Attachment E A C D

On Simulation and Optimization of Freeway Network Operations

B. Wiwatanapataphee, Yong Hong Wu
Curtin University of Technology

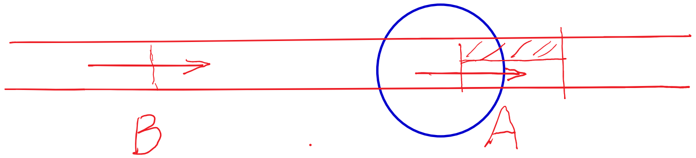
Progress from last PSG meeting

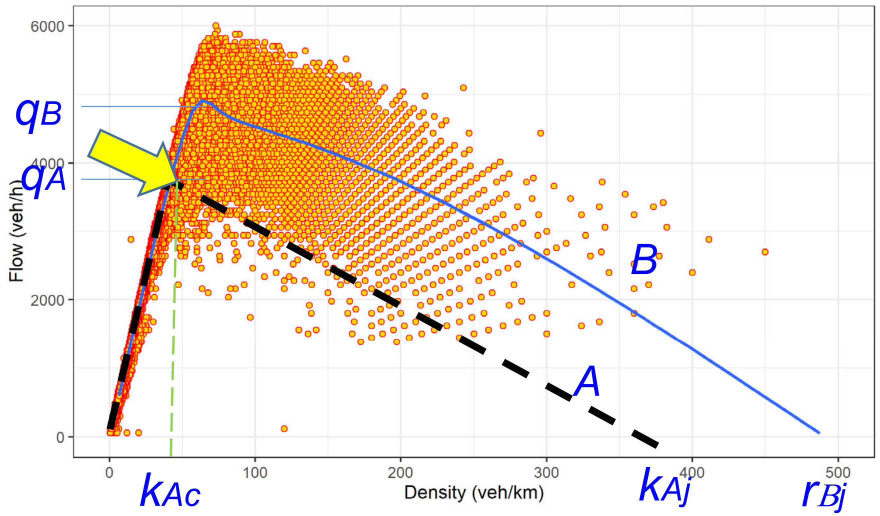
Analysis and computation of optimal VSL and RM under non-recurrent events with lane closure

1. Analysis of the Problem

Assume that 1 or 2 lanes close at location A
due to the occurrence of a non-recurrent event

Capacity drop due to Lane Closure





Fundamental diagram of traffic flow

- Land closure leads to capacity drop as shown above
- Without control, traffic will build up quickly at location A, so k_A ↑ ⇒ congestion
- by reducing speed limits of vehicles toward A, it is possible to max the throughput at *A*

2.The optimisation model

$$\max_{r_p(t), V_l(t)} \sum_{t=t0}^{T_{end}} q_{critical}\{k_i[r_p(t), V_l(t)]\}\,\Delta t$$

subject to

- $\frac{n_i \partial k_i}{\partial t} + \frac{\partial}{\partial x}\Delta q_i(t) = 0, \qquad 0 \le k_i(t) \le k_{jam,i}$

$$\Delta q_i(t) = q_i^{in}(t-1) - q_i^{out}(t-1) + r_i(t-1) - s_i(t-1)$$

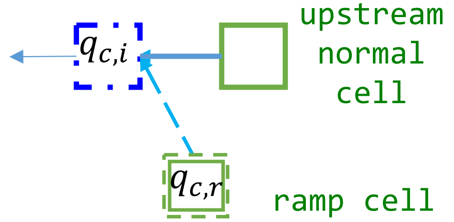
$$r_i(\mathrm{t}) = \min \begin{bmatrix} n_{i,r} q_{c,r};\ \beta_{i,r} v_{f,r} k_{i,r}(t-1); \\ \max\{\ r_i^{\alpha}(t);\ queue_{i,r}(t))\} \end{bmatrix}$$

- $queue_{i,r}(t) = arr_{i,r}(t-1) - \frac{1}{T}\left(\widehat{m}_{i,r} - m_{i,r}(t-1)\right);$
- $m_{i,r}(t) = m_{i,r}(t-1) + T(arr_{i,r}(t-1) - r_i(\mathrm{t})) \le \widehat{m}_{i,r}$
- $r_i^{\alpha}(\mathrm{t}) = r_i^{\alpha}(\mathrm{t}-1) + \boldsymbol{\alpha_i(t)} \frac{L_i}{T}(n_i k_{c,i} - k_i(t-1)) > 0$

Metering parameter

- **Capacity constraints**

$$\sum_{t=\tau}^{t_{end}} T\left\{\sum_{i=1}^{rs} (\Delta q_i(t) - q_{c,i})\right\} \le 0$$



Green duration $\quad g_i(t) = \frac{r_i(t)}{r_s(t)} C_i$

$T = t_{record}/3600$

- As in practice, $V_i(t),\ \alpha_i(t)$ and $\beta_{i,r}(t)$ cannot be changed continuously, they are approximated by

