Highway Capacity Software

- Based on the Highway Capacity Manual (HCM)
  - Special Report 209
  - Transportation Research Board (TRB), National Research Council (NRC)

Ten Modules

1. Freeways
2. Weaving
3. Ramps
4. Multi-lane Highways
5. Two-lane Highways
6. Signalized Intersections
7. Unsignalized Intersections
8. Arterials
9. Transit
10. Pedestrians

Modules Included in CE 4640

- Signalized Intersections
- Unsignalized Intersections
- Multi-lane Highways
- Two-lane Highways

Signalized Intersections

- Capacity
  - Defined for each lane group
    - Lane group: one or more lanes that accommodate traffic and have a common stopline
  - Lane group capacity: maximum rate of flow for the subject lane group that may pass through the intersection under prevailing traffic, roadway and signalized conditions

- Traffic Conditions
  - Approach volumes (left, through, right)
  - Vehicle type
  - Location of bus stops
  - Pedestrian crossing flows
  - Parking movement

- Roadway Conditions
  - Number and width of lanes
  - Grades
  - Lane use
    - Including parking lanes
- Signalized Conditions
  - Signal phasing
  - Signal timing
  - Type of control
  - Signal progression

Level of Service (LOS)

- Defined in terms of delay as a measure of
  - driver discomfort
  - Driver frustration
  - Fuel consumption
  - Lost travel time

Signalized Intersections

- Delay experienced by a motorist includes many factors:
  - Signal control
  - Geometrics
  - Incidents

- Total delay:
  - Difference between actual travel time and ideal travel time
    - In the absence of traffic control, geometric delay, incidents and when there are no vehicles on the road
  - In HCS only control delay is quantified
    - initial deceleration delay
    - Queue move-up time
    - Stopped delay
    - Final acceleration delay

- Previous versions of HCM/HCS (1994 version or earlier)
  - Only included stopped time delay

LOS

- LOS criteria are stated in terms of average control delay per vehicle
  - Delay is dependent on
    - Quality of progression
    - Cycle length
    - Green ratio
    - V/c ratio for lane group
- Designated by letters A - F

LOS Criteria for Signalized Intersections

LEVEL OF SERVICE	CONTROL DELAY PER VEHICLE (SEC/VEHICLES)
A	≤ 10
B	>10 and ≤ 20
C	>20 and ≤ 35
D	>35 and ≤ 55
E	>55 and ≤ 80
F	> 80

LOS A

- Describes operations with very low control delay, up to 10 sec/veh
  - Occurs when progression is extremely favorable
  - When most cars arrive during the green
  - Most vehicles do not stop at all
  - Short cycle lengths may also contribute to low delay

LOS B

- Describes operations with control delay > 10 and up to 20 sec/veh
  - Occurs with good progression, short cycle lengths or both
  - More vehicles stop than with LOS A
    - Causing higher levels of average delay

LOS C

- Describes operations with control delay greater than 20 and up to 35 sec/veh
  - Fair progression, longer cycle lengths, or both
  - Individual cycle failures may begin to appear at this level
  - No. of vehicles stopping is significant
    - Many still pass without stopping

LOS D

- Describes operations with control delay > 35 and up to 55 sec/veh
  - Influence of congestion becomes more noticeable
  - Longer delays result
    - Unfavorable progression
    - Long cycle lengths
    - High v/c ratios
  - Many vehicles stop
    - Proportion of vehicles not stopping declines
  - Individual cycle failures are noticeable

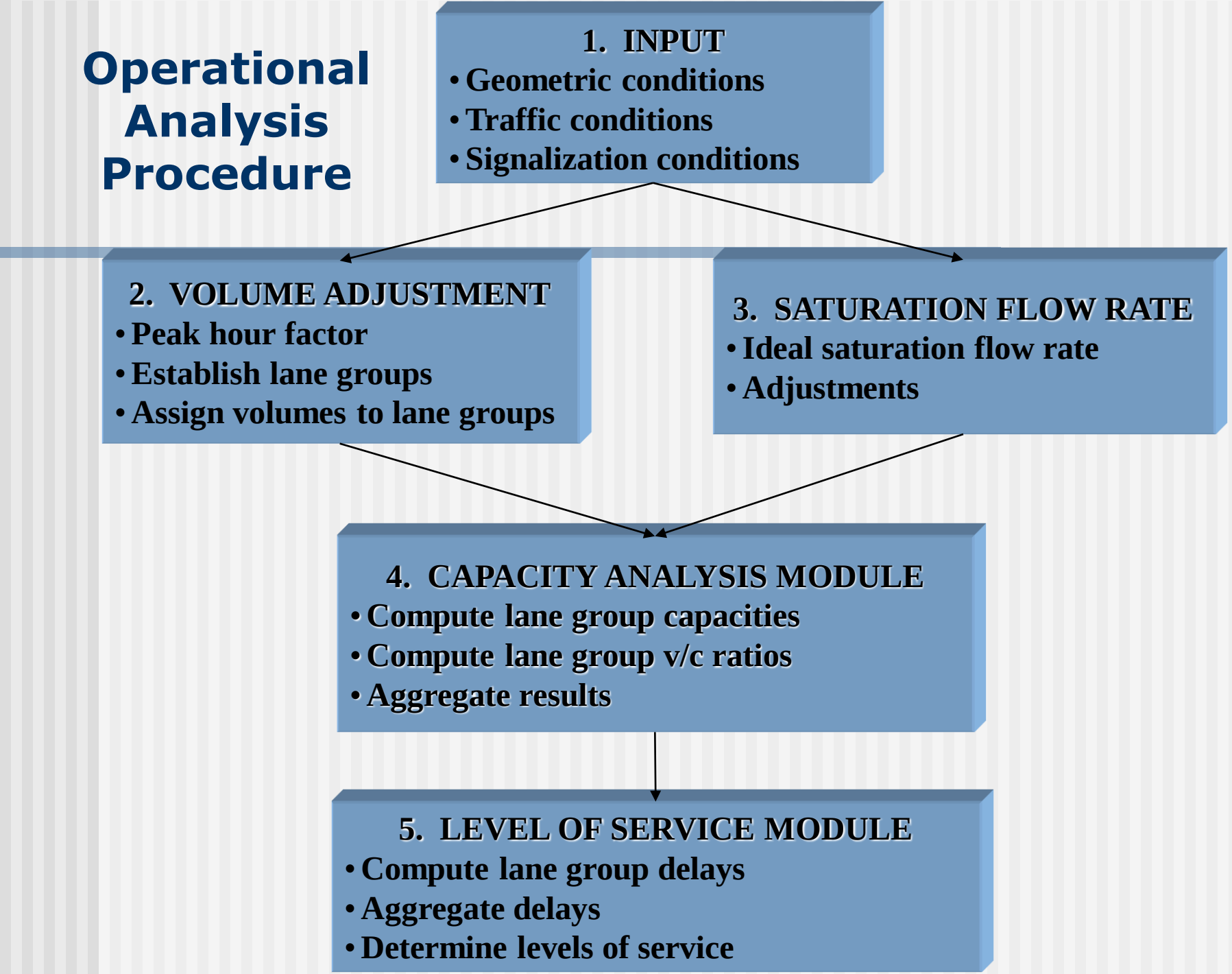
LOS E

- Describes operations with delay > 55 and up to 80 sec/veh
  - The limit of acceptable delay
  - Indicate poor progression, long cycle lengths and high v/c ratios
  - Individual cycle failures are frequent occurrences

LOS F

- Describes operations with delay > 80 sec/veh
  - Considered unacceptable to most drivers
  - Occurs with oversaturation
    - When arrival flow rates exceed the capacity of the intersection
  - Occurs at high v/c rations below 1.0 with many individual cycle failures
  - Poor progression and long cycle lengths may also contribute

