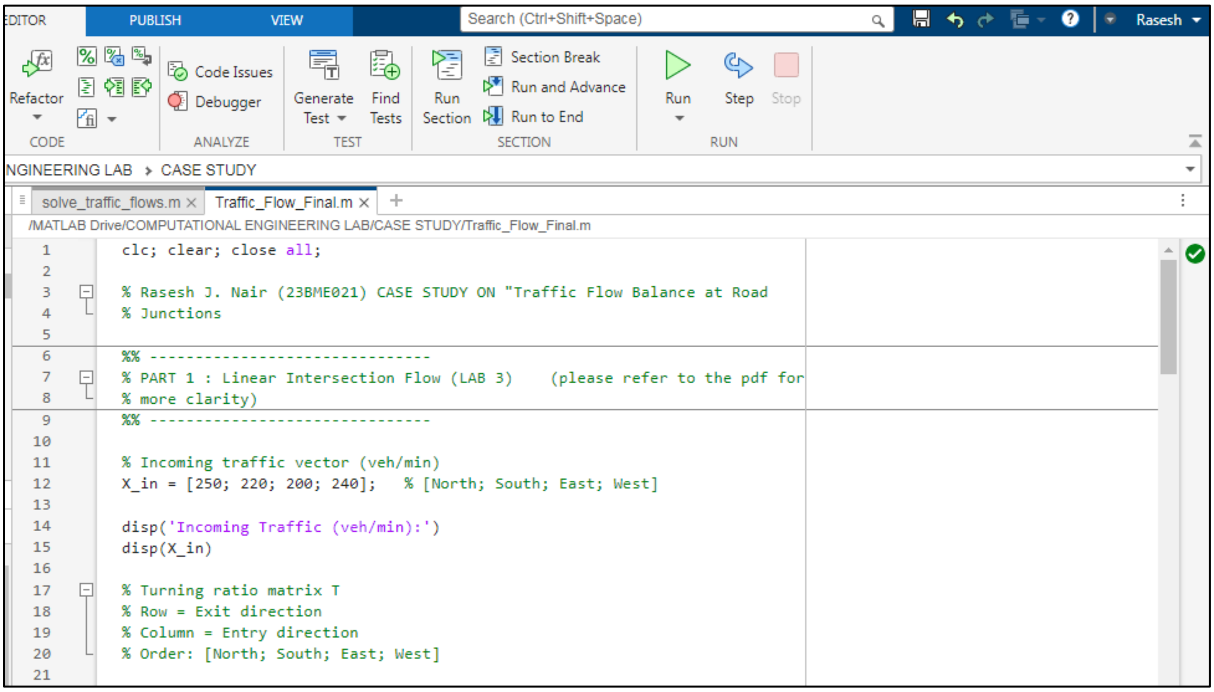
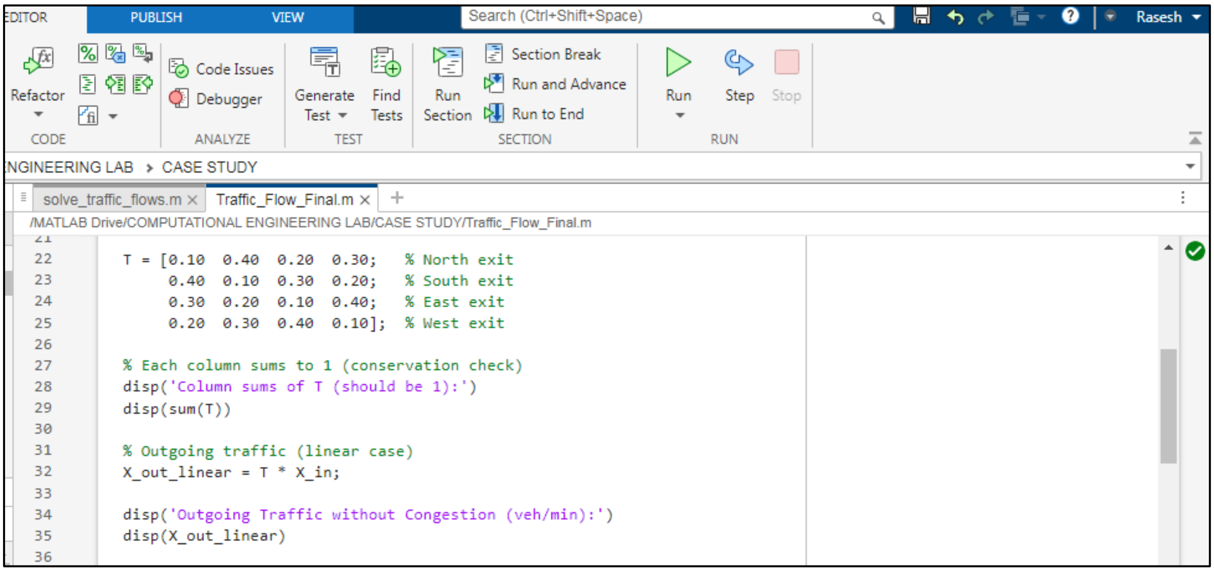
Aim: Traffic Flow Balance at Road Junctions – Using Conservation of Vehicles at intersections to form linear equations and compute traffic flows.