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

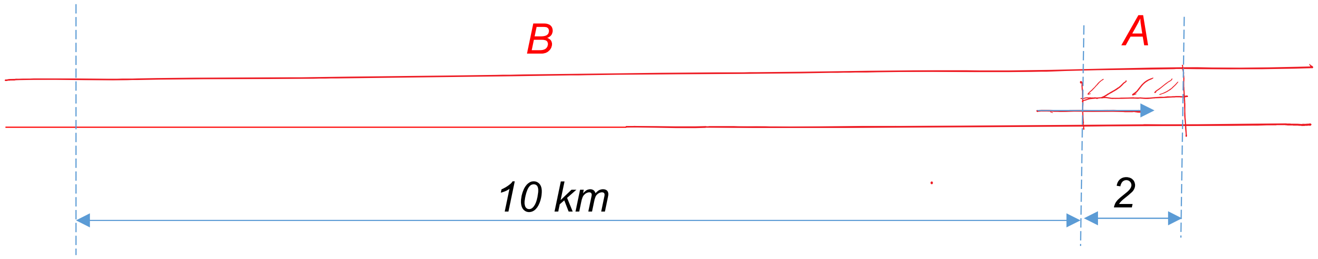
$$\alpha_i(t) = \begin{cases} \alpha_{i1} & \text{if } \ t \in [t_0, t_0 + T_c) \\ \alpha_{i2} & \text{if } \ t \in [t_0 + T_c, t_0 + 2T_c) \\ \vdots & \\ \alpha_{im} & \text{if } \ t \in [t_0 + (m-1)T_c, t_0 + mT_c) \end{cases} \qquad (i=1,\dots, n_r)$$

- Hence, the optimal control problem becomes the following optimization problem:

$$\max_{V_{lj},\alpha_{pj},\beta_{pj}} \sum_{t=t_0}^{t_0+mT_c} q_{critical}\left\{k_i(t, V_{lj}, \alpha_{pj}, \beta_{pj})\right\}$$

