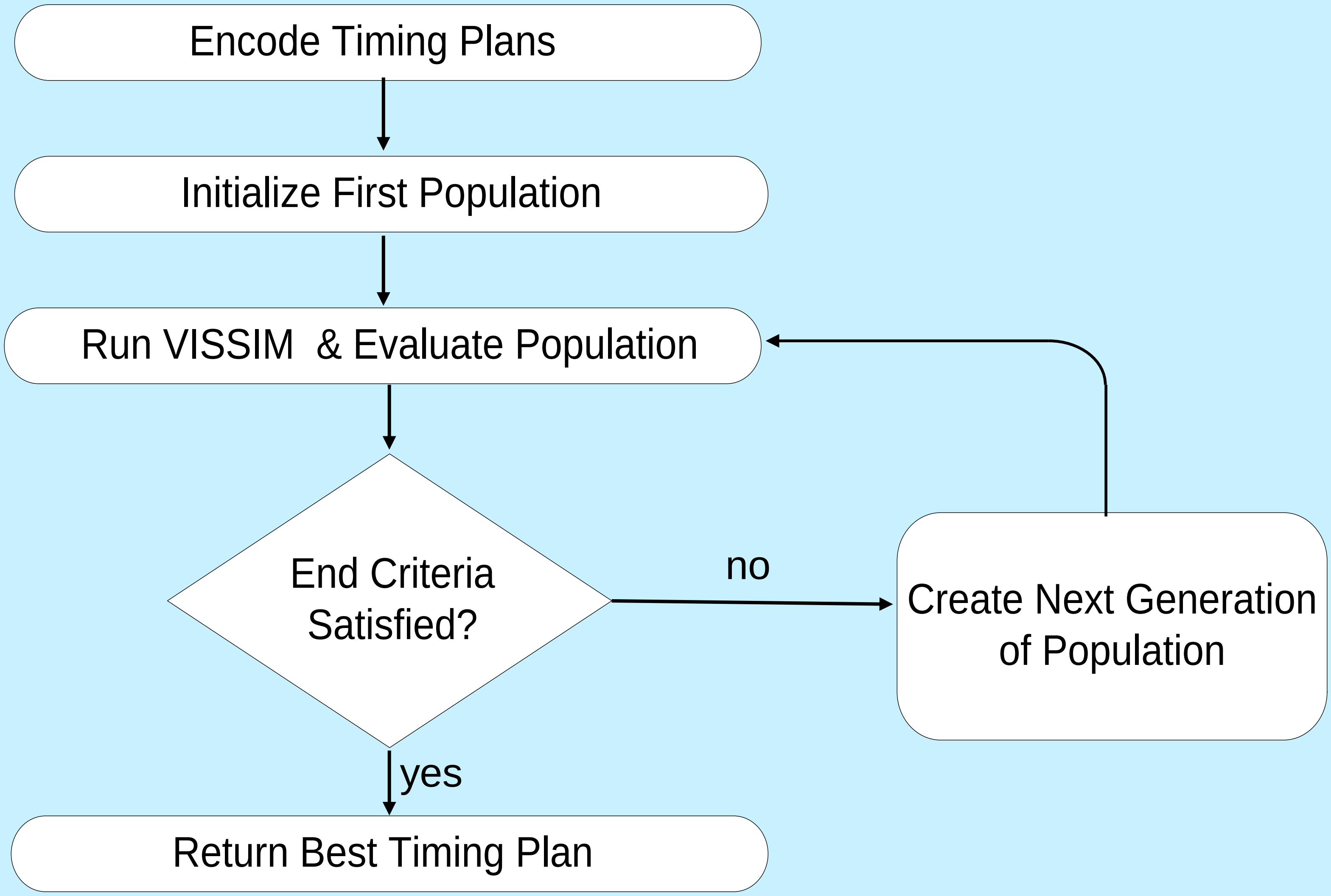