Operational Analysis Procedure




HCS-3
HCS
Highway Capacity Software™
by McTrans™
Signals
STOP
Exit

HCS-3 Signals - [Signal1]

File Edit View Window Help

Input Quick Jump | Report Quick Jump

Open

SIGNALIZED INTERSECTIONS OPERATIONAL ANALYSIS

Intersection		Project No.	
City/State		Time Period Analyzed	
Analyst		Date 9/10/2001	Units: U. S. Customary
East/West Street Name		North/South Street Name	

HCS: Signalized Intersections Release 3.2

Inter:
Analyst:
Date: 9/10/2001
E/W St:

City/St:
Proj #:
Period:
N/S St:

SIGNALIZED INTERSECTION SUMMARY

	Eastbound			Westbound			Northbound			Southbound		
	L	T	R	L	T	R	L	T	R	L	T	R
No. Lanes	0	0	0	0	0	0	0	0	0	0	0	0
LGConfig												
Volume												
Lane Width												
RTOR Vol												

Duration 0.25 Area Type: All other areas

Signal Operations

Phase Combination	1	2	3	4	5	6	7	8
EB Left					NB Left			
Thru					Thru			

Intersection: []

Open an existing document

SIGNALIZED INTERSECTIONS OPERATIONAL ANALYSIS

Intersection		Project No.	
City/State		Time Period Analyzed	
Analyst		Date 9/10/2001	Units: U. S. Customary
East/West Street Name		North/South Street Name	

VOLUME

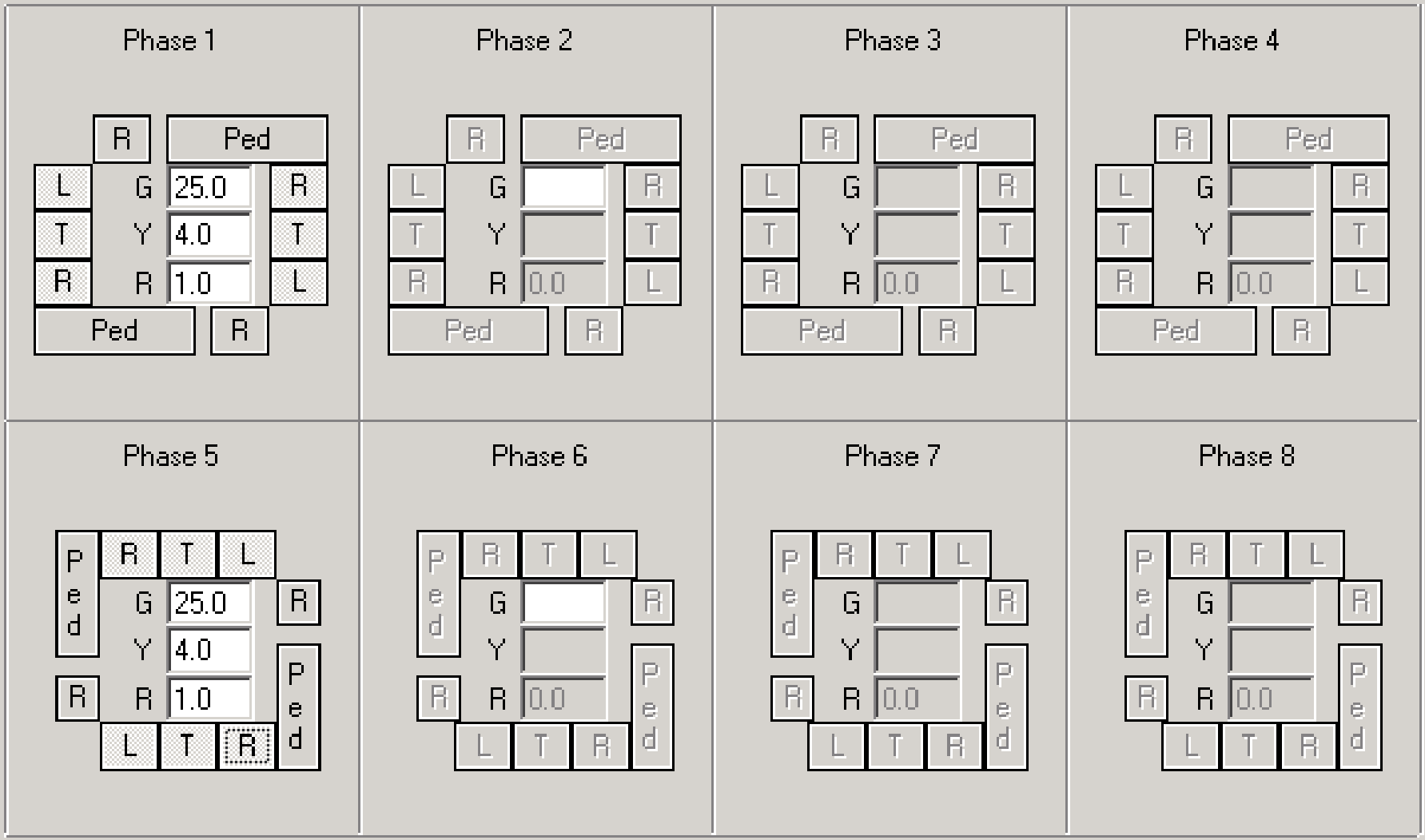
Duration 0.25 hours

Eastbound			Westbound			Northbound			Southbound		
Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right
Number of Lanes and Usage											
0	0	0	0	0	0	0	0	0	0	0	0
Shared	Shared		Shared	Shared		Shared	Shared		Shared	Shared	
Volume (vph)											
0	0	0	0	0	0	0	0	0	0	0	0
Peak Hour Factor, PHF											
0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Peak-15 Minute Volume (v)											
Right Turns on Red (vph)											
RTOR 0			RTOR 0			RTOR 0			RTOR 0		

OPERATING PARAMETERS

	Eastbound		Westbound			Northbound			Southbound		
	TR	R	L	LT					L	T	R
Initial Unmet Demand (veh)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arrival Type or Percent Arriving during Green	3	3	3	3	3	3	3	3	3	3	3
Unit Extension (sec)	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Upstream Filtering/Metering Adjustment Factor, I	I = 1.000		I = 1.000			I = 1.000			I = 1.000		
Start-up Lost Time (sec)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Extension of Effective Green (sec)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Pedestrian Speed (ft/sec), Travel Distance (ft), and Minimum Green (sec)	4.0	0.0	0.0	4.0	0.0	0.0	4.0	0.0	0.0	4.0	0.0	0.0

PHASING DESIGN



Cycle Length 60.0

Ideal Saturation Flow Rate (pcphgpl)

1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900	1900

Lane Width (ft)

12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0

Percent Heavy Vehicles (%)

0	0	0	0	0	0	0	0	0	0	0	0

Percent Grade (%)

0	0	0	0

Parking Maneuvers per hour

Yes 20	Yes 20	Yes 20	Yes 20	Yes 20	Yes 20	Yes 20	Yes 20	Yes 20	Yes 20	Yes 20	Yes 20

Bus Stops per hour

0	0	0	0	0	0	0	0	0	0	0	0

Area Type ☐ CBD or Similar

Highest Single Lane Volume in Lane Group (vph). ☐ Field data available.

Conflicting Pedestrians per hour

Peds 0		Peds 0		Peds 0		Peds 0	

Percent Right-Turns Using Protected Phase

0	0	0	0

Adjustment Factors

f_W	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_{HV}	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_g		1.000			1.000			1.000			1.000	
f_p		1.000	1.000		1.000	1.000		1.000	1.000		1.000	1.000
f_{bb}	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
f_a		1.00			1.00			1.00			1.00	
f_{LU}	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
f_{RT}		1.000	1.000		1.000	1.000		1.000	1.000		1.000	1.000
f_{LT}	1.000	1.000	Pri.	1.000	1.000	Pri.	1.000	1.000	Pri.	1.000	1.000	Pri.
f_{LT}	1.000	Sec.		1.000	Sec.		1.000	Sec.		1.000	Sec.	