subject to the dynamic equations and capacity constraints as given before

3 A simple test Example



v_f=100km/h,

$$k_{jB} = 0.1 \text{ (vehicle /m)}$$

$$q(k) = v_f k \left(1 - \frac{k}{k_j}\right)$$

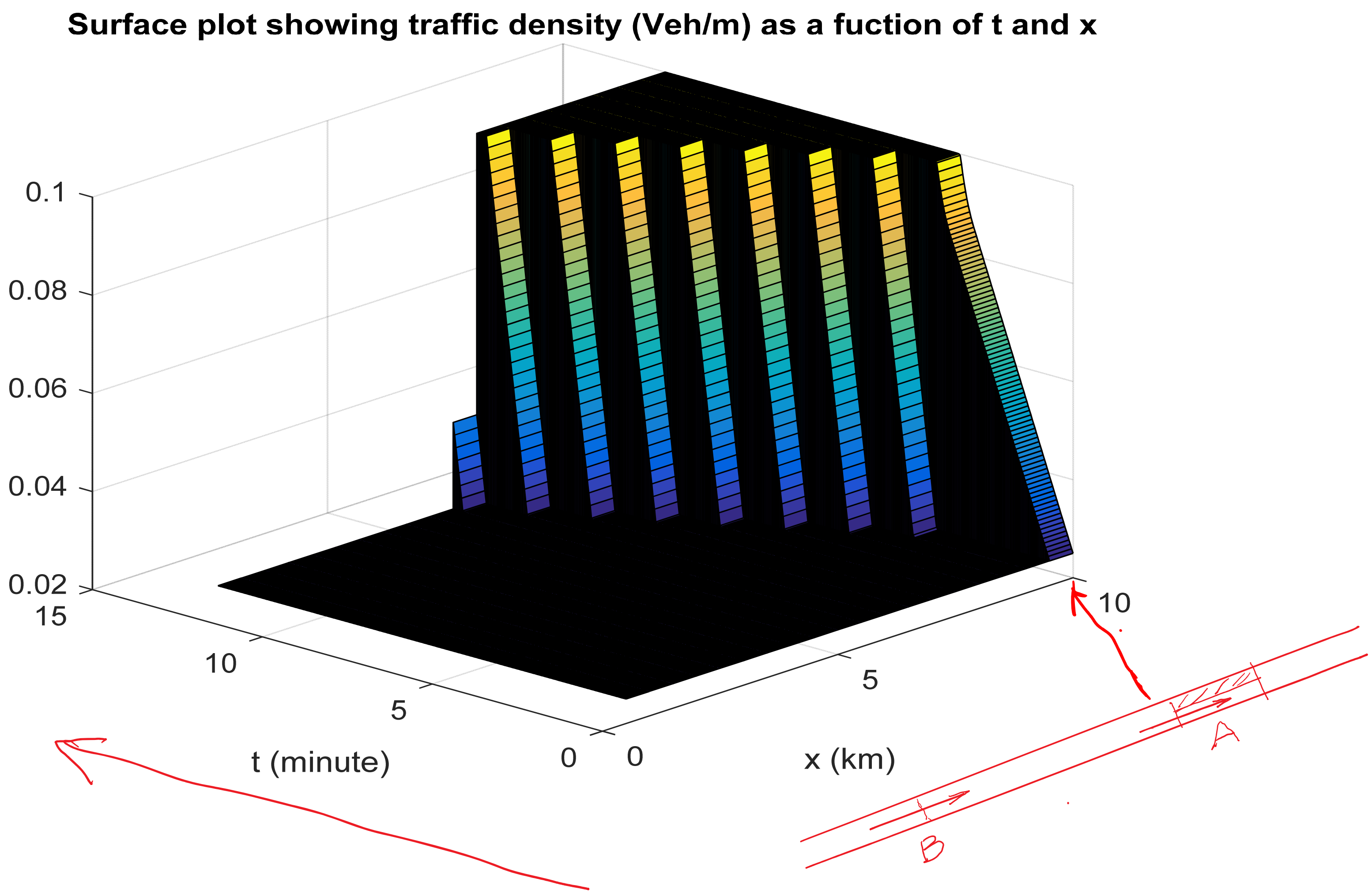
Capacity drops by 50% at A

Duration for handling the incident T = 12 minutes

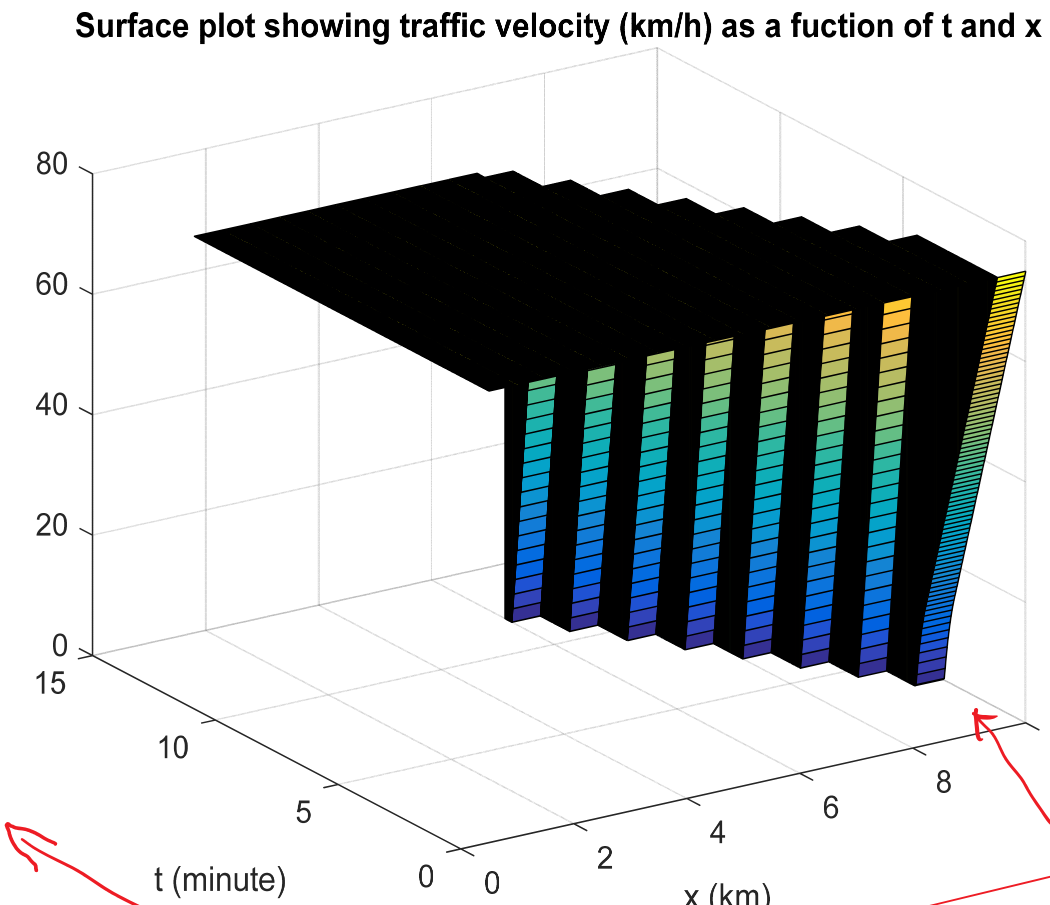
The **Objective** is to avoid traffic jam & maximize the throughput over the time period *T*