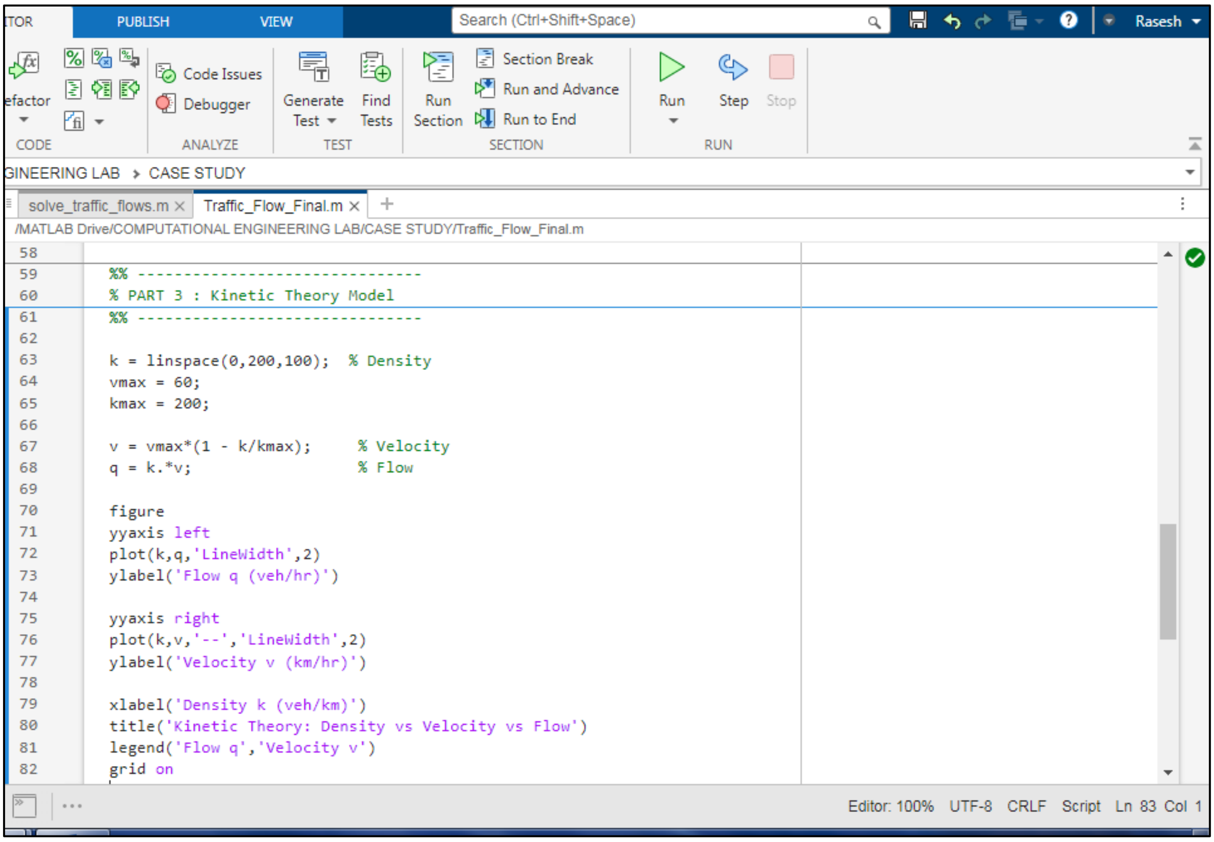
```
clc; clear; close all;

% Rasesh J. Nair (23BME021) CASE STUDY ON "Traffic Flow Balance at Road
% Junctions

%% ------------------------------
% PART 1 : Linear Intersection Flow (LAB 3)    (please refer to the pdf for
% more clarity)
%% ------------------------------

% Incoming traffic vector (veh/min)
X_in = [250; 220; 200; 240];   % [North; South; East; West]

disp('Incoming Traffic (veh/min):')
disp(X_in)

% Turning ratio matrix T
% Row = Exit direction
% Column = Entry direction
% Order: [North; South; East; West]