Adjusted Saturation Flow Rate, vphg

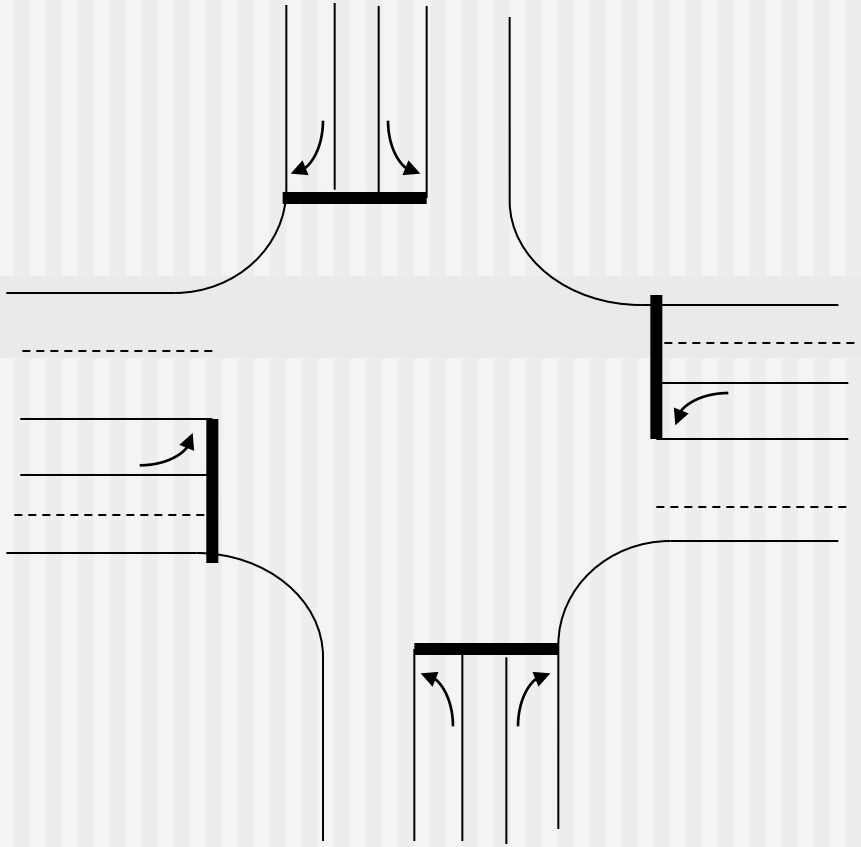
0	0	0	0	0	0	0	0	0	0	0	0	
0	Secondary		0	Secondary		0	Secondary		0	Secondary		

RESULTS

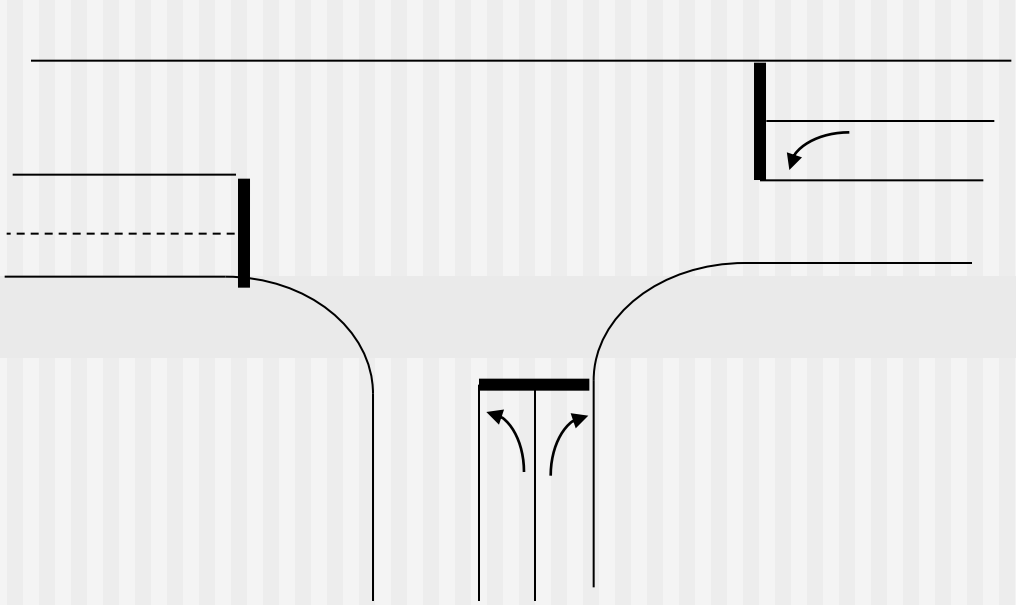
	Eastbound			Westbound			Northbound			Southbound		
Lane Group Capacity, (vph)	0	0	0	0	0	0	0	0	0	0	0	0
Lane Group v/c Ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Critical Lane Group												
Lane Group Delay, (sec/veh)												
Lane Group Level of Service												
Final Unmet Demand, (v)												
Approach Delay, (sec/veh)												
Approach Level of Service												