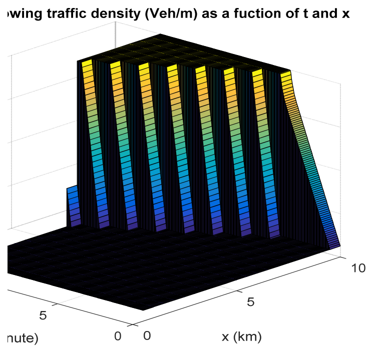
The Cell Transmission model is used for numerical simulation of the traffic flow

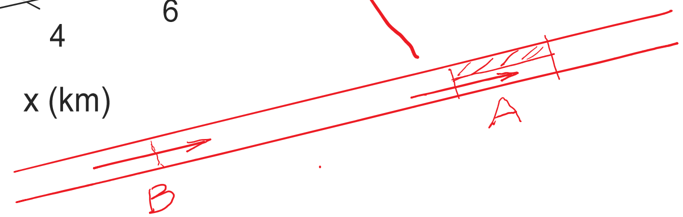
Results with no Control



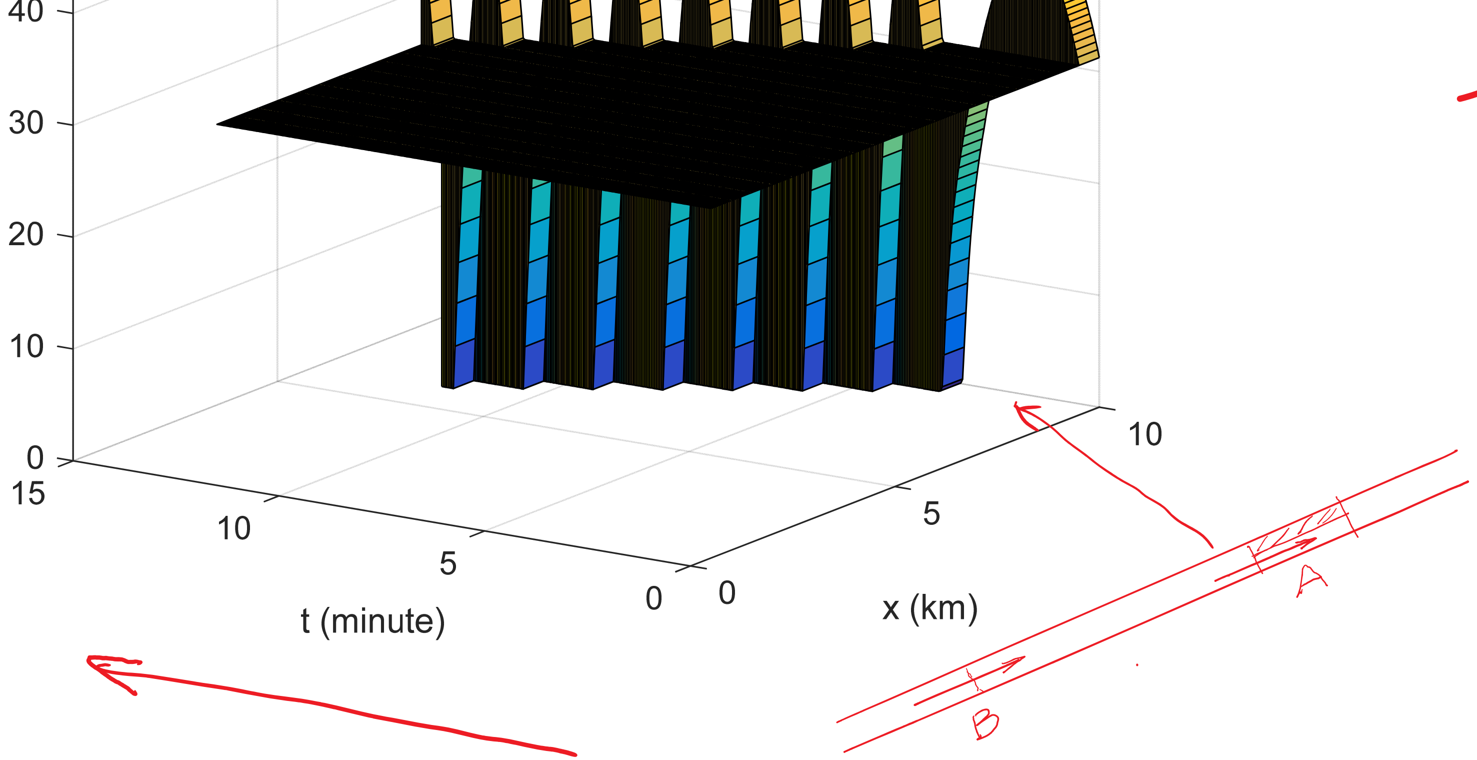
Surface plot showing traffic density (Veh/m) as a fuction of t and x
0.1
0.08
0.06
0.04
0.02
15
10
5
0
t (minute)
0
5
10
x (km)
A
B

