On Simulation and Optimization of Freeway Network Operations

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Progress from last PSG meeting

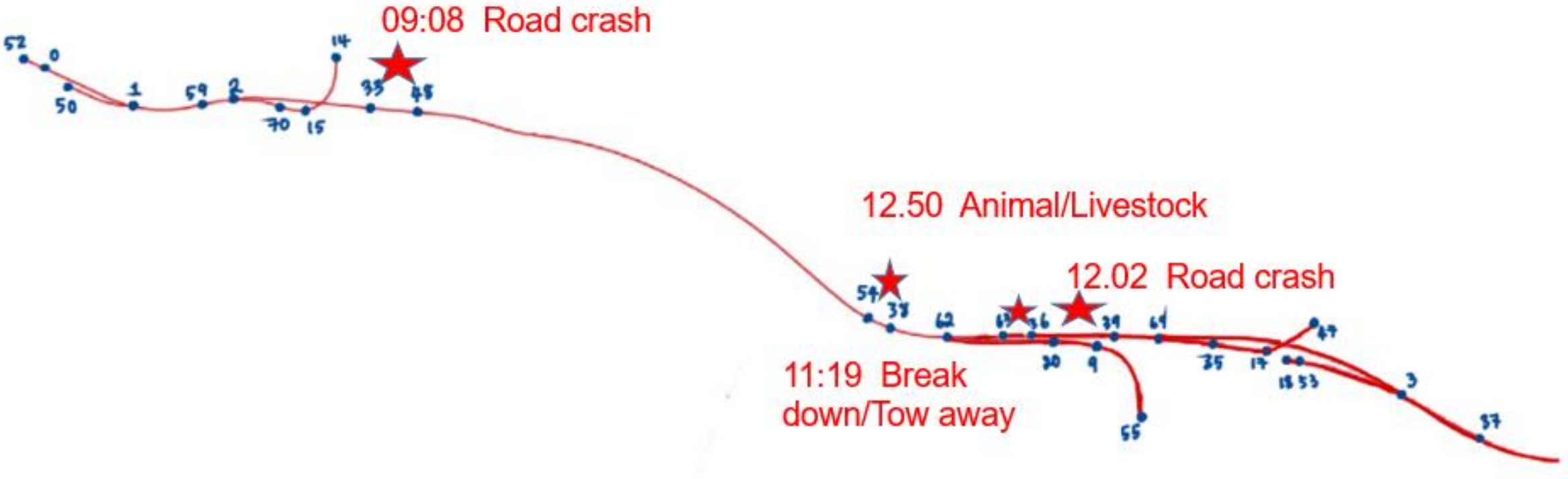
I. VSL and RM Control in a Scenario with lane closure due to non-recurrent events

II. Traffic Control Interface in SUMO

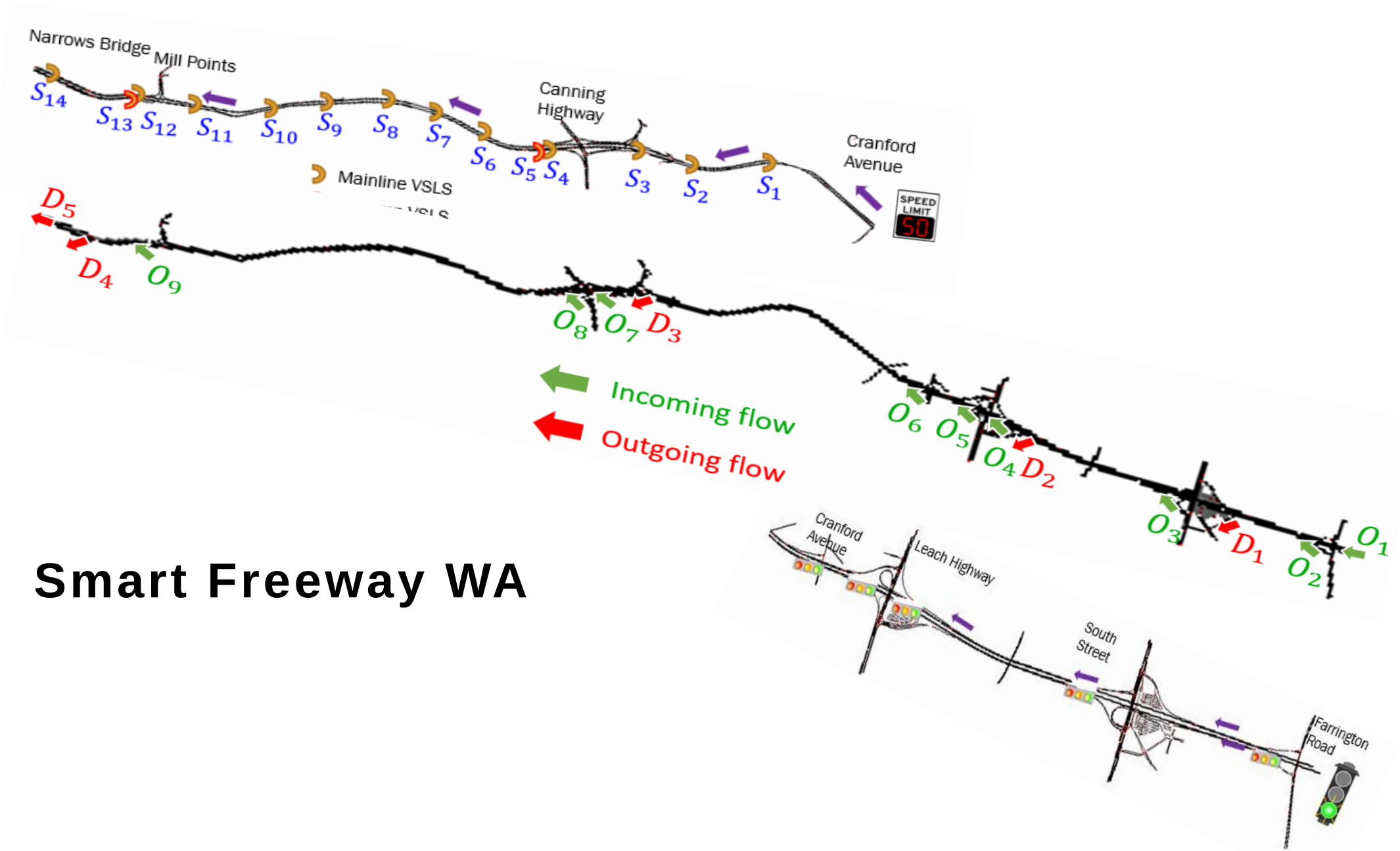
III VSL and RM Control in Another Scenario in morning Rush Hours