Cycle Length 0.0 sec Intersection Delay sec/veh Intersection LOS

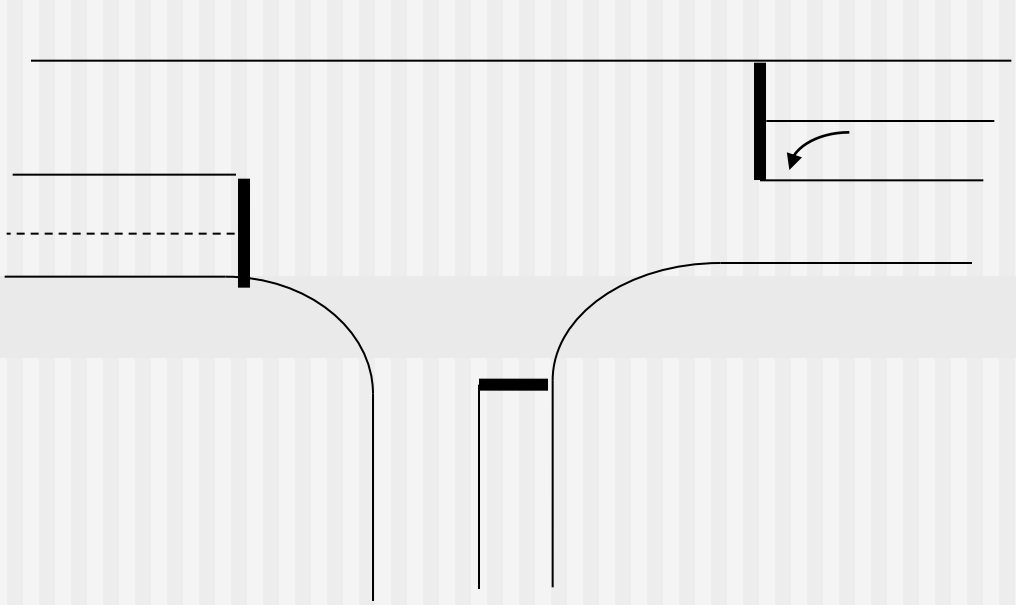
Laneage Coding Examples



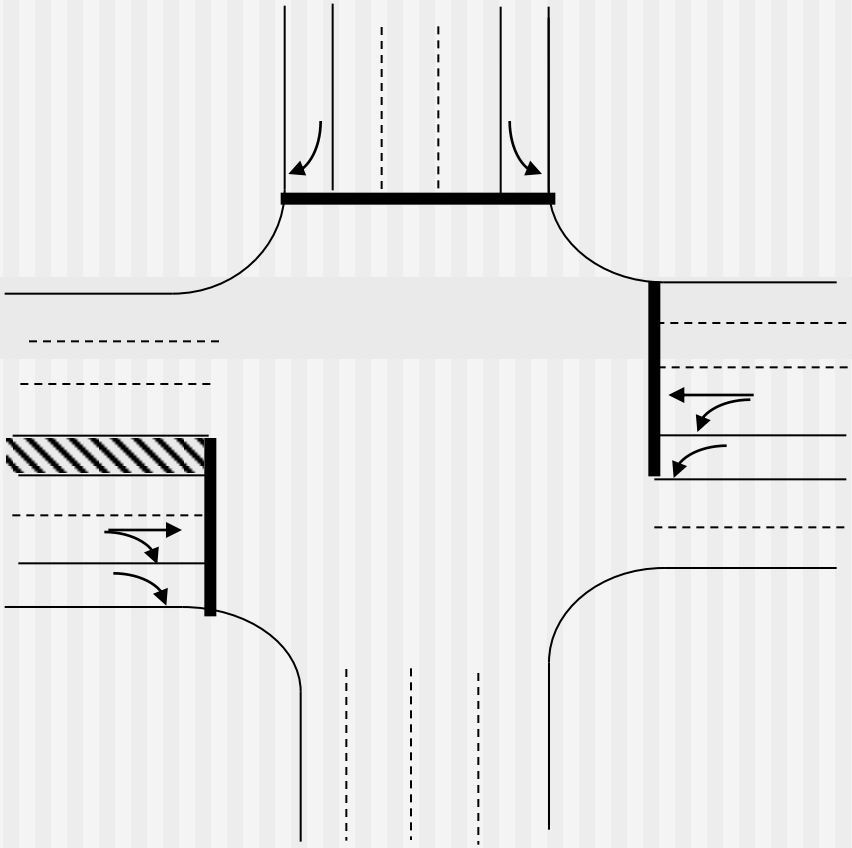
Eastbound			Westbound			Northbound			Southbound		
Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right
Number of Lanes and Usage											
1	2	0	1	2	0	1	1	1	1	1	1
Shared	Shared		Shared	Shared		Shared	Shared		Shared	Shared	
L	TR		L	TR		L	T	R	L	T	R



	Eastbound			Westbound			Northbound			Southbound		
	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right
Number of Lanes and Usage	0	2	0	1	1	0	1	0	1	0	0	0
	Shared	Shared		Shared	Shared		Shared	Shared		Shared	Shared	
		TR		L	T		L		R			



Eastbound			Westbound			Northbound			Southbound		
Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right
Number of Lanes and Usage											
0	2	0	1	1	0	0	0	0	0	0	0
Shared	Shared		Shared	Shared		Shared	Shared		Shared	Shared	
TR			L	T		LR					



Eastbound			Westbound			Northbound			Southbound		
Left	Thru	Right	Left	Thru	Right	Left	Thru	Right	Left	Thru	Right
Number of Lanes and Usage											
0	2	1	1	3	0	0	0	0	1	3	1
Shared	Shared		Shared	Shared		Shared	Shared		Shared	Shared	
TR	R		L	LT					L	T	R

Default Values

- May be used without compromising analysis
- Results become approximate
  - As more default values are used

Default Values for Use

- Ideal saturation flow rate = 1,900 pcphpgpl
- Conflicting pedestrian volume
  - None: 0 peds/hr
  - Low: 50 peds/hr
  - Moderate: 200 peds/hr
  - High: 400 peds/hr
- Percent heavy vehicles = 2
- Grade = 0
- No. of stopping buses = 0/hr

- Parking conditions: No Parking
- Parking maneuvers = 20/hr, where parking exists
- Arrival type
  - Lane groups with through movements:
    - 3 if isolated
    - 4 if coordinated
  - Lane group without through movement = 3
- Peak-hour factor = 0.90
- Lane width = 12 feet
- Area type = non CBD

Right Turns on Red (RTOR)

- When RTOR is permitted
  - Right turn volume may be reduced
- Number of vehicles able to turn right on red is a function of:
  - Approach lane uses
  - Right turn demand
  - Sight distance
  - Left-turn phasing on conflicting street
  - Conflicts with pedestrians

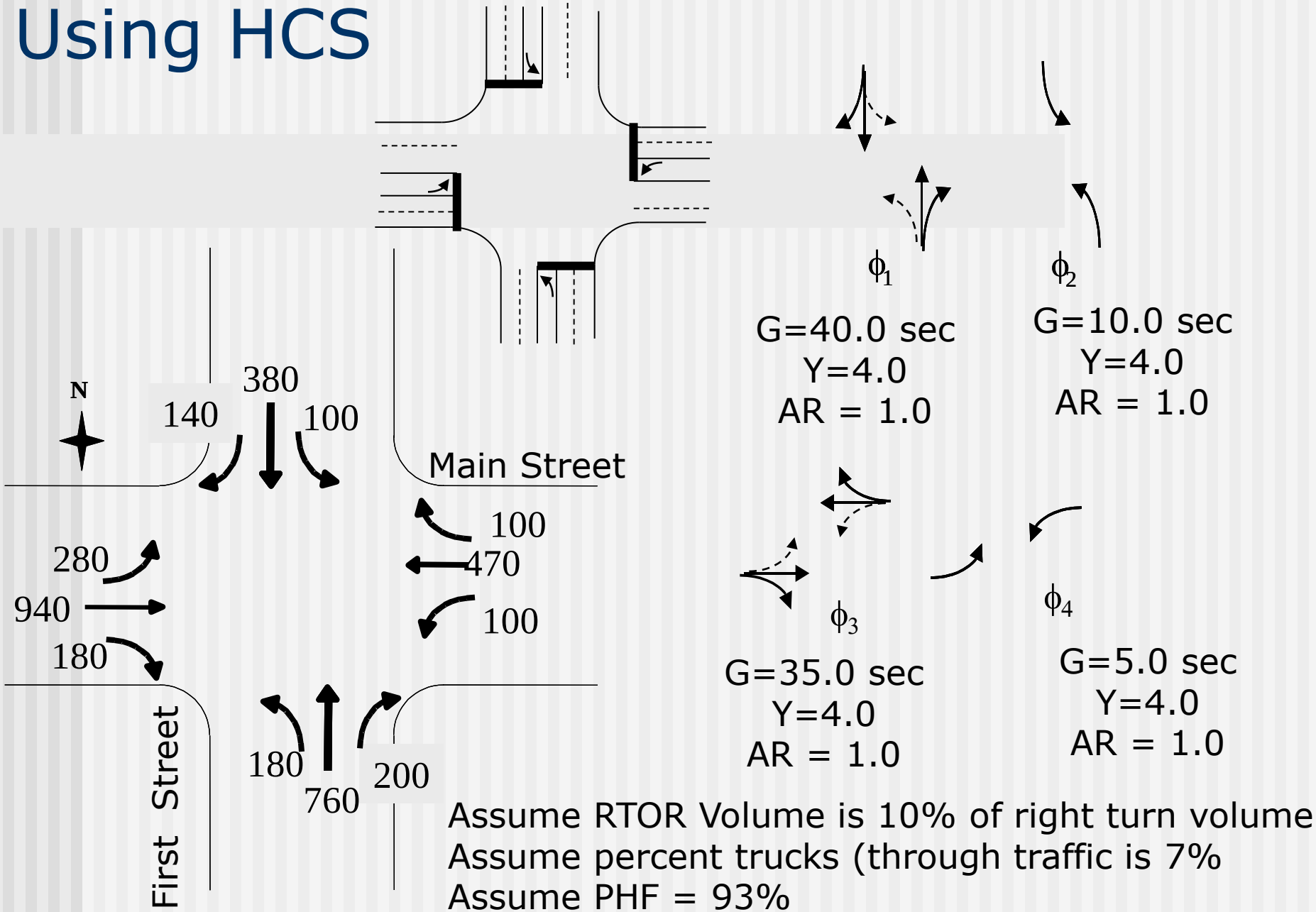
Arrival Types

- Quantifies the quality of progression
  - Type 1: dense platoon, arriving at the start of the red, *very poor progression*
  - Type 2: Moderately dense platoon arriving in the middle of the red phase, *unfavorable progression*
  - Type 3: random arrivals, isolated intersections