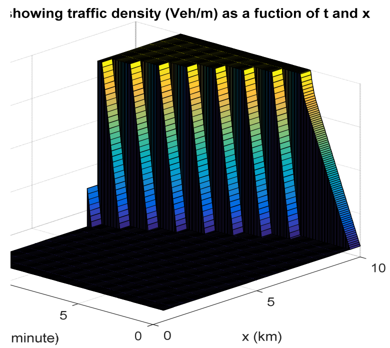

Surface plot showing traffic velocity (km/h) as a fuction of t and x
t (minute)
x (km)


wing traffic density (Veh/m) as a fuction of t and x
nute)
x (km)


A
B

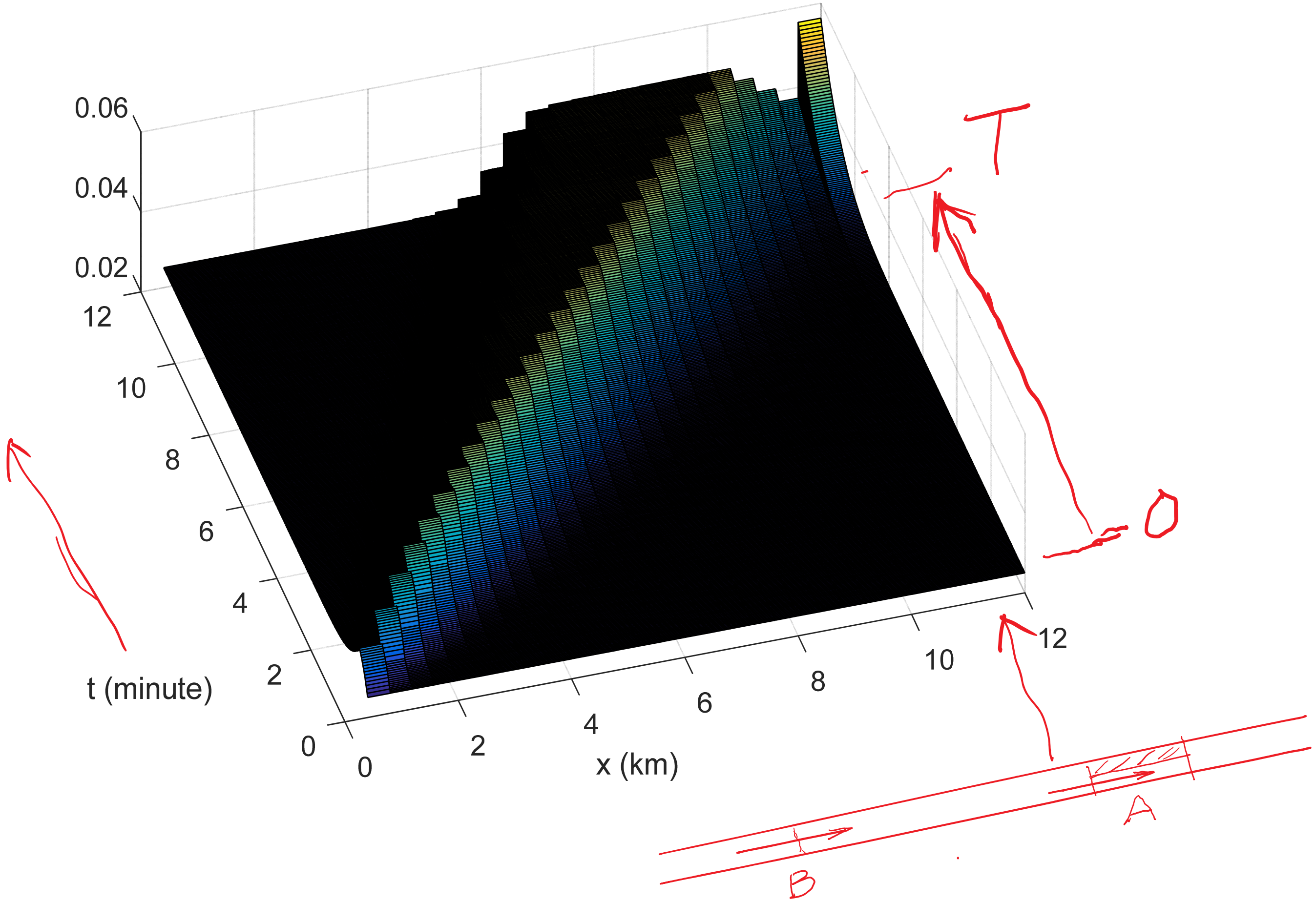
Surface plot showing traffic flow (Veh/min) as a fuction of t and x