```



```
T = [0.10  0.40  0.20  0.30;   % North exit
     0.40  0.10  0.30  0.20;   % South exit
     0.30  0.20  0.10  0.40;   % East exit
     0.20  0.30  0.40  0.10];  % West exit

% Each column sums to 1 (conservation check)
disp('Column sums of T (should be 1):')
disp(sum(T))

% Outgoing traffic (linear case)
X_out_linear = T * X_in;

disp('Outgoing Traffic without Congestion (veh/min):')
disp(X_out_linear)

```

```

figure

bar([X_in X_out_linear])

xlabel('Road Number (1=N, 2=S, 3=E, 4=W)')
ylabel('Flow (veh/min)')
title('Incoming vs Outgoing Traffic at Junction (Matrix Model)')
legend('Incoming','Outgoing (Linear)')
grid oN
```

```

%% ------------------------------
% PART 2 : Congestion Effect (Nonlinear)  (LAB 5 concept)
%% ------------------------------

capacity = 400;  % congestion parameter  - vehicle/min

% Nonlinear congestion effect
X_out_cong = X_out_linear .* (1 - X_out_linear/capacity);

disp('Outgoing Traffic with Congestion (veh/min):')
disp(X_out_cong)

% Plot comparison
figure
bar([X_out_linear X_out_cong])
legend('Without Congestion','With Congestion')
xlabel('Road Number (1=N,2=S,3=E,4=W)')
ylabel('Flow (veh/min)')
title('Effect of Congestion at Junction (Matrix Model)')
grid on
```



```matlab

%% ------------------------------
% PART 3 : Kinetic Theory Model
%% ------------------------------

k = linspace(0,200,100);  % Density
vmax = 60;
kmax = 200;

v = vmax*(1 - k/kmax);     % Velocity
q = k.*v;                  % Flow

figure
yyaxis left
plot(k,q,'LineWidth',2)
ylabel('Flow q (veh/hr)')

yyaxis right
plot(k,v,'--','LineWidth',2)
ylabel('Velocity v (km/hr)')

xlabel('Density k (veh/km)')
title('Kinetic Theory: Density vs Velocity vs Flow')
legend('Flow q','Velocity v')
grid on
```

Command Window

```
Incoming Traffic (veh/min):
   250
   220
   200
   240

Column sums of T (should be 1):
     1     1     1     1

Outgoing Traffic without Congestion (veh/min):
   225
   230
   235
   220

Outgoing Traffic with Congestion (veh/min):
   98.4375
   97.7500
   96.9375
   99.0000

>>
```