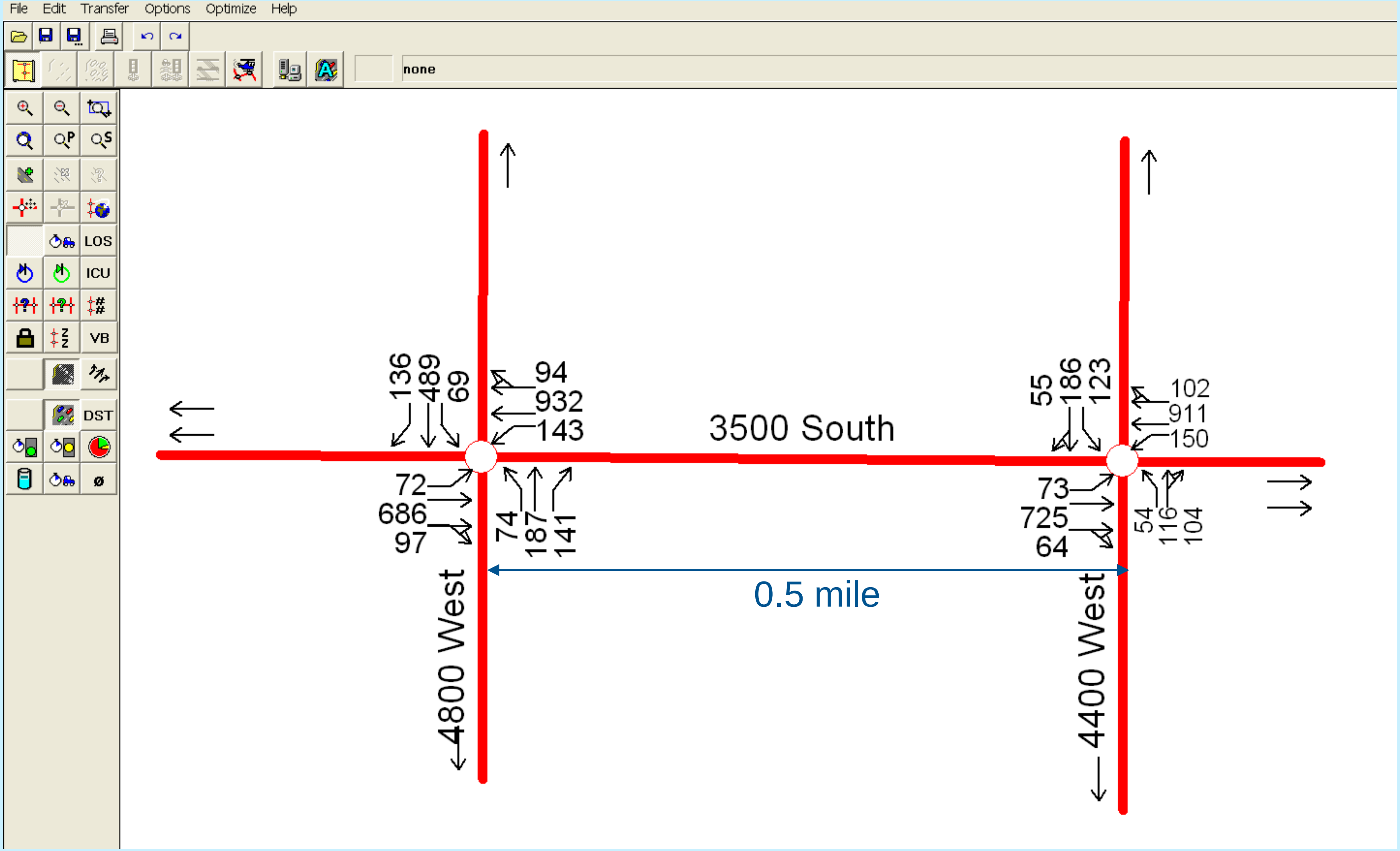