- Type 4: Moderately dense platoon arriving at the start of the green phase, *favorable progression*
- Type 5:Dense to moderately dense platoon, arriving at the start of the green phase, *highly favorable progression*
- Type 6: *exceptional progression quality* on routes with near-ideal characteristics

- Effective green time
  - Time that is effectively available to a movement,
    - generally taken to be the green time plus the clearance interval minus the lost time
- Lost time
  - Time during which the intersection is not effectively used by any movement, which occurs
    - During the clearance interval
    - Start-up delay

Example:Evaluate Intersection LOS, Using HCS



Assume RTOR Volume is 10% of right turn volume
Assume percent trucks (through traffic is 7%
Assume PHF = 93%

Unsignalized Intersections

- Two types
  - Two-Way Stop Controlled Intersections (TWSC)
  - All-Way Stop Controlled Intersections (AWSC)
- Capacity- TWSC
  - Depends on driver interaction of drivers on the minor street approach and drivers on the major street
  - Gap acceptance models are used in HCS to describe this interaction

Level of Service (LOS)-TWSC

- Determined by the computed control delay and is defined for each minor movement.
- LOS is not defined for an intersection as a whole

LOS Criteria for Unsignalized Intersections

LEVEL OF SERVICE	AVG CONTROL DELAY PER VEHICLE (SEC/VEHICLES)
A	≤ 10
B	>10 and ≤ 15
C	>15 and ≤ 25
D	>25 and ≤ 35
E	>35 and ≤ 50
F	> 50

- LOS Criteria for unsignailzed intersections is slightly different than for signalized intersections
  - Because driver perception is different
- Expectation is that a signalized intersection is designed to carry higher traffic volumes and experience greater delay than at unsignalized intersections

Data Input

- Similar to those for signalized intersections
  - Geomerty
  - Intersection control
  - Traffic volumes
- Key features
  - Number and uses of lanes
  - Channelization
  - Two-way left turn lane (TWLTL)
  - Raised or striped median storage
  - Existence of flared approaches on the minor street

- Presence of upstream traffic signals on the major street
  - Produce nonrandom flows
  - Affect the capacity of the minor street approaches if the signal is within 0.25 miles of the intersection

Critical Gap and Follow Up Time

- Critical gap
  - Minimum time interval in the major street traffic that allows one vehicle in the minor street traffic to enter the main street traffic.
  - Minimum gap that would be acceptable
  - A driver would reject any gaps less than the critical gap and would accept gaps greater than or equal to the critical gap.
- Follow up time
  - The time needed for more than one vehicle to complete a turn if an adequate gap is available.

Critical Gaps

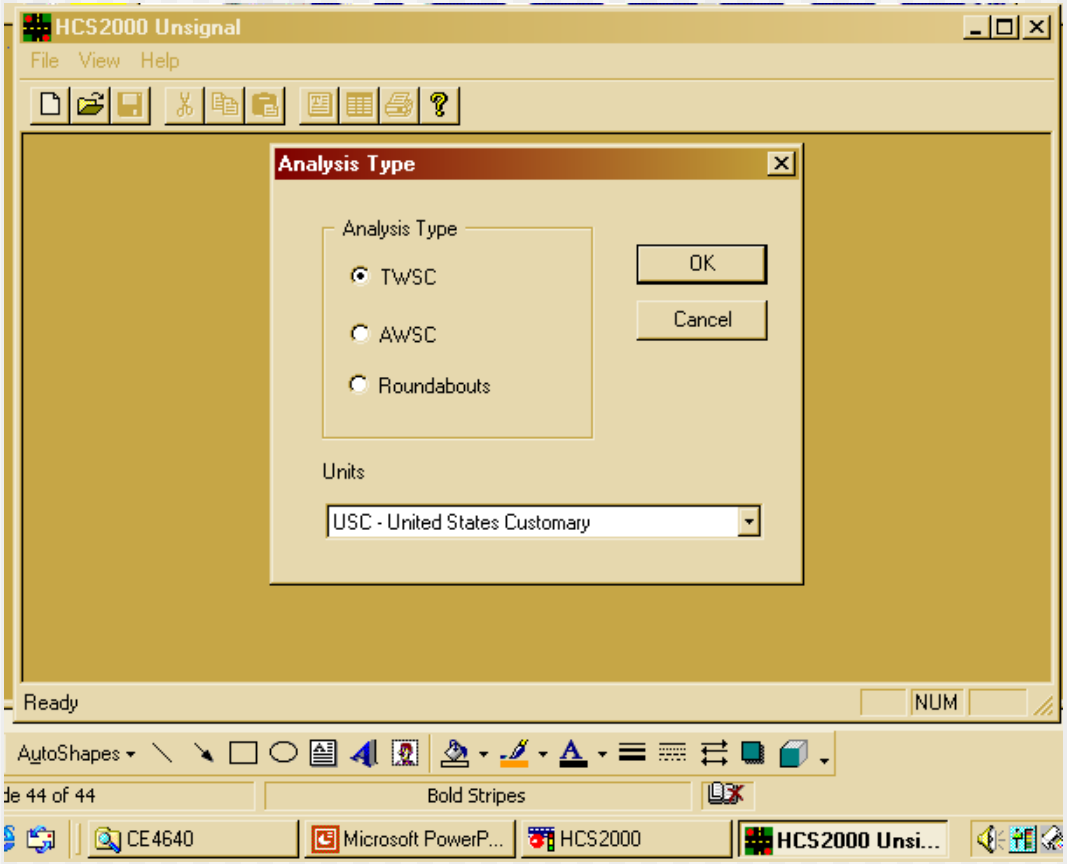
	Two-Lane Major Street	Four Lane Major Street	Base Follow-up Time
Left turn from vehicles	4.1	4.1	2.2
Right turn from minor	6.2	6.9	3.3
Through traffic on minor	6.5	6.5	4.0
Left turn traffic from minor	7.1	7.5	3.5