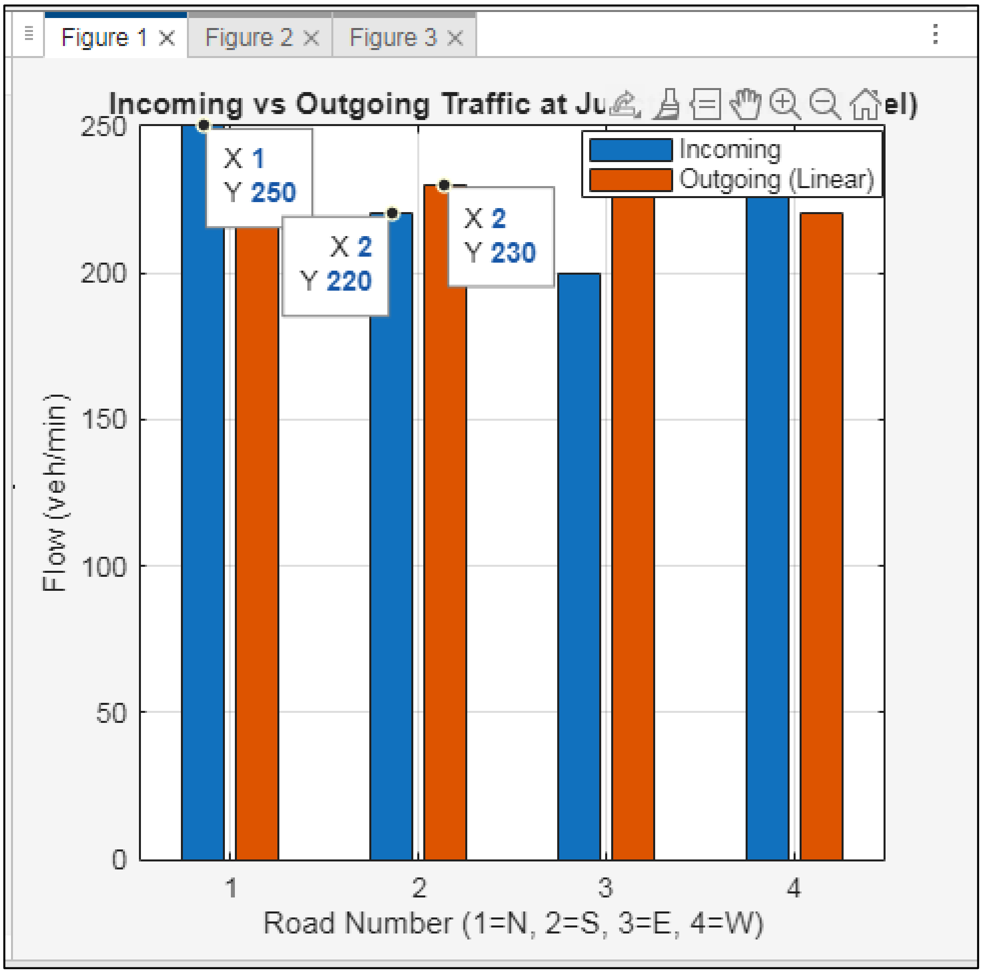


Figure 1
Figure 2
Figure 3
Incoming vs Outgoing Traffic at Ju
el)
Incoming
Outgoing (Linear)
X 1
Y 250
X 2
Y 220
X 2
Y 230
Flow (veh/min)
0
50
100
150
200
250
1
2
3
4
Road Number (1=N, 2=S, 3=E, 4=W)