Figure 2.4. MEC01 version 7.0 modal emission cycle.

VISGAOST – Basic Steps



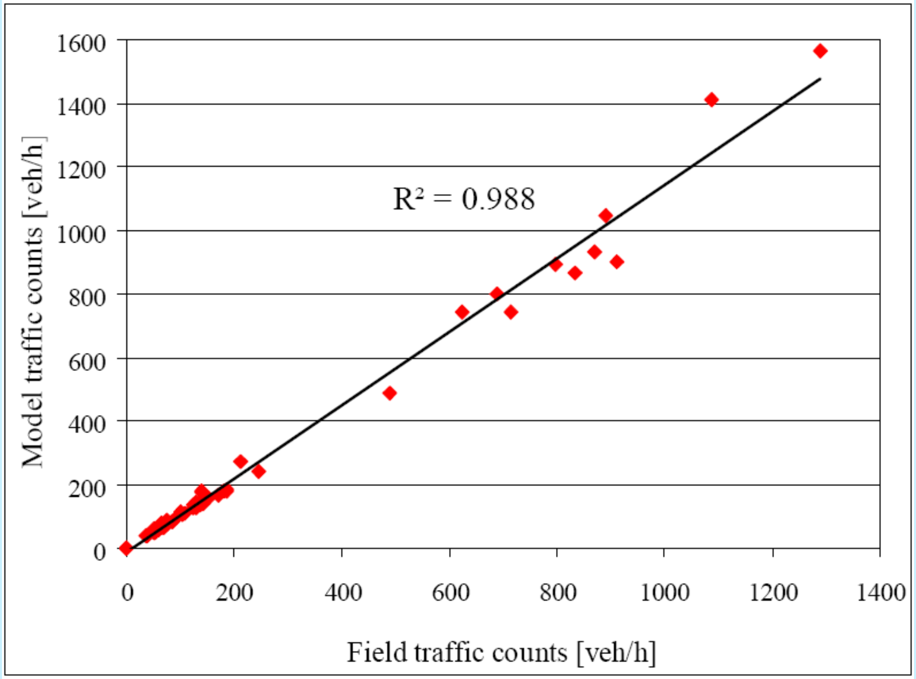
Test-bed Network

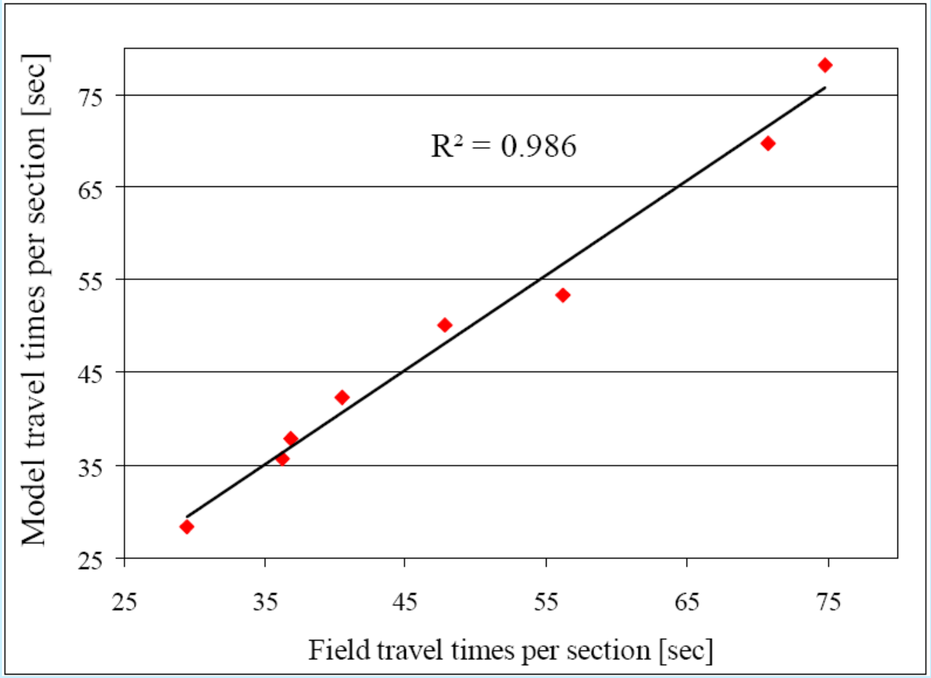


Why 2-intersection Network?

