Chapter 6- Application and Results

6.1. Application

The above proposed methodology is applied to an arterial street network made up of three links. A loop detector is placed at the 800 ft mark from the stop line of each link. The length of main link i is 1600ft.

The traffic data is obtained from the loop detector as simulated by CORSIM. The travel times on the main link i are calculated based on the data from the loop detector. The conditions on link i are affected by the conditions on link i+1 and link i-1.

Three different time interval updates by the loop detector are carried on to test the sensitivity of the results to various time updates based on the same intersection cycle length of 100 seconds and with the same incoming volumes. The three time updates are 60sec, 100 sec and 120 sec respectively. The first simulation is based on a time interval update of 100 seconds, which also represents the observed cycle length of the downstream intersection of link i.

The loop detector in CORSIM provides three types of traffic data: the cumulative number of vehicle passing the detector, the cumulative average speed detected by the detector (mph), and the cumulative dwelling time (sec). Based on these data, the average dwelling time during the observed time interval is calculated as follows:

$$\frac{Total\_dwelling\_time\_during\_observed\_\mathrm{int}erval}{number\_of\_vehicle\_counted\_during\_observed\_\mathrm{int}erval};$$

The density Ktd is calculated as the ratio of flow/speed.

The cycle length for the observed intersection is 100 sec with 60 seconds green time in the observed direction. The free flow speed (speed limit) is 45 mph. There is a left turn pocket lane on link i. The layout information of the experiment is shown in Figures 6-1 and 6-2. Figure 6-2 shows the CORSIM visualization simulation output for the main link. The saturated departure flow rate in green time is simulated by CORSIM to be 1800 veh/h/ln. The intersection capacity is 1800*60/100=1080 veh/h/ln. And the capacity of link i-1 is 1395veh/h/ln, since the green time is 75 seconds out of a 100 seconds cycle length.

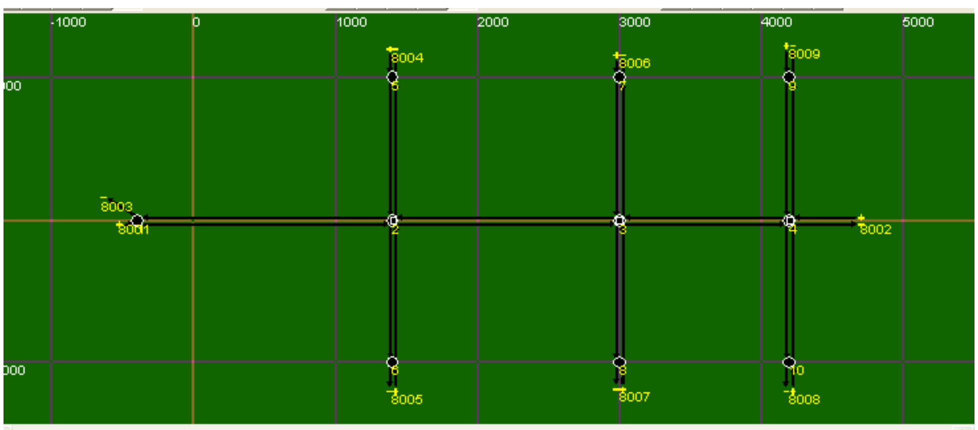

Figure 6 - 1 Arterial Streets Network in CORSIM

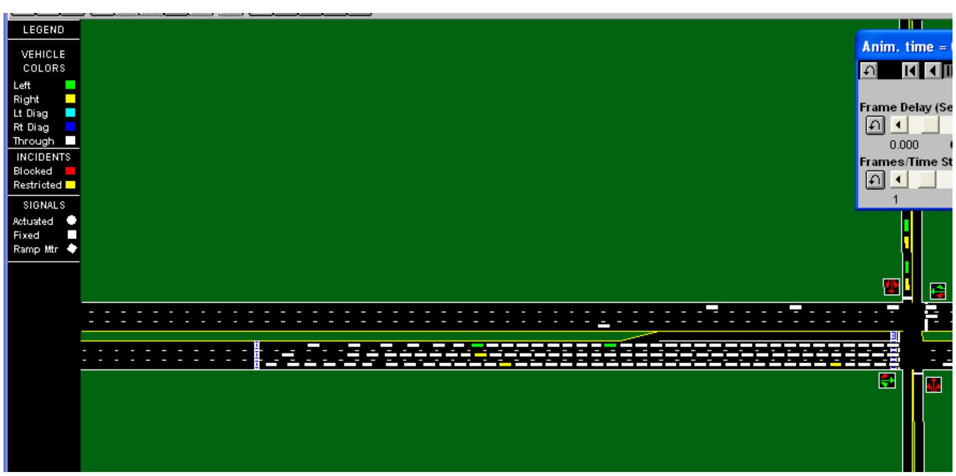

Figure 6 - 2 Vision of Simulation in CORSIM

6.2 The analysis for 100 sec. time interval.

The input volume is shown in Table 6-1 as it is fed into the CORSIM simulator:

Table 6 - 1 Input Volume

100 sec interval	Volume(veh/h)
0-100	900
100-200	2550
200-300	3900
300-400	5400
400-500	5100
500-600	4200
600-700	3000
700-800	1200
800-900	900
900-1000	600
1000-1100	600

The data collected from the loop detector in CORSIM is shown in Table 6-2:

Table 6 - 2 Loop Detector Data

	A	B	C
Time period	cumulative number of vehicle detected(3 lanes)	cumulative average speed by detector(mph)	cumulative dwelling time(secs)
1	73	38.3	24.9
2	134	39.3	44.3
3	227	38.6	74.5
4	337	38.1	109.4
5	474	36.7	156.1
6	580	34.3	210.1
7	684	30.9	284.8
8	754	28.8	369
9	782	28.7	387.2
10	807	29.1	395.2

The data calculated for each time interval using Table 6-2 is shown in Table 6-3

Table 6 - 3 Data Transfer From Loop Detector

Time period	Detector(veh /cycle length/ln) count	average speed by detector(mile /h)	Occupancy (%)	Density Ktd(veh/mile)	average dwelling time sec/veh
1	24.3	38.3	8.3	22.9	0.34
2	20.3	40.5	6.5	18.1	0.32
3	31	37.6	10.1	29.7	0.32
4	36.7	37.1	11.6	35.6	0.32
5	45.7	33.3	15.6	49.4	0.34
6	35.3	23.6	18	54	0.51
7	34.7	11.9	24.9	104.5	0.72
8	23.3	8.3	28.1	101.4	1.2
9	9.3	26	6.1	12.9	0.65
10	8.3	41.6	2.7	7.2	0.32

Column 1 in Table 6-3 is obtained by using column A in Table 6-2 as follows:

$\frac{(A_t)-(A_{t-1})}{3}$. For example, at time interval 1 in Table 6-3, the number of vehicles detected is (73-0)/3=24.33 veh/ln/cycle length, where 3 represents the number of lanes.

The average speed at time t in Table 6-3 is calculated using columns A and B in Table 6-2 as follows; $\frac{A_t \times B_t - A_{t-1} \times B_{t-1}}{A_t - A_{t-1}}$ (mph);

The average dwelling time is calculated using columns C and A as follows; $\frac{C_t - C_{t-1}}{A_t - A_{t-1}}$,(sec/veh);

The average occupancy at the detector= (average dwelling time)*CL/3600*100%;

Density (Ktd) at time t $= \frac{(A_t) - (A_{t-1})}{3} \times \frac{3600}{CL} \div (speed\_in\_table\_3)$, (veh/mile)

In this experiment the travel time update is equal to the cycle length which is 100secs. So, we chose 10 travel time updates for a total of 1000 secs., and consequently the CORSIM simulation is run for 1000secs. We found out that 1000secs were enough for the vehicle queue to build up to reach the detector and to completely dissipate within this period.

Travel Time for Time Interval 1:

In the first time interval, there is no initial queue. From Table 6-3, the detected volume is 24.33 veh/ ln. These 24.33 veh are the observed group whose travel time to traverse link i is to be computed for time interval 1. The average speed detected by detector is 38.3mph.

The Volume in an hour as opposed to 100 secs is: 24.33/100*3600=876vph;

V/C=876/1080=0.811;

The density is Ktd =flow/speed=24.33/100*3600/38.3.=22.87 veh/mile;

h1=100/24.3=4.11 sec/veh

h2=2 sec/veh

S1=38.3mph,S2=6.5 mph

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{38.3 \times 4.11 - 19}{38.3 - 6.5} = 4.35;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{4.35 \times 2}{4.35 - 2} = 3.7 \text{ sec/veh}$$

From Equation 4-14, the average uniform stopped delay for this observed group is computed as follows:

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times \frac{40}{4.11} \times (\frac{40}{4.11} \times 3.7 + 40)}{24.33} = 15.2 \sec/veh;$$

The over-saturation delay is zero since V is smaller than the intersection capacity

$d2 = 0$;

The initial queue d3 is equal to zero since there is no initial queue at this time period.

$$W_d = \frac{C - V}{k_q - k_{td}} = \frac{1080 - 876}{135 - 22.87} = 1.82 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{\mathrm{d}t}\right) = \left(876 - 1080 - 1.82 \times 22.87\right) = -245.6 veh/h$$

The number of vehicles in the queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL = -245.6 \times \frac{100}{3600} = -7 veh$$

Then the initial queue for the next time interval is $Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 0$.

Hence, from Equation 3-9 the travel time for this group is:

$$Travel - time = \frac{L - QL}{speed\_by\_\det ector} + d1 + d2 + d4$$
$$= \frac{1600 - 0}{38.3 \times 5280 \div 3600} + 15.2 + 0 + 0 = 43.7 \sec$$

Hence, **the travel time in time interval 1 is 43.7 sec.**, and the initial queue for next time interval is zero.

Travel Time for Time Interval 2:

In the second time interval, there is no initial queue based on the previous computation, and the average dwelling time 0.32sec/veh is smaller than 0.6sec/veh.

Hence, there is no blackout on the loop detector. From Table 6-3, the detected volume is 20.33 veh/ln. These 20.33 veh is the observed group whose travel time is to be computed for time interval 2. The average speed detected by detector is 40.5mph.

Volume: 20.33/100*3600=732vph;

V/C=732/1080=0.678;

The density is Ktd =flow/speed=20.33/100*3600/40.5.=18.1 veh/mile;

h1=100/20.3=4.9 sec/veh

h2=2 sec/veh

S1=40.49mph,S2=6.5 mph

From Equation 4-13;

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{40.49 \times 4.9 - 19}{40.49 - 6.5} = 5.3;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{5.3 \times 2}{5.3 - 2} = 3.21 \text{sec/veh}$$

From Equation 4-14, the average uniform stopped delay for this observed group is computed as follows:

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times \frac{40}{4.9} \times (\frac{40}{4.9} \times 3.21 + 40)}{20.3} = 13.2 \sec/veh;$$

The over-saturation delay is zero since V is smaller than intersection capacity

$$d2 = 0;$$

Since there is no initial queue for this incoming group, the initial queue d3=0sec.

$$W_d = \frac{C - V}{k_q - k_{td}} = \frac{1080 - 732}{135 - 18.1} = 2.97 mile/hour$$

The queuing rate QR(veh/h) is:

$$QR = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{dt}\right) = \left(732 - 1080 - 2.97 \times 18.1\right) = -401.8 veh/h$$

The number of vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL = -401.8 \times \frac{100}{3600} \approx -11 veh/\ln$$

Then the initial queue for the next time interval is $Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 0$.

Hence, from Equation 3-9, the travel time for this group is :

$$Travel - time = \frac{L - QL}{speed\_by\_\det ector} + d1 + d2 + d4$$
$$= \frac{1600 - 0}{40.49 \times 5280 \div 3600} + 13.2 + 0 + 0 = 40.1 \sec$$

Therefore, the **travel time for time interval 2 is 40.1 sec**., and the initial queue for the next time interval is zero.

Travel Time for Time Interval 3:

In third time interval, there is no initial queue based on the calculation of the previous time period 2, and the average dwelling time 0.32sec/veh is smaller than 0.6sec/veh. Hence, there is no blackout on the loop detector. From Table 6-3, the detected volume is 31 veh /ln. The average speed detected by detector is 37.59 mph.

Volume: 31/100*3600=1116vph;

V/C=1116/1080=1.033;

The density is Ktd =flow/speed=31/100*3600/37.59.=29.7 veh/mile;

Since, V is greater than C, use the capacity as the input volume to estimate the uniform stopped delay d1:

h1=100/30=3.33 sec/veh

h2=2 sec/veh

S1=37.6mph,S2=6.5 mph;

From Equation 4-13;

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{37.6 \times 3.33 - 19}{37.6 - 6.5} = 3.42;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{3.42 \times 2}{3.42 - 2} = 4.82 \text{ sec/veh}$$

From Equation 4-14, the average uniform stopped delay for this observed group is computed as follows:

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times \frac{40}{3.3} \times (\frac{40}{3.3} \times 4.82 + 40)}{31} = 18.9 \text{ sec}/veh;$$

Since there is no initial queue for this incoming group, the initial queue d3=0sec.

$$W_u = \frac{V - C}{k_{td} - k_q} = \frac{1116 - 1080}{29.7 - 135} = -0.34 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{dt}\right) = \left(1116 - 1080 + 0.34 \times 29.7\right) = 46.1 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL = 46.1 \times \frac{100}{3600} \approx 1 veh/\ln$$

Then the initial queue for the next time interval is $Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 1 veh/\ln$.

The initial queue for next time interval is 1 veh.

The queue length is

(19)*1=19ft.

Since Qm is greater than zero, there is an over-saturation delay. From Equation 4-27,

$$d2 = \frac{area(B) + area(C)}{V \times CL} = \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{0.5 \times Q_m \times Q_m \times h2}{V \times CL} + \frac{Q_m \times r}{V \times CL};$$
$$= \frac{0.5 \times 1 \times 100}{31} + \frac{0.5 \times 1 \times 1 \times 2}{31} + \frac{1 \times 40}{31} = 2.9\sec$$

According to Equation 3-10, the travel time for this group is computed as follows:

$$Travel - time = \frac{L_{TD} - QL}{speed\_by\_loop\_\det ector \times 2} + \frac{L - L_{TD}}{speed\_\lim it} + d1 + d2 + d4$$
$$= \frac{800 - 19}{37.5 \times \frac{3600}{5280} \times 2} + \frac{800}{45 \times \frac{3600}{5280}} + 18.9 + 2.9 + 0 = 41.2\sec$$

Therefore, the **travel time for time interval 3 is 41.2 sec**., and the initial queue for the next time interval is one vehicle.

Travel Time for Time Interval 4

In time interval 4, there is an initial queue based on the calculation of the previous time periods, and the average dwelling time at the detector is smaller than 0.6sec/veh. Hence, there is no blackout on the loop detector. From Table 6-3, the detected volume is 36.66 veh/ln. These 36.66 veh represent the observed group whose travel time is to be calculated for time interval 4. The average detected speed is 37.01 mph.