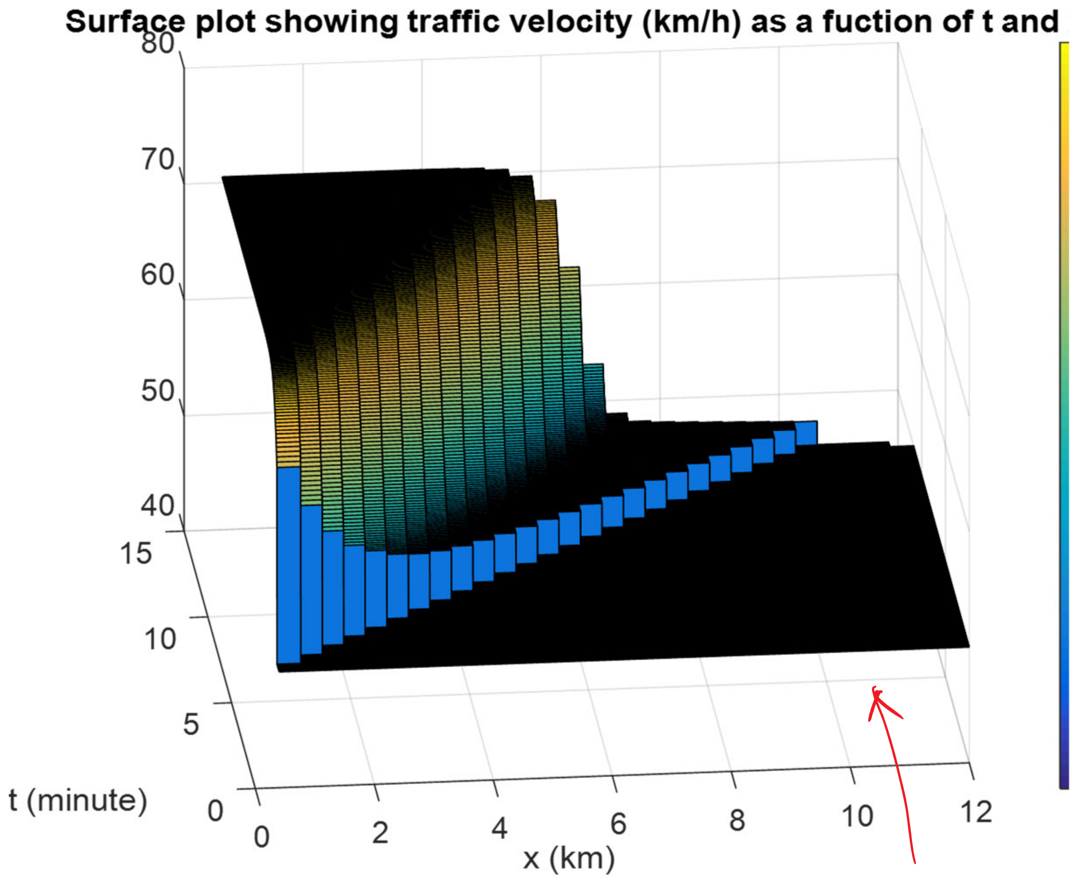


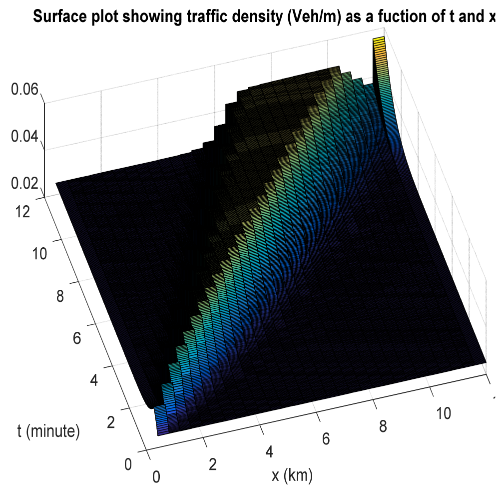


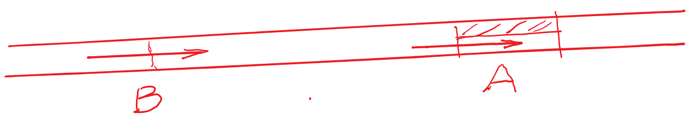
Results with VSL Control

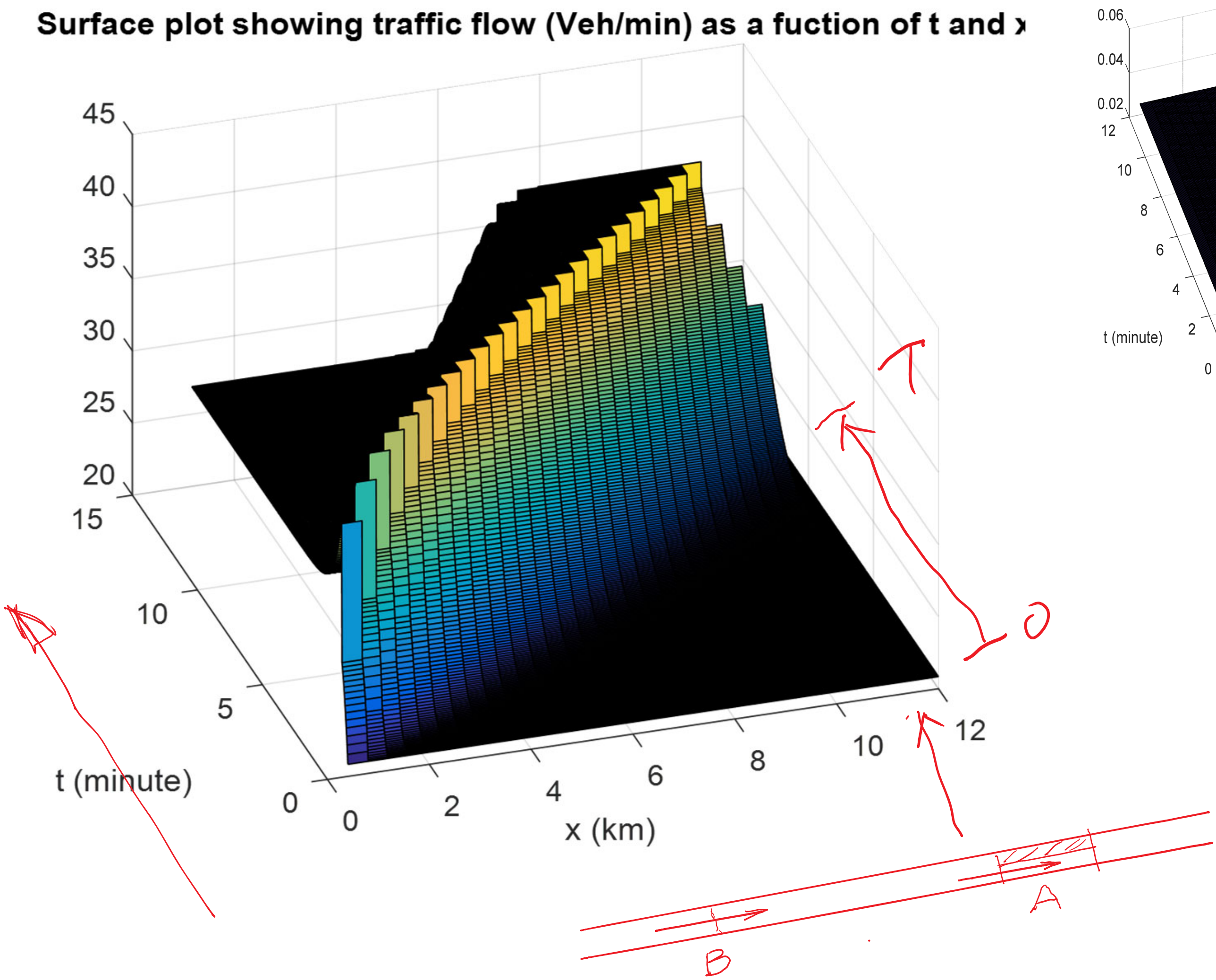
Surface plot showing traffic density (Veh/m) as a fuction of t and x

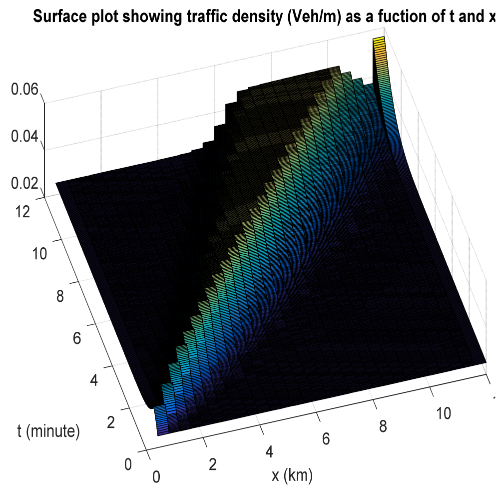



Surface plot showing traffic velocity (km/h) as a fuction of t and
80
70
60
50
40
15
10
5
0
t (minute)
0
2
4
6
8
10
12
x (km)