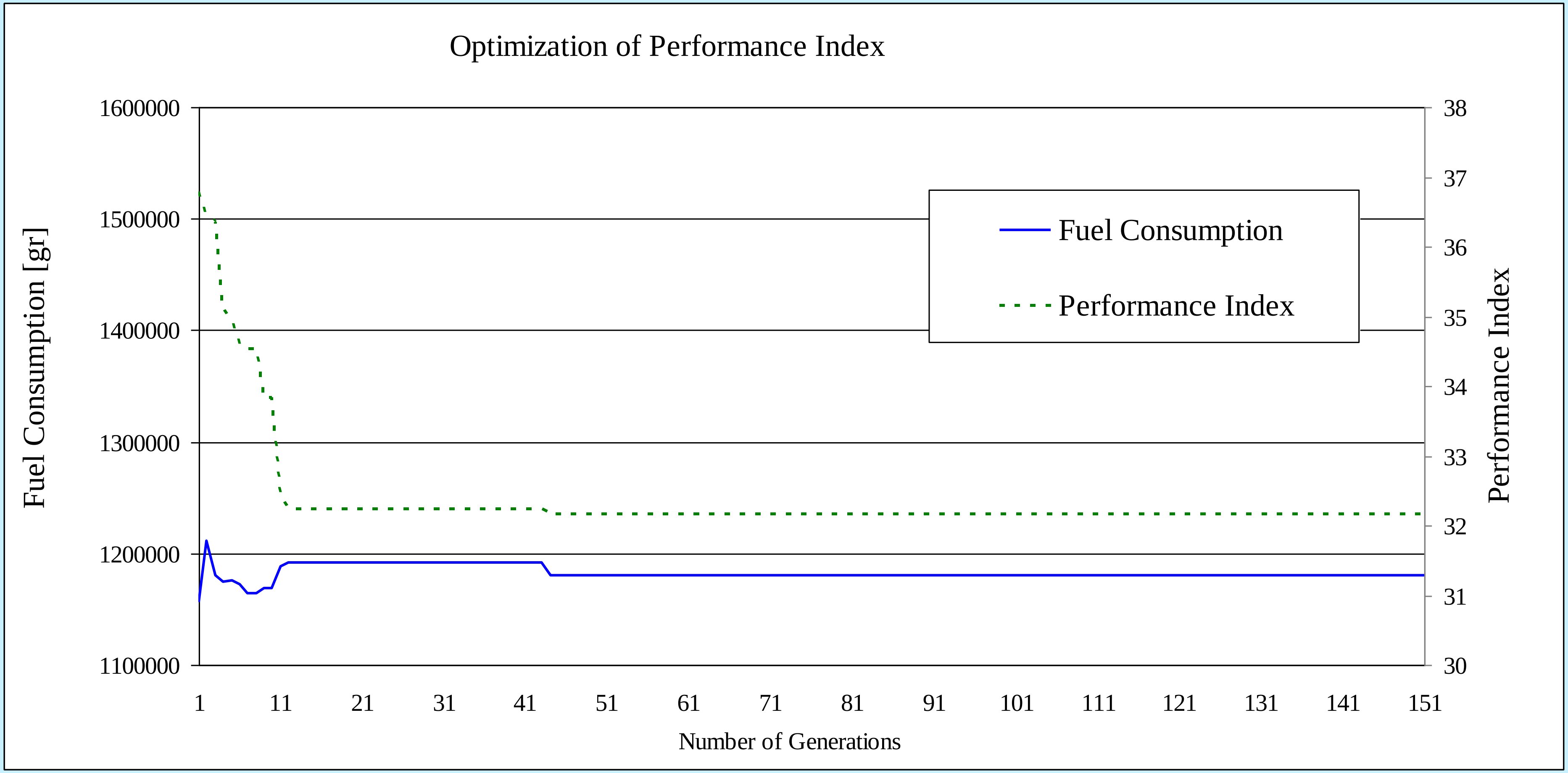
- Simplest coordinated operations
- Low number of signal timings to optimize
  - Short computational time - increased chances to find an ‘optimum’ (local or global)
  - Ability to understand what is going on after an optimal solution is found
- Properly calibrated and validated network
- Relatively heavy side-street traffic
- Different speeds on main & side streets