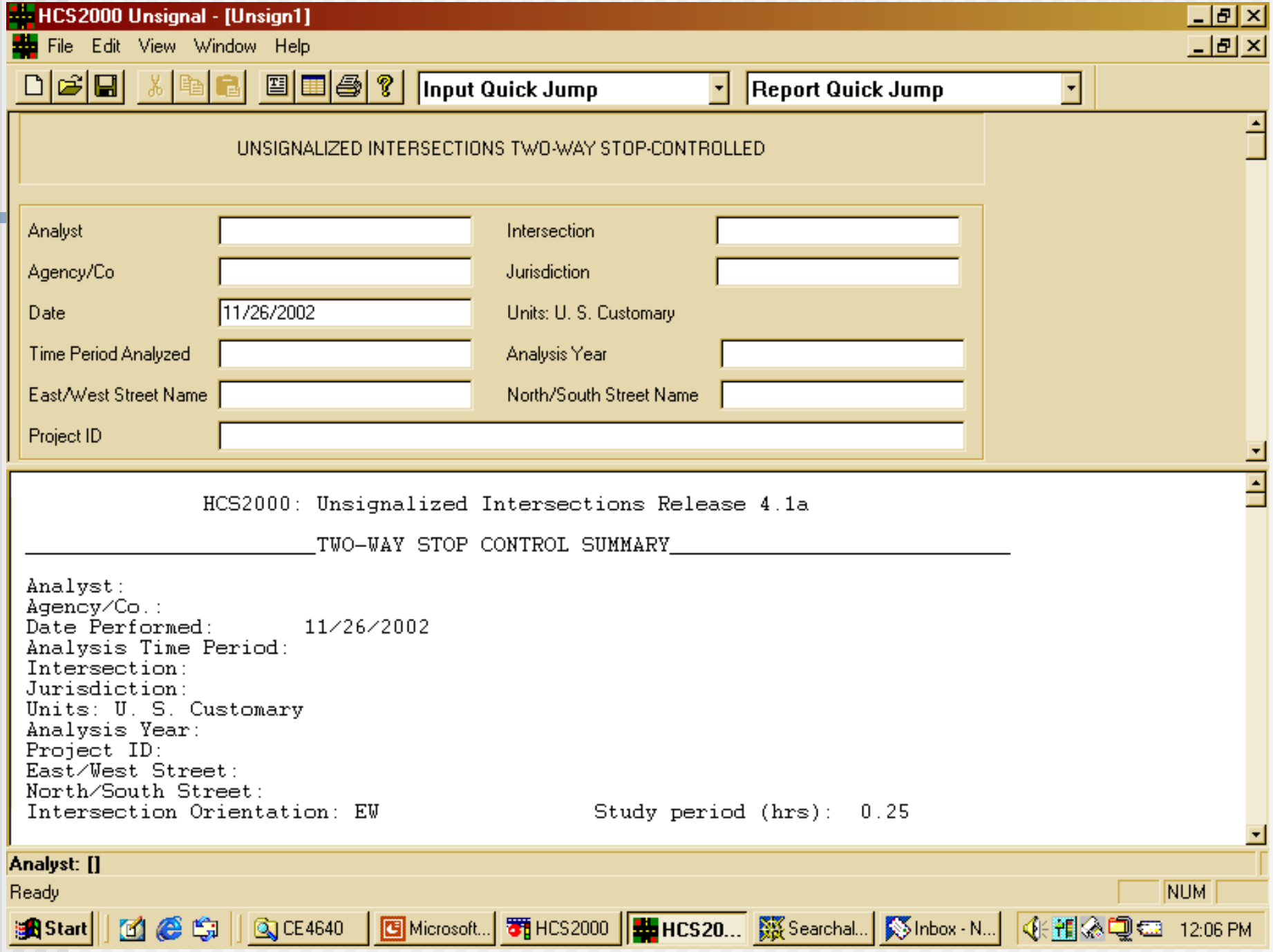
Unsignalized Intersections



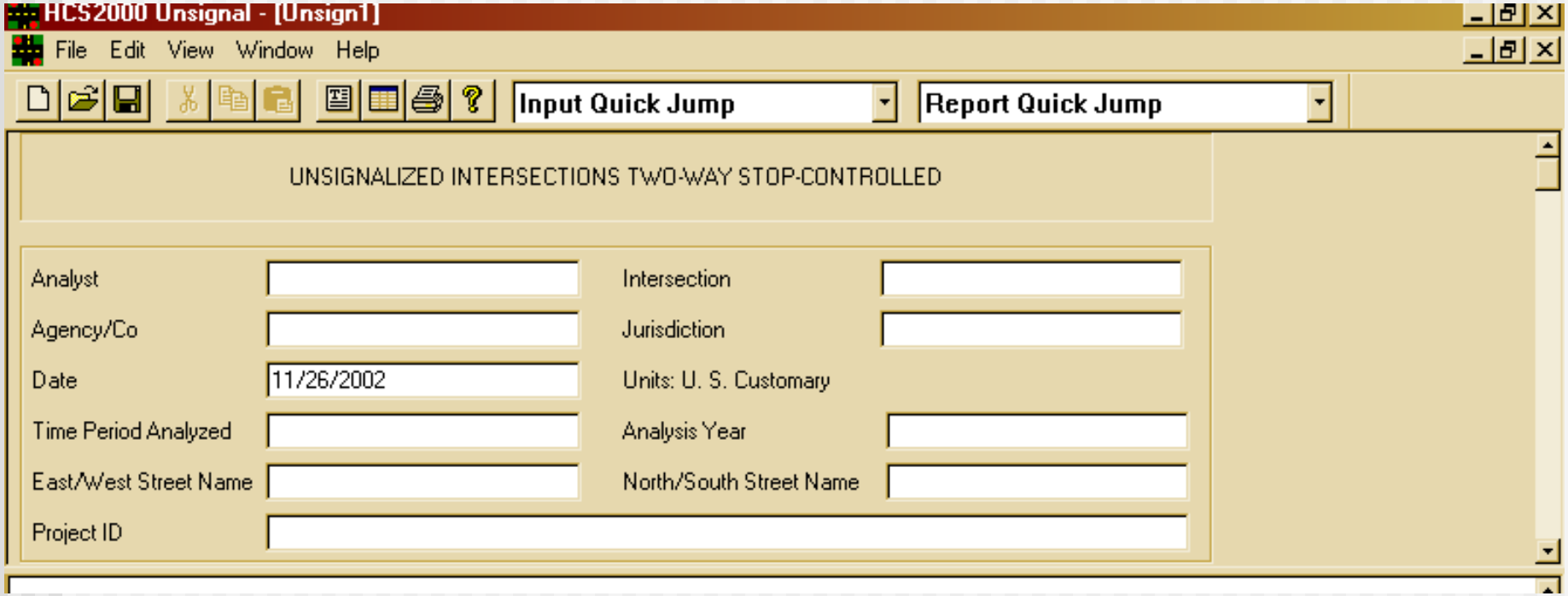
Commands

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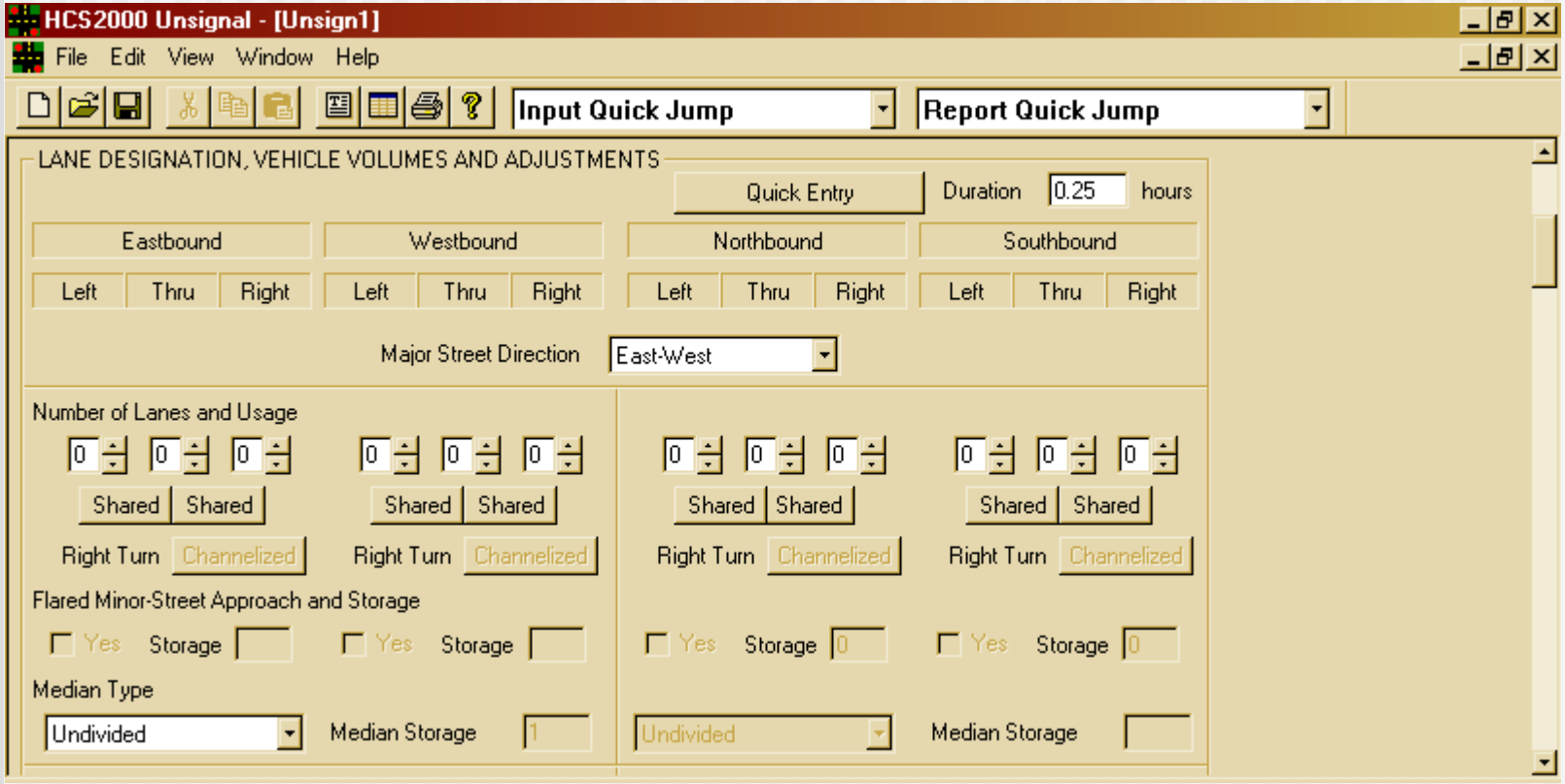



HCS2000 Unsignal - [Unsign1]
File Edit View Window Help
Input Quick Jump
Report Quick Jump
UNSIGNALIZED INTERSECTIONS TWO-WAY STOP-CONTROLLED
Analyst
Agency/Co
Date
11/26/2002
Time Period Analyzed
East/West Street Name
Project ID
Intersection
Jurisdiction
Units: U. S. Customary
Analysis Year
North/South Street Name
