Assignment 2

Signalized Intersection Design

(Walkers Line and Mainway, Burlington ON)

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Introduction to Transportation Engineering

CIVENG 3K03

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1. Intersection Layout

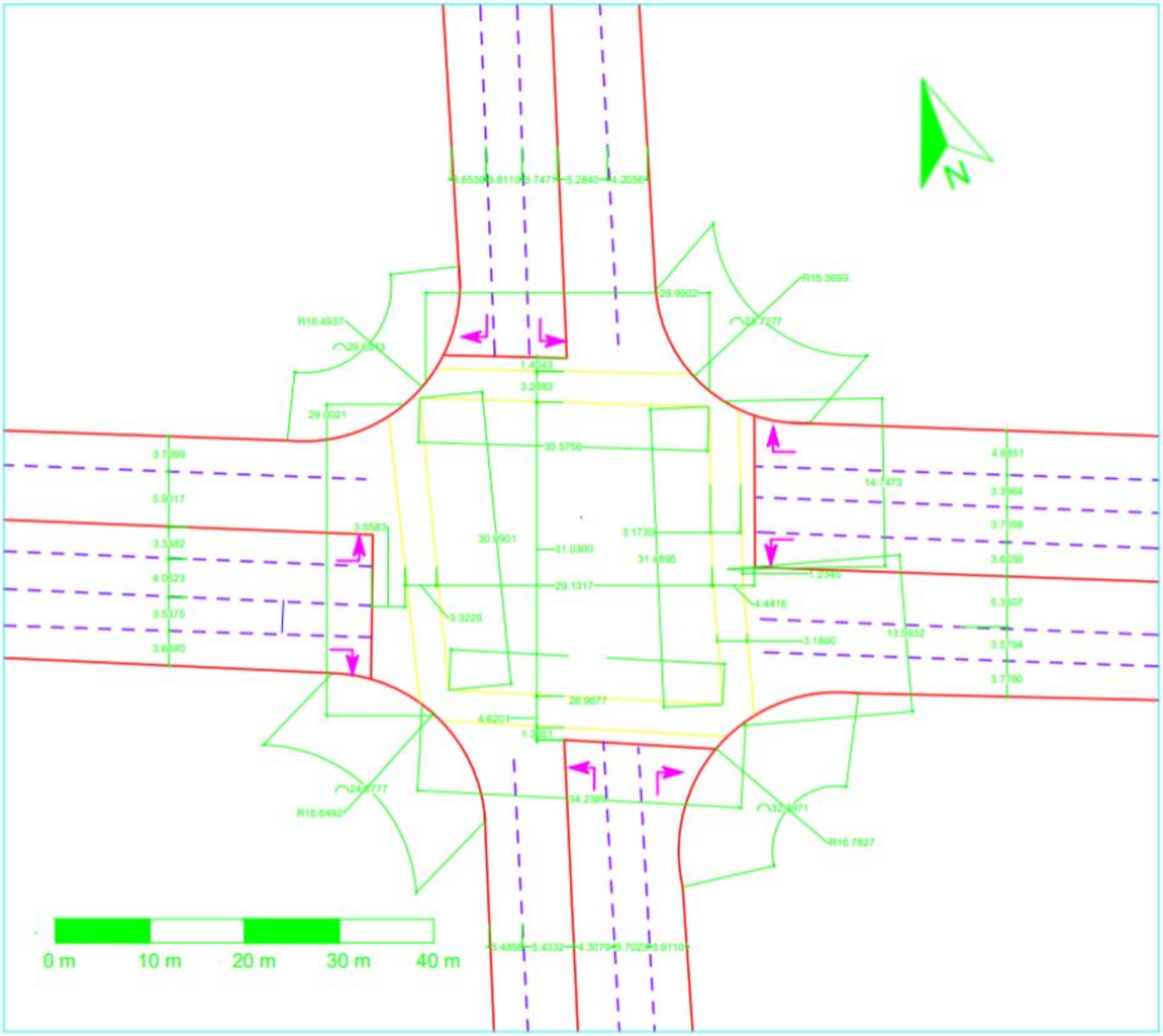

Figure 1. Intersection Layout

2. Existing Cycle Length and Phasing Diagram

Existing cycle length = 130 sec

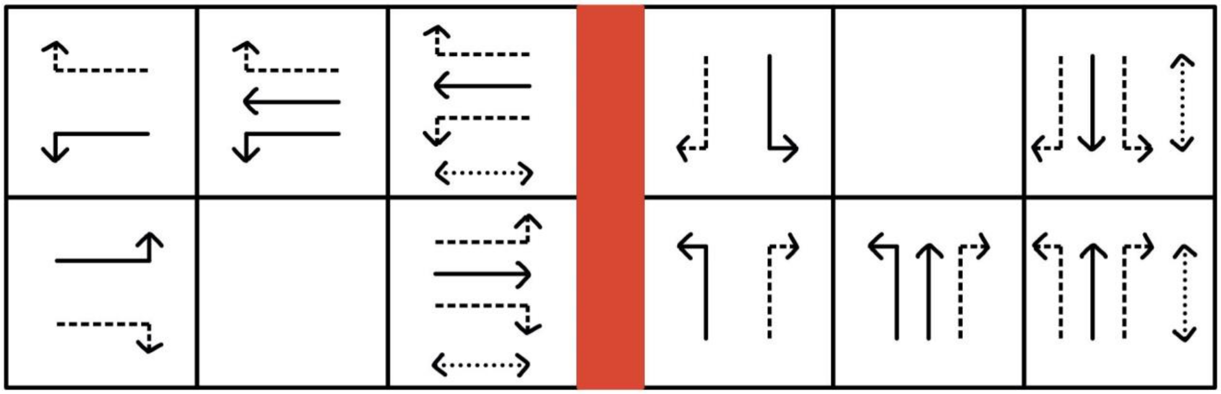

Figure 2. Existing Phasing Diagram

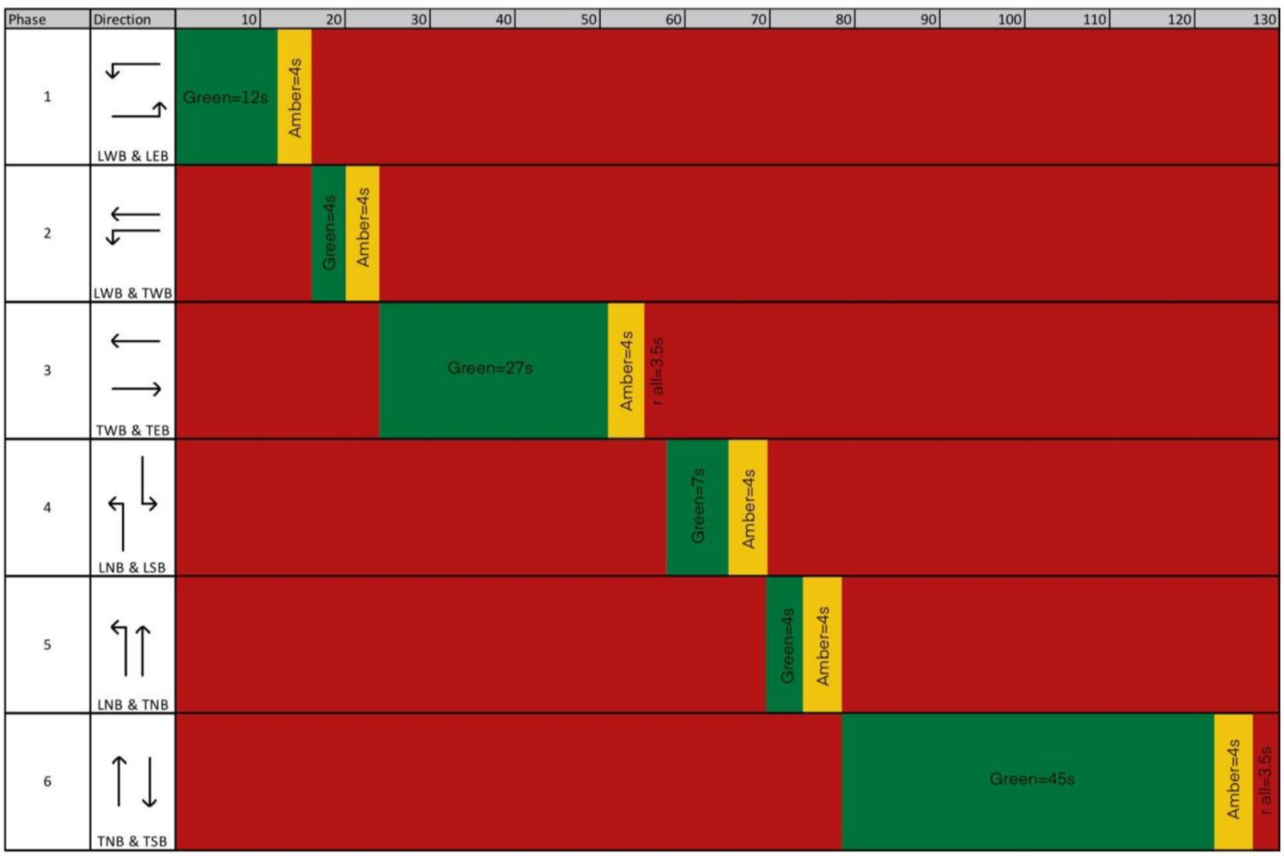

Figure 3. Existing Time Phasing Diagram

3. Vehicular Arrival Flow Data

3.1.

3.2. Northbound