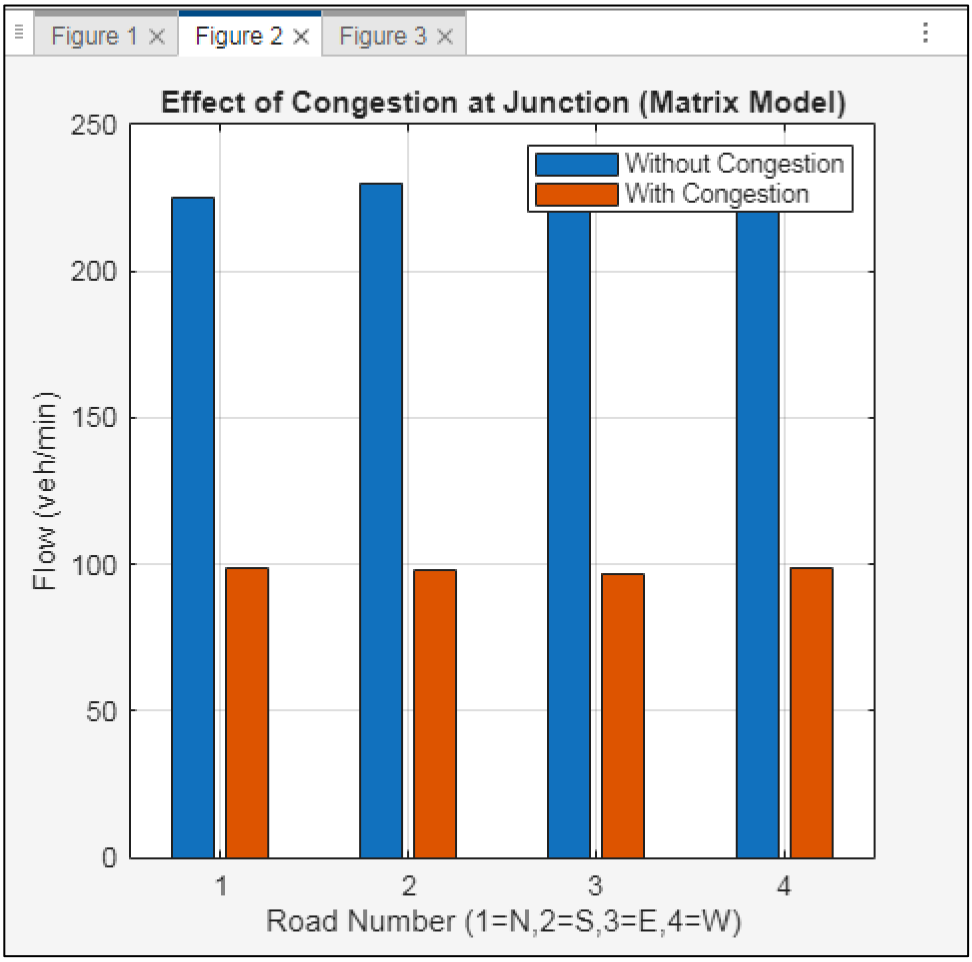


Figure 1
Figure 2
Figure 3
Effect of Congestion at Junction (Matrix Model)
Without Congestion
With Congestion
Flow (veh/min)
0
50
100
150
200
250
1
2
3
4
Road Number (1=N,2=S,3=E,4=W)