I. VSL and RM Control in a Scenario with lane closure due to non-recurrent events

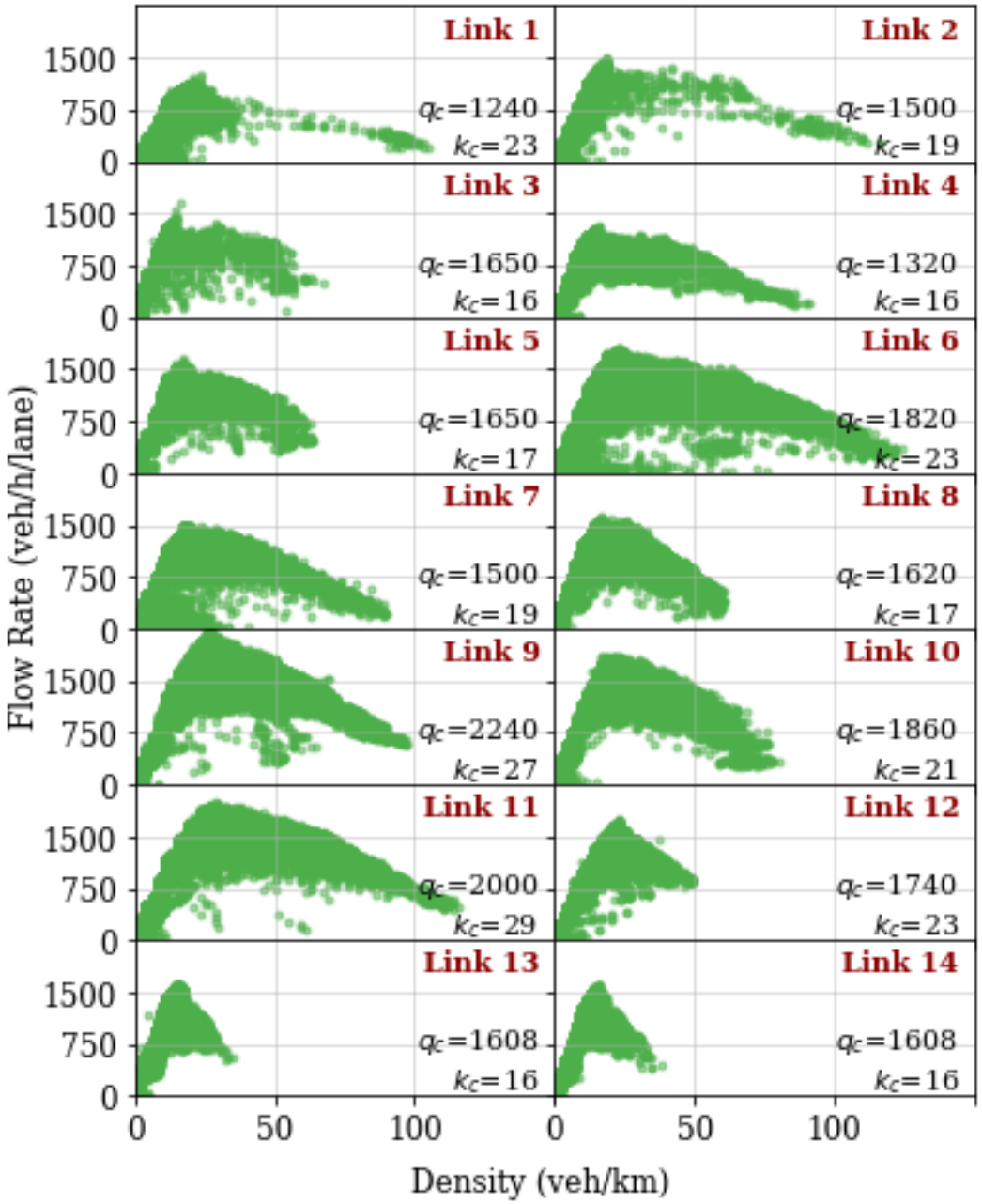

Link.csv, node.csv
27 August 2018

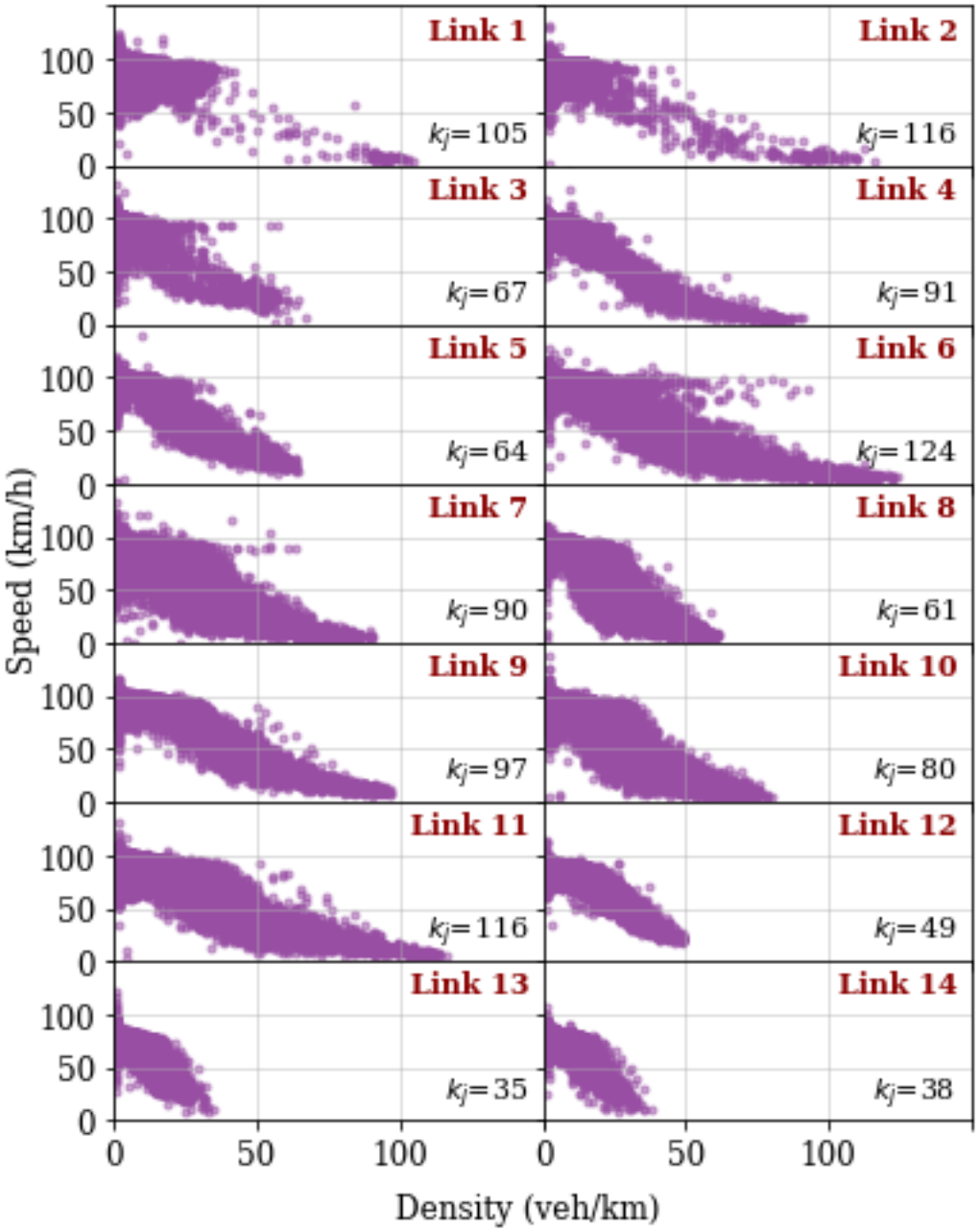

09:08 Road crash
12.50 Animal/Livestock
12.02 Road crash
11:19 Break down/Tow away

Smart Freeway WA

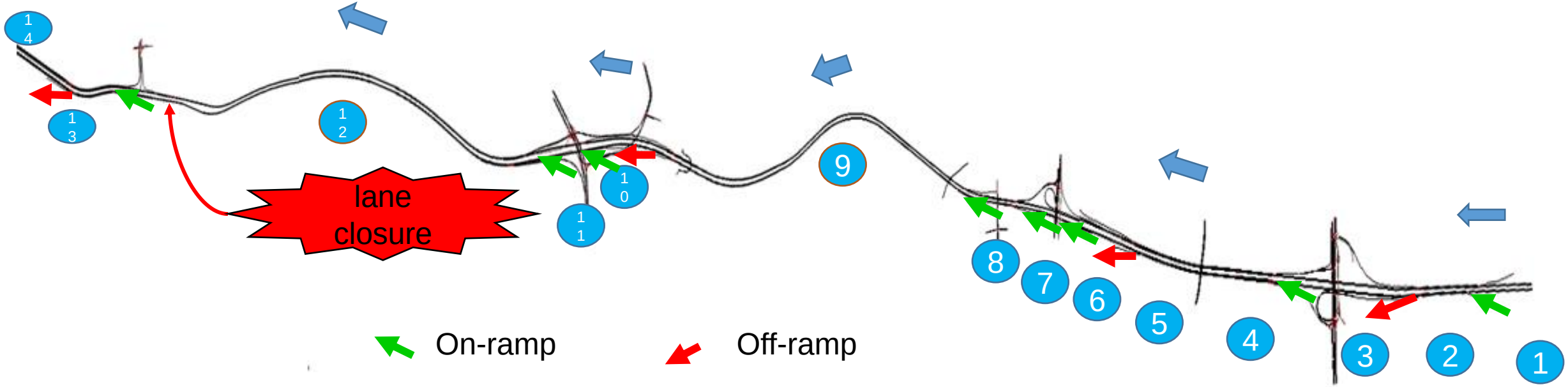


Fundamental diagrams





Study on the Kwinana Freeway Northbound



14 Links of the Kwinana Freeway Northbound

Objective function: $f = \min(TTS + \gamma D)$

$$TTS = \sum_{t=1}^{\tau} T\left\{\sum_{i=1}^{rs}\left(L_i k_{i,t}(\alpha,\beta)\right) + \sum_{i=1}^{rm} m_{i,t}(\alpha,\beta)\right\}; \qquad D = \sum_{t=1}^{\tau} T\left\{\sum_{i=1}^{rs}\left(L_i k_{i,t}\right) - \sum_{i=1}^{rs}\left(\frac{L_i q_{i,t}}{\beta v_f}\right)\right\}$$

Decision variables: $X \in R^{m\times n};^{\gamma}\ \tau = t_0 + mT_c,\ \ n = n_r + n_v$

$$X = \left(\alpha_{1,t}, \alpha_{2,t}, \dots, \alpha_{n_r,t}, \beta_{1,t}, \beta_{2,t}, \dots, \beta_{n_v,t}\right)_{t=1}^{m}, \qquad \begin{cases} \alpha_{min} \le \alpha_{i,t} \le \alpha_{max} \\ \beta_{min} \le \beta_{i,t} \le \beta_{max} \end{cases}$$

$$\alpha_i(t) = \begin{cases} \alpha_{i1} & \text{if } t \in [t_0, t_0 + T_c) \\ \alpha_{i2} & \text{if } t \in [t_0 + T_c, t_0 + 2T_c) \\ \vdots & \\ \alpha_{im} & \text{if } t \in [t_0 + (m-1)T_c, t_0 + mT_c) \end{cases} \qquad (i=1,\dots, n_r)$$

$$\beta_i(t) = \begin{cases} \beta_{i1} & \text{if } t \in [t_0, t_0 + T_c) \\ \beta_{i2} & \text{if } t \in [t_0 + T_c, t_0 + 2T_c) \\ \vdots & \\ \beta_{im} & \text{if } t \in [t_0 + (m-1)T_c, t_0 + mT_c) \end{cases} \qquad (i=1,\dots,n_v)$$

- **Traffic flow constraints**

$$k_{i,t}(\alpha,\beta) = k_{i,t-1}(\alpha,\beta) + \frac{T}{n_i L_i}\left(n_{i-1}q_{i-1,t-1}(\alpha,\beta) - n_i q_{i,t-1}(\alpha,\beta) + n_r r_{i,t-1} - n_s s_{i,t-1}\right)$$