q right			q left			q through			q arrival		
Vehicle	# Counted	PCU	Vehicle	# Counted	PCU	Vehicle	# Counted	PCU	Vehicle	# Counted	PCU
Car	26	26	Car	49	49	Car	236	236	Car	311	311
Single Unit Truck	1	1.5	Single Unit Truck	3	4.5	Single Unit Truck	1	1.5	Single Unit Truck	5	7.5
						Bus	1	2	Bus	1	2

Table 1. Northbound Arrival Flow Data

3.3. Eastbound

q right			q left			q through			q arrival		
Vehicle	# Counted	PCU	Vehicle	# Counted	PCU	Vehicle	# Counted	PCU	Vehicle	# Counted	PCU
Car	46	46	Car	35	35	Car	37	37	Car	118	118
Single Unit Truck	1	1.5	Single Unit Truck	1	1.5	Single Unit Truck	1	1.5	Single Unit Truck	3	4.5
Bus	1	2							Bus	1	2

Table 2. Eastbound Arrival Flow Data

3.4. Southbound

q right			q left			q through			q arrival		
Vehicle	# Counted	PCU	Vehicle	# Counted	PCU	Vehicle	# Counted	PCU	Vehicle	# Counted	PCU
Car	26	26	Car	10	10	Car	232	232	Car	268	268
Single Unit Truck	2	3	Motorcycle	1	0.5	Single Unit Truck	2	3	Single Unit Truck	4	6
						Bus	3	6	Bus	3	6
									Motorcycle	1	0.5

Table 3. Southbound Arrival Flow Data

3.5. Westbound

q right			q left			q through			q arrival		
Vehicle	# Counted	PCU	Vehicle	# Counted	PCU	Vehicle	# Counted	PCU	Vehicle	# Counted	PCU
Car	28	28	Car	59	59	Car	82	82	Car	169	169
			Single Unit Truck	1	1.5	Single Unit Truck	3	4.5	Single Unit Truck	4	6
			Bus	1	2				Bus	1	2