Volume: 36.66/100*3600=1320vph;

V/C=1320/1080=1.222;

The density is Ktd =flow/speed=36.66/100*3600/37.01.=35.67 veh/mile;

Since, V is greater than C, use the capacity as the input volume to estimate the uniform stopped delay d1.

h1=100/30=3.33 sec/veh

h2=2 sec/veh

S1=37. mph,S2=6.5 mph

From Equation 4-8, $(n-1)\times g \le \frac{Q_{t-1}}{D_s} \le n\times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{1}{1800 \div 3600} = 2\sec$,and g=60, n=1

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n)\times red\_time = \frac{1}{1800 \div 3600} + (1)\times 40 = 42\sec$

$$W_u = \frac{V-C}{k_{td}-k_q} = \frac{1320-1080}{35.67-135} = -2.41 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{\mathrm{dt}}\right) = 326 veh/h$$

The number of vehicles in the queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL \approx 9 veh/\ln$$

Then the initial queue for the next time interval is

$$Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 1 + 9 = 10 veh/\ln\ .$$

In this time interval, d3 is smaller than the cycle length and volume is greater than the capacity. Figure 4-17 and its corresponding equations, as shown in Chapter 4, are used to compute the d1 in this time interval.

From Equation 4-13 to 2-15;

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{37 \times 3.33 - 19}{37 - 6.5} = 3.4\,;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{3.4 \times 2}{3.4 - 2} = 4.82\,\text{sec/veh}$$

$$m = \frac{r}{h1} = \frac{40}{3.33} = 12veh$$

$$k = m + Iq - \frac{g1}{h3} = 12 + 1 - \frac{2}{4.82} = 12.6$$

Based on Figure 4-17 and equations from Equation 4-15 to 2-19, we can get:

g1=2sec, and g2=58 sec

$$L = m + Iq - \frac{g1 + g2}{h3} = 12 + 1 - \frac{60}{4.82} = 0.55\,;$$

$$i = 1$$

$$t4 - t3 = (i - L) \times h1 = (1 - 0.55) \times 3.33 = 1.5\,\text{sec}$$

$$a = 0.5 \times (k + L) \times g2 = 0.5 \times (12.6 + 0.55) \times 58 = 380\,\text{sec}$$

$$\begin{aligned} b &= 0.5 \times (L + i) \times (t4 - t3) + i \times (red - (t4 - t3)) \\ &= 0.5 \times (0.55 + 1) \times 1.5 + 1 \times (40 - 1.5) = 40\,\text{sec} \end{aligned}$$

$$c = 0.5 \times i \times i \times h2 = 0.5 \times h2 \times i^2 = 0.5 \times 2 = 1$$

The average stopped delay is computed as follows

$$d1 = \frac{a + b + c}{V \times CL} = \frac{380 + 40 + 1}{37} = 11.5\,\text{sec}$$

Since, Qm*h2 is smaller than g2, Over-saturation delay is computed as follows:

$$d2 = \frac{area(B) + area(C)}{V \times CL} = \frac{0.5 \times 9 \times 100}{36.7} + \frac{0.5 \times 9 \times 9 \times 2}{36.7} = 14.5$$

Since d3 is smaller than cycle length and the volume is greater than the capacity Equation 4-29 and 4-30 are used to compute the d4.And the new value of k and m should be computed based on the actual volume which is 36.7 veh per 100 seconds.

The k’ and m’ is 15.4 and 14.6 respectively.

$$d4 = \frac{0.5 \times r \times m' + 0.5 \times (m' + k') \times g1}{Total\_vehicle\_in\_the\_Observed\_Group}$$
$$= \frac{0.5 \times 40 \times 14.6 + 0.5 \times (14.6 + 15.4) \times 2}{36.7} = 8.8 \sec$$

$$Travel - time = \frac{L_{TD} - QL}{speed\_by\_\det ector \times 2} + \frac{L - L_{TD}}{Speed\_\lim it} + d1 + d2 + d4$$
$$= \frac{800 - 19 \times 1}{37.06 \times 5280 \div 3600} + \frac{1600 - 800}{45 \times 5280 \div 3600} + 11.5 + 14.5 + 8.8 = 61.3 \sec$$

Hence, **the travel time for time interval 4 is 61.3 sec.** The initial queue for next time interval is 10 veh.

Travel Time for Time Interval 5

In time interval 5, there is an initial queue of 10veh, and the average dwelling time at the detector is 0.34 sec/veh which is smaller than 0.6sec/veh. Hence, there is no blackout at the loop detector. From Table 6-3, the detected volume is 45.66 veh/ln, and the average detected speed is 33.25 mph.

Volume: 45.66/100*3600=1644vph;

V/C=1644/1080=1.522;

The density is Ktd =flow/speed=1644/33.25.=49.43 veh/mile;

From Equation 4-8, $(n-1) \times g \le \frac{Q_{t-1}}{D_s} \le n \times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{10}{1800 \div 3600} = 20 \sec$,and g=60, n=1

From Equation 4-8, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n) \times red\_time = \frac{10}{1800 \div 3600} + (1) \times 40 = 60 \sec$

g1=20sec, and g2=40 sec

Since V is greater than Capacity, use the capacity as the incoming volume to estimate the uniform stopped delay.

h1=100/30=3.33 sec/veh

h2=2 sec/veh

S1=33. mph,S2=6.5 mph

$$W_u = \frac{V - C}{k_{td} - k_q} = \frac{1644 - 1080}{49.43 - 135} = -6.6 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{dt}\right) = \left(1644 - 1080 + 6.6 \times 49.43\right) = 900 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL = 900 \times \frac{100}{3600} \approx 24 veh/\ln$$

Then the initial queue for the next time interval is

$$Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 10 + 24 = 34 veh/\ln .$$

The queue length is 19*34=646 ft

In time interval 5, the d3 is smaller than the cycle length and volume is greater than the intersection capacity. Figure 4-17 and its corresponding equations, as shown in Chapter 4, are used to compute the d1 in this time interval.

From Equation 4-13 to 2-15, we can get

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{33 \times 3.33 - 19}{33 - 6.5} = 3.4;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{3.4 \times 2}{3.4 - 2} = 4.82 \text{ sec/veh}$$

$$m = \frac{r}{h1} = \frac{40}{3.33} = 12 veh$$

$$k = m + Iq - \frac{g1}{h3} = 12 + 10 - \frac{20}{4.82} = 17.8$$

$$L = m + Iq - \frac{g1 + g2}{h3} = 12 + 10 - \frac{60}{4.82} = 9.5\,;$$

$$i = 10$$

$$t4 - t3 = (i - L) \times h1 = (10 - 9.5) \times 3.33 = 1.6$$

$$a = 0.5 \times (k + L) \times g2 = 0.5 \times (17.8 + 9.5) \times 40 = 546\,\sec$$

$$\begin{aligned} b &= 0.5 \times (L + i) \times (t4 - t3) + i \times (red - (t4 - t3)) \\ &= 0.5 \times (9.5 + 10) \times 1.6 + 10 \times (40 - 1.6) = 399.5\,\sec \end{aligned}$$

$$c = 0.5 \times i \times i \times h2 = 0.5 \times h2 \times i^2 = 0.5 \times 2 \times 100 = 100$$

The average stopped delay

$$d1 = \frac{a + b + c}{V \times CL} = 22.9\,\sec$$

Since g2 can not dissipate all the vehicles in Qm, Equation 4-28 is used to compute the over-saturation delay.

i'= Qm-g2/h2=24-40/2=4veh

Over-saturation delay is

$$\begin{aligned} d2 &= \frac{area(A) + area(B) + area(C) + area(D)}{V \times CL} \\ &= \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{0.5 \times (i' + Q_m) \times g2}{V \times CL} + \frac{r \times i}{V \times CL} + \frac{0.5 \times i' \times i' \times h2}{V \times CL} \\ &= \frac{0.5 \times Q_m \times CL + 0.5 \times (i' + Q_m) \times g2 + r \times i' + 0.5 \times h2 \times i'^2}{V \times CL} \\ &= \frac{0.5 \times 24 \times CL + 0.5 \times (4 + 24) \times 40 + 40 \times 4 + 0.5 \times 2 \times 4^2}{45.6} = 38.89\,\sec/veh \end{aligned}$$

Since d3 is smaller than cycle length and the volume is greater than the capacity Equation 4-29 and 4-30 are used to compute the d4. In addition, the new value of k and m should be computed based on the actual volume which is 45.7 veh per 100 seconds.

The k' and m' is 28.2 and 18.3 respectively.

$$d4 = \frac{0.5 \times r \times m' + 0.5 \times (m' + k') \times g1}{Total\_vehicle\_in\_the\_Observed\_Group}$$
$$= \frac{0.5 \times 40 \times 18.3 + 0.5 \times (18.3 + 28.2) \times 20}{46} = 18.2\sec$$

Since, there is no blackout at the loop detector; Equation 3-10 is used to compute the travel time as follows:

$$Travel - time = \frac{L_{TD} - QL}{speed\_by\_\det ector \times 2} + \frac{L - L_{TD}}{Speed\_\lim it} + d1 + d2 + d4$$
$$= \frac{800 - 19 \times 10}{33.25 \times 5280 \div 3600} + \frac{1600 - 800}{45 \times 5280 \div 3600} + 22.9 + 38.89 + 18.2 = 104.6\sec$$

Therefore, the **travel time for time interval 5 is 104.6 sec**., and the initial queue for the next time interval is 34.

Travel Time for Time interval 6

In time interval 6, there is an initial queue of 34 veh, and the average dwelling time is 0.509 which is smaller than 0.6sec/veh. From Table 6-3, the detected volume is 35.33 veh/ln. These 35.33 vehicles are the observed group which represents the travel time at time interval 6. The average detected speed is 23.56 mph.

Volume: 35.33/100*3600=1272vph;

V/C=1272/1080=1.18;

The density is Ktd =flow/speed=1272/23.56.= 53.97166 veh/mile;

From Equation 4-8, $(n-1) \times g \le \frac{Q_{t-1}}{D_s} \le n \times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{34}{1800 \div 3600} = 72\sec$,and g=60, n=2

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n) \times red\_time = \frac{34}{1800 \div 3600} + (2) \times 40 = 148\sec$

g1=8sec, and g2=52 sec;

$$W_u = \frac{V - C}{k_{td} - k_q} = -2.37 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{\mathrm{dt}}\right) = 320 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL = 320 \times \frac{100}{3600} \approx 8 veh/\ln$$

Then the initial queue for the next time interval is

$$Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 8 + 34 = 42 veh/\ln.$$

Since V is greater than Capacity, use the capacity as the incoming volume to estimate the uniform stopped delay. Since d3 is greater than a cycle length, all vehicles in the observed group are assumed to be in the queue when they dissipate the intersection. Figure 4-18 and its corresponding equations, as shown in Chapter 4, are used to compute the d1 in this time interval..

h1=100/30=3.33 sec/veh

h2=2 sec/veh

$$m = C \times CL = 30 veh$$

$$i = m - \frac{g2}{h2} = 30 - \frac{52}{2} = 4 veh$$

The area of A is

$$a = 0.5 \times (i + m) \times g2 = 0.5 \times (4 + 30) \times 52 = 884 \sec;$$

The area of B and C are

$b = r \times i = 4 \times 40 = 160\sec$;

$c = 0.5 \times (i \times h2) \times i = 0.5 \times h2 \times i^2 = 0.5 \times 2 \times 4^2 = 16\sec$

The average stopped delay $d1 = \frac{a+b+c}{V \times CL} = \frac{884+160+16}{35} = 30\sec/veh$

Since, the Qm*h2 is smaller than g2, Equation 4-27 is used to compute the Over-Saturation delay as follows:

$$d2 = \frac{area(B)+area(C)}{V \times CL} = \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{0.5 \times Q_m \times Q_m \times h2}{V \times CL}$$
$$= \frac{0.5 \times 8 \times 100}{45.6} + \frac{0.5 \times 8 \times 8 \times 2}{45.6} = 13.13\sec$$

Since d3 is greater than cycle length, Equation 4-33 is used to compute the d4..

$$d4 = \frac{0.5 \times V \times CL^2}{V \times CL} + d3 - CL = d3 - 0.5 \times CL = 148 - 50 = 98\sec$$

Since there is no blackout on the loop detector, Equation 3-10 is used to compute the travel time of the observed group as follows:

$$Travel-time = \frac{L_{TD} - QL}{speed\_by\_detector \times 2} + \frac{L - L_{TD}}{Speed\_limit} + d1 + d2 + d4$$
$$= \frac{800 - 19 \times 34}{23.6 \times 5280 \div 3600} + \frac{1600 - 800}{45 \times 5280 \div 3600} + 30 + 13.13 + 98 = 157.7\sec$$

Therefore, the **travel time for time interval 6 is 157.7 sec**., and the initial queue for the next time interval is 42 veh.

The queue length is 19*42=798 ft

Travel Time for Time Interval 7

In time interval 7, there is an initial queue of 42 veh, and the average dwelling time is larger than 0.6sec/veh which is the critical value for a blackout situation. Hence, there is a blackout situation and the average incoming group of vehicles is based on the detected volume of the upstream link i-1 in time intervals 6 and 7.

Algorithm 3 in chapter 5 is used to estimate the travel time in this interval.

The turning movement is calculated first. The cumulative volume detected by link i-1 for the first 6 intervals is 629 veh and there is no blackout on link i-1 during the 6th time interval. The cumulative volume detected by link i for the first 6 intervals is 580 veh. Each link has 3 lanes. The maximum number of vehicles that can dissipate departing from link i-1 is:

$$N_{i-1} \times S_{i-1} \times \frac{g_{i-1}}{CL_{i-1}} \times \frac{6 \times time\_interval}{3600} = 3 \times 1800 \times \frac{75}{100} \times \frac{6 \times 100}{3600} = 765 .$$

Since 765 is greater than 629 vehicles, all the 629 vehicles can dissipate through the intersection in the 6 time intervals.

Since there is only 6 time intervals before the blackout situation to obtain data for establishing the turning movement, the percentage of change for turning movement is t%= $\frac{580-629}{629} = -7.79\%$

The volume detected by link i-1 during time interval 6 is 39veh/ln, and 26veh/ln in time interval 7. The average is (39+26)/2=33 veh/ln. Based on the pervious volume observations on link i-1, we have determined the cumulative initial queues at its intersection. The calculations are shown below.

Table 6-4 shows the detected volume on link i-1. The capacity of link i-1 is 1350 vph which is equal to 37.5 veh per 100 seconds. Therefore, the queue at the end of time period 6 is approximately (46.67+47.33+38.33)-37.5*3=19.83 veh

Table 6 - 4 Input volume to Link i-1

link i-1	
Time period	Detector count(veh/100 sec)
1	17
2	24
3	36.3
4	46.7
5	47.3
6	38.3
7	26
8	11
9	8.3
10	5.7

Hence, V_{i-1} +Vq= 33+19.85=52.85 veh/ln/100 secs cycle length which translates to 1902.6 veh/h/ln. It is bigger than the capacity of link i-1 which is 1395veh/hr/ln.

Therefore, the incoming volume for link i is the capacity of link i-1 which is 1395*3600/100*(1-7.79%)=1286veh/h/ln.

