CIVE 440

Traffic Engineering and Simulation – Traffic Studies

McGill
Faculty of Engineering
Department of Civil Engineering and Applied Mechanics
Fall 2016

TRAFFIC DATA COLLECTION

Purpose:

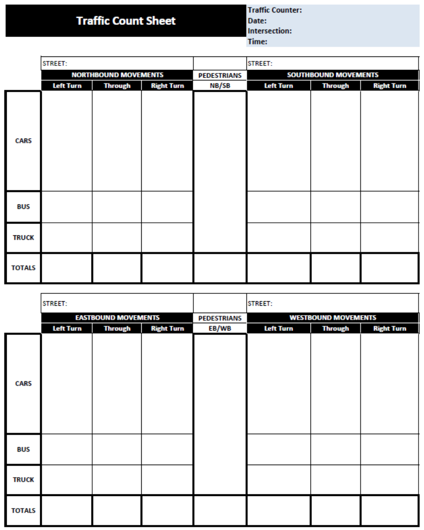
- Manage the