Table 4. Westbound Arrival Flow Data

4. Pedestrians Arrival Flow Data

North Crosswalk	East Crosswalk	South Crosswalk	West Crosswalk
2	0	1	2

Table 5. Pedestrian Arrival Flow Data

5. Tentative Phasing Diagram

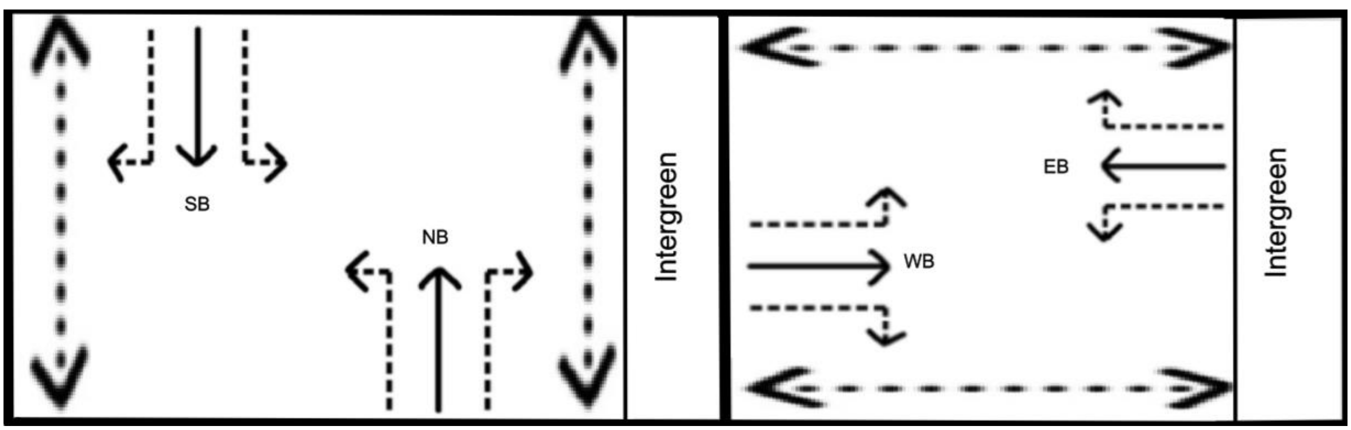

Figure 4. Tentative Phasing Diagram

Legend	
	Pedestrian Movement
	Vehicle Movement

	Permitted Movement

4.

6. Saturation Flow Data

6.1. Left-Northbound

Cycle	Queue at the start of green	PCU in time intervals (s)								Depart at amber	Queue at end of amber
		0 to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40		
1	7	2	1	0						2	1
2	4	2	1	1						0	0
3	4	1	3	0						0	0
4	7	2	3	2						1	0
5	4	1	3	1						0	0
6	8	1	2	2						2	1
7	2	2	0	0						0	0
8	9	1	3	3						3	1.5
Vs		12	16	9							
ns		8	7	5							
Si		1080	1646	1296							
S average	1363										

Table 6. Left-Northbound Saturation Flow Data

6.2. Through-Northbound

Cycle	Queue at the start of green	PCU in time intervals (s)											Depart at amber	Queue at end of amber
		0 to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40	40 to 45	45 to 50	50 to 55		
1	13	2	5	4	3	0	1	2	1	4	5	3	2	2
2	16	3	3	6	3	4	0	1	0	0	0	1	2	1
3	16	2	5	4	5.5	2	3	0	0	1	0	0	3	1
4	21	3	5	5	5	5	2	1	0	0	0	0	0	0
5	19	2	4	4	6	3	1	3	0	2	1	0	0	0
6	19	2	6	3	6	3	6	5	3	0	1	0	0	0

7	31.5	2	5.5	4	4	5	3	2	6	3	6	4	4	4
Vs		16	33.5	30	32.5	22	16	14	10	10	13	8		
ns		7	7	7	7	6	6	6	3	4	4	3		
Si		1646	3446	3086	3343	2640	1920	1680	2400	1800	2340	1920		
S average	2881													

Table 7. Through-Northbound Saturation Flow Data

6.3. Left-Eastbound

Cycle	Queue at the start of green	PCU in time intervals (s)								Depart at amber	Queue at end of amber
		0 to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40		
1	5	1	2	2						0	1
2	6	1	3	1						2	0
3	4	1	3	1						0	0
4	2	1	1	0						0	0
5	2	1	1	1						0	0
6	3	1	2	0						0	0
7	4	1	2	1						1	0
Vs		7	14	6							
ns		7	7	5							
Si		720	1440	864							
S average	1080										