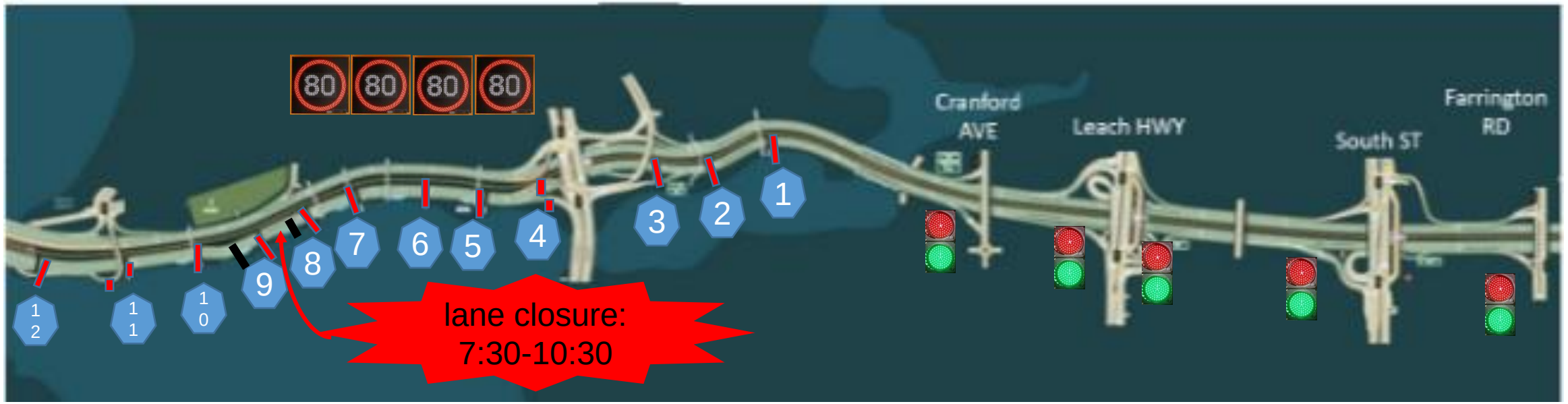
$$m_{i,t} = m_{i,t-1} + T\left(d_{i,t-1} - r_{i,t-1}\right), \qquad 0 \le m_{i,t} \le m_{i\,max}$$

$$r_{i,t} = \begin{cases} min\left\{n_r q_{i\,max};\quad max\left[r_{i,t}^{LC};\ \hat{r}_{i,t}\right]\right\} & \text{RM control} \\ min\left\{n_r q_{i\,max};\quad \beta_{i,t-1} v_f k_{i,t-1}\right)\} & \text{VSL control} \end{cases}$$

$$\hat{r}_{i,t} = \hat{r}_{i,t-1} - \frac{1}{T}\left(m_{i\,max} - m_{i,t-1}\right); \qquad r_{i,t}^{LC} = r_{i,t-1}^{LC} + \frac{L_i}{T}\left(n_i k_{max,i} - k_{i,t-1}\right);$$

- **Road Capacity constraints**

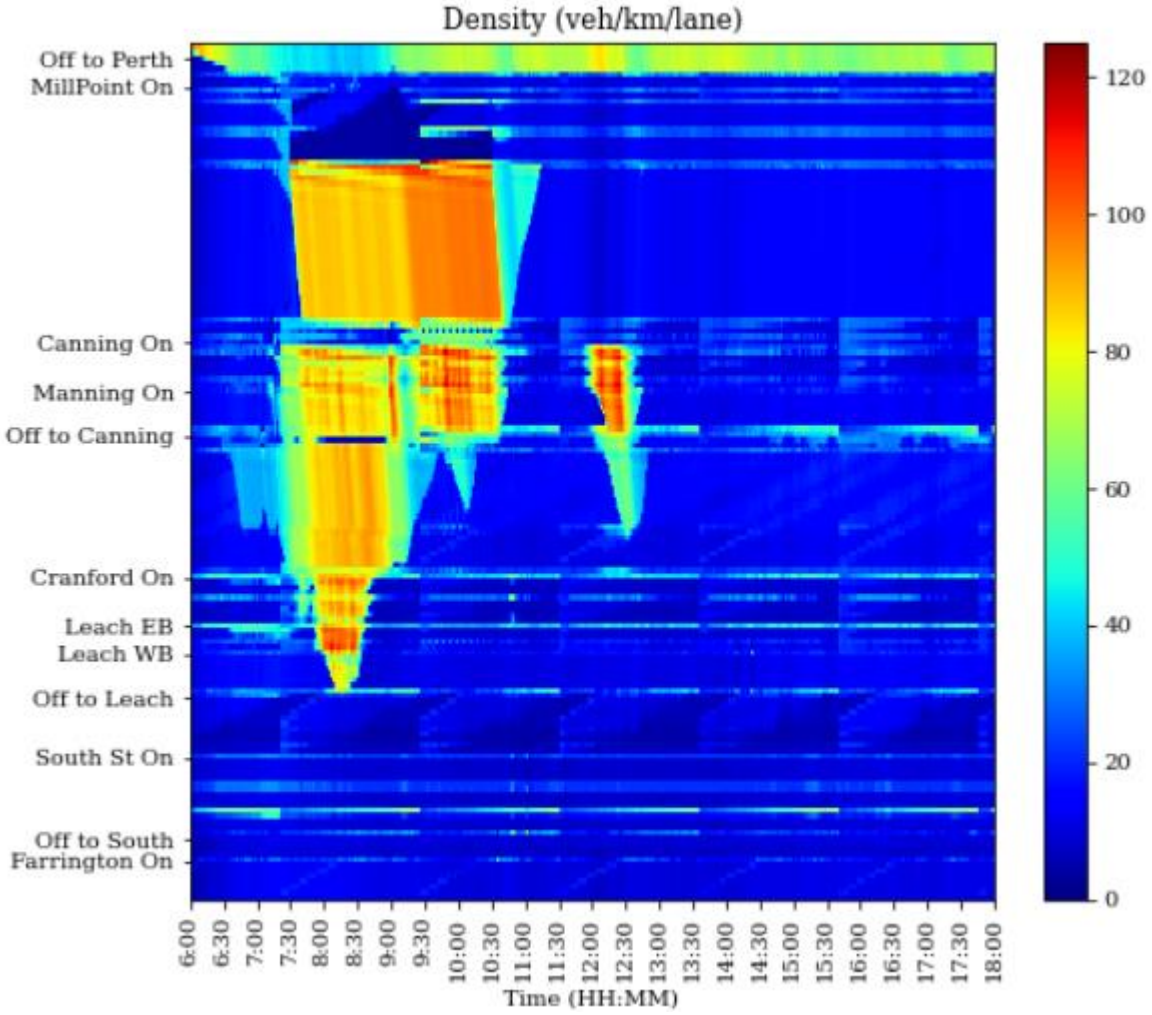
$$n_{i-1}q_{i-1,t}(\alpha,\beta) + n_r r_{i,t} - n_s s_{i,t} - n_i q_{max,i} \le 0, \qquad t = 1,\dots,\tau$$

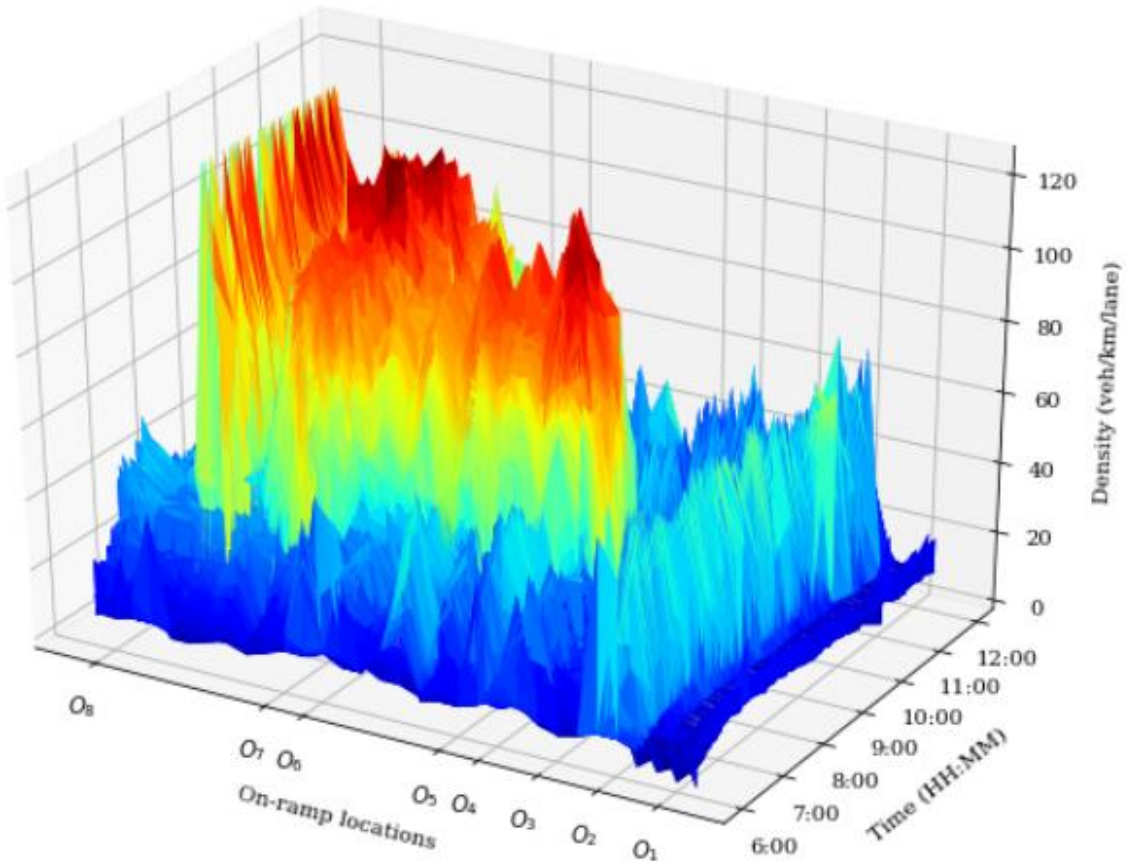


	1	2	3	4	5	6	7	8	9	10	11	12
VSLS	LUMS 212	LUMS 211	LUMS 210	LUMS 209	LUMS 208	LUMS 207	LUMS 206	LUMS 205	LUMS 204	LUMS 203	LUMS 202	LUMS 201
Road seg.	18 (1443)	19 (269)	20 (757)	21-24 (577)	25 (218)	26 (493)	27 (665)	28 (550)	29 (746)	30 (711)	31 (274)	32 (219)
Lanes	3	3	3	4	4	4	4	4	4	4	4	5