Hence, V/C=1286/1080=1.19;

From Equation 4-8, $(n-1)\times g \le \frac{Q_{t-1}}{D_s} \le n\times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{42}{1800 \div 3600} = 84\sec$,and g=60, n=2

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n)\times red\_time = \frac{42}{1800 \div 3600} + (2)\times 40 = 164\sec$

g1=24sec, and g2=36 sec

Use the capacity as the incoming volume to estimate the uniform stopped delay, because it is less than the incoming volume of the observed group. Since d3 is greater than the cycle length, all vehicles in the observed group are assumed to be in the queue when they dissipate the intersection. Figure 4-18 and its corresponding equations, as shown in Chapter 4, are used to compute the d1 in this time interval.

h1=100/30=3.33 sec/veh

h2=2 sec/veh

$$m = C \times CL = 30veh$$

$$i = m - \frac{g2}{h2} = 30 - \frac{36}{2} = 12veh$$

The area of A is

$$a = 0.5 \times (i + m) \times g2 = 0.5 \times (12 + 30) \times 36 = 756\sec;$$

The area of B and C are

$$b = r \times i = 12 \times 40 = 480\sec;$$

$$c = 0.5 \times (i \times h2) \times i = 0.5 \times h2 \times i^2 = 0.5 \times 2 \times 12^2 = 144\sec$$

The average stopped delay $d1 = \frac{a + b + c}{V \times CL} = \frac{756 + 480 + 144}{35} = 38.6\sec/veh$

Because of the blackout situation, the shockwave method is not reliable to estimate the queue length. Instead, a base method is used to calculate Qm as $(V - C) \times CL$, which is explained in algorithm 3 in Chapter 5.

At the end of time interval 7, the number of vehicles in queue is computed as follows:

$QL_{in\_time\_i-1} + (V - C) \times CL$ = 42+(1286-1080)*100/3600 =47 veh/ln

Qm= $(V - C) \times CL$ = 5.7 veh.

Since Qm*h2 is smaller than the g2, the over-saturation delay is computed as follows:

$$d2 = \frac{area(B) + area(C)}{V \times CL} = \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{0.5 \times Q_m \times Q_m \times h2}{V \times CL}$$

$$= \frac{0.5 \times 5.7 \times 100}{35.7} + \frac{0.5 \times 5.7 \times 5.7 \times 2}{35.7} = 8.7\sec$$

Since d3 is greater than cycle length, Equation 4-33 is used to compute the d4..

$$d4 = \frac{0.5 \times V \times CL^2}{V \times CL} + d3 - CL = d3 - 0.5 \times CL = 164 - 50 = 114\sec$$

Since the queue length is longer than the location of loop detector, Equation 3-11 is used to estimate the average travel time as follows:

$$Travel - time = \frac{L - QL}{Speed\_\lim it \div 2} + d1 + d2 + d4$$
$$= \frac{1600 - 912}{45 \times 5280 \div 3600 \div 2} + 38.6 + 8.7 + 114 = 185.6\sec$$

Therefore, the **travel time for time interval 7 is 185.6 sec**., and the initial queue for the next time interval is 48 veh. The queue length is 19*47=893ft :

Travel Time for Time Interval 8

In time interval 8, there is an initial queue of 48 veh, and the average dwelling time is bigger than 0.6sec/veh. Hence, there is a blackout situation during this time interval too. The detected traffic data is not reliable due to the blackout situation. Therefore the incoming group of vehicles is based on the average upstream link volume in time intervals 7 and 8.

The percentage of turning movement is t%=7.79% , which is the same as time interval 7 since the conditions did not change.

The volume detected by link i-1 during time interval 7 is 26 veh/ln and 11 veh/ln in time interval 8. The initial queue for time interval 7 is approximately 8.33 veh. The same procedure as in interval 7 is utilized in determining the initial queue, so we will not repeat all the detailed calculations here.

The incoming volume is ((26+11)/2+ 8.33)*(1-7.79%)*3600/100=907.2 (veh/h/ln), which is smaller than the capacity of link i-1.

From Equation 4-8, $(n-1)\times g \le \frac{Q_{t-1}}{D_s} \le n\times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{47}{1800 \div 3600} = 94\sec$,and g=60, n=2

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n-1)\times red\_time = \frac{47}{1800 \div 3600} + (2)\times 40 = 174\sec$

Similar to the calculations in the previous interval, the number of vehicle in queue at the end of time interval 8 is $QL_{in\_time\_i-1} + (V-C)\times CL =$ 47+(903-1080)*100/3600 =42 veh/ln

g1=34sec, and g2=26 sec

Since d3 is greater than the cycle length, all vehicles in observed group are assumed to be in the queue when they start to dissipate the intersection. Figure 4-18 and its corresponding equations are used to estimate the uniform stopped delay.

h2=2 sec/veh

$m = V \times CL = 25.2veh$

$i = m - \frac{g2}{h2} = 12.2veh$

The area of A is

$a = 0.5\times(i+m)\times g2 = 0.5\times(12.2+25.2)\times 26 = 486.2\sec$;

The area of B and C are

$b = r\times i = 13.7\times 40 = 488\sec$;

$c = 0.5\times(i\times h2)\times i = 0.5\times h2\times i^2 = 148.8\sec$.

The average uniform stopped delay $d1 = \frac{a+b+c}{V \times CL} = \frac{526+550+188}{26.7} = 44.5\sec/veh$

$d2 = 0\sec$

Since d3 is greater than cycle length, Equation 4-33 is used to compute the d4..

$$d4 = \frac{0.5 \times V \times CL^2}{V \times CL} + d3 - CL = d3 - 0.5 \times CL = 174 - 50 = 124\sec$$

Since Qm is equal to zero, and since there is a blackout situation, Equation 3-11 is used to estimate the average travel time as follows:

$$Travel - time = \frac{L - QL}{Speed\_\lim it \div 2} + d1 + d2 + d4$$
$$= \frac{1600 - 47 \times 19}{45 \times 5280 \div 3600 \div 2} + 44.5 + 0 + 124 = 190\sec.$$

Therefore, the **travel time for time interval 8 is 190 sec**., and the initial queue for the next time interval is 42 veh.

Travel Time for Time interval 9

In this time interval there is an initial queue of 42 veh, and the average dwelling time is smaller than 0.6sec/veh. Hence, there is no blackout situation. From Table 6-3, the detected volume is 9.333 veh/ln. These 9.33 vehicles are the observed group which represents the travel time at time interval 9. The average detected speed is 26 mph.

Volume: 9.33/100*3600=336vph;

V/C=336/1080=0.31; The density is Ktd =flow/speed= 12.919 veh/mile;

From Equation 4-8, $(n-1) \times g \le \frac{Q_{t-1}}{D_s} \le n \times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{42}{1800 \div 3600} = 84\sec$,and g=60, n=2

From Equation 4-9, the initial delay is

$$\text{d3}=\frac{Q_{t-1}}{D_s}+(n-1)\times red\_time=\frac{42}{1800\div 3600}+(2)\times 40=164\,\text{sec}$$

$$W_d=\frac{C-V}{k_q-k_{td}}=\frac{1080-336}{135-12.9}=6.09 mile/hour$$

The queuing rate QR(veh/h) is:

$$\text{QR}=\frac{\text{dn}}{\text{dt}}=\left(V-C-\text{W}_d\times \text{k}_{dt}\right)=\left(336-1080-6.09\times 12.9\right)=-823 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m=QR\times CL=-823\times\frac{100}{3600}\approx -23 veh/\ln$$

Then the initial queue for the next time interval is

$$Q_{t-1}=\max(0,\sum_{m=1}^{t}Q_m)=42-23=19 veh/\ln\ .$$

The queue length is 19*19=361ft :

g1=24sec, and g2=36 sec

Since the d3 is greater than the cycle length, all vehicles in observed group are assumed to be in the queue when they start to dissipate the intersection. Figure 4-18 and its corresponding equations are used to estimate the uniform stopped delay..

h2=2 sec/veh

$$m=V\times CL=9.33 veh$$

$$i=m-\frac{g2}{h2}<0$$

Hence, all the vehicles will dissipate the intersection in g2.

The area of A is

$a = 0.5 \times m \times m \times h2 = 0.5 \times 9.33 \times 9.33 \times 2 = 87.11 \sec$;

The area of B and C are

$b = c = 0$;

The average uniform stopped delay $d1 = \dfrac{a+b+c}{V \times CL} = \dfrac{87.11}{9.33} = 9.33 \sec/veh$

$d2 = 0 \sec$ since Qm is smaller than zero

Since d3 is greater than cycle length, Equation 4-33 is used to compute the d4..

$$d4 = \frac{0.5 \times V \times CL^2}{V \times CL} + d3 - CL = d3 - 0.5 \times CL = 164 - 50 = 114 \sec$$

Since there is no blackout situation, Equation 3-11 is used to estimate the travel time as follows:

$$Travel-time = \frac{L_{TD} - QL}{speed\_by\_detector \times 2} + \frac{L - L_{TD}}{Speed\_limit} + d1 + d2 + d4$$
$$= \frac{800 - 19 \times 43}{26 \times 5280 \div 3600} + \frac{1600 - 800}{45 \times 5280 \div 3600} + 9.33 + 0 + 114 = 135.5 \sec$$

Therefore, the **travel time for time interval 9 is 135.5 sec**., and the initial queue for the next time interval is 19 veh.

Travel Time for Time Interval 10

In time interval 10, there is an initial queue of 19 veh based on the calculation of the previous time period. And the average dwelling time is smaller than 0.7sec/veh. Hence, there is no blackout situation. The detected volume is 8.33 veh/ln. These 8.33 veh are the observed group which represents the travel time at time interval 10. The average speed detected by detector is 41.6 mph.

Volume: 8.33/100*3600=300vph;

V/C=300/1080=0.2788;

The density is Ktd =flow/speed= 7.2 veh/mile;

From Equation 4-8, $(n-1)\times g \le \frac{Q_{t-1}}{D_s} \le n \times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{19}{1800 \div 3600} = 38\sec$,and g=60, n=1

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n) \times red\_time = \frac{19}{1800 \div 3600} + (1) \times 40 = 78\sec$

$$W_d = \frac{C-V}{k_q - k_{td}} = \frac{1080-300}{135-7.2} = 6.1 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{\mathrm{dt}}\right) = \left(300 - 1080 - 6.10 \times 7.2\right) = -824 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL = -824 \times \frac{100}{3600} \approx -23 veh/\ln$$

Then the initial queue for the next time interval is

$$Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = \min(0,19-23) = 0 veh/\ln .$$

The queue length is 0*19=0 ft :

Since the d3 is smaller than a cycle length, Figure 4-10 and its relative equations are used to estimate the uniform stopped delay,

g1=38sec,g2=22 sec

h1=100/8.33=12 sec/veh

h2=2 sec/veh

S1=41.6mph, S2=6.5 mph

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = 13.7;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{13.7 \times 2}{13.7 - 2} = 2.34 \text{ sec/veh}$$

Since volume of last time interval is smaller than the intersection capacity, Figure 4-20 in Chapter 4 and the relative equations are used to compute the uniform stopped delay in this time interval.

And the t4-t3 in time interval 9 is zero.

$$L = m + Iq - \frac{g1 + g2}{h3} = \text{-}2.2 < 0$$

$$k = m + Iq - \frac{g1}{h3} = \frac{40}{12} + 19 - \frac{40}{2.34} = 6.3veh$$

Since L is small than zero, all vehicles in the observed group will dissipate the intersection in g2.

the uniform stopped delay for this observed group is

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times k \times (k \times h3)}{8.33} = 5.5 \text{ sec}/veh;$$

d2=0, since V is smaller than the capacity.

Since d3 is smaller than the cycle length and the volume is smaller than the capacity in this time interval, Equation 4-29 and 4-30 are used to computed the d4 with the same k and m values.

$$d4 = \frac{0.5 \times r \times m + 0.5 \times (m + k) \times g1}{Total\_vehicle\_in\_the\_Observed\_Group}$$
$$= \frac{0.5 \times 40 \times 3.33 + 0.5 \times (3.33 + 6.11) \times 38}{8.33} = 29.53 \text{ sec}$$

The average travel time is computed as follows:

$$Travel-time=\frac{L_{TD}-QL}{speed\_by\_detector\times 2}+\frac{L-L_{TD}}{Speed\_limit}+d1+d2+d4$$

$$=\frac{800-19\times 20}{26\times 5280\div 3600}+\frac{1600-800}{45\times 5280\div 3600}+5.5+0+29.53=54.1\sec$$

And the initial queue for next time interval is 0 veh.

Figure 6-3 illustrates the variation of the travel time on link i over the analysis period of 10 time updates. The travel time components are all displayed in this figure, which include the uniform delay, the oversaturation delay, the initial delay, and the travel time on the other part of the link which is not influenced by the intersection. The update time is 100 seconds and the intersection cycle length is 100 seconds. The figure shows that the link travel time increases with the increase in volume and is particularly influenced by the size of the initial delay.

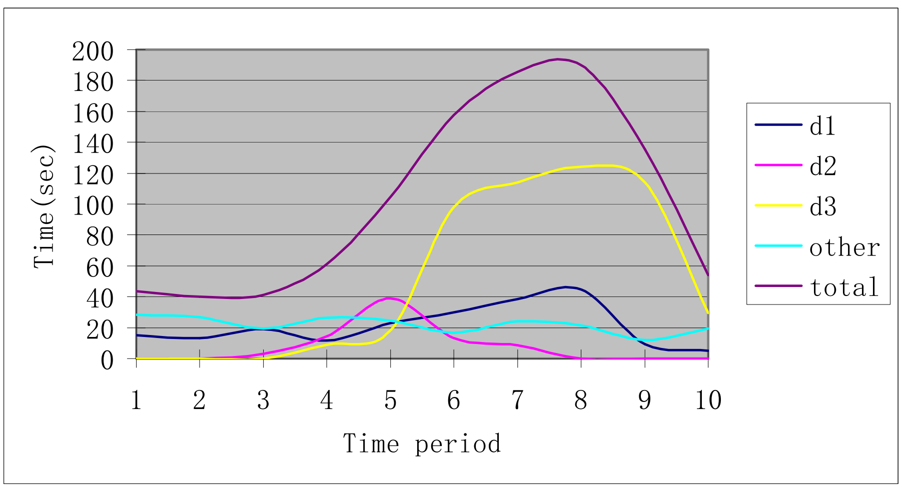

Figure 6 - 3 Travel Time Comparison for 100 sec Time Interval Update

6.3 The Analysis for the 60 sec Time Interval

The same above calculations are repeated here for a time interval update of 60 secs, which is the normal update period from the detector. The next section deals with the travel time update of 120 secs which is two minutes. This travel time update of 2 minutes may be more appropriate for real time application.

The reader may wish to skip these two sections to avoid the same repetitious calculations and go directly to section 4-5, which describes the bottleneck condition on Link i+1 and to section 4-6 which describes the comparison of results with CORSIM and their justification.

In order to have the same input volume as for the 100 seconds time interval simulation, the CORSIM simulation is separated into 23 time intervals as shown in Table 6-5. However, the maximum number of time interval setting in CORSIM is only 19. Hence, this condition limited our experiment to 8 cycle lengths or 8 time intervals of 100 secs, which is 800 seconds. Chapter 3 has explained how to convert the detector volume to input volume for different cycle lengths. Table 6-5 uses the conversion methodology in Chapter 3 to obtain the input volume in 100secs interval.