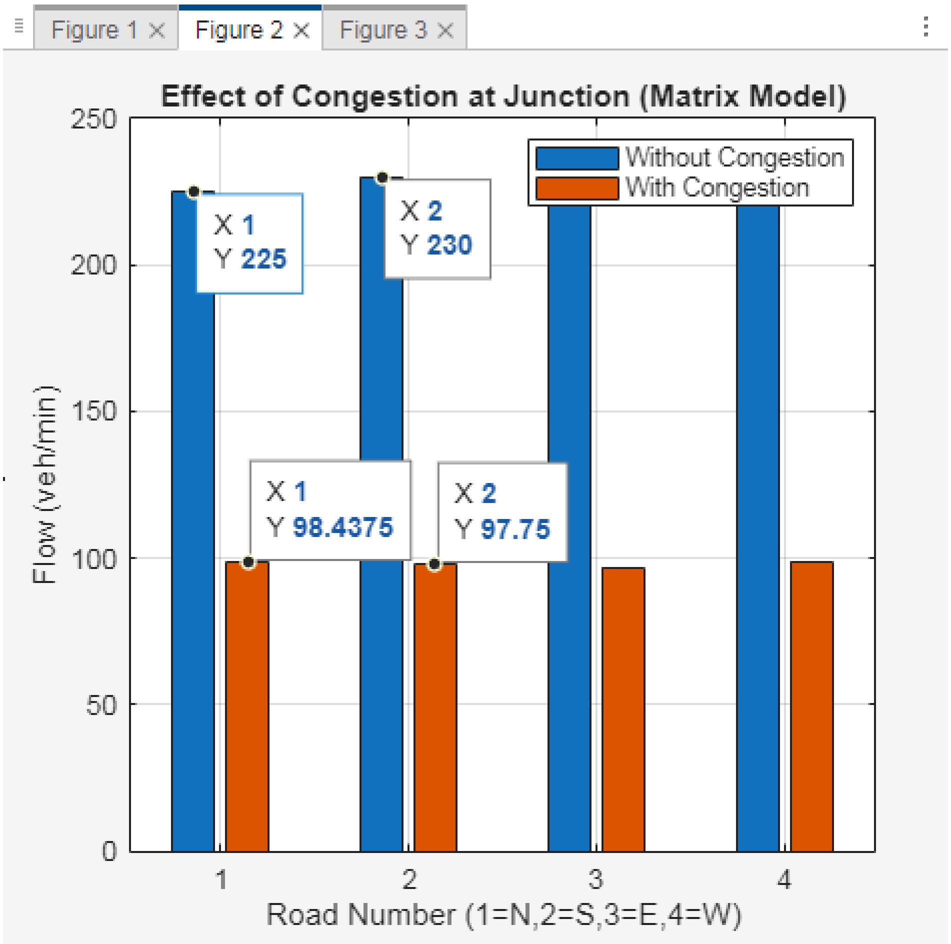


Figure 1
Figure 2
Figure 3
Effect of Congestion at Junction (Matrix Model)
Without Congestion
With Congestion
X 1
Y 225
X 2
Y 230
X 1
Y 98.4375
X 2
Y 97.75
Flow (veh/min)
250
200
150
100
50
0
1
2
3
4
Road Number (1=N,2=S,3=E,4=W)

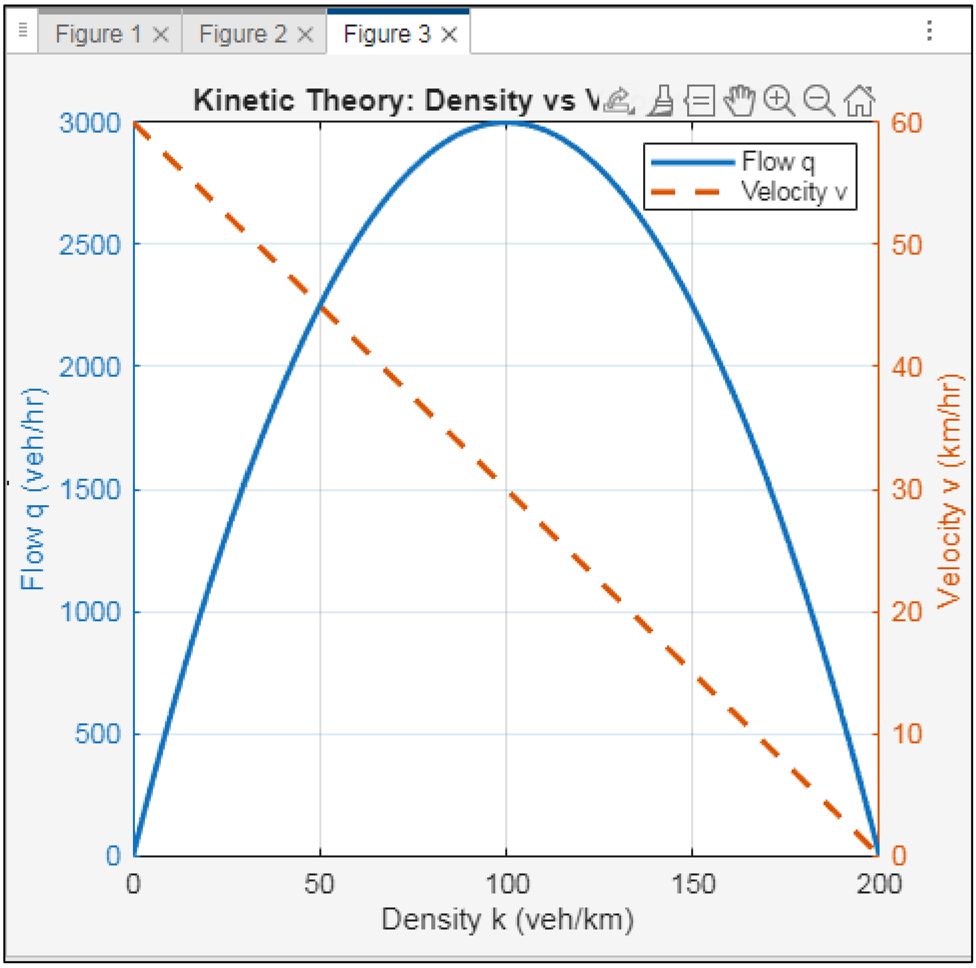


Figure 1
Figure 2
Figure 3
Kinetic Theory: Density vs V
Flow q
Velocity v
Flow q (veh/hr)
Velocity v (km/hr)
Density k (veh/km)
3000
2500
2000
1500
1000
500
0
60
50
40
30
20
10
0
0
50
100
150
200