Calibration & Validation Results

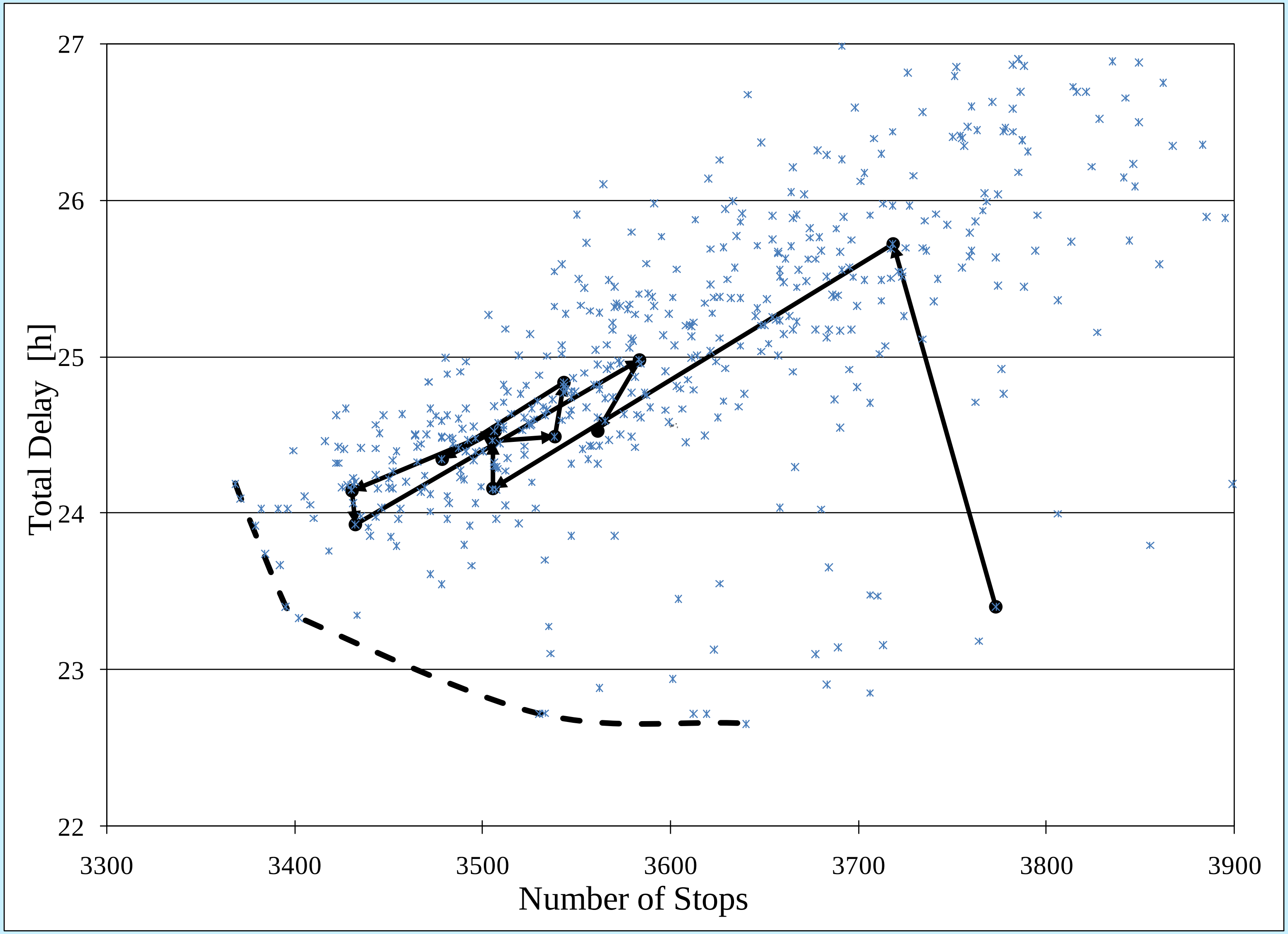




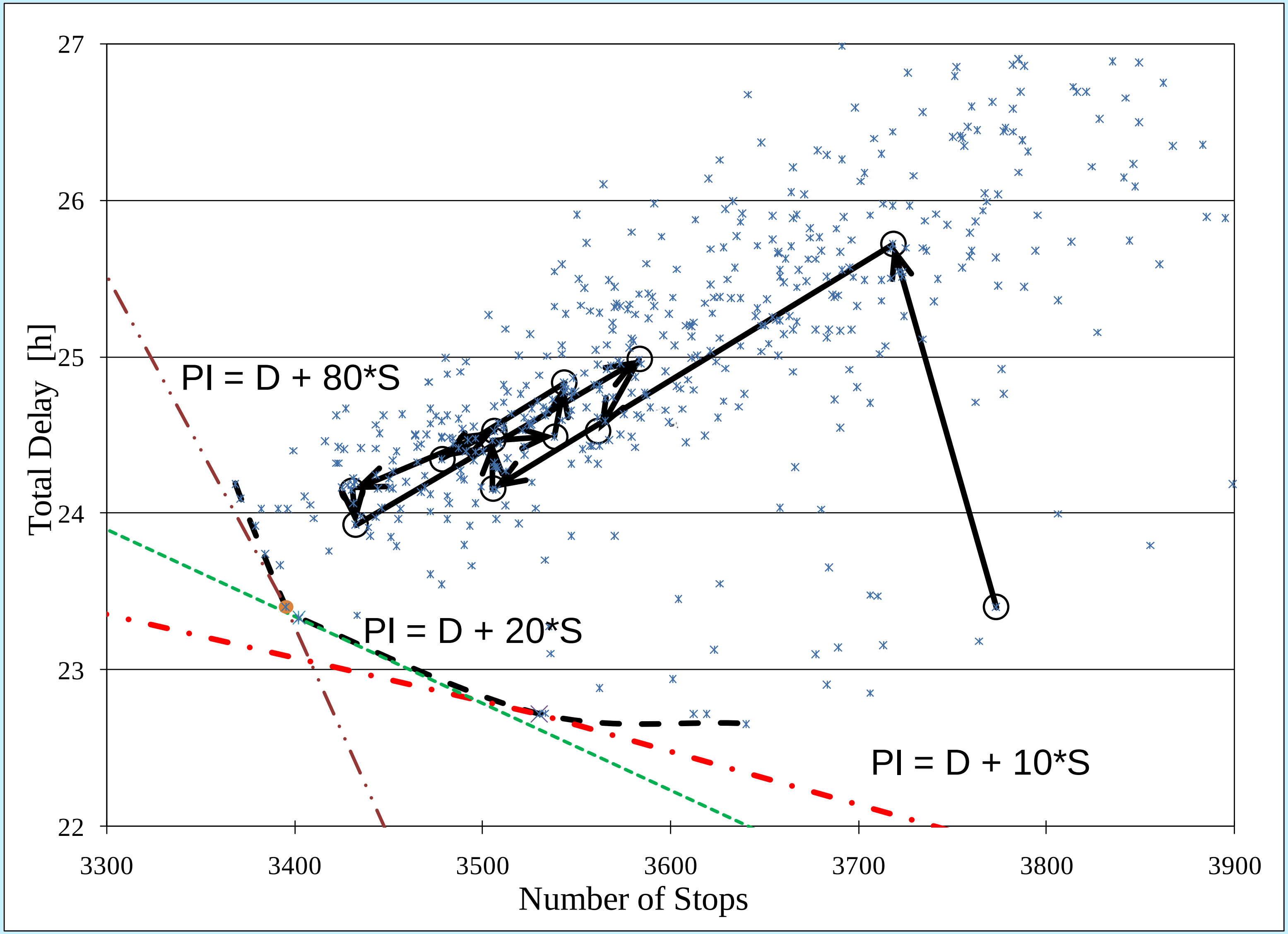
FC Change during PI Optimization



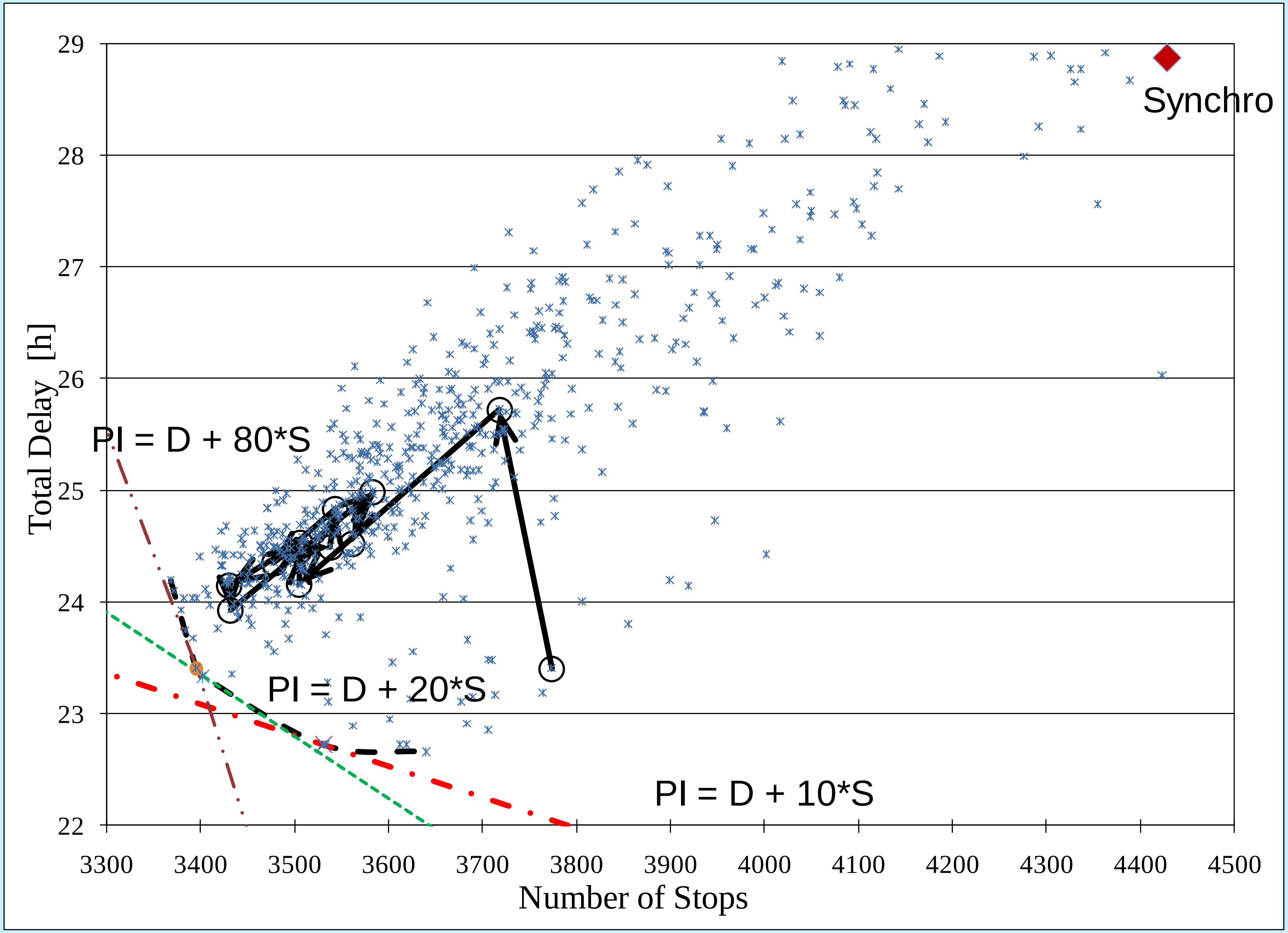
Optimizing FC in Delay & Stops Space