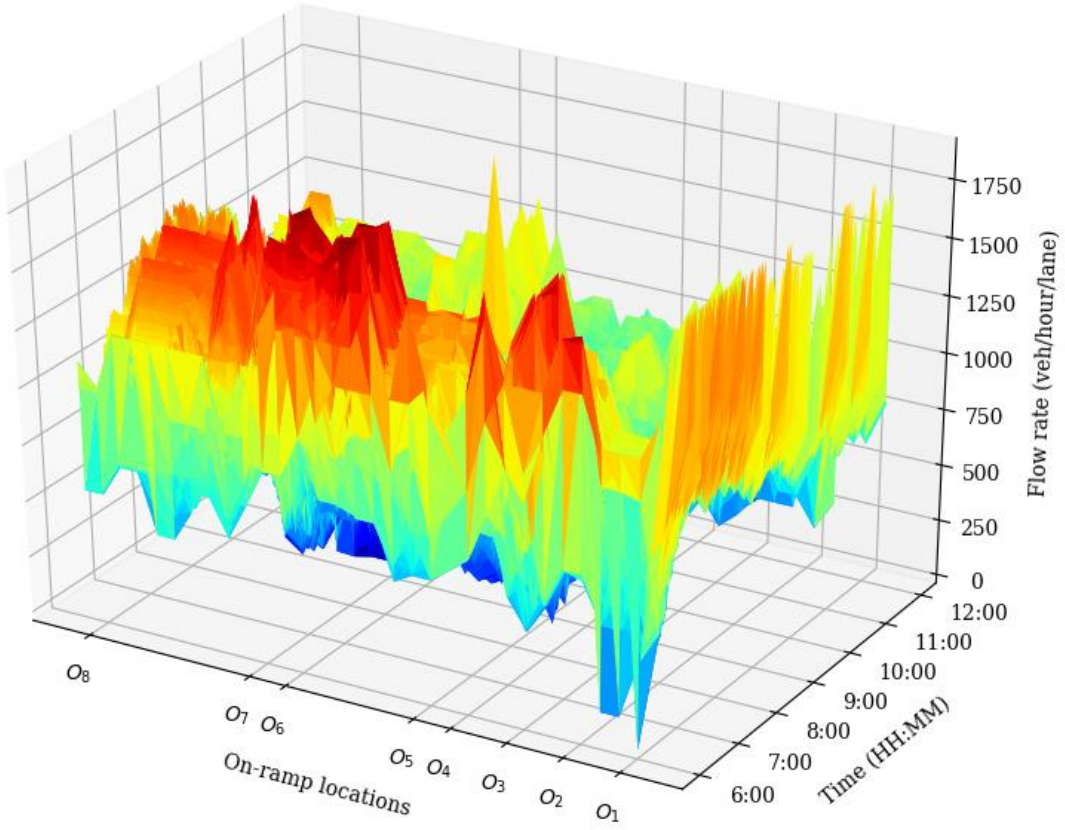
Scenario : closure of 3 lanes due to a non-recurrent event at the location shown above