Table 6 - 5 Input Volume Table

	Input volume by user		Converted volume to cycle length	
	60 sec interval	volume(veh/h)	100 sec interval	Volume(veh/h)
1	60	900	0-100	900
2	60-100	900	100-200	2550
3	100-120	2550	200-300	3900
4	120-180	2550	300-400	5400
5	180-200	2550	400-500	5100
6	200-240	3900	500-600	4200
7	240-300	3900	600-700	3000
8	300-360	5400	700-800	1200
9	360-400	5400	800-900	900
10	400-420	5100	900-1000	600
11	420-480	5100	1000-1100	600
12	480-500	5100		
13	500-540	4200		
14	540-600	4200		
15	600-660	3000		
16	660-700	3000		
17	700-720	1200		

18	720-780	1200
19	780-800	1200
20	800-840	900
21	840-900	900
22	900-960	600
23	960-1000	600

Data collected from the loop detector in CORSIM is shown in Table 6- 1

Table 6 - 6 Detector Data (60sec)

		A	B	C
Time period	Time	Cumulative Vehicles counted	Cumulative Average speed(mph)	Cumulative dwelling time(sec)
1	60	45	38.8	15.7
2	120	56	39.9	19
3	180	110	39.8	37.3
4	240	160	39.5	52.4
5	300	210	39.6	69.6
6	360	287	39.1	93.2
7	420	336	38.4	109.9
8	480	431	36.4	147
9	540	486	34.2	177.3
10	600	565	30.9	235.3
11	660	604	29.3	295.3
12	720	659	27.5	354.6
13	780	721	25.7	414.6
14	800	730	25.5	422.6

The number of vehicles at time period t in Table 6-6 is equal to $\frac{(A_t)-(A_{t-1})}{3}$ where 3 represent the number of lanes.

The average speed at time t in Table 6-5 is calculated using columns A and B in Table 6-2 as follows; $\frac{A_t \times B_t - A_{t-1} \times B_{t-1}}{A_t - A_{t-1}}$ (mph);

The average dwelling time is calculated using columns C and A as follows;

$\frac{C_t - C_{t-1}}{A_t - A_{t-1}}$,(sec/veh);

The average occupancy at the detector= (average dwelling time)*CL/3600*100%;

The data calculated for each time interval using Table 6-6 is shown in Table 6-7.

Table 6 - 7 Data for Each Time Interval(60sec)

	D	E	F	G
Time	Veh counted	Dwelling time(sec)	Average speed(mph)	Average dwelling time(sec/veh)
60	15	5.2	38.8	0.35
120	3.7	1.1	44.4	0.3
180	18	6.1	39.7	0.34
240	16.7	5	38.8	0.3
300	16.7	5.7	39.9	0.34
360	25.7	7.9	37.7	0.31
420	16.3	5.6	34.3	0.34
480	31.7	12.4	29.3	0.39
540	18.3	10.1	17	0.55
600	26.3	19.3	10.6	0.73
660	13	20	6.1	1.54
720	18.3	19.8	7.7	1.09
780	20.7	20	6.6	0.97
800	3	2.7	9.5	0.89

Since the algorithms are based on the intersection cycle length which is 100 secs, the 60 secs data is transferred to 100 seconds time interval. The results are tabulated in Table 6-8.

Table 6 - 8 Tabulated Result

		H	I	J	K
Time period	Time	Veh count	On time(sec)	Average speed(mph)	Average dwelling time(sec/veh)
1	100	17.4	6	39.6	0.34
2	200	24.8	8.1	39.7	0.33
3	300	27.8	9.1	39.5	0.33
4	400	36.6	11.6	36.7	0.32
5	500	43.2	17.6	28.2	0.41
6	600	38.6	26.1	12.6	0.68
7	700	25.2	33.2	6.9	1.32
8	800	33.7	33.3	6.8	0.99

Equation 3-1 is used to transfer the data of 60 seconds to 100 seconds.

For example, in time period 2, t=2.

180≤200≤240 Hence, n=1, k=3.

$$V_t = \frac{[(n+1)\times 60-(t-1)\times 100]}{60}\times V_{(n+1)\times 60} + \frac{100\times t-60\times k}{60}\times V_{(k+1)\times 60} + (k-n-1)\times V_{k\times 60}$$

$$= \frac{[(1+1)\times 60-(2-1)\times 100]}{60}\times H_{(1+1)\times 60} + \frac{100\times 2-60\times 3}{60}\times H_{(3+1)\times 60} + (3-1-1)\times H_{3\times 60}$$
$$= \frac{20}{60}\times H_{120} + \frac{20}{60}\times H_{240} + (3-2)\times H_{180}$$
$$= \frac{20}{60}\times 3.667 + \frac{20}{60}\times 16.667 + (3-2)\times 18 = 24.77 veh$$

Travel Time for Time Interval 1:

In the first time interval, there is no initial queue. From Table 6-8 the detected volume is 17.44 veh/ ln. These 17.44 vehicles are the observed group whose travel time to traverse link i is to be computed for time interval 1. The average detected speed is 39.75mph.

Volume: 17.44/100*3600=628vph;

V/C=628/1080=0.58;

The density is Ktd =flow/speed=15.86 veh/mile;

h1=100/17.44=5.7 sec/veh

h2=2 sec/veh

S1=39.5mph, S2=6.5 mph

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{39.5 \times 5.7 - 19}{39.5 - 6.5} = 6.28;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{6.28 \times 2}{6.28 - 2} = 2.93 \text{sec/veh}$$

From Equation 4-14, the uniform stopped delay for this observed group is

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times \frac{40}{5.7} \times (\frac{40}{5.7} \times 2.93 + 40)}{17.44} = 12.09 \sec/veh;$$

The over-saturation delay is zero since volume of the observed group is smaller than the intersection capacity

$$d2 = 0;$$

Since there is no initial queue for this incoming group, the initial queue d3=0sec.

$$W_d = \frac{C - V}{k_q - k_{td}} = \frac{1080 - 628}{135 - 15.86} = 3.79 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{\mathrm{d}t}\right) = \left(628 - 1080 - 3.79 \times 15.86\right) = -512 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL = -512 \times \frac{100}{3600} = -14 veh$$

Then the initial queue for the next time interval is $Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 0$.

Hence, from Equation 3-9 the travel time for this group is:

$$Travel - time = \frac{L}{speed\_by\_\det ector} + d1 + d2 + d4$$

$$= \frac{1600}{39.6 \times 5280 \div 3600} + 12.09 + 0 + 0 = 39.7\sec$$

Hence, **the travel time for time interval 1 is 39.7 sec**. And the initial queue for next time interval is zero.

Travel Time for Time Interval 2:

In the second time interval, there is no initial queue based on the previous computation, and the average dwelling time is smaller than 0.6sec/veh. Hence, there is no blackout on the loop detector. From Table 6-8, the detected volume is 24.77 veh/ln. These 24.77 veh is the observed group whose travel time is to be computed for time interval 2. The average detected speed is 39.7 mph.

Volume: 24.77/100*3600=892vph;

V/C=892/1080=0.825;

The density is Ktd =flow/speed=22.44 veh/mile;

h1=100/24.8=4 sec/veh

h2=2 sec/veh

S1=40mph, S2=6.5 mph

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{40 \times 4 - 19}{40 - 6.5} = 4.25;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{4.25 \times 2}{4.25 - 2} = 3.77\ \text{sec/veh}$$

From Equation 4-14, the average uniform stopped delay for this observed group is computed as follows:

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times \frac{40}{4} \times (\frac{40}{4} \times 3.77 + 40)}{24.8} = 15.5\,\text{sec}/veh\,;$$

The over-saturation delay is zero since volume of the observed group is smaller than the intersection capacity

$d2 = 0\,;$

Since there is no initial queue for this incoming group, the initial queue d3=0sec.

$$W_d = \frac{C - V}{k_q - k_{td}} = \frac{1080 - 900}{135 - 22.44} = 1.67 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{dt}\right) = \left(892 - 1080 - 1.67 \times 22.44\right) = -225 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL \approx -6 veh/\ln$$

Then the initial queue for the next time interval is $Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 0$.

Hence the travel time for this group is :

$$Travel - time = \frac{L - QL}{speed\_by\_\det ector} + d1 + d2 + d4$$

$$= \frac{1600 - 0}{39.7 \times 5280 \div 3600} + 15.5 + 0 + 0 = 42.9ec$$

Hence, the travel time for **time interval 2 is 48.3 sec.** And the initial queue for the next time interval is zero.

Travel Time for Time Interval 3:

In time interval 3, there is no initial queue based on the calculation of the previous time periods, and the average dwelling time is smaller than 0.6sec/veh. Hence, there is no blackout on the loop detector. From Table 6-8, the detected volume is 27.7 veh /ln. The average detected speed is 39.5 mph.

Volume: 27.7/100*3600=1008vph;

V/C=1000/1080=0.925;

The density is Ktd =flow/speed=25.32 veh/mile;

h1=100/27.77=3.6 sec/veh

h2=2 sec/veh

S1=39.5mph, S2=6.5 mph

From Equation 4-13;

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{39.5 \times 3.6 - 19}{39.5 - 6.5} = 3.7;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{3.7 \times 2}{3.7 - 2} = 4.31 \text{sec/veh}$$

From Equation 4-14, the average uniform stopped delay for this observed group is computed as follows:

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times \frac{40}{3.6} \times (\frac{40}{3.6} \times 4.31 + 40)}{27.8} = 17.57 \text{sec}/veh;$$

And d2=0 since there Qm=0

Since there is no initial queue for this incoming group, the initial queue d3=0sec.

$$W_u = \frac{V - C}{k_{td} - k_q} = \frac{1000 - 1080}{24.98 - 135} = 0.844 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{\mathrm{dt}}\right) = \left(1000 - 1080 + 0.844 \times 25.32\right) = -101 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL \approx -3 veh/\ln$$

Then the initial queue for the next time interval is

$$Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 0 veh/lh \,.$$

Hence the travel time for this group is :

$$Travel - time = \frac{L - QL}{speed\_by\_\det ector} + d1 + d2 + d4$$
$$= \frac{1600 - 0}{39.4 \times 5280 \div 3600} + 17.57 + 0 + 0 = 45.2 \sec$$

Hence, the **travel time for time interval 3 is 45.2 sec**. And the initial queue for next time interval is 0 veh.

Travel Time for Time Interval 4

In time interval 4, there is no initial queue based on the calculation of the previous time periods, and the average dwelling time at the detector is smaller than 0.6sec/veh. Hence, there is no blackout on the loop detector. From Table 6-8, the detected volume is 36.6 veh/ln. These 36.6 veh represent the observed group whose travel time is to be calculated for time interval 4. The average detected speed is 36.7

mph.

Volume: 36.6/100*3600=1332vph;

V/C=1368/1080=1.21;

The density is Ktd =flow/speed=35.8 veh/mile;

Since the Volume is greater than the capacity, the capacity is used as the incoming volume to estimate the d1

h1=100/30=3.33 sec/veh

h2=2 sec/veh

S1=36.7mph,S2=6.5 mph

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{36.7 \times 3.33 - 19}{36.7 - 6.5} = 3.42\,;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{3.42 \times 2}{3.42 - 2} = 4.82\,\text{sec/veh}$$

The uniform stopped delay for this observed group is computed as follows:

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times \frac{40}{3.3} \times (\frac{40}{3.3} \times 4.82 + 40)}{36.5} = 16\,\text{sec}/\,veh\,;$$

Since there is no initial queue for this incoming group, the initial queue d3=0sec.

$$W_u = \frac{V - C}{k_{td} - k_q} \quad = -2.4 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{dt}\right) = 321 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL \approx 9veh/\ln$$

Then the initial queue for the next time interval is

$$Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 9veh/\ln .$$

The queue length is 9*19=171 ft :

Since the Qm is 9 veh, the over-saturation delay is computed as follows:

$$d2 = \frac{area(B) + area(C)}{V \times CL} = \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{r \times Q_m}{V \times CL} + \frac{0.5 \times Q_m \times Q_m \times h2}{V \times CL}$$
$$= 24.37\sec/veh$$

$$Travel - time = \frac{L_{TD} - QL}{speed\_by\_\det ector \times 2} + \frac{L - L_{TD}}{Speed\_\lim it} + d1 + d2 + d4$$
$$= \frac{800 - 19 \times 9}{36.7 \times 5280 \div 3600} + \frac{1600 - 800}{45 \times 5280 \div 3600} + 16 + 24.37 + 0 = 67.3\sec$$

Hence, the travel time for time **interval 4 is 67.3 sec**. And the initial queue for next time interval is 9 veh.

Travel Time for Time Interval 5

In the time interval 5, there is an initial queue based on the calculation of the previous time period. And the average dwelling time is 0.41sec/veh which is smaller than 0.6sec/veh. Hence, there is no blackout on the loop detector. The detected volume is 43.22 veh/ln. And the average detected speed is 28.2 mph.

Volume: 43.22/100*3600=1556vph;

V/C=1556/1080=1.44;

The density is Ktd =flow/speed=55.16 veh/mile;

From Equation 4-8, $(n-1) \times g \le \frac{Q_{t-1}}{D_s} \le n \times g$;

Since $\dfrac{Q_{t-1}}{D_s} = \dfrac{9}{1800 \div 3600} = 18\sec$,and g=60, n=1

From Equation 4-9, the initial delay is

d3=$\dfrac{Q_{t-1}}{D_s} + (n) \times red\_time = \dfrac{9}{1800 \div 3600} + (1) \times 40 = 58\sec$

g1=18sec, and g2=42 sec

Since, V is greater than C, use the capacity as the input volume to estimate the uniform stopped delay d1.

h1=100/30=3.33 sec/veh

h2=2 sec/veh

S1=28.2 mph,S2=6.5 mph

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{28.2 \times 3.33 - 19}{28.2 - 6.5} = 3.45;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{3.45 \times 2}{3.45 - 2} = 4.74 \text{ sec/veh}$$

$$m = \frac{r}{h1} = \frac{40}{3.33} = 12 veh$$

$$k = m + Iq - \frac{g1}{h3} = 12 + 9 - \frac{20}{4.74} = 17.2$$

$$L = m + Iq - \frac{g1 + g2}{h3} = 12 + 9 - \frac{60}{4.74} = 8.36;$$

$i = 9$

$t4 - t3 = (i - L) \times h1 = (9 - 8.36) \times 3.33 = 2.13$

$a = 0.5 \times (k + L) \times g2 = 0.5 \times (17.2 + 8.36) \times 40 = 537 \text{ sec}$

$$b = 0.5 \times (L + i) \times (t4 - t3) + i \times (red - (t4 - t3))$$
$$= 0.5 \times (8.36 + 9) \times 2.13 + 9 \times (40 - 2.13) = 359.3\sec$$

$c = 0.5 \times i \times i \times h2 = 0.5 \times h2 \times i^2 = 0.5 \times 2 \times 9 \times 9 = 81$

The average uniform stopped delay

$$d1 = \frac{a+b+c}{V \times CL} = 22.6\sec$$

$$W_u = \frac{V-C}{k_{td} - k_q} = -6 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{\mathrm{dt}}\right) = 804.9 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL \approx 22 veh/\ln$$

Then the initial queue for the next time interval is

$$Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 9 + 22 = 31 veh/\ln .$$

The queue length is 19*31=589 ft:

Since the g2 can not dissipate all vehicles in Qm,

i'= Qm-g2/h2=22-42/2=1veh

Over-saturation delay is computed as follows:

$$\begin{aligned}
d2 &= \frac{area(A) + area(B) + area(C) + area(D)}{V \times CL} \\
&= \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{0.5 \times (i' + Q_m) \times g2}{V \times CL} + \frac{r \times i}{V \times CL} + \frac{0.5 \times i' \times i' \times h2}{V \times CL} \\
&= \frac{0.5 \times Q_m \times CL + 0.5 \times (i' + Q_m) \times g2 + r \times i' + 0.5 \times h2 \times i'^2}{V \times CL} \\
&= \frac{0.5 \times 24 \times CL + 0.5 \times (1 + 22) \times 40 + 40 \times 1 + 0.5 \times 2 \times 1^2}{43.2} = 37.6 \sec/veh
\end{aligned}$$

Since d3 is smaller than cycle length and the volume is greater than the capacity Equation 4-29 and 4-30 are used to compute the d4. In addition, the new value of k and m should be computed based on the actual volume which is 43.2 veh per 100 seconds.