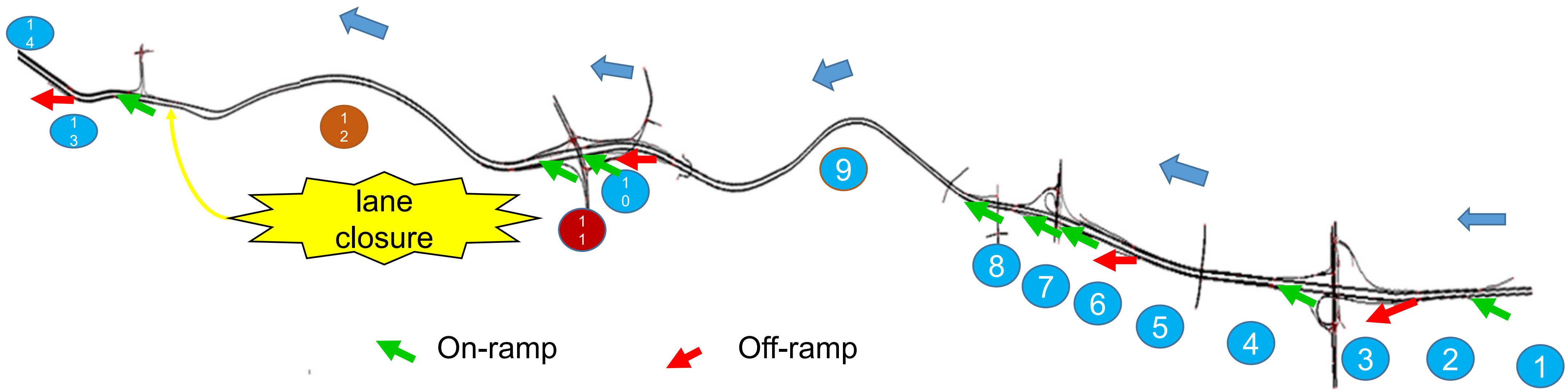

Surface plot showing traffic density (Veh/m) as a fuction of t and x
0.06
0.04
0.02
12
10
8
6
4
2
0
t (minute)
0
2
4
6
8
10
x (km)


B
A


Surface plot showing traffic flow (Veh/min) as a fuction of t and x
45
40
35
30
25
20
15
10
5
0
t (minute)
0
2
4
6
8
10
12
x (km)
B
A

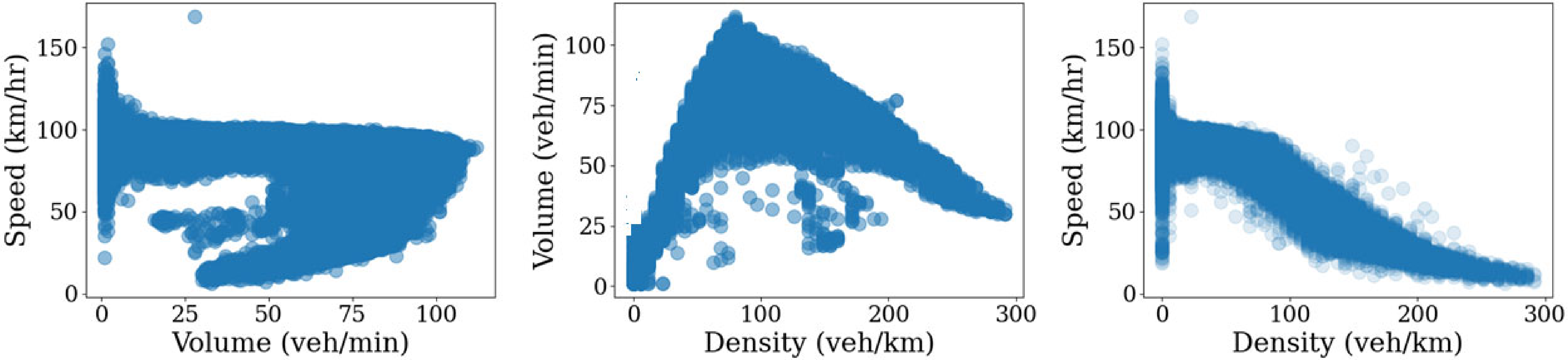

Surface plot showing traffic density (Veh/m) as a fuction of t and x
0.06
0.04
0.02
12
10
8
6
4
2
0
t (minute)
0
2
4
6
8
10
x (km)

4. Study on the Kwinana Freeway Northbound



14 Links of the Kwinana Freeway Northbound

Fundamental diagrams



	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	3	3	3	3	3	4	5

Scenario 1: 1 or 2 lanes close due to a non-recurrent event at the location shown above

- Numerical results will be presented in the next meeting

ACKNOWLEDGEMENTS

The project is funded by the Australian Research Council, Main Roads WA, and Roads and Maritime Services NSW.

Acknowledgement is made to the Australian Research Council, Main Roads WA, Roads and Maritime Services NSW, and the Australia's Sustainable Built Environment National Research Centre (SBEnrc) for their support.

THANK YOU

For Your Attention