Simulated data with no control - Density distribution

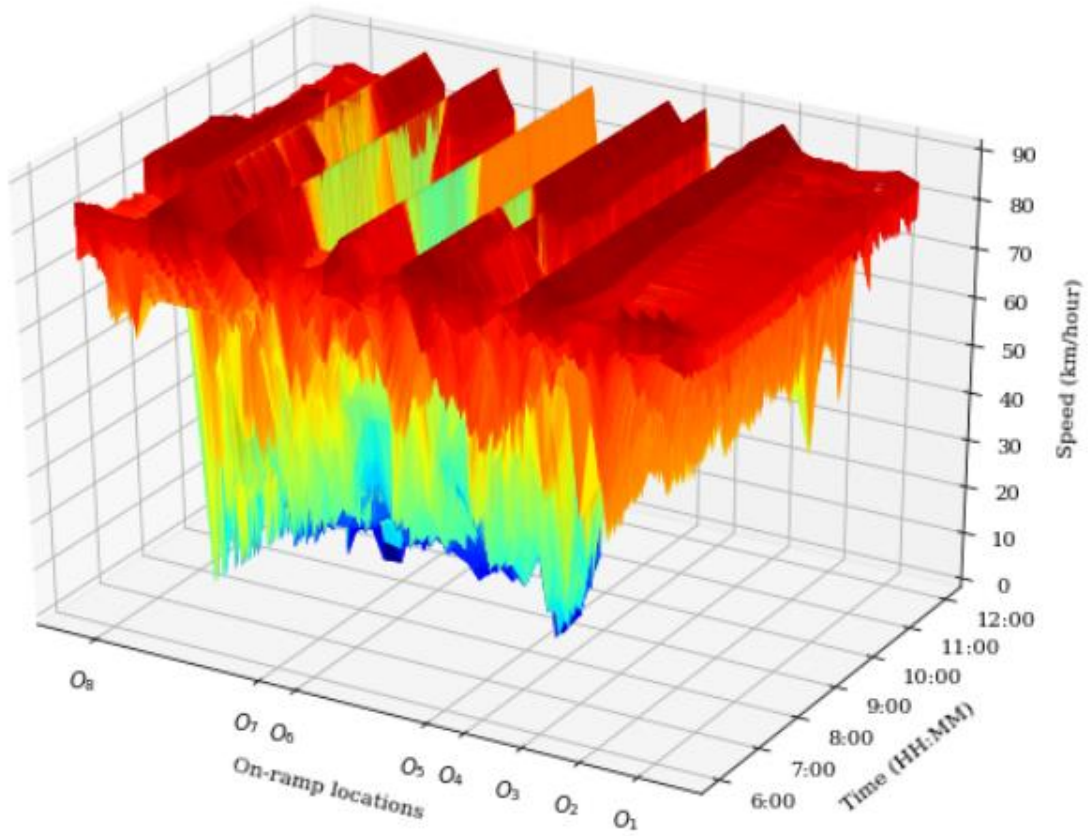




Simulated data with no control

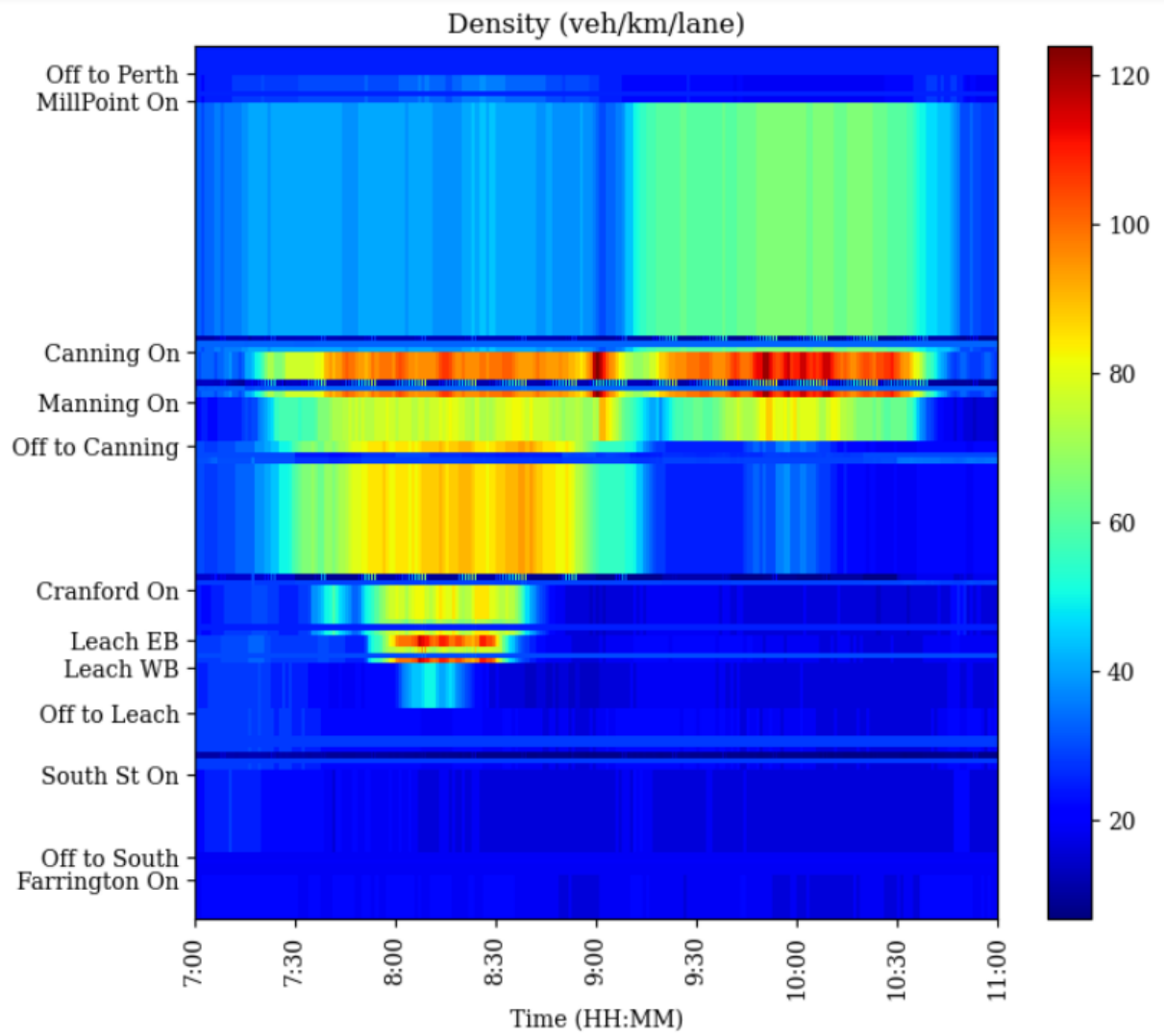


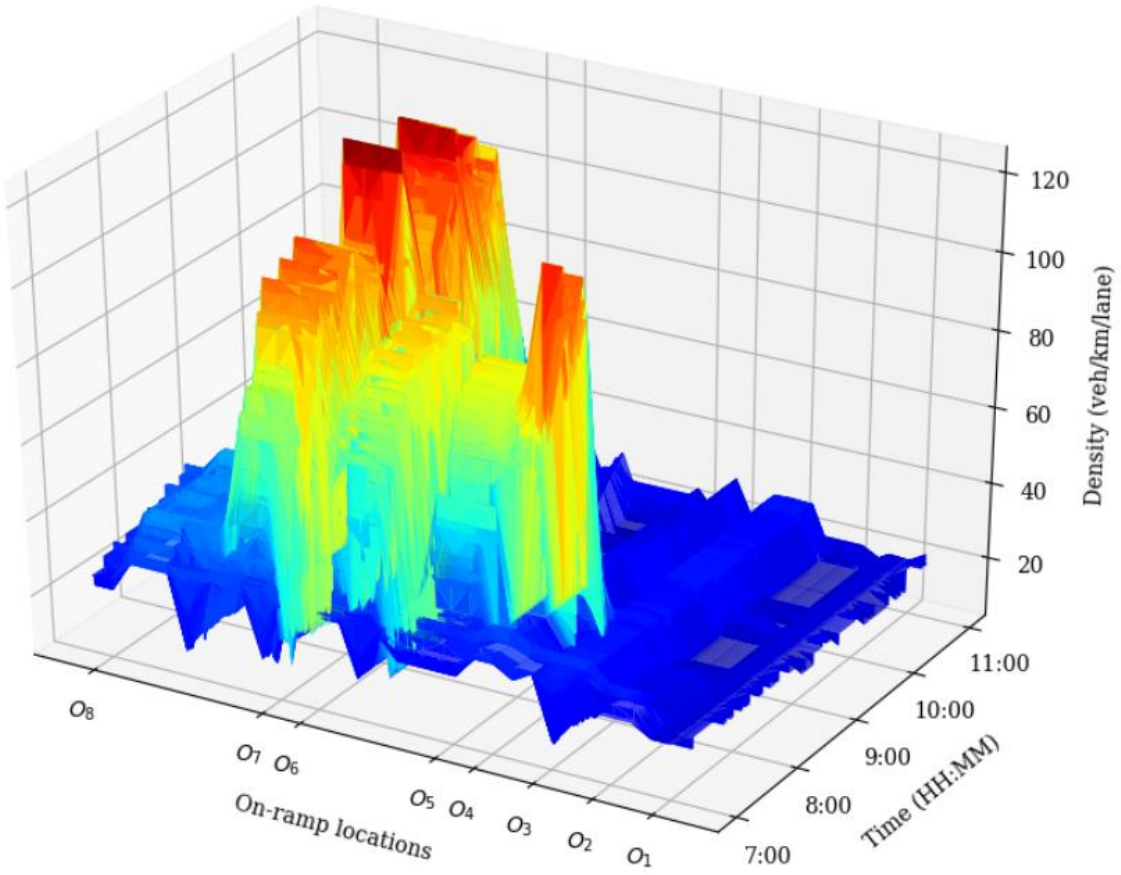
Flow rate (veh/hour/lane)



Speed (km/hour)