Table 8. Left-Eastbound Saturation Flow Data

6.4. Through-Eastbound

Cycle	Queue at the start of green	PCU in time intervals (s)								Depart at amber	Queue at end of amber
		0 to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40		
1	2	1	2	0	0					0	2
2	4	2	3	1	0					1	0
3	6	2	3	1	1					0	0
4	3	2	3	1	0					0	0
5	4	2	2	0	0					1.5	2

6	3	2	1	0	0					0	0
7	6	1	4	0	2					0	0
Vs		12	18	3	3						
ns		7	7	3	2						
Si		1235	1852	720	1080						
S average	1544										

Table 9. Through-Eastbound Saturation Flow Data

a.

6.5. Left-Southbound

Cycle	Queue at the start of green	PCU in time intervals (s)								Depart at amber	Queue at end of amber
		0 to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40		
1	1	1								0	0
2	1	1								0	0
3	1	1								0	0
Vs		3									
ns		3									
Si		720									
S average	720										

Table 10. Left-Southbound Saturation Flow Data

6.6. Through-Southbound

Cycle	Queue at the start of green	PCU in time intervals (s)									Depart at amber	Queue at end of amber
		0 to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40	40 to 45		
1	27	3	9	8	6	7	6.5	1	0	0	0	0
2	21.5	5.5	7	4	6	4	3	4	4	2	1	0
3	19	3	4	8	4	2	1	1	4	1	2	1
4	11	3	4	3	0	1	2	3	4.5	3	2	2
5	9	3	7	4	0	1	3	2	2	1	0	1

6	12	4	7	3	0	0	1	2	2	5	2	3
7	19.5	4	5	6.5	5	4	1	3	3	2	1	1
Vs		25.5	43	36.5	21	19	17.5	16	19.5	14		
ns		7	7	7	4	6	7	7	6	6		
Si		2623	4423	3755	3780	2280	1800	1646	2340	1680		
S average	3646											

Table 11. Through-Southbound Saturation Flow Data

b.

6.7. Left-Westbound

Cycle	Queue at the start of green	PCU in time intervals (s)								Depart at amber	Queue at end of amber
		0 to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40		
1	3	1	3	0	0					0	1
2	4	2	3	0	0					0	0
3	4	1	3	0	0					0	0
4	2.5	1	1.5	2	0					0	1
5	4	2	2	3	2					0	2
6	11	2	2	3	3					1	2
7	6	2	3	1	0					1	1
Vs		11	17.5	9	5						
ns		7	7	4	3						
Si		1132	1800	1620	1200						
S average	1518										

Table 12. Left-Westbound Saturation Flow Data

6.8. Through-Westbound

Cycle	Queue at the	PCU in time intervals (s)	Depart at	Queue

	start of green	0 to 5	5 to 10	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40	amber	at end of amber
1	2	2	1	0	0	0				0	0
2	0	0	0	0	0	0				1	0
3	2.5	1	1.5	0	0	0				0	0
4	2	2	3	4	4	3				1	0
5	15	3	4	3	4	4				3	5.5
6	17.5	3.5	6	5	3	2				2	3
7	9	3	3	1	1	2				2	0
Vs		14.5	18.5	13	12	11					
ns		6	6	4	4	4					
Si		1740	2220	2340	2160	1980					
S average	2115										

Table 13. Through-Westbound Saturation Flow Data

5.

7. Amber intervals

$A = t_{pr} + v/(2a+2gG)$

v=14m/s, tpr=1, a=3m/s2

A=1+14/(2(3)+2(0/100))

A=3.33 seconds -> 4 seconds

Amber interval = 4 seconds

8. Inter-green periods

$I = i + (W_c + L_{veh}) / v_c$

$i = A-1 = 4-1 = 3$; $L_{veh} = 6m$; $v_c = 36km/h = 10m/s$

Northbound:

$W_c = 1.3 + 4.6 + 31.5 + 3.3 = 40.7m$

I = 3 + (40.7 + 6)/10

I = 7.67s

Southbound:

$W_c = 1.4 + 3.3 + 31.5 + 4.6 = 40.8$

$I = 3 + (40.8 + 6)/10m$

$I = 7.68$ s

Eastbound:

$W_c = 3.6 + 3.3 + 29.1 + 3.2 = 39.2m$

$I = 3 + (39.2 + 6)/10$

$I = 7.52$ s

Westbound:

$W_c = 1.2 + 3.2 + 30.6 + 3.3 = 38.3m$

$I = 3 + (38.3 + 6)/10$

$I = 7.43$ s

Approach Lane	Phase	Inter-green periods
Northbound	1	7.67
Southbound	1	7.68
Eastbound	2	7.52
Westbound	2	7.43

Table 14. Inter-green periods

9. All-red periods

$r_{all} = I - A$

Northbound:

$r_{all} = 7.67 - 4 = 3.67$ s

Southbound:

$r_{all} = 7.68 - 4 = 3.68$ s

Eastbound:

$r_{all} = 7.52 - 4 = 3.52$ s

Westbound:

r, = 7.43 - 4 = 3.43 s

Approach Lane	Phase	All-red periods
Northbound	1	3.67
Southbound	1	3.68
Eastbound	2	3.52
Westbound	2	3.43

Table 15. All-red periods

10. Lost time

lj = Ij - 1.0

Northbound:

lj = 7.67 - 1.0 = 6.67 s

Southbound:

lj = 7.68 - 1.0 = 6.68 s

Eastbound:

lj = 7.52 - 1.0 = 6.52 s

Westbound:

lj = 7.43 - 1.0 = 6.43 s

Approach Lane	Phase	Lost Time
Northbound	1	6.67
Southbound	1	6.68
Eastbound	2	6.52
Westbound	2	6.43

Table 16. Lost time

11. Pedestrians Clearance time

Walking speed = 1.2m/s

Northbound:

Distance = 30m

Wc = 30/1.2 = 25s

Southbound:

Distance = 34.2m

Wc = 34.2/1.2 = 28.5s

Eastbound:

Distance = 14.7 + 13.6 = 28.3m

Wc = 28.3/1.2 = 23.6s

Westbound:

Distance = 29m

Wc = 29/1.2 = 24.2s

Crosswalk	Phase	Pedestrians Clearance Time(seconds)
Northbound	1	25
Southbound	1	28.5
Eastbound	2	23.6
Westbound	2	24.2

Table 17. Pedestrian clearance time

12. Pedestrians minimum Cycle Length

$$C_{ped\ min} = \sum_j \max(W_{min\,i} + W_{clear\,i})_j$$

Cped min = (10+29)+(10+25)

Cped min = 74 s

Crosswalk	Phase	Walk Interval(s)	Clearance Period (s)
Northbound	1	10	29
Southbound	1	10	29
Westbound	2	10	25
Eastbound	2	10	25

Table 18. Pedestrians minimum Cycle Length

13. Intersection Flow Ratio and Critical Flow

13.1. Summary of arrival flows

Approach lane	Flow of passenger cars per hour	Flow of single unit Truck per hour	Flow of buses per hour	Flow of Motorcycle per hour	Arrival flow (veh/h) (1)	Arrival flow (pcu/h) (2)	Arrival flow (person/h) (3)
NB	311	5	1	0	317	321	497
SB	268	4	3	1	276	282	441
EB	118	3	1	0	122	125	203
WB	169	4	1	0	174	177	272

Table 19. Summary of arrival flows

6. (Flow of passenger cars per hour + Flow of Truck per hour + Flow of buses per hour + Flow of Motorcycle per hour)
7. Flow of passenger cars per hour + Flow of Truck per hour*1.5 + Flow of buses per hour*2+ Flow of Motorcycle per hour*0.5
8. (Flow of passenger cars per hour*1.5 + Flow of Truck per hour*2 + Flow of buses per hour*20+ Flow of Motorcycle per hour)

a.