The k' and m' is 25.7 and 17.3 respectively.

$$d4 = \frac{0.5 \times r \times m' + 0.5 \times (m' + k') \times g1}{Total\_vehicle\_in\_the\_Observed\_Group}$$
$$= \frac{0.5 \times 40 \times 17.3 + 0.5 \times (25.7 + 17.3) \times 20}{43.2} = 17\sec$$

$$Travel - time = \frac{L_{TD} - QL}{speed\_by\_\det ector \times 2} + \frac{L - L_{TD}}{Speed\_\lim it} + d1 + d2 + d4$$
$$= \frac{800 - 19 \times 9}{28.2 \times 5280 \div 3600} + \frac{1600 - 800}{45 \times 5280 \div 3600} + 22.6 + 37.6 + 17 = 104.5\sec$$

Hence, the travel time for time **interval 5 is 104.5 se**c. And the initial queue for next time interval is 31 veh.

Travel Time for Time Interval 6

In time interval 6, there is an initial queue of 31 vehicles. And the average dwelling time 0.68 is greater than 0.6sec/veh. Hence, it is the critical value for a blackout situation. Hence, there is a blackout situation and the average incoming group of vehicles is based on the detected volume of the upstream link i-1 in time intervals 5 and 6. Algorithm 3 in chapter 5 is used to estimate the travel time in this interval.

The turning movement is calculated first. As stated in the Chapter 3, the closest accepTable time interval here is time interval 5 which is 300 seconds away from the beginning. The cumulative volume detected by link i-1 from 1-300 seconds is 224 vehicles, and 210 on link i. Thus t%=(210-224)/224=-0.0625=-6.25%

The average volume of link i-1 in time interval 5 and 6 is 43*3600/100=1548vph

Since the capacity of link i-1 is only 1395vph, the incoming volume in time interval 6 on link i is 1395*(1-6.25%)=1307vph

V/C=1307/1080=1.21;

From Equation 4-8, $(n-1)\times g \le \frac{Q_{t-1}}{D_s} \le n\times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{31}{1800 \div 3600} = 62\sec$,and g=60, n=2

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n)\times red\_time = \frac{31}{1800\div 3600} + (2)\times 40 = 142\sec$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$QL_{in\_time\_i-1} + (V-C)\times CL =$ 31+(1307-1080)*100/3600 =37 veh/ln

The queue length is 19*37=703 ft :

g1=2sec, and g2=58 sec

Use the capacity as the incoming volume to estimate the uniform stopped delay, because it is less than the incoming volume of the observed group. Since d3 is greater than the cycle length, all vehicles in the observed group are assumed to be in the queue when they dissipate the intersection. Figure 4-18 and its corresponding equations, as shown in Chapter 4, are used to compute the d1 in this time interval.

h1=100/30=3.33 sec/veh

h2=2 sec/veh

$m = C\times CL = 30veh$

$$i = m - \frac{g2}{h2} = 30 - \frac{58}{2} = 1veh$$

The area of A is

$$a = 0.5 \times (i + m) \times g2 = 0.5 \times (1 + 30) \times 58 = 899\sec;$$

The area of B and C are

$$b = r \times i = 1 \times 40 = 40\sec;$$

$$c = 0.5 \times (i \times h2) \times i = 0.5 \times h2 \times i^2 = 0.5 \times 2 \times 1^2 = 1\sec$$

The average stopped delay is computed as follows:

$$d1 = \frac{a + b + c}{V \times CL} = \frac{899 + 40 + 1}{36.3} = 25.9\sec/veh$$

The over-saturation delay is computed as follows:

$$d2 = \frac{area(B) + area(C)}{V \times CL} = \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{0.5 \times Q_m \times Q_m \times h2}{V \times CL}$$
$$= \frac{0.5 \times 6 \times 100}{36.3} + \frac{0.5 \times 6 \times 6 \times 2}{36.3} = 9.2\sec$$

Since d3 is greater than cycle length in this time interval, Equation 4-33 is used to compute the d4..

$$d4 = \frac{0.5 \times V \times CL^2}{V \times CL} + d3 - CL = d3 - 0.5 \times CL = 142 - 50 = 92\sec$$

$$Travel - time = \frac{L - QL}{Speed\_\lim it \div 2} + d1 + d2 + d4$$
$$= \frac{1600 - 31 \times 19}{45 \times 5280 \div 3600 \div 2} + 25.9 + 9.2 + 92 = 157.7\sec$$

Therefore, the **travel time for time interval 6 is 157.7 sec**., and the initial queue for the next time interval is 37 veh.

Travel Time for Time Interval 7

In time interval 7, there is an initial queue of 37 veh, and the average dwelling time is bigger than 0.6sec/veh. Hence, there is a blackout situation during this time interval too. The detected traffic data is not reliable due to the blackout situation. Therefore the incoming group of vehicles is based on the average upstream link volume in time intervals 6 and 7.

The detected volume on link i-1 in time interval 6 is 39veh/ln,and 26veh/ln in the time interval 7. The average is (39.5+25.3)/2=33 veh/ln. Based on the pervious observation on link i-1, and the initial queue on link i-1 in time period 6 is approximately 19.8 veh which is computed earlier in 100 seconds update. Hence, V_{i-1} +Vq= 33+19.8=52.8 veh/ln= 1900 veh/h/ln. It is bigger than the capacity of link i-1. Hence, the incoming volume for link i is the capacity of link i times turning factor which is 1395*(1-6.25%)=1307veh/h/ln.

V/C=1307/1080=1.2;

From Equation 4-8, $(n-1)\times g \le \frac{Q_{t-1}}{D_s} \le n \times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{37}{1800 \div 3600} = 74\sec$,and g=60, n=2

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n)\times red\_time = \frac{37}{1800 \div 3600} + (2)\times 40 = 154\sec$

At the end of time interval 7, the number of vehicle in queue is $QL_{in\_time\_i-1} + (V-C)\times CL =$ 37+(1307-1080)*100/3600 =43 veh/ln

Then the initial queue for the next time interval is

The queue length is 19*43=817ft :

g1=14sec, and g2=46 sec

Use the capacity as the incoming volume to estimate the uniform stopped delay, because it is less than the incoming volume of the observed group. Since d3 is greater than the cycle length, all vehicles in the observed group are assumed to be in the queue when they dissipate the intersection. Figure 4-18 and its corresponding equations, as shown in Chapter 4, are used to compute the d1 in this time interval.

h1=100/30=3.33 sec/veh

h2=2 sec/veh

$$m = C \times CL = 30veh$$

$$i = m - \frac{g2}{h2} = 30 - \frac{46}{2} = 7veh$$

The area of A is

$$a = 0.5 \times (i + m) \times g2 = 0.5 \times (7 + 30) \times 46 = 851\sec;$$

The area of B and C are

$$b = r \times i = 7 \times 40 = 280\sec;$$

$$c = 0.5 \times (i \times h2) \times i = 0.5 \times h2 \times i^2 = 0.5 \times 2 \times 7^2 = 49\sec$$

The average uniform stopped delay

$$d1 = \frac{a + b + c}{V \times CL} = \frac{851 + 280 + 49}{36.8} = 32.4\sec/veh$$

Over-saturation delay is

$$d2 = \frac{area(B) + area(C)}{V \times CL} = \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{0.5 \times Q_m \times Q_m \times h2}{V \times CL}$$
$$= \frac{0.5 \times 6 \times 100}{35.7} + \frac{0.5 \times 6 \times 6 \times 2}{35.7} = 9.3\sec$$

Since d3 is greater than cycle length, Equation 4-33 is used to compute the d4..

$$d4 = \frac{0.5 \times V \times CL^2}{V \times CL} + d3 - CL = d3 - 0.5 \times CL = 154 - 50 = 104 \sec$$

Since the queue length is longer than the location of loop detector, the travel time is computed as follows:

$$Travel - time = \frac{L - QL}{Speed\_\lim it \div 2} + d1 + d2 + d4$$
$$= \frac{1600 - 37}{45 \times 5280 \div 3600 \div 2} + 32.4 + 9.3 + 154 = 173 \quad \sec$$

Therefore, the **travel time for time interval 7 is 173 sec** and the initial queue for next time interval is 43 veh.

Travel Time for Time Interval 8

In time interval 8, there is an initial queue of 43 veh, and the average dwelling time is bigger than 0.6sec/veh. Hence, there is a blackout situation during this time interval too. The detected traffic data is not reliable due to the blackout situation. Therefore the incoming group of vehicles is based on the average upstream link volume in time intervals 7 and 8.

The turning movement: the turning movement is -6.25%.

The detected volume on link i-1 during time interval 7 is 25.33 veh/ln and 12.22 veh/ln in time interval 8. The initial queue for time interval 7 is approximately 8.33 which is computed earlier. Hence, the incoming volume is ((25.33+12.22)/2+8.33)*3600/100*(1-6.25%)=922.4 (veh/h/ln). It is smaller than the capacity of link i-1.

Therefore, 922.4 v/h/ln is the incoming volume.

From Equation 4-18, $(n-1)\times g \le \frac{Q_{t-1}}{D_s} \le n\times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{43}{1800 \div 3600} = 96\sec$,and g=60, n=2

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n)\times red\_time = \frac{43}{1800 \div 3600} + (2)\times 40 = 166\sec$

Since the Ktd in this time interval is not reliable due to the blackout, the shockwave method is not good in this situation to estimate the queue length. A base method is used instead of it.

At the end of time interval 7, the number of vehicle in queue is $QL_{in\_time\_i-1} + (V-C)\times CL =$ 43+(922 -1080)*100/3600 =38 veh/ln

g1=26sec, and g2=34sec

Since the d3 is greater than a cycle length, all vehicles in observed group are in the queue when dissipating the intersection is assumed.

h2=2 sec/veh

$m = V \times CL = 25.6veh$

$i = m - \frac{g2}{h2} = 8.62veh$

The area of A is

$a = 0.5\times(i+m)\times g2 = 0.5\times(8.62+25.6)\times 34 = 582.14\sec$;

The area of B and C are

$b = r\times i = 8.62\times 40 = 344.9\sec$;

$c = 0.5\times(i\times h2)\times i = 0.5\times h2\times i^2 = 74.3\sec$

The average uniform stopped delay $d1 = \frac{a+b+c}{V \times CL} = 39.1 \sec / veh$

$d2 = 0 \sec$ since Qm is smaller than zero

Since d3 is greater than cycle length, Equation 4-33 is used to compute the d4..

$$d4 = \frac{0.5 \times V \times CL^2}{V \times CL} + d3 - CL = d3 - 0.5 \times CL = 166 - 50 = 116 \sec$$

$$Travel - time = \frac{L - QL}{Speed\_\lim it \div 2} + d1 + d2 + d4$$
$$= \frac{1600 - 43 \times 19}{45 \times 5280 \div 3600 \div 2} + 39.1 + 0 + 166 = 178.8 \sec.$$

Figure 6-5 provides the variation of travel time over the 8 time intervals of 100 secs, with detector data obtained at 60 secs updates. The same results as in case 1 of 100 secs detector input data are shown, except that the 8 simulated periods were not enough to allow the volume to decrease and consequently get rid of the built up queues.

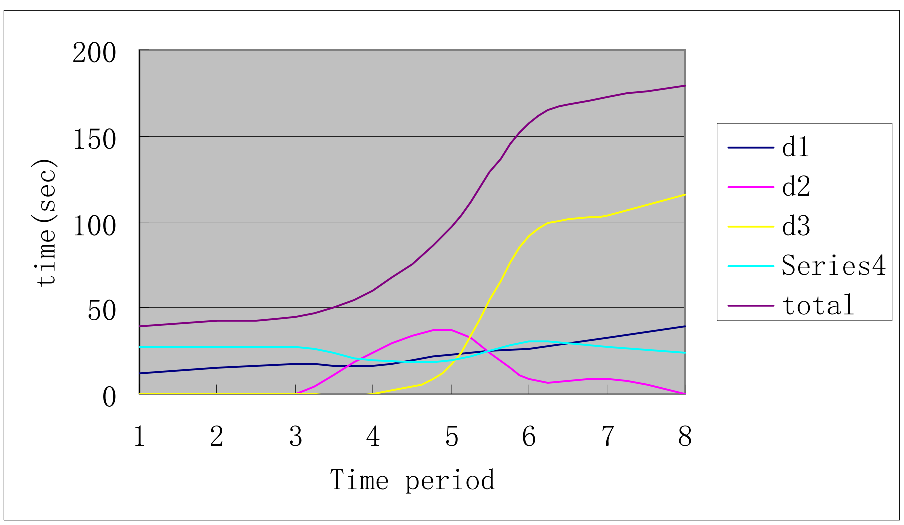

Figure 6 - 4 Travel Time Comparison for 60 ses Time Interval Update

6.4 The analysis for 120 second time interval.

In this experiment, the travel time update is 120s while the cycle length is 100secs. Similar to the Section 4-3 the CORSIM simulation is separated into 19 time intervals instead of 10 time intervals. It is shown in Table 6-9.

Table 6 - 9 Input Volume Table

	120 sec interval	volume(vph)	100 sec interval	Volume(vph)
1	100	900	0-100	900
2	120	2550	100-200	2550
3	200	2550	200-300	3900
4	240	3900	300-400	5400
5	300	3900	400-500	5100
6	360	5400	500-600	4200
7	400	5400	600-700	3000
8	480	5100	700-800	1200
9	500	5100	800-900	900
10	600	4200	900-1000	600
11	700	3000	1000-1100	600
12	720	1200		
13	800	1200		
14	840	900		
15	900	900		
16	960	600		
17	1000	600		
18	1080	600		

The data collected from the loop detector in CORSIM is shown in Table 6-10.

Table 6 - 10 Loop Detector Cumulative Data

Time period	Time	Veh counted	Cumulative On time(sec)	Cumulative Average speed(mph)
1	120	57	19.3	39.2
2	240	160	54	39.3
3	360	291	95.3	39.3
4	480	433	147.9	36.7
5	600	568	238.5	31.1
6	720	661	358.5	27.7
7	840	752	439.5	25.6
8	960	783	450.1	26.2
9	1080	805	457.3	26.7

The data calculated for each time interval using Table 6-10 is shown in Table 6-11:

Table 6 - 11 Loop Detector Data

.Time period	Time	Veh counted	On time(sec/120sec)	Occupancy	Average speed(mph)	Average dwelling time(sec/veh)
1	120	19	6.4	10.7	39.2	0.34
2	240	34.3	11.6	19.3	39.4	0.34
3	360	43.7	13.8	22.9	39.3	0.32
4	480	47.3	17.5	29.2	31.4	0.37
5	600	45	30.2	50.3	13.1	0.67
6	720	31	40	66.7	6.9	1.29
7	840	30.3	27	45	10.3	0.89
8	960	10.3	3.5	5.9	40.8	0.34
9	1080	7.3	2.4	4	44.5	0.33

Since the algorithms are based on the intersection cycle length which is 100 secs, the 120 secs data is transferred to 100 seconds time interval. The results are tabulated in Table 6-12. And Equation 3-2 and 1-3 are used.