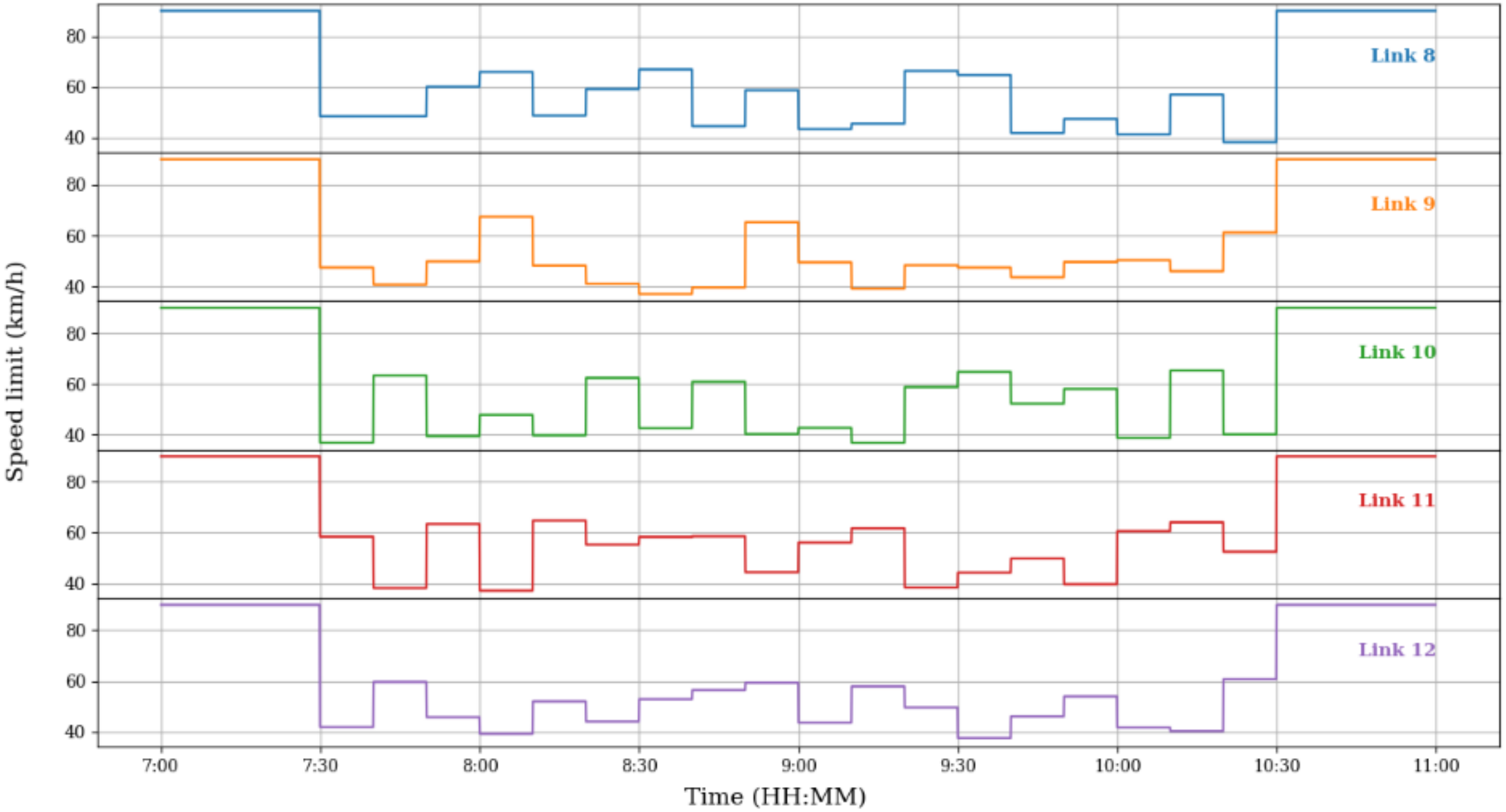
Simulated data with VSL & RM controls



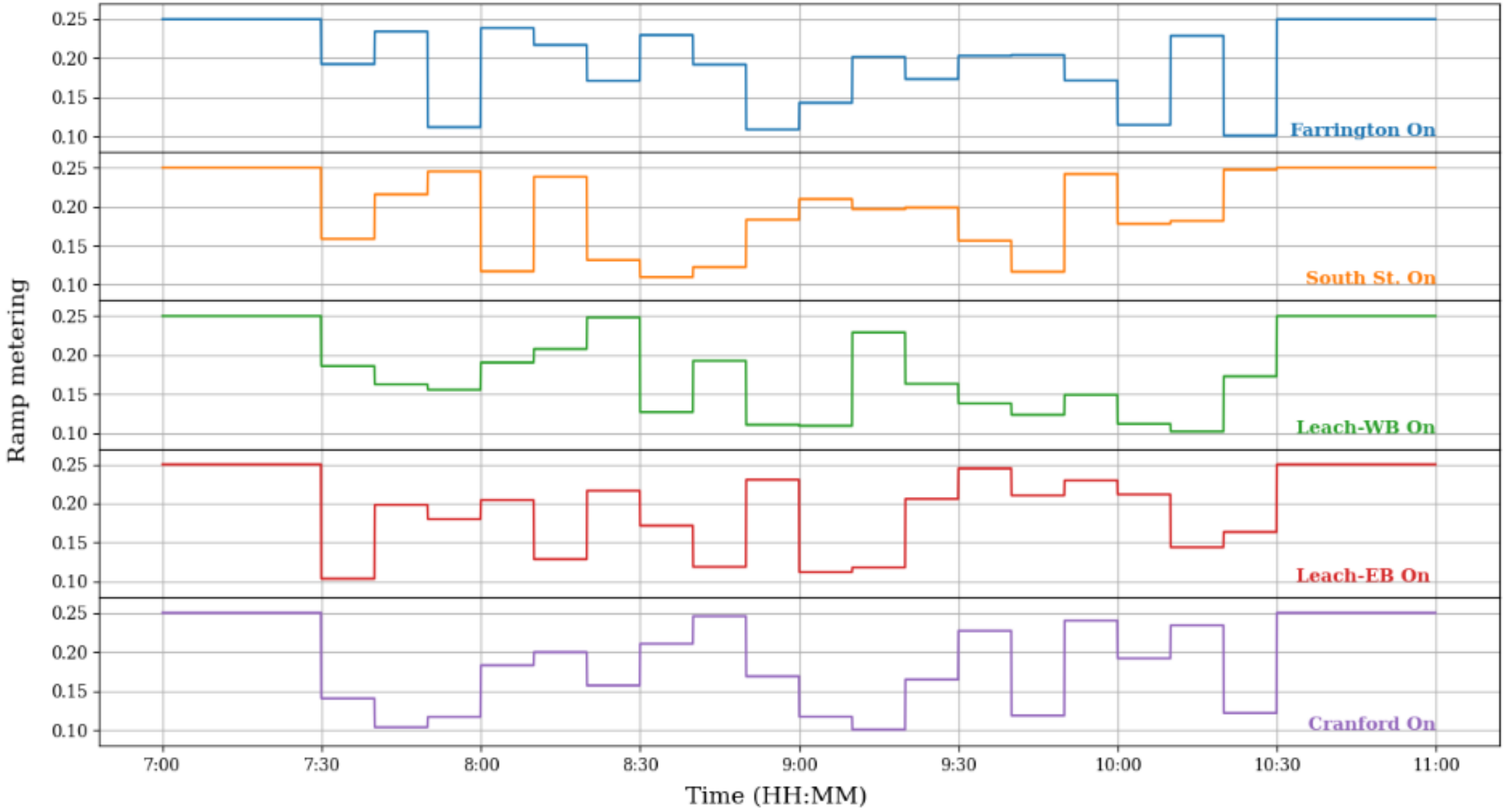


Density (veh/km/lane)