HCS2000: Unsignalized Intersections Release 4.1a
TWO-WAY STOP CONTROL SUMMARY
Analyst:
Agency/Co.:
Date Performed: 11/26/2002
Analysis Time Period:
Intersection:
Jurisdiction:
Units: U. S. Customary
Analysis Year:
Project ID:
East/West Street:
North/South Street:
Intersection Orientation: EW
Study period (hrs): 0.25
Analyst: []
Ready
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Start
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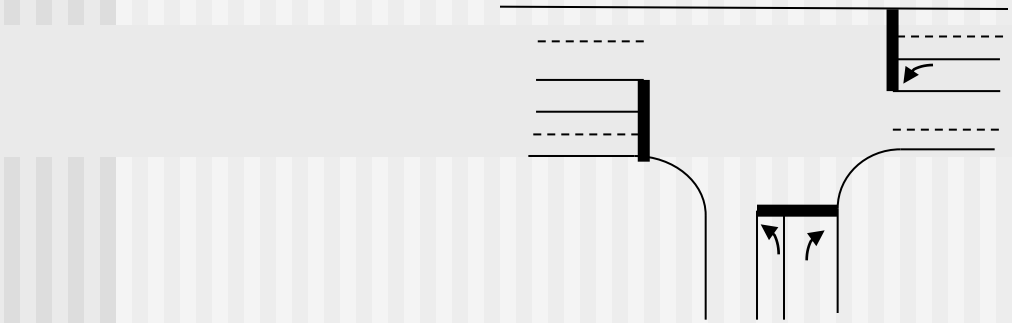
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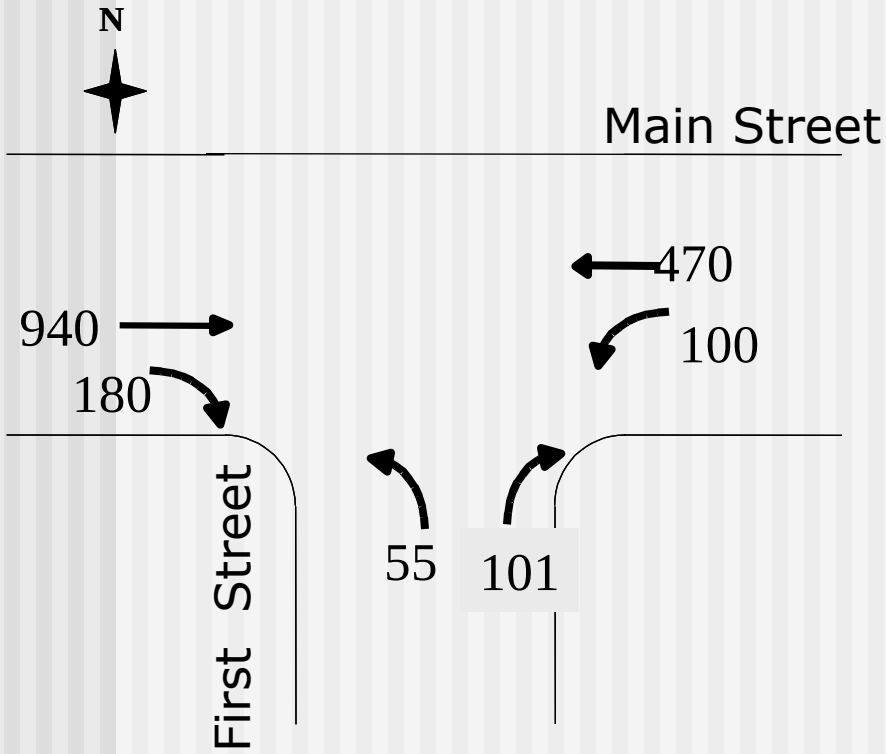