For example,For the 100-200 seconds, it composes of the traffic data in the last 20 second from the data of 0-120, and 80 seconds traffic data from 120-240. Hence:

$$V_2 = 19 \times \frac{20}{120} + 34.33 \times \frac{80}{120} = 26.05 veh$$

On time for time interval 1 is $6.43 \times \frac{20}{120} + 11.5 \times \frac{80}{120} = 8.78 \sec$;

The average speed is $\dfrac{39.2 \times 19. \times \frac{20}{120} + 39.35 \times 34.33 \times \frac{80}{120}}{26.05} = 39.33 (mph)$

Average dwelling time is 8.78/26.05=0.337sec/veh

The result is shown in Table 6-12.

Table 6 - 12 Data Transfer From Loop Detector

Time period	Time	Veh counted	On time(sec/120sec)	Occupancy	Average speed(mph)	Average dwelling time(sec/veh)
1	100	15.8	5.4	5.4	39.2	0.34
2	200	26.1	8.8	8.8	39.3	0.34
3	300	33.3	10.7	10.7	39.3	0.32
4	400	37.6	12.7	12.7	36	0.34
5	500	39.1	16.7	16.7	27.9	0.43
6	600	37.5	25.2	25.2	13.1	0.67
7	700	25.8	33.3	33.3	6.9	1.29
8	800	25.4	24.7	24.7	9.7	0.97
9	900	15.3	10.8	10.8	20.6	0.70
10	1000	7.6	2.6	2.6	42	0.34

Travel Time for Time Interval 1:

In the first time interval, there is no initial queue. From Table 6-12 the detected volume is 15.8 veh/ ln. These 15.8 veh are the observed group whose travel time to traverse link i is to be computed for time interval 1. The average speed detected by detector is 39.2mph.

Volume: 15.83/100*3600=576vph;

V/C=570/1080=0.53;

The density is Ktd =flow/speed=14.5 veh/mile;

Since there is no initial queue for this incoming group, the initial queue d3=0sec.

$$W_d = \frac{C-V}{k_q - k_{td}} = \frac{1080-570}{135-14.5} = 4.23 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{dt}\right) = \left(570 - 1080 - 4.23 \times 14.5\right) = -571.7 veh / h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL = -16 veh$$

Then the initial queue for the next time interval is $Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 0$.

h1=100/15.8=6.3 sec/veh

h2=2 sec/veh

S1=39.2mph, S2=6.5 mph

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{39.2 \times 6.3 - 19}{39.2 - 6.5} = 7;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{7 \times 2}{7 - 2} = 2.8 \text{ sec/veh}$$

From Equation 4-14, the average uniform stopped delay for this observed group is computed as follows:

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times \frac{40}{7} \times (\frac{40}{7} \times 2.8 + 40)}{15.9} = 11.5 \text{sec}/veh;$$

Since the over-saturation delay is zero and volume of observed group is smaller than the intersection capacity

$$d2 = 0;$$

Hence the travel time for this group is computed as follows:

$$Travel - time = \frac{L}{speed\_by\_\det ector} + d1 + d2 + d4$$

$$= \frac{1600}{39.2 \times 5280 \div 3600} + 11.5 + 0 + 0 = 39.37 \sec$$

Therefore, the travel time for time interval 1 is 39.37 sec and the initial queue for next time interval is zero.

Travel Time for Time Interval 2:

In the second time interval, there is no initial queue based on the previous computation, and the average dwelling time is smaller than 0.6sec/veh. Hence, there is no blackout on the loop detector. From Table 6-12, the detected volume is 26.05 veh/ln. These 26.05 veh is the observed group whose travel time is to be computed for time interval 2. The average speed detected by detector is 39.33mph..

Volume: 26.05/100*3600=938vph;

V/C=938/1080=0.87;

The density is Ktd =flow/speed=23.84 veh/mile;

h1=100/26.1=3.83 sec/veh

h2=2 sec/veh

S1=39.3mph, S2=6.5 mph

From Equation 4-13;

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{39.3 \times 3.83 - 19}{3.83 - 6.5} = 4;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{4 \times 2}{4 - 2} = 3.98 \text{ sec/veh}$$

From Equation 4-14, the average uniform stopped delay for this observed group is computed as follows:

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times \frac{40}{3.83} \times (\frac{40}{3.83} \times 3.98 + 40)}{26} = 16.3 \text{sec}/veh;$$

The over-saturation delay is zero since V is smaller than Capacity

$$d2 = 0;$$

Since there is no initial queue for this incoming group, the initial queue d3=0sec.

$$W_d = \frac{C-V}{k_q - k_{td}} = \frac{1080-938}{135-23.84} = 1.277 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{\mathrm{dt}}\right) = -172 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL \approx -5 veh/\ln$$

Then the initial queue for the next time interval is $Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 0$.

Hence the travel time for this group is computed as follows::

$$Travel - time = \frac{L - QL}{speed\_by\_\det ector} + d1 + d2 + d4$$
$$= \frac{1600-0}{39.3 \times 5280 \div 3600} + 16.3 + 0 + 0 = 44 \sec$$

Therefore, the travel time for time interval 2 is 44 sec. And the initial queue for the next time interval is zero.

Travel Time for Time Interval 3:

In third time interval, there is no initial queue based on the calculation of the previous time period 2, and the average dwelling time is smaller than 0.6sec/veh. Hence, there is no blackout on the loop detector. From Table 6-12, the detected volume is 33.27 veh /ln. The average speed detected by detector is 39.31 mph.

Volume: 33.27/100*3600=1198vph;

V/C=1198/1080=1.11;

The density is Ktd =flow/speed=30.47 veh/mile;

Since, V is greater than C, use the capacity as the input volume to estimate the uniform stopped delay d1:

h1=100/30=3.33 sec/veh

h2=2 sec/veh

S1=39.3 mph,S2=6.5 mph

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{39.3 \times 3.33 - 19}{39.3 - 6.5} = 3.42;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{3.42 \times 2}{3.42 - 2} = 4.82 \text{ sec/veh}$$

The uniform stopped delay for this observed group is computed as follows

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times \frac{40}{3.3} \times (\frac{40}{3.3} \times 4.82 + 40)}{33} = 17.65 \text{sec}/veh;$$

Since there is no initial queue for this incoming group, the initial queue d3=0sec.

$$W_u = \frac{V - C}{k_{td} - k_q} = -1.38 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{\mathrm{dt}}\right) = = 152 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL \approx 4 veh/\ln$$

Then the initial queue for the next time interval is

$$Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 4 veh/lh \,.$$

The Qm is 4 veh, the over-saturation delay is computed as follows:

$$d2 = \frac{area(B) + area(C)}{V \times CL} = \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{0.5 \times Q_m \times Q_m \times h2}{V \times CL} + \frac{Q_m \times red}{V \times CL}$$
$$= \frac{0.5 \times 4 \times 100}{33.27} + \frac{0.5 \times 4 \times 4 \times 2}{33.27} + \frac{4 \times 40}{33.27} = 11.29 \sec$$

Hence the travel time for this group is computed as follows :

$$Travel - time = \frac{L_{TD} - QL}{speed\_by\_detector \times 2} + \frac{L - L_{TD}}{Speed\_limit} + d1 + d2 + d4$$
$$= \frac{800 - 19 \times \frac{0+4}{2}}{39.3 \times 5280 \div 3600} + \frac{1600 - 800}{45 \times 5280 \div 3600} + 17.65 + 11.29 + 0 = 48.13 \sec$$

Therefore, the travel time for time interval 3 is 48.13 sec. And the initial queue for next time interval is 4 veh.

Travel Time for Time Interval 4

In time interval 4, there is an initial queue based on the calculation of 4 veh, and the average dwelling time at the detector is smaller than 0.6sec/veh. Hence, there is no blackout on the loop detector. From Table 6-12, detected volume is 37.6 veh/ln. These 37.6 veh represent the observed group whose travel time is to be calculated for time interval 4. The average detected speed is 35.97 mph.

Volume: 37.6/100*3600=1354vph;

V/C=1354/1080=1.25;

The density is Ktd =flow/speed=37.6 veh/mile;

From Equation 4-8, $(n-1) \times g \le \frac{Q_{t-1}}{D_s} \le n \times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{4}{1800 \div 3600} = 30\sec$,and g=60, n=1

From Equation 4-9, the initial delay is

d3=$\frac{Q_{t-1}}{D_s} + (n) \times red\_time = \frac{4}{1800 \div 3600} + (1 \times 40 = 48\sec$

Since, V is greater than C, use the capacity as the input volume to estimate the uniform stopped delay d1:

g=8sec,g2=52 sec

h1=100/30=3.33 sec/veh

h2=2 sec/veh

S1=36 mph,S2=6.5 mph

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{36 \times 3.33 - 19}{36 - 6.5} = 3.4\,;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{3.4 \times 2}{3.4 - 2} = 4.8\,\text{sec/veh}$$

$$m = \frac{r}{h1} = \frac{40}{3.33} = 12veh$$

$$k = m + Iq - \frac{g1}{h3} = 12 + 4 - \frac{2}{4.8} = 14.3$$

$$W_u = \frac{V - C}{k_{td} - k_q} \quad = -2.8 mile/hour$$

$$L = m + Iq - \frac{g1 + g2}{h3} = 12 + 4 - \frac{60}{4.80} = 3.52\,;$$

$$i = 4$$

$$t4 - t3 = (i - L) \times h1 = (4 - 3.52) \times 3.33 = 1.6$$

$$a = 0.5 \times (k + L) \times g2 = 0.5 \times (14.4 + 3.52) \times 52 = 464\sec$$

$$b = 0.5 \times (L + i) \times (t4 - t3) + i \times (red - (t4 - t3)) = 160\sec$$

$$c = 0.5 \times i \times i \times h2 = 0.5 \times h2 \times i^2 = 0.5 \times 2 \times 4 \times 4 = 16$$

The average stopped delay is computed as follows:

$$d1 = \frac{a+b+c}{V \times CL} = \frac{464+160+16}{37.6} = 17\sec$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{\mathrm{d}t}\right) = 380 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL \approx 11 veh/\ln$$

Then the initial queue for the next time interval is

$$Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 15 veh/\ln \,.$$

The queue length is 29*19=551 ft :

Over-saturation delay is computed as follows:

$$d2 = \frac{area(B) + area(C)}{V \times CL} = 17.8$$

Since d3 is smaller than cycle length and the volume is greater than the capacity Equation 4-29 and 4-30 are used to compute the d4. In addition, the new value of k and m should be computed based on the actual volume which is 45.7 veh per 100 seconds.

The k' and m' is 18.1 and 15 respectively.

$$d4 = \frac{0.5 \times r \times m' + 0.5 \times (m' + k') \times g1}{Total\_vehicle\_in\_the\_Observed\_Group}$$

$$= \frac{0.5 \times 40 \times 15 + 0.5 \times (15 + 18.1) \times 8}{37.6} = 11.5\sec$$

$$Travel-time=\frac{L_{TD}-QL}{speed\_by\_\det ector\times 2}+\frac{L-L_{TD}}{Speed\_\lim it}+d1+d2+d4$$

$$=\frac{800-19\times 4}{35.97\times 5280\div 3600}+\frac{1600-800}{45\times 5280\div 3600}+17+17.8+11.5=72.2\sec$$

Therefore, the travel time for time interval 4 is 72.2sec and the initial queue for next time interval is 15 veh.

Travel Time for Time Interval 5

In time interval 5, there is an initial queue of 10veh, and the average dwelling time at the detector is smaller than 0.6sec/veh. Hence, there is no blackout at the loop detector. From Table 6-12, the detected volume is 45.66 veh/ln, and the average detected speed is 27.87 mph.

Volume: 39.05/100*3600=1406vph;

V/C=1406/1080=1.3;

The density is Ktd =flow/speed=50.4 veh/mile;

From Equation 4-8, $(n-1)\times g\leq\frac{Q_{t-1}}{D_s}\leq n\times g$;

Since $\frac{Q_{t-1}}{D_s}=\frac{15}{1800\div 3600}=30\sec$,and g=60, n=1

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s}+(n)\times red\_time=\frac{15}{1800\div 3600}+(1)\times 40=70\sec$

g1=30sec, and g2=30 sec

Since V is greater than Capacity, use the capacity as the incoming volume to estimate the uniform stopped delay.

h1=100/30=3.33 sec/veh

h2=2 sec/veh

S1=27.8, S2=6.5 mph

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = \frac{27.8 \times 3.33 - 19}{27.8 - 6.5} = 3.45\,;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{3.45 \times 2}{3.45 - 2} = 4.74\,\text{sec/veh}$$

$$m = \frac{r}{h1} = \frac{40}{3.33} = 12veh$$

$$k = m + Iq - \frac{g1}{h3} = 12 + 15 - \frac{30}{4.72} = 20.7$$

$$L = m + Iq - \frac{g1 + g2}{h3} = 14.35\,;$$

$$i = 15$$

$$t4 - t3 = (i - L) \times h1 = (15 - 14.35) \times 3.33 = 2.2$$

$$a = 0.5 \times (k + L) \times g2 = 0.5 \times (20.67 + 14.35) \times 30 = 525\,\text{sec}$$

$$b = 0.5 \times (L + i) \times (t4 - t3) + i \times (red - (t4 - t3)) = 599\,\text{sec}$$

$$c = 0.5 \times i \times i \times h2 = 0.5 \times h2 \times i^2 = 0.5 \times 2 \times 15 \times 15 = 225$$

The average stopped delay

$$d1 = \frac{a + b + c}{V \times CL} = 34.5\,\text{sec}/\,veh$$

$$W_u = \frac{V - C}{k_{td} - k_q} = -3.86 mile / hour$$

The queuing rate QR(veh/h) is:

$$\text{QR} = \frac{\text{dn}}{\text{dt}} = \left(V - C - \text{W}_d \times \text{k}_{\text{dt}}\right) = 520 veh / h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL = 520 \times \frac{100}{3600} \approx 14 veh / \ln$$

Then the initial queue for the next time interval is

$$Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = 15 + 14 = 29 veh / \ln .$$

The queue length is 19*29=551 ft:

Over-saturation delay is computed as follows:

$$d2 = \frac{area(B) + area(C)}{V \times CL} = \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{0.5 \times Q_m \times Q_m \times h2}{V \times CL}$$
$$= \frac{0.5 \times 14 \times 100}{39} + \frac{0.5 \times 14 \times 14 \times 2}{39} = 23 \sec / veh$$

Since d3 is smaller than cycle length and the volume is greater than the capacity Equation 4-29 and 4-30 are used to compute the d4. In addition, the new value of k and m should be computed based on the actual volume which is 45.7 veh per 100 seconds.

The k' and m' is 27.8 and 15.6 respectively.

$$d4 = \frac{0.5 \times r \times m' + 0.5 \times (m' + k') \times g1}{Total\_vehicle\_in\_the\_Observed\_Group}$$
$$= \frac{0.5 \times 40 \times 15.6 + 0.5 \times (15.6 + 27.8) \times 30}{45.66} = 24.7 \sec$$

$$Travel - time = \frac{L_{TD} - QL}{speed\_by\_\det ector \times 2} + \frac{L - L_{TD}}{Speed\_\lim it} + d1 + d2 + d4$$
$$= \frac{800 - 19 \times 15}{27.9 \times 5280 \div 3600} + \frac{1600 - 800}{45 \times 5280 \div 3600} + 34.6 + 23 + 24.7 = 107 \sec$$

Hence, the travel time for time interval 5 is 107sec. And the initial queue for next time interval is 29 veh.