13.2. Determination of adjusted saturation flows

Approach lane	Basic saturation flow (pcu/h)	Adjusted lane saturation flow (pcu/h)	% cars (1)	% single unit Truck (1)	% Buses (1)	% Motorcycle (1)	Adjusted saturation flow S(veh/h) (2)
NB	1830	1830	98.11	1.58	0.315	0	1810
SB	1830	1830	97.10	1.45	1.09	0.362	1801
EB	1830	1830	96.72	2.46	0.820	0	1794
WB	1830	1830	97.13	2.30	0.575	0	1799

Table 20. determination of adjusted saturation flows

Assume (1830) as basic saturation because intersection is in a low activity area

1. Flow of passenger Veh per hour/ Arrival flow * 100%
2. S(veh/h)=Spcu/h / (% qcar (1.0 / 100)+% qtruck (1.5 / 100)+% qbus (2.0 / 100)+% qMotorcycle (0.5 / 100))

Lane	Direction	Phase	Adjusted lane arrival flow q (pcu/h)	Adjusted lane saturation flow S (pcu/h)	Lane flow ratio (y = q/S)	Flow ratios for critical lanes ycrit
1	NB	1	321	1830	0.175	0.175
2	SB	1	282	1830	0.154	
3	EB	2	125	1830	0.068	
4	WB	2	177	1830	0.097	0.097

					Intersection flow ratio Y =Σycrit=	0.272

Table 21. Intersection Flow Ratio and Critical Flow

14. Minimum and Optimum Cycle lengths

14.1. Minimum cycle time for vehicular flow

L = l phase1 + l phase2 = 7.0 + 7.0 = 14.0 s

Cmin = L / (1-Y) = 14 / (1 - 0.272) = 19.28 s rounds to 20.0 s

14.2. Optimum cycle time for vehicular flows

Copt = (1.5 L + 5) / (1-Y) = (1.5 x 14.0 + 5) / (1 - 0.272) = 35.71 s rounds to 36 s

14.3. Cycle time selection

Cmin & Copt < Cped min, therefore assume C or Cadj = Cped min

Cadj= 74 s

9.

15. Green times

15.1. Vehicular requirements

Σ gj = C - Σ Ij = 74.0 - (8.0 + 8.0) = 58.0 s.

15.2. For phase 1:

g1= Σ gj* y1 / Y = 58 x 0.175 / 0.272 = 37.32 rounds to 37.0 s

15.3. For phase 2:

g2= Σ gj* y2 / Y = 58 x 0.097 / 0.272 = 20.68 rounds to 21.0 s

15.4. Green Time check

Phase 1:(37 + 8) ≥ (10 + 29)

Phase 2:(21 + 8) ≥ (10 + 25)

g2 does not satisfy the check, therefor g2adj= Cped min for that phase

g2adj = 35s

using this “g2= Σ gj y2 / Y” equation Σ gj adj can be found

Σ gj adj = 99s

using Σ gj adj a new g1 must be found

g1adj = Σ gj adj * y1 / Y= 99 x 0.175 / 0.272= 63.69 round to 64s

Because of the changes to the green times the clearance time needs to be re-estimated

Cadj2 = 115s

16. Queue Length Evaluations

16.1. effective green interval (s)

ge = g + 1= 64+1=65

Lane	Arrival flow (q) (pcu/h)	Effective green ge (s)	Average queue length at the end of red Qr (pcu) (1)	Average queue length at the end of red Qr (m) (2)
1	321	65	4.46	27
2	282	65	3.92	24
3	125	36	2.74	17
4	177	36	3.88	23

Table 22. Queue Length Evaluation

1. Qr(pcu) = q (c - ge) / 3600
2. Qr(m)=Qr(pcu)*6.0m

17. Summary Timetable

Interval or Period	Notation	Duration(s)
Green (Phase 1)	g_1	64
Intergreen (Phase 1)	I_1	8
Green (Phase 2)	g_2	35
Intergreen (Phase 2)	I_2	8
Total Cycle Time	c	115