Lane Designation



Example:Evaluate Intersection LOS, Using HCS

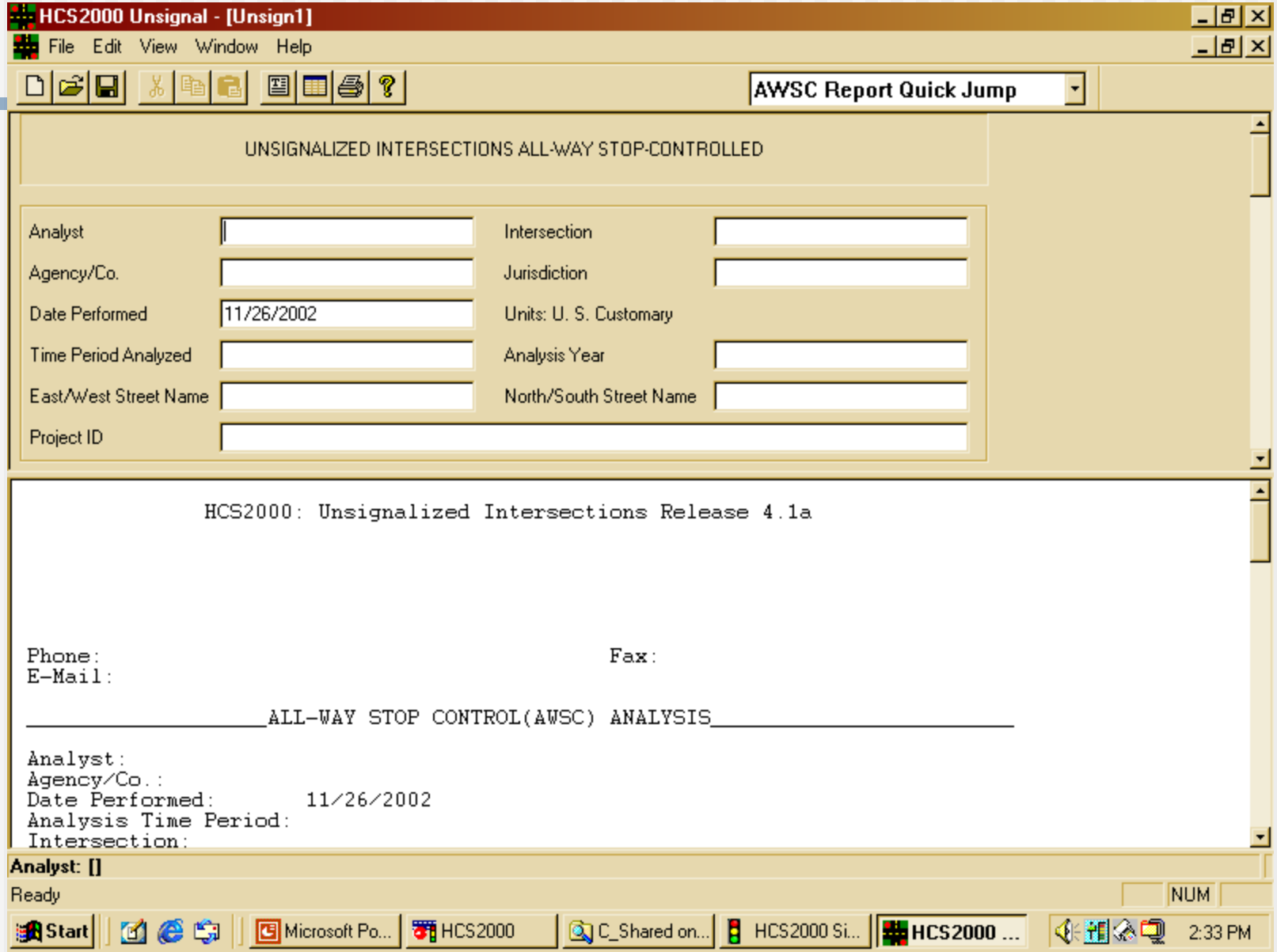


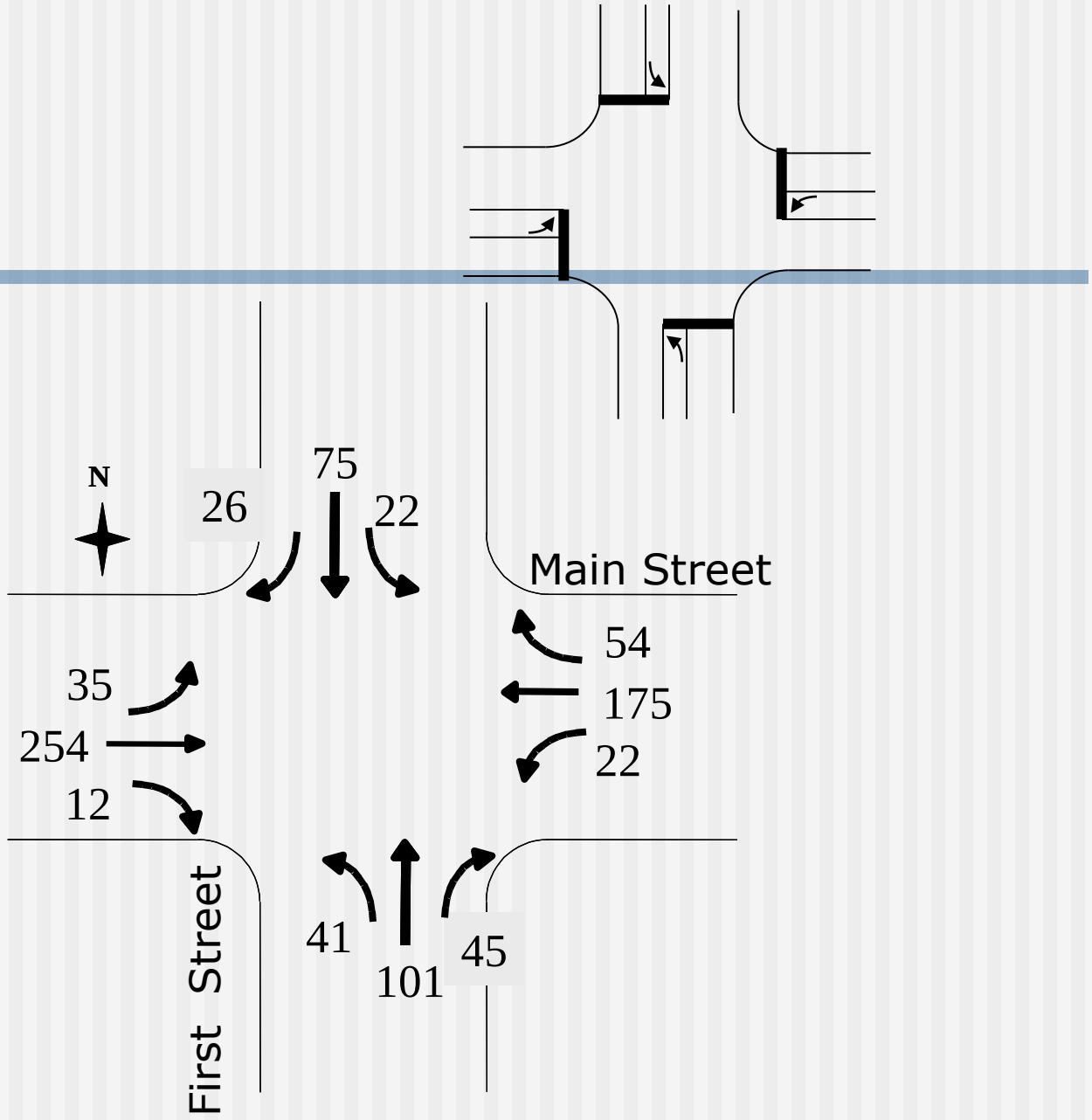


AWSC Intersections

- Each approach is analyzed independently
- Opposing approach and the conflicting approaches creates conflicts with vehicles on the subject approach (the approach under study)
- Drivers on all approaches are required to stop before entering the intersection

AWSC Intersections




N
26
75
22
Main Street
54
175
22
35
254
12
First Street
41
101
45

RESULTS

Intersection Performance Summary

Appr/ Lane Grp	Lane Group Capacity	Adj Sat Flow Rate (s)	Ratios v/c	Ratios g/C	Lane Group Delay	Lane Group LOS	Approach Delay	Approach LOS
Eastbound								
L	458		0.68	0.500	39.3	D		
TR	1284	3531	0.95	0.364	50.0	D	47.8	D
Westbound								
L	315		0.35	0.500	42.4	D		
TR	1281	3523	0.49	0.364	28.4	C	30.5	C
Northbound								
L	356		0.56	0.409	39.6	D		
TR	1116	3506	0.94	0.318	51.7	D	49.8	D
Southbound								
L	233		0.48	0.409	50.4	D		
TR	1106	3475	0.51	0.318	32.2	C	35.2	D

Intersection Delay = 43.3 (sec/veh) Intersection LOS = D

HCS: Signalized Intersections Release 3.2