Travel Time for Time Interval 6

In the time interval 6, there is an initial queue of 29 vehicles. And the average dwelling time 0.67 is greater than 0.6sec/veh but smaller than 0.7 sec/veh. Hence, it is the critical value for a blackout situation. Hence, there is a blackout situation and the average incoming group of vehicles is based on the detected volume of the upstream link i-1 in time intervals 5 and 6. Algorithm 3 in chapter 5 is used to estimate the travel time in this interval.

There is no acceptable time period to estimate the t% before 600 seconds since we can not use the data from the detector in the middle of the cycle length. Hence use the data in time 1200 seconds to estimate the t%. At the end of 1200 seconds, there is no blackout, the total number of vehicles detected on link i-1 from 0-1200 seconds is 823 and 809 on link i. Hence the t%=(809-823)/823=-1.7%

The average volume of link i-1 in time interval 5 and 6 is (45.77+40)/2*3600/100=1548vph

But the capacity of link i-1 is only 1395vph.

Hence, the incoming volume in time interval 6 on link i is 1395*(1-1.7%)=1371vph

V/C=1371/1080=1.26;

From Equation 4-8, $(n-1)\times g \le \frac{Q_{t-1}}{D_s} \le n \times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{29}{1800 \div 3600} = 58\sec$,and g=60, n=1

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n)\times red\_time = \frac{29}{1800 \div 3600} + (2)\times 40 = 98\sec$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$QL_{in\_time\_i-1} + (V - C) \times CL =$ 29+(1371-1080)*100/3600 =37 veh/ln

The queue length is 19*37=703 ft :

Since there is a blackout situation, we can assume all vehicles in the observed group are in the queue when the first vehicle of the group arrived at the intersection.

g1=58sec, and g2=2 sec

h1=100/30=3.33 sec/veh

h2=2 sec/veh

$m = C \times CL = 30veh$

$i = m - \frac{g2}{h2} = 30 - \frac{2}{2} = 29veh$

The area of A is

$a = 0.5 \times (i + m) \times g2 = 0.5 \times (29 + 30) \times 2 = 59\sec;$

The area of B and C are

$b = r \times i = 29 \times 40 = 1160\sec;$

$c = 0.5 \times (i \times h2) \times i = 0.5 \times h2 \times i^2 = 0.5 \times 2 \times 29^2 = 841\sec$

The average uniform stopped delay $d1 = \frac{a + b + c}{V \times CL} = \frac{59 + 1160 + 841}{38.1} = 54\sec/veh$

i'= Qm-g2/h2=8-2/2=7veh

Over-saturation delay is computed as follows:

$$
\begin{aligned}
d2 &= \frac{area(A) + area(B) + area(C) + area(D)}{V \times CL} \\
&= \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{0.5 \times (i' + Q_m) \times g2}{V \times CL} + \frac{r \times i}{V \times CL} + \frac{0.5 \times i' \times i' \times h2}{V \times CL} \\
&= 19.34\sec/veh
\end{aligned}
$$

Since d3 is close to cycle length, Equation 4-33 is used to compute the d4..

$$d4 = \frac{0.5 \times V \times CL^2}{V \times CL} + d3 - CL = d3 - 0.5 \times CL = 98 - 50 = 48\sec$$

$$Travel - time = \frac{L - QL}{Speed\_\lim it \div 2} + d1 + d2 + d3$$

$$= \frac{1600 - 29 \times 19}{45 \times 5280 \div 3600 \div 2} + 54.1 + 19.4 + 48 = 155.2 \sec$$

Therefore, the **travel time for time interval 6 is** 155.2 seconds. And the initial queue for next time interval is 37 veh.

Travel Time for Time Interval 7

In time interval 7, there is an initial queue of 37 veh, and the average dwelling time is bigger than 0.6sec/veh. Hence, there is a blackout situation during this time interval too. The detected traffic data is not reliable due to the blackout situation. Therefore the incoming group of vehicles is based on the average upstream link volume in time intervals 6 and 7.

The detected volume on link i-1 during time interval 6 is 40veh/ln,and 24veh/lnthe in time interval 7. The average is (40+24)/2=32 veh/ln. Based on the pervious observation on link i-1, we can assume the initial queue for time period 6 is approximately 19.8 veh according to the early computation . Hence, V_{i-1} +Vq is bigger than the capacity of link i-1 which is 1395veh/h/ln

Therefore, the incoming volume for link i is 1395*(1-0.017)=1371 veh/h/ln

V/C=1371/1080=1.26;

From Equation 4-8, $(n-1) \times g \le \frac{Q_{t-1}}{D_s} \le n \times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{37}{1800 \div 3600} = 74 \sec$,and g=60, n=2

From Equation 4-9, the initial delay is

d3= $\dfrac{Q_{t-1}}{D_s}+(n)\times red\_time=\dfrac{37}{1800\div 3600}+(2)\times 40=154\,\text{sec}$

Since the Ktd in this time interval is not reliable due to the blackout, the shockwave method is not good in this situation to estimate the queue length. A base method is used instead of it.

At the end of time interval 7, the number of vehicle in queue is $QL_{in\_time\_i-1}+(V-C)\times CL=$ 37+(1371-1080)*100/3600 =45 veh/ln

Then the initial queue for the next time interval is 45

The queue length is 19*45=855ft ,

g1=14sec, and g2=46 sec

Since V is greater than Capacity, use the capacity as the incoming volume to estimate the uniform stopped delay. And since the d3 is greater than a cycle length, all vehicles in observed group are in the queue when dissipating the intersection is assumed.

h1=100/30=3.33 sec/veh

h2=2 sec/veh

$m=C\times CL=30veh$

$i=m-\dfrac{g2}{h2}=30-\dfrac{46}{2}=7veh$

The area of A is

$a=0.5\times(i+m)\times g2=0.5\times(7+30)\times 46=851\,\text{sec}$;

The area of B and C are

$b=r\times i=7\times 40=280\,\text{sec}$;

$c = 0.5 \times (i \times h2) \times i = 0.5 \times h2 \times i^2 = 0.5 \times 2 \times 7^2 = 49 \sec$

The average uniform stopped delay $d1 = \frac{a+b+c}{V \times CL} = \frac{851+280+49}{38.1} = 31 \sec/veh$

Over-saturation delay is computed as follows:

$$d2 = \frac{area(B)+area(C)}{V \times CL} = \frac{0.5 \times Q_m \times CL}{V \times CL} + \frac{0.5 \times Q_m \times Q_m \times h2}{V \times CL}$$
$$= \frac{0.5 \times 8 \times 100}{38.1} + \frac{0.5 \times 8 \times 8 \times 2}{38.1} = 12.2 \sec/veh$$

Since d3 is greater than cycle length, Equation 4-33 is used to compute the d4..

$$d4 = \frac{0.5 \times V \times CL^2}{V \times CL} + d3 - CL = d3 - 0.5 \times CL = 154 - 50 = 104 \sec$$

Since the queue length is longer than the location of loop detector, the travel time is computed as follows:

$$Travel - time = \frac{L - QL}{Speed\_\lim it \div 2} + d1 + d2 + d4$$
$$= \frac{1600 - 37 \times 19}{45 \times 5280 \div 3600 \div 2} + 31 + 12.2 + 104 = 174 \quad \sec$$

Therefore, the **travel time for time interval 7 is** 174 seconds. And the initial queue for next time interval is 45 veh.

Travel Time for Time Interval 8

In time interval 8, there is an initial queue of 45 veh, and the average dwelling time is bigger than 0.6sec/veh. Hence, there is a blackout situation during this time interval too. The detected traffic data is not reliable due to the blackout situation. Therefore the incoming group of vehicles is based on the average upstream link volume in time intervals 7 and 8..

The turning movement: the turning movement is -1.7%.

And the volume detected by the link i-1 during time interval 7 is 23.88 veh/ln and 12.77 veh/ln in time interval 8. The initial queue for time interval 7 is approximately 8.3 as computed easily. Hence, the incoming volume is

((23.88+12.77)/2+8.33)*3600/100=967 (veh/h/ln).

It is smaller than the capacity of link i-1.

Therefore, 967 veh/h/ln represents the incoming volume of link i in time interval 8.

From Equation 4-8, $(n-1)\times g \le \frac{Q_{t-1}}{D_s} \le n\times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{45}{1800 \div 3600} = 90\,\text{sec}$,and g=60, n=2

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n)\times red\_time = \frac{45}{1800 \div 3600} + (2)\times 40 = 170\,\text{sec}$

At the end of time interval 8, the number of vehicle in queue is $QL_{in\_time\_i-1} + (V-C)\times CL =$ 45+(967-1080)*100/3600 =41 veh/ln

g1=30sec, and g2=30 sec

Since the d3 is greater than a cycle length, all vehicles in observed group are in the queue when dissipating the intersection is assumed.

h2=2 sec/veh

$m = V \times CL = 26.86 veh$

$$i = m - \frac{g2}{h2} = 11.9veh$$

The area of A is

$$a = 0.5 \times (i + m) \times g2 = 0.5 \times (11.86 + 26.86) \times 30 = 581\sec;$$

The area of B and C are

$$b = r \times i = 11.86 \times 40 = 474.6\sec;$$

$$c = 0.5 \times (i \times h2) \times i = 140.8\sec$$

The average uniform stopped delay $d1 = \frac{a + b + c}{V \times CL} = 44.5\sec/veh$

$d2 = 0\sec$ since Qm is equal to zero

Since d3 is greater than cycle length, Equation 4-33 is used to compute the d4..

$$d4 = \frac{0.5 \times V \times CL^2}{V \times CL} + d3 - CL = d3 - 0.5 \times CL = 170 - 50 = 120\sec$$

$$Travel - time = \frac{L - QL}{Speed\_\lim it \div 2} + d1 + d2 + d4$$
$$= \frac{1600 - 45 \times 19}{45 \times 5280 \div 3600 \div 2} + 44.5 + 0 + 120 = 187.1\sec.$$

Therefore, the **travel time for time interval 8 is** 187.1 seconds. And the initial queue for next time interval is 41 veh.

Travel Time for Time Interval 9

In the time interval 9, the average dwelling time is bigger than 0.7sec/veh. Hence, there is a blackout situation. he detected traffic data is not reliable due to the blackout situation. Therefore the incoming group of vehicles is based on the average upstream link volume in time intervals 8 and 9.

The turning movement: the turning movement is -1.7%.

And the detected volume by the link i-1 during time interval 8 is 10.55 veh/ln and 8.33 veh/ln in time interval 9. The initial queue for time interval 8 on link i-1 is approximately 0. Hence, the incoming volume is (10.55+8.33)/2*3600/100=380 (veh/h/ln). It is smaller than the capacity of link i-1.

V/C=380*(1-1.7%)*/1080=0.34;

From Equation 4-8, $(n-1)\times g \le \frac{Q_{t-1}}{D_s} \le n \times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{41}{1800 \div 3600} = 82\sec$,and g=60, n=2

From Equation 4-9, the initial delay is

d3= $\frac{Q_{t-1}}{D_s} + (n)\times red\_time = \frac{41}{1800 \div 3600} + (2)\times 40 = 162\sec$

At the end of time interval 9, the number of vehicle in queue is $QL_{in\_time\_i-1} + (V-C)\times CL =$ 41+(373-1080)*100/3600 =21veh/ln

g1=22sec, and g2=38 sec

Since the d3 is greater than a cycle length, all vehicles in observed group are in the queue when dissipating the intersection is assumed.

h2=2 sec/veh

$m = V \times CL = 10.37 veh$

$i = m - \frac{g2}{h2} < 0$

Hence, all the vehicles will dissipate the intersection in g2.

The area of A is

$a = 0.5 \times m \times m \times h2 = 0.5 \times 10.37 \times 10.37 \times 2 = 107\sec$;

The area of B and C are

$b = c = 0$;

The average uniform stopped delay $d1 = \frac{a+b+c}{V \times CL} = \frac{107}{10.37} = 10.37\,\text{sec}/\,veh$

$d2 = 0\,\text{sec}$ since Qm is smaller than zero

Since d3 is greater than cycle length, Equation 4-33 is used to compute the d4..

$$d4 = \frac{0.5 \times V \times CL^2}{V \times CL} + d3 - CL = d3 - 0.5 \times CL = 162 - 50 = 112\,\text{sec}$$

$$Travel - time = \frac{L - QL}{Speed\_\lim it \div 2} + d1 + d2 + d4$$
$$= \frac{1600 - 43 \times 19}{45 \times 5280 \div 3600 \div 2} + 10.37 + 0 + 112 = 147\,\text{sec}\,.$$

Therefore, the **travel time for time interval 9 is 147 sec** and the initial queue for next time interval is 21 veh.

Travel Time for Time Interval 10

In time interval 10, there is an initial queue of 21 veh based on the calculation of the previous time period. And the average dwelling time is smaller than 0.7sec/veh. Hence, there is no blackout situation. And from Table 6-12, the detected volume is 7.6 veh/ln. These 7.6 veh are the observed group which represents the travel time at time interval 10. The average speed detected by detector is 41.95 mph.

Volume: 7.6/100*3600=274vph;

V/C=274/1080=0.25;

The density is Ktd =flow/speed= 6.53 veh/mile;

From Equation 4-8, $(n-1) \times g \le \frac{Q_{t-1}}{D_s} \le n \times g$;

Since $\frac{Q_{t-1}}{D_s} = \frac{21}{1800 \div 3600} = 42\sec$,and g=60, n=1

From Equation 4-9, the initial delay is

d3=$\frac{Q_{t-1}}{D_s} + (n) \times red\_time = \frac{21}{1800 \div 3600} + (1) \times 40 = 82\sec$

$$W_d = \frac{C - V}{k_q - k_{td}} = 6.27 mile/hour$$

The queuing rate QR(veh/h) is:

$$\mathrm{QR} = \frac{\mathrm{dn}}{\mathrm{dt}} = \left(V - C - \mathrm{W}_d \times \mathrm{k}_{\mathrm{d}t}\right) = -846 veh/h$$

The number of the vehicles in queue which is built during the observed cycle length t will be:

$$Q_m = QR \times CL = -846 \times \frac{100}{3600} \approx -24 veh/\ln$$

Then the initial queue for the next time interval is

$$Q_{t-1} = \max(0, \sum_{m=1}^{t} Q_m) = \min(0, 23 - 24) = 0 veh/\ln .$$

The queue length is 0*19=0 ft :

Since the d3 is smaller than a cycle length and the volume of last observed group is smaller than the capacity, use the case 4 of the uniform stopped delay, but in the time interval 9, the t4-t3 is equal to zero.

g1=42sec,g2=18 sec

h1=100/7.6=13.13 sec/veh

h2=2 sec/veh

S1=42mph, S2=6.5 mph

$$t = \frac{S1 \times h1 - 19}{(S1 - S2)} = 15;$$

$$h3 = \frac{t \times h2}{t - h2} = \frac{15 \times 2}{15 - 2} = 2.3 \text{sec/veh}$$

$$L = m + Iq - \frac{g1 + g2}{h3} = -1.9$$

$$k = m + Iq - \frac{g1}{h3} = \frac{40}{12} + 21 - \frac{42}{2.3} = 6.1 veh$$

Since L is smaller than zero, all vehicles in the observed group will dissipate the intersection in g2.

The uniform stopped delay for this observed group is computed as follows:

$$d1 = \frac{0.5 \times Q_{\max} \times Q_t}{Total\_arrival} = \frac{0.5 \times k \times (k \times h3)}{7.6} = 5.7 \text{sec}/ veh;$$

d2=0, since V is smaller than the capacity.