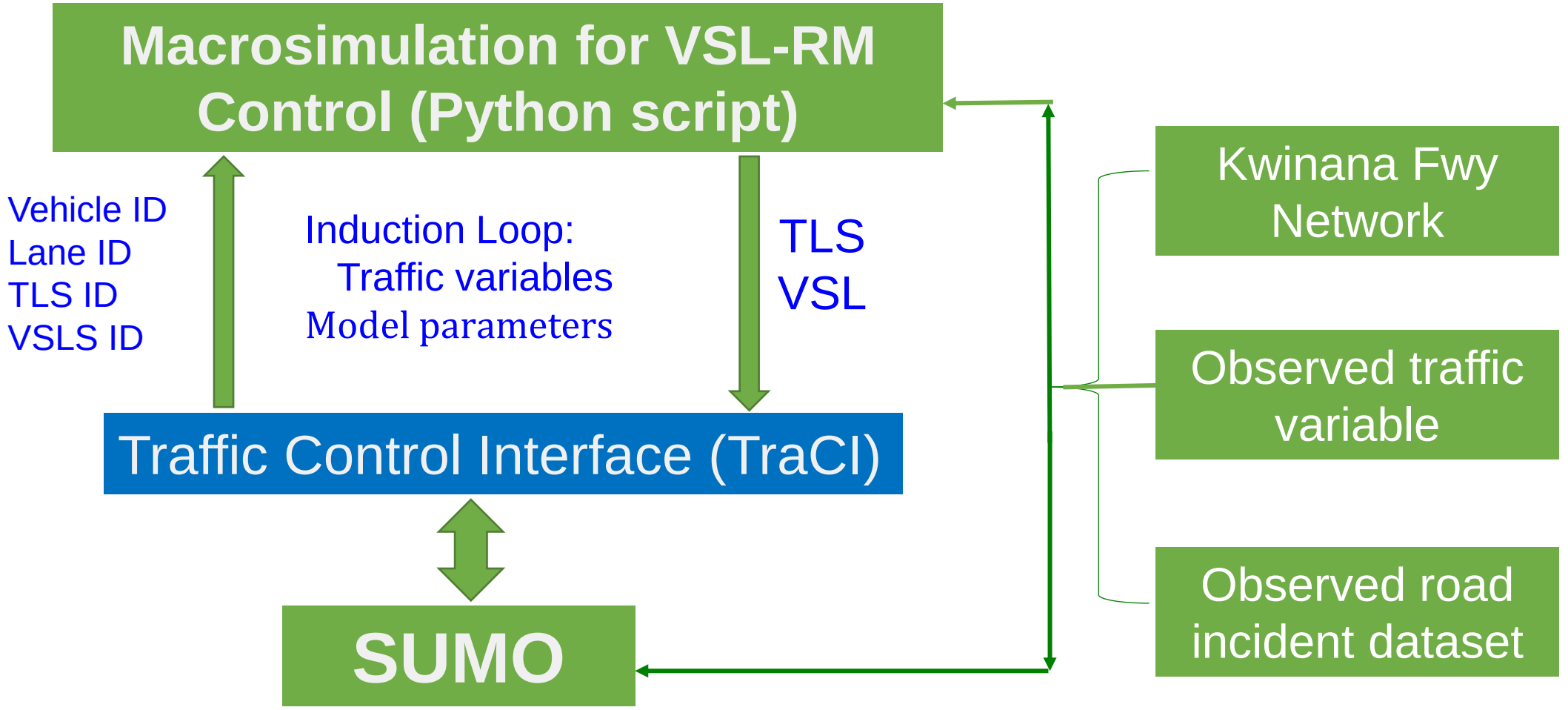
VSL profiles



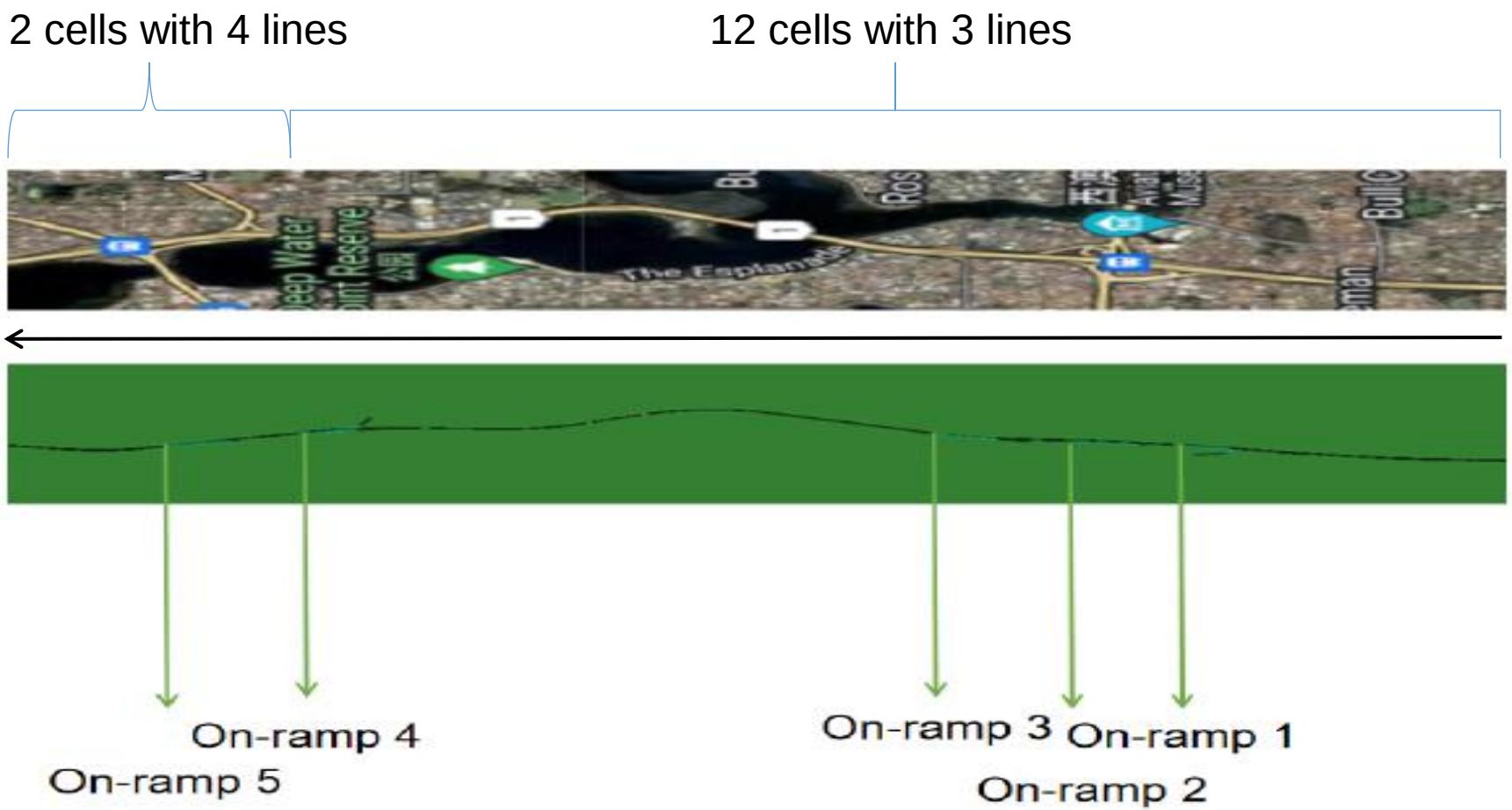
RM profiles

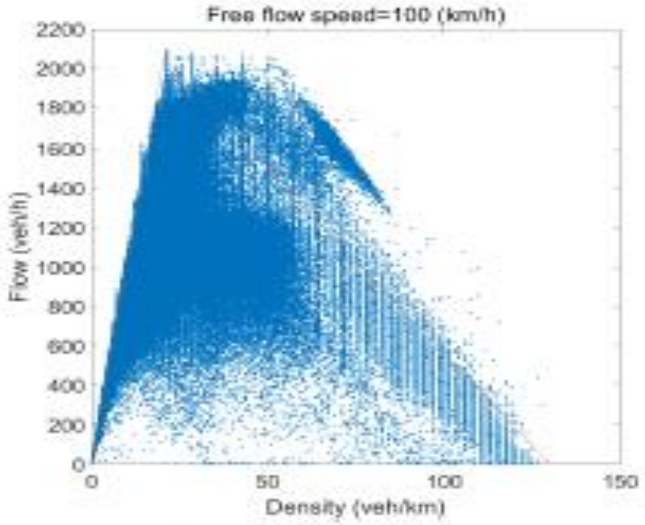

Ramp metering
0.25
0.20
0.15
0.10
Farrington On
South St. On
Leach-WB On
Leach-EB On
Cranford On
7:00
7:30
8:00
8:30
9:00
9:30
10:00
10:30
11:00
Time (HH:MM)

II. Traffic Control Interface in SUMO

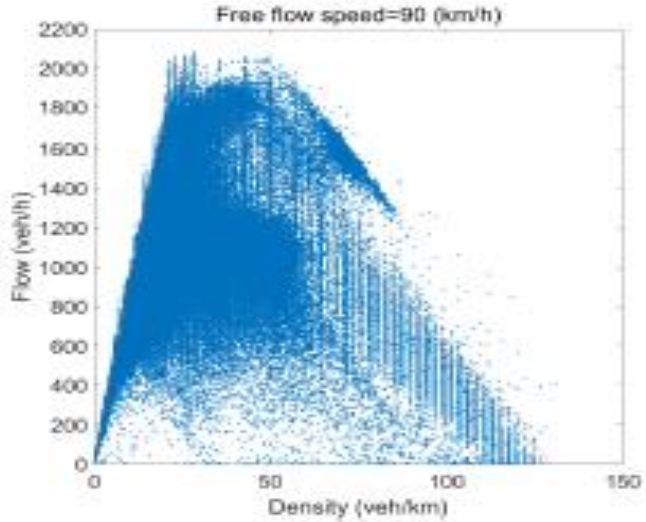


III VSL and RM Control in Another Scenario in morning Rush Hours

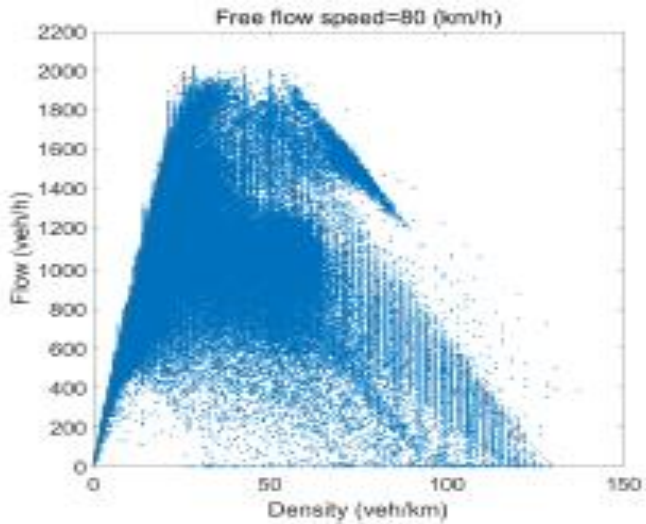




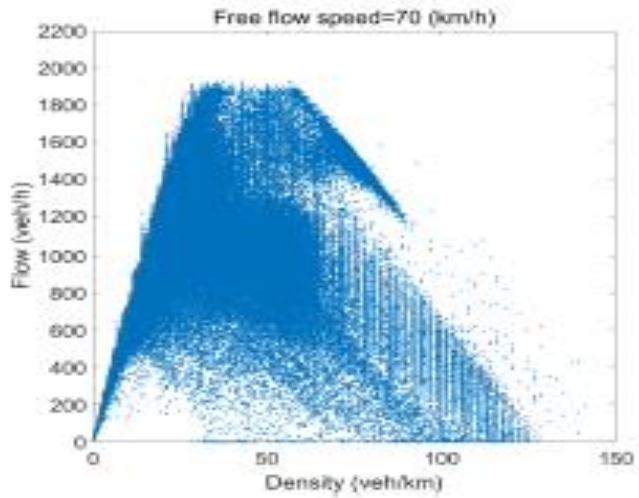
(a) Fundamental diagram for free flow speed=100 (km/h)



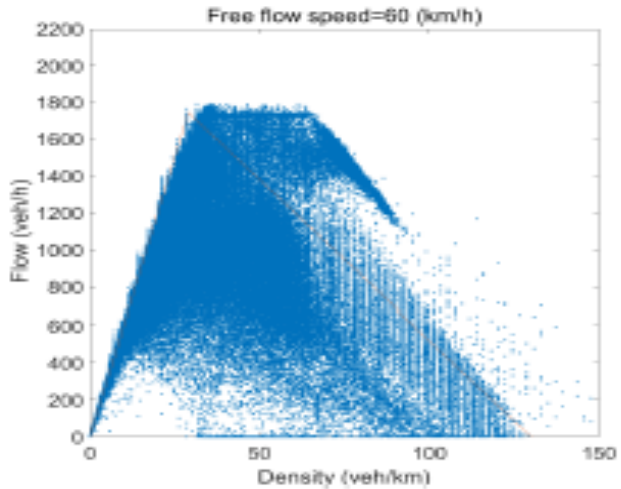
(b) Fundamental diagram for free flow speed=90 (km/h)



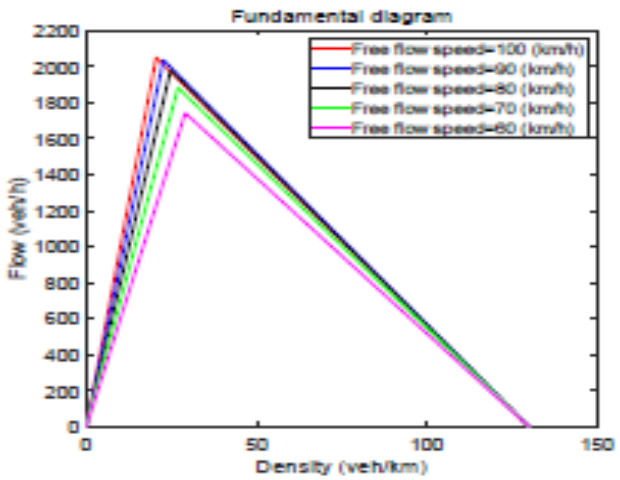
(c) Fundamental diagram for free flow speed=80 (km/h)



(d) Fundamental diagram for free flow speed=70 (km/h)



(e) Fundamental diagram for free flow speed=60 (km/h)



(f) Fundamental diagram

Model:

Total spent time

$$(\text{DMP}) \min_{r,b} Z = \sum_{t=0}^{T} \sum_{i=1}^{I} (\rho_{i,t} \Delta x_i \Delta t + q_{i,t} \Delta t)$$

s.t.