Table 23. Summary Timetable

18. Final Coloured Phasing Diagram

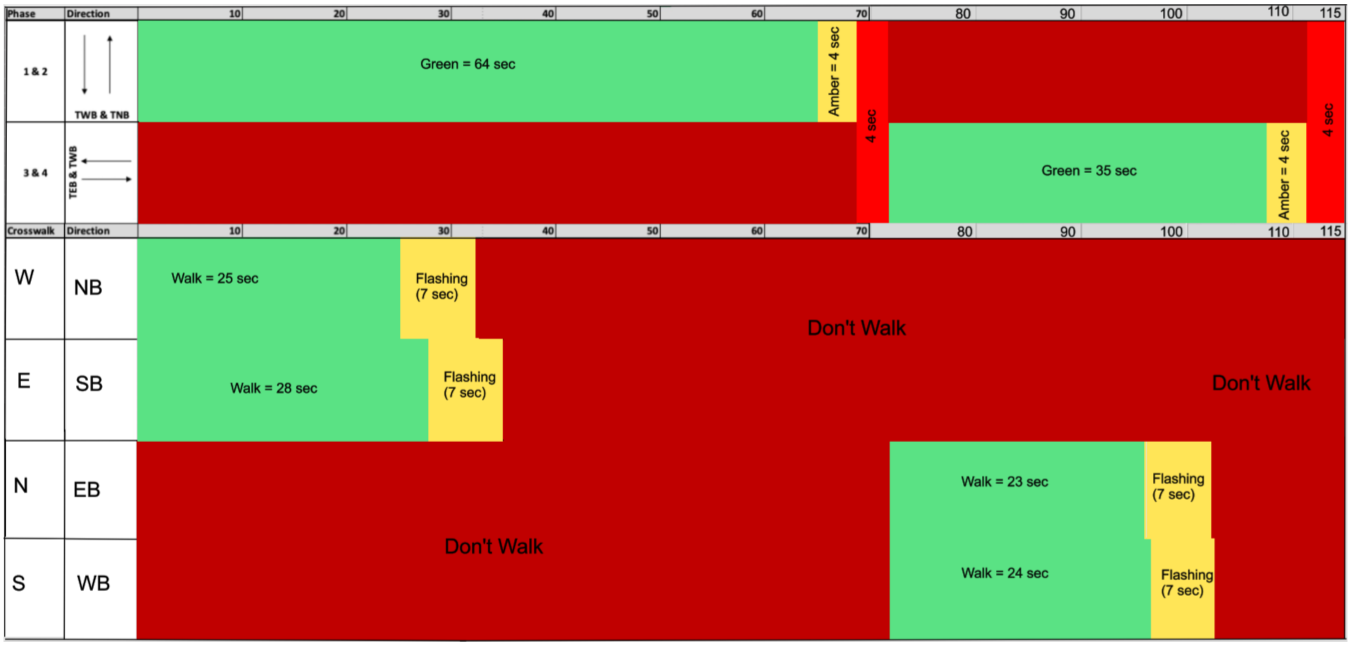

Figure 5. Final Time Phasing Diagram

19. Final Remarks and Recommendations

In conclusion, after final calculations and adjustments made to the phasing diagram, the completed and final time phasing diagram can be seen in Figure 5. The variations to the existing phasing diagram include changes to the amber intervals, inter-green periods and red periods such as the allocations of the green periods have changed significantly from the existing time phasing diagram. The existing time phasing diagram had 6 different phases while the final time phasing diagram now only has 4 with 2 groups of identical phases. One similarity between the two diagrams are that the NB/SB directions have a greater green period than the EB/WB directions for both phases as well as crosswalks.

The existing time phasing diagram represents the average of all the cycles recorded due to the signals being fully actuated, while the final time phasing diagram represents the signals when not changing which results in the significant differences in the allocations and time lengths. Possible errors that could have affected the final results can include miscalculating the cycle lengths and queue times which could in return affect the final values such as determination of arrival, saturation and vehicular flows.

20. References

20.1. Section 12- 17

a. *Canadian Capacity Guide [Online].https://avenue.cllmcmaster.ca/d2l/le/content/409695/viewContent/3403019/View [Accessed: 30-Nov-2021].*

20.2. PCU Conversion

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20.3. Section 1

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