Since d3 is smaller than the cycle length and the volume is smaller than the capacity in this time interval, Equation 4-29 and 4-30 are used to computed the d4 with the same k and m values.

$$d4 = \frac{0.5 \times r \times m + 0.5 \times (m + k) \times g1}{Total\_vehicle\_in\_the\_Observed\_Group}$$
$$= \frac{0.5 \times 40 \times 3.04 + 0.5 \times (3.03 + 5.8) \times 42}{7.6} = 32.5 \text{sec}$$

$$Travel - time = \frac{L_{TD} - QL}{speed\_by\_\det ector \times 2} + \frac{L - L_{TD}}{Speed\_\lim it} + d1 + d2 + d4$$
$$= \frac{800 - 19 \times 23}{41.95 \times 5280 \div 3600} + \frac{1600 - 800}{45 \times 5280 \div 3600} + 6.1 + 0 + 32.5 = 56.3 \text{sec}$$

Therefore, the **travel time for time interval 10 is 53.1 sec** and the initial queue for next time interval is 0 veh.

Figure 6-5 is the illustration of travel time model components for 10 time period analysis with 120 seconds data updates.

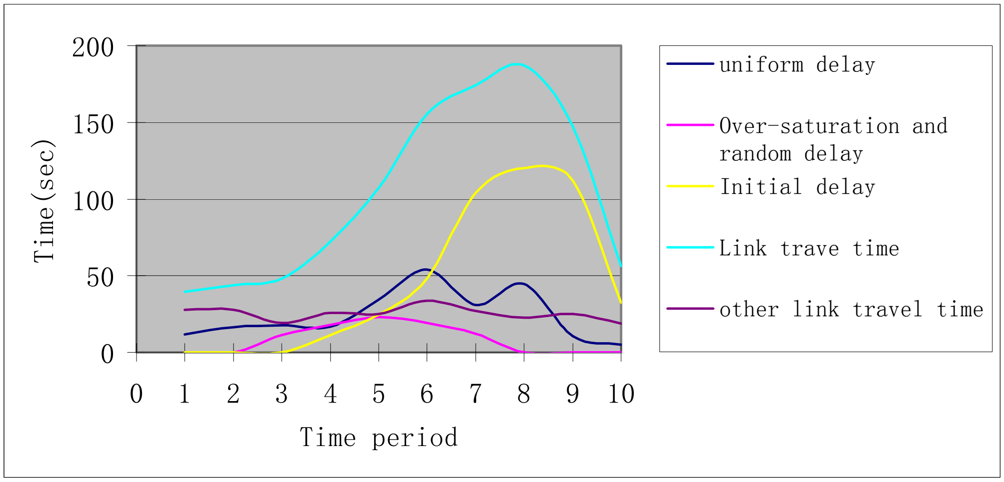

Figure 6 - 5 Travel Time Comparison with 120 Time Interval Update

6.5 Bottleneck on Downstream Link

In this situation, there is a bottleneck at the intersection which is caused by the traffic jam of the downstream link i+1. This influences the capacity of link i as discussed in Chapter 5. The goal of this simulation is to validate the determination of the new intersection capacity of link i. The volume detected by the detector at link i+1 minus the volume of turning vehicles (Vturn as discussed and computed earlier) represents the maximum departure volume of link i. The maximum departure volume of link i is the new capacity of link i.

In order to create a bottleneck in the simulation, the number of lanes on link i+1 is changed from 3 to 2 and the link length was dropped from 1600 ft to 400ft. The loop detector on link i+1 is located at the 200 ft from the stop line of link i+1. Another loop detector on link i is located at 5ft from the stop line of link i in order to make sure that the departure rate on link i is consistent with the detected volume on link i+1. Table 6-13 shows the simulation data from both loop detectors. The detected volumes are similar which permits us to use the detected volumes on link i+1 to compute the capacity on link i. There are no turning movements in this simulation.

Table 6 - 13 Number of vehicles detected by loop detector

Link i			Link i+1	
Time period	Veh detected		Time period	Veh detected
1	44		1	45
2	39		2	42
3	47		3	47
4	45		4	47
5	43		5	42

In Table 6-13, the number of dissipated vehicles on link i is almost the same as the number of detected vehicles on link i+1.

Therefore, the new capacity of the link i for time interval n can be represented as discussed in Chapter 5: C= $\frac{V_{i-1} \times N_{i-1} - Vturn}{N_i}$;

For example, the new capacity of link i for time interval 1 can be computed as follows:

C= $\frac{V_{i-1} \times N_{i-1} - Vturn}{N_i} = \frac{45}{3} = 15 veh/h/\ln$;

The capacity for the remaining intervals is similarly computed. Once the new capacity of link i is determined, the rest of the calculations remain the same .

6.6 Comparison of CORSIM results with proposed Algorithms

This section is divided into the following parts:

a) Understanding the outputs from CORSIM

b) Understanding and fixing the CORSIM results to match the objectives of this study.

c) Comparing the adjusted CORSIM results with the algorithms results.

6.6.1 The relevant Outputs from CORSIM

The CORSIM outputs that are of interest to this study are:

- Vehicle Trips - The number of vehicles that have been discharged from the link for each time interval.
- Vehicle Miles - The vehicle trips times the length of link.

- Total Time (veh-min) - Total time on the link for all vehicles for a defined time interval.
- Average Speed (miles per hr) - Total vehicle miles divided by the total travel time.
- Number of vehicles detected by the loop detector (V*CL).
- Control Delay per vehicle for all the vehicles occupying the link for a defined time interval, (sec per veh).

6.6. 2-Adjusting the CORSIM Outputs

Before starting the comparison phase, an independent step is carried out to make sure that the computed travel times and speeds in CORSIM are reliable. The average travel speed in CORSIM is statistically computed at the end of each time interval as the ratio of vehicles-miles traveled divided by the total vehicle travel times. Sometimes due a rapid drop in incoming volume the computed speed by CORSIM does not respond quickly to this sudden change and the average travel time increases instead of decreasing with the drop in volume as shown in intervals 9 and 10 of Table 6-14.

Table 6 - 14 CORSIM Data

Time interval	Average Speed in CORISM(mph)	Travel time by CORSIM(sec)	Travel time by Algorithm(sec)	speed by detector
1	20.4	53.47593583	43.687095	38.3
2	23.8	45.83651642	40.16358201	40.49672131
3	26.8	40.70556309	41.24545839	37.59139785
4	21.8	50.04170142	87.27552627	37.06818182
5	18.2	59.94005994	140.1613914	33.25620438
6	13.7	79.6284008	205.4808915	23.56792453
7	10.6	102.915952	235.6443025	11.93846154
8	8.7	125.3918495	239.9911279	8.28
9	7.1	153.6491677	185.480762	26.00714286
10	9.7	112.4648547	98.96646764	41.612
11	30.8			

The input volume by the user during time intervals 9 and 10 dropped rapidly as shown in Table 6-1. In interval 8, there was a black out condition and the incoming volume started to decrease. Hence, the queue at the intersection should be decreased too. As a result, the average speed on the link should increase and the total travel time on link i should be reduced. A look at the detector output shows that the average detected speed within these two time intervals has increased. On the contrary, the average speed on link i in time intervals 9 and 10 in CORSIM have decreased, which is not reasonable.

In Table 6-1, the input volume during time intervals 9, 10, and 11 are very similar. The speed at time interval 11 is 30.8mph in CORSIM, where no queue at the intersection is realized through the CORSIM visualizer. So, if the speed at interval 11 is considered correct, then we can interpolate the other two speeds for intervals 9 and 10 by taking the speeds of intervals 8 and 11 as the end points. After executing the interpolation procedure the speeds in intervals 9 and 10 are 16.00 and 23.3 mph respectively as shown in Table 6-15.

Now, we can use the new average speed to get the new total travel time on link i in time periods 9 and 10 as follows: $\frac{veh\_miles}{average\_speed}$.

Table 6 - 15 New CORSIM Data

Time interval	Average Speed in CORISM(mph)	Travel time by CORSIM(sec)	speed by detector
1	20.4	53.5	38.3
2	23.8	45.8	40.5
3	26.8	40.7	37.6
4	21.8	50	37.1
5	18.2	59.9	33.3
6	13.7	79.6	23.6
7	10.6	102.9	11.9
8	8.7	125.4	8.3
9	16.0	68.2	26.0
10	23.3	46.8	41.6

6.6. 3 Manipulating the CORSIM Output to Fit our Objectives

The control delay in CORSIM is the average control delay for all the vehicles occupying link i during a time interval. It is composed of two parts: a) the intersection delay experienced by the vehicles that can clear the intersection during this time interval b) the deceleration delay or the stopped delay experienced by those vehicles that can not clear the intersection during this time interval. CORSIM calculates only the average delay for one time interval. However, as we have explained earlier, the travel time of the observed group of vehicles may last for more than one time interval in order to clear the intersection. Hence, CORSIM's control delay under estimates the intersection control delay obtained from our algorithms for the observed group, particularly when there is an initial queue at the intersection.

Similarly, the average speed in CORSIM can not be used to compute the travel time of the observed group since it only represents the average speed on the link in one time interval.

In conclusion, CORSIM does not compute the extra time needed by the observed group to clear the intersection beyond a time interval, which is the initial queue delay which we referred to in Chapters 3 and 4 as d3.

To address this issue the following procedure is adopted:

i) Determine the average time it takes the observed group of vehicles to occupy the link, assuming that the average time of the observed group is represented by the average time of all the vehicles occupying the link for that particular time interval, and

ii) Determine the average time it takes the initial queue to clear the intersection d3, irrespective of how many time intervals it requires.

The average travel time for all vehicles on the link during a time interval can be computed as follows:

Let t_{ave} be the average time on the link during the observed time interval in CORSIM. $t_{ave} = \frac{Total\_travel\_time\_for\_all\_vehicles}{Inco\min g\_vehilces + vehicles\_in\_queue}$.

Where;

Number of incoming vehicles is the number of vehicles detected by the detector during the time interval.

The vehicles in the queue are counted visually from the visualizer.

The initial queue, the detected incoming volume, and the t_{ave} are computed from CORSIM output and are shown in Table 6-16.

Table 6 - 16 Adjusted Data From CORSIM

Time interval	Total time(sec/ln)	Initial queue	Income vehicle veh/ln/CL	t_{ave}(sec)
4	1536	14	36.67	30.3
5	2012	19	45.67	31.1
6	2440	33	35.33	35.7
7	2960	39	35.73	39.6
8	3740	47	25.2	51.8
9	1657	39	9.33	34.3
10	1062	19	8.33	38.9

The initial queue delay d3 has been computed manually based on the visual observations from CORSIM output and based on the calculations provided in Chapter 4.

Combining these two delays, the total travel time for the observed group in CORSIM for each time interval is computed and is shown in Table 6-17.

The adjusted CORSIM results would remain the same irrespective of the loop detector time interval update because the cycle length at the intersection is 100 secs for all the three experiments.

Table 6 - 17 Revised Travel time of the observed group in CORSIM

Time interval	blackout	Travel time by CORSIM(sec)
1	N	53.5
2	N	45.8
3	N	40.7
4	N	53.5
5	N	62.2
6	N	131.7
7	Y	147.6
8	Y	175.8
9	N	157.7
10	N	58.4

6.6. 4 Comparison of Results

The comparison of the travel time of the observed group in CORSIM with those of the algorithms for different detector outputs are shown in Table 6-18 and in Figure 6-6.

Table 6 -18 Travel time in CORSIM Vs. the Algorithms travel time for 100,120 and 60 seconds Update

Time interval	Travel time by CORSIM(sec)	Travel time by Algorithm(100 sec)	Travel time by Algorithm(120 sec)	Travel time by Algorithm(60 sec)
1	53.5	43.7	39.4	39.7
2	45.8	40.2	44.0	42.9
3	40.7	41.2	48.0	45.2
4	53.5	61.3	72.2	67.4
5	62.2	104.6	107.1	104.5
6	131.7	157.7	155.2	157.8
7	147.6	185.6	174.3	172.9
8	175.8	190.0	187.1	178.8
9	157.7	135.5	147.3	
10	58.4	54.1	56.5	

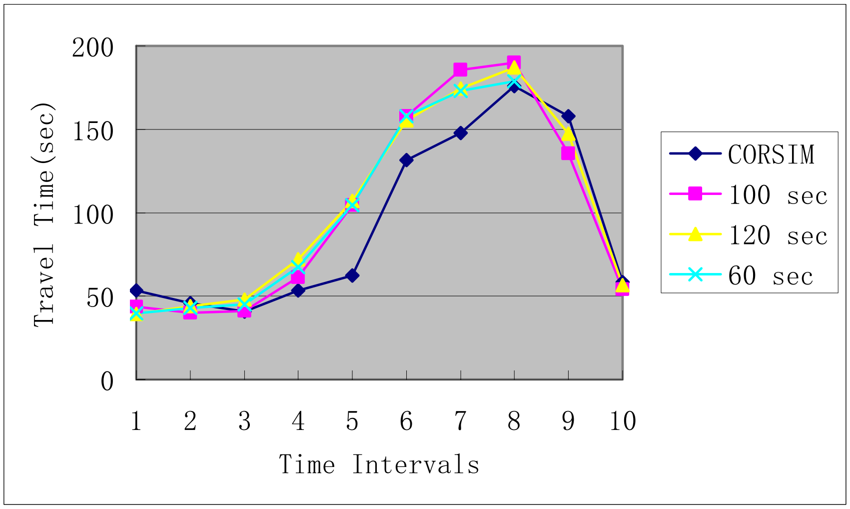

Figure 6 - 6 Travel Times Comparison with Different Detector Time Interval Update

The Mean Absolute Error (MAE) is used to compare the fitness of the algorithm results with revised CORSIM results.

The Mean Absolute Error is calculated as $MAE = \frac{\sum_{i=1}^{n} Observed - Estimated}{n}$.

The MAE and the average percent of difference are shown in Table 6-19

Table 6 -19 Results of MAE and Percentage Difference with CORSIM

Time interval	Difference(100)	% of difference	Difference (120)	% of difference	Difference (60sec)	% of difference
1	9.8	18.3	14.1	26.4	13.8	25.8
2	5.7	12.4	1.8	3.9	2.9	6.3
3	0.5	1.3	7.3	18.0	4.5	11.0
4	7.8	14.5	18.7	35.0	13.9	26.0
5	42.4	68.2	44.9	72.2	42.3	68.0
6	26.0	19.7	23.5	17.8	26.1	19.8
7	38.0	25.8	26.7	18.1	25.3	17.1
8	14.2	8.1	11.3	6.4	3.0	1.7
9	22.2	14.1	10.4	6.6		
10	4.3	7.4	2.0	3.4		
MAE	17.1	19.0	16.1	20.8	16.5	22.0

From Table 6-19, the average MAE is around 16 sec and the average percent difference is around 20%. The biggest difference is in time interval 5 which has a percent difference of 68.2%. In Table 6-16, the volume of the observed group in time interval 5 is about 50% over the capacity which will take an additional amount of time to clear the intersection. As stated earlier, this over saturation delay is underestimated in CORSIM, because it takes several intervals to clear the intersection.

In general, the results show that the algorithms are robust and provide good accurate results when compared with CORSIM.

A statistical test is utilized to test the difference in travel time results obtained by using100, 120 and 60 detector update time intervals. The statistical test results indicate that under 95% confidence level there is no significant difference among the results obtained from 100sec, 120sec, and 60 sec detector update time interval. Since there is no significant difference in the results, we recommend the use of 120 secs (2 minutes update) for its ease of real time application.