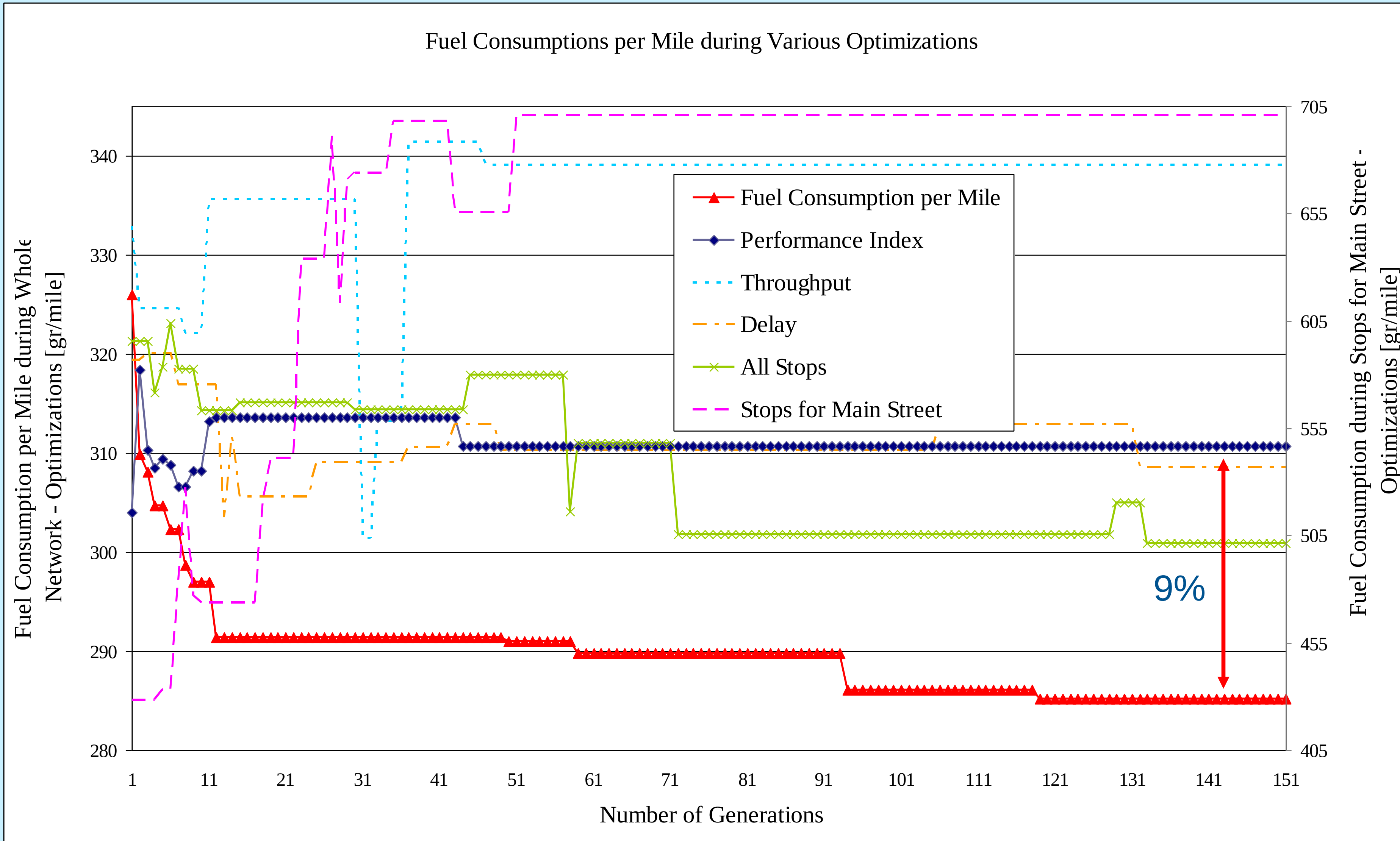
PIs with various weights for stops



Delay & Stops for Synchro's Solution



Various Objective Functions – Minimize FC



Conclusions

- FC can be reduced 5-10% when FC is minimized (used as an objective function) instead of minimizing surrogate performance measures
- FC for each case might be unique, and depends on:
  - Side-street and main street: traffic volumes and speed limits
  - % of heavy vehicles, terrain, AC usage, …
- FC optimizations very time consuming
- Need to investigate if there is a better surrogate performance measure
- Interest to reduce FC in traffic community still low

The End

Questions & Comments?