$$\rho_{i,t+1} = \rho_{i,t} + \frac{\Delta t}{\Delta x_i}(f_{i-1,t} - f_{i,t} + r_{i,t} - s_{i,t}),$$

$$f_{i,t} = \min\{f^D_{i,t}, f^S_{i+1,t} - \theta r_{i+1,t}\},$$

$$f^D_{i,t} = \min\left\{v_{f,i}\rho_{i,t}, \left[C_i + \alpha C_i(\frac{\rho_{i,t} - \rho_{cr,i}}{\rho_{cr,i} - \rho_{max,i}})\right]\right\},$$

$$f^S_{i+1,t} = \min\{C_{i+1}, w_{i+1}(\rho_{max,i+1} - \rho_{i+1,t})\},$$

$$q_{i,t+1} = q_{i,t} + \Delta t(d_{i,t} - r_{i,t}),$$

$$0 \le r_{i,t} \le r_{max,i},$$

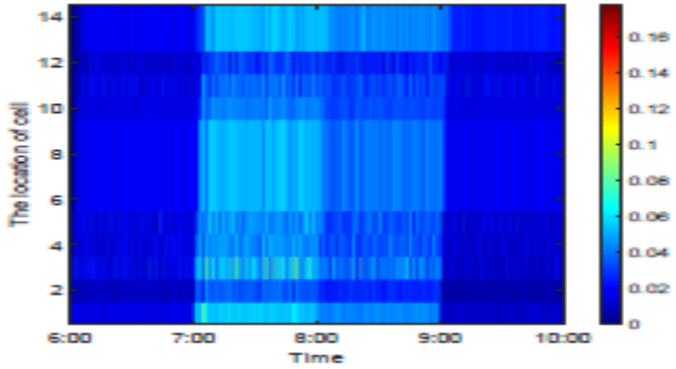
$$0 \le q_{i,t} \le q_{max,i},$$

$$v_{f,i}[b_{i,t}] = v_{f,i} b_{i,t},$$

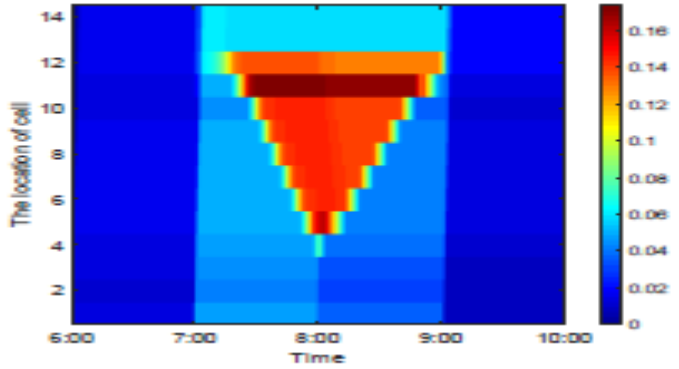
$$\rho_{cr,i}[b_{i,t}] = \rho_{cr,i}(1 + A_i(1 - b_{i,t})),$$

$$b_{min,i} \le b_{i,t} \le 1.$$

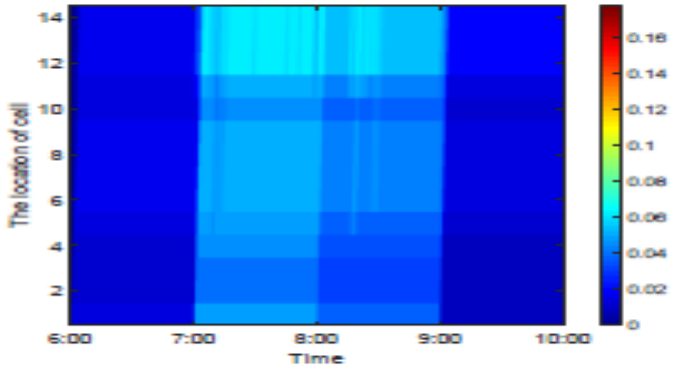
Results:



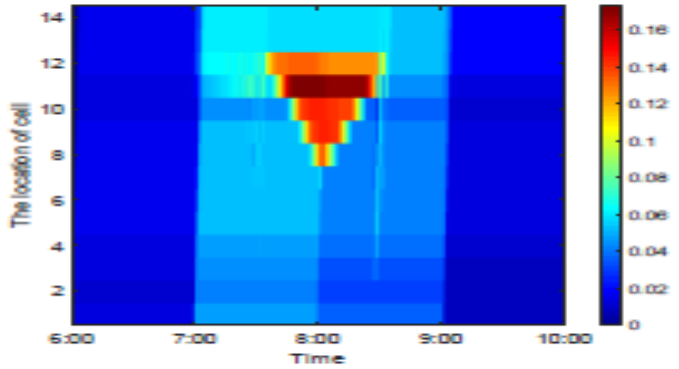
(a) Density (veh/m) for simulation



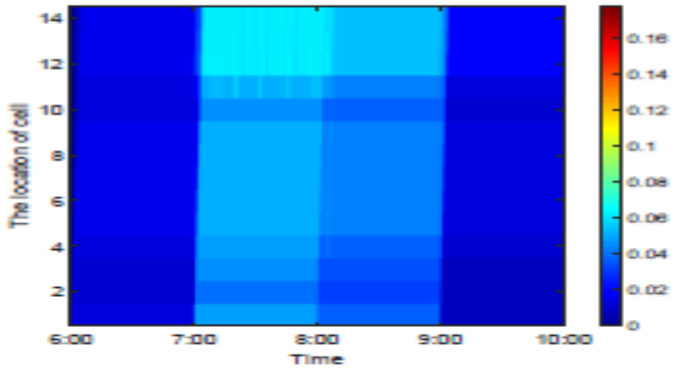
(b) Density (veh/m) for no control



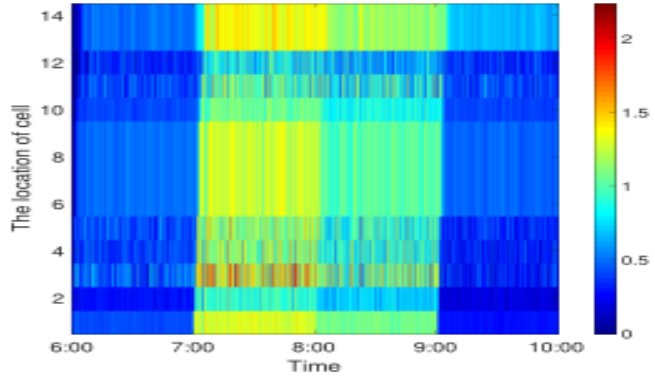
(c) Density (veh/m) for RM



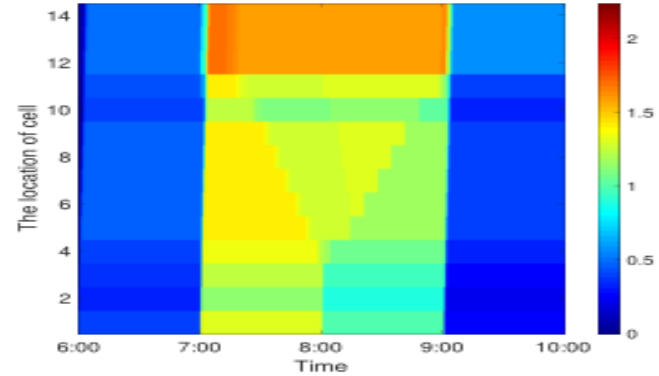
(d) Density (veh/m) for VSL



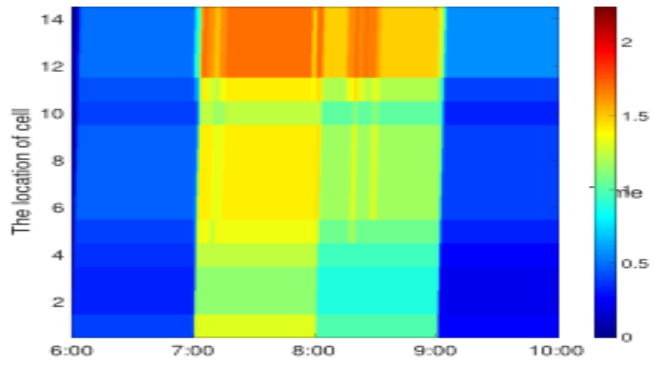
(e) Density (veh/m) for RM and VSL



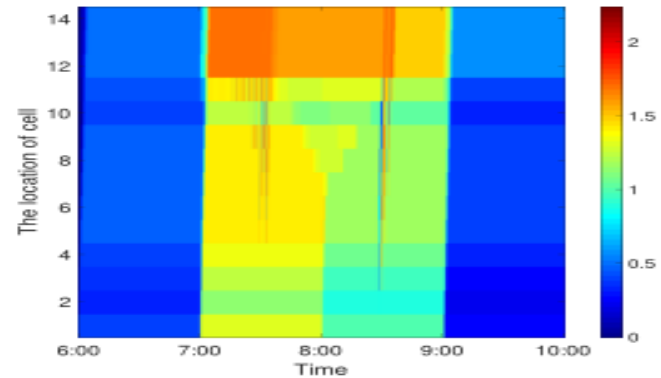
(a) Flow (veh/s) for simulation



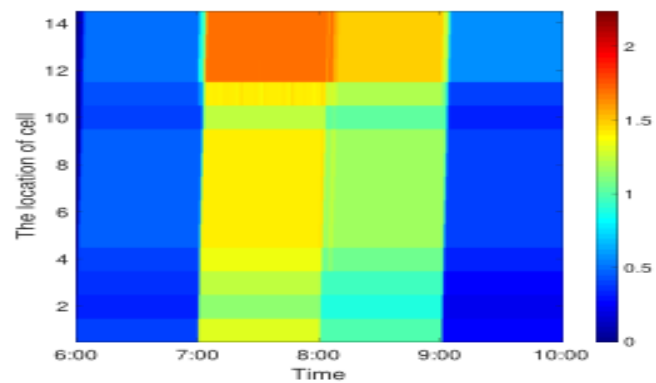
(b) Flow (veh/s) for no control



(c) Flow (veh/s) for RM



(d) Flow (veh/s) for VSL



(e) Flow (veh/s) for RM and VSL

Table 2 Total Time Spent and ramp delay for different strategies

Name of model	Total time spent (h)	Ramp delay (h)	Percentage of reduction for total time spent	Percentage of reduction for ramp delay
Simulation	1255.655h	434.3h	0%	0%
No control	1251.744h	0h	0.311%	100%
Only RM	994.756h	144.673h	20.778%	66.689%
Only VSL	1000.716h	0h	20.303%	100%
VSL and RM	886.999h	20.562h	29.36%	95.265%

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THANK YOU

For Your Attention