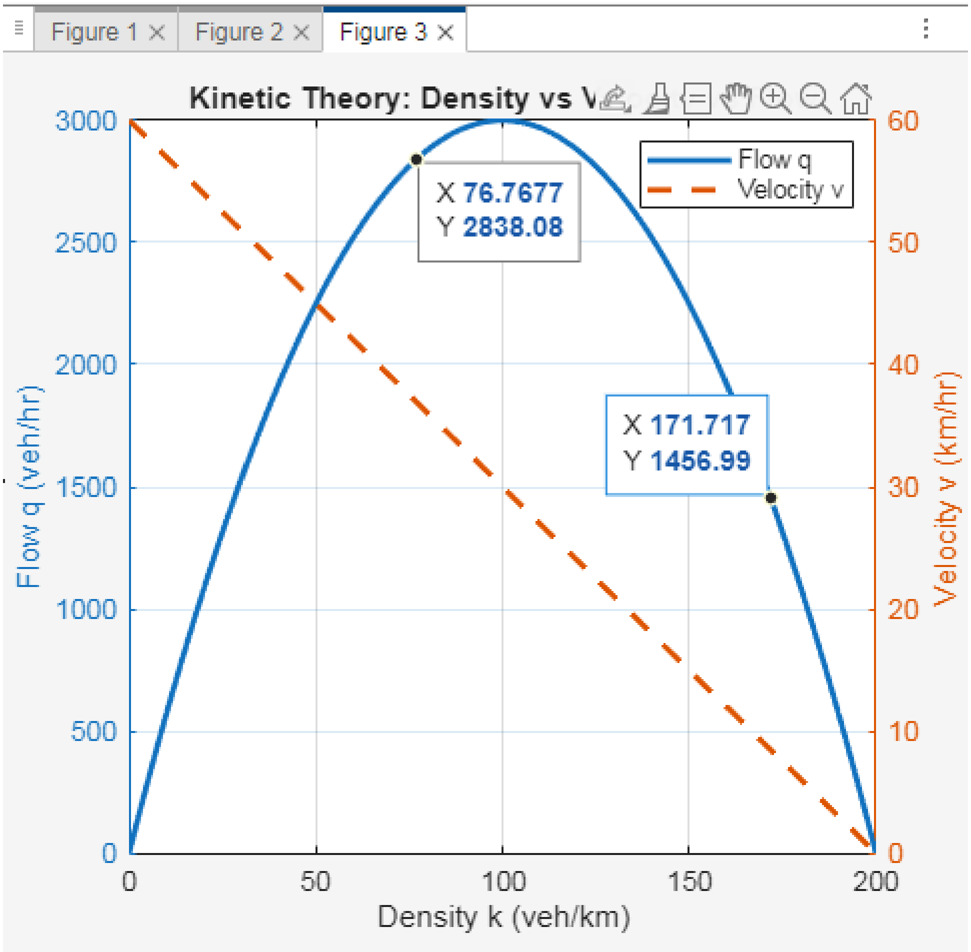


Figure 1
Figure 2
Figure 3
Kinetic Theory: Density vs V
Flow q
Velocity v
X 76.7677
Y 2838.08
X 171.717
Y 1456.99
Flow q (veh/hr)
Velocity v (km/hr)
Density k (veh/km)
3000
2500
2000
1500
1000
500
0
60
50
40
30
20
10
0
0
50
100
150
200

CEL LAB
(Case Study)

No. of vehicles (entering) = No. of vehicles (leaving)

4 Roads →

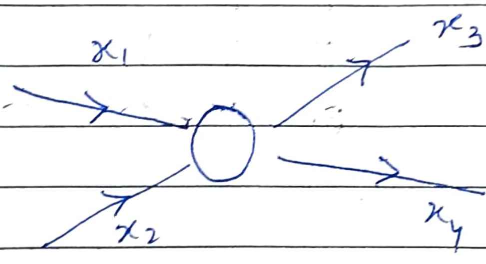
x_1, x_2 : Incoming traffic flows

x_3, x_4 : outgoing traffic flows

Conservatⁿ Law:

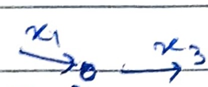
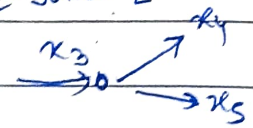
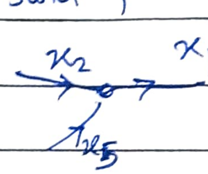
$$x_1 + x_2 = x_3 + x_4$$

$$x_1 + x_2 - x_3 - x_4 = 0$$



★ Multiple ~~Roads~~ Junctⁿˢ → multiple eqⁿ

x_1, x_2, x_3, x_4, x_5 → Cars per hour on that road

@ Junctⁿ 1	@ Junctⁿ 2	@ Junctⁿ 4
		
$x_1 + x_2 = x_3$	$x_3 = x_4 + x_5$	$x_2 + x_5 = x_1$
$x_1 + x_2 - x_3 = 0$	$x_3 - x_4 - x_5 = 0$	$x_2 + x_5 - x_1 = 0$
← (1)	← (2)	← (3)

$$x_1 + x_2 - x_3 = 0 \quad \text{(Junct}^n\text{ 1)}$$
$$x_3 - x_4 - x_5 = 0 \quad \text{(Junct}^n\text{ 2)}$$
$$x_2 + x_5 - x_1 = 0 \quad \text{(Junct}^n\text{ 3)}$$

Putting in Matrix form

$$A \cdot x = b$$

Coeff from eq^n — unknown Traffic flow — zero vector (because of conservat^n)

$$A = \begin{array}{ccccc} x_1 & x_2 & x_3 & x_4 & x_5 \end{array}$$
$$\begin{bmatrix} 1 & 1 & -1 & 0 & 0 \\ 0 & 0 & 1 & -1 & -1 \\ -1 & 1 & 0 & 0 & 1 \end{bmatrix}$$

$$b = [0 \quad 0 \quad 0]$$

$$x = A/b$$

Kinetic theory

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Date : / /

4-Road Junction

(North, South, East, West)

Let:

x_1 = flow from North to Junction (vehicle/min)
x_2 = " " South " " "
x_3 = " " East " " "
x_4 = " " West " " "

At the Junction:

10% vehicle take U-Turn
20% turn Right
30% turn left
40% go straight

Outgoing flow:

East exit = 180 veh
West " = ~~160~~ 16
North " = 150
South " = 170

★ Conservation of vehicle

Total inflow = Total Outflow

e.g.:

1) Vehicles leaving to $\boxed{\text{East}}$ come from:

1.) Straight from West (40% of x_4)
2.) Left from North (30% of x_1)
3.) Right " South (20% of x_2)
4.) U-Turn " East (10% of x_3)

$$0.4x_4 + 0.3x_1 + 0.2x_2 + 0.1x_3 = 180$$

2) West exit

$$0.4x_3 + 0.3x_2 + 0.2x_1 + 0.1x_4 = 160$$

3) North exit

$$0.4x_2 + 0.3x_4 + 0.2x_3 + 0.1x_1 = 150$$

4) South exit

$$0.4x_1 + 0.3x_3 + 0.2x_4 + 0.1x_2 = 170$$

* Matrix

$$AX = B$$

$$A = \begin{bmatrix} 0.3 & 0.2 & 0.1 & 0.4 \\ 0.2 & 0.3 & 0.4 & 0.1 \\ 0.1 & 0.4 & 0.2 & 0.3 \\ 0.4 & 0.1 & 0.3 & 0.2 \end{bmatrix} \quad X = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} \quad B = \begin{bmatrix} 180 \\ 160 \\ 150 \\ 170 \end{bmatrix}$$

$$X = A \backslash B$$

Non - Linearing

Congestion effect

$F = x(1 - \alpha x)$

$\alpha = 0.0005$

$0.3x_1(1 - 0.0005x_1) + \ldots$

2) Kinetic theory

Flow = Density x Velocity

$$q = kv$$

Assuming vel. ↓ses with density

$$v = v_{max}(1 - k/k_{max})$$

then,

$$q = k\,v_{max}\left(1 - \frac{k}{k_{max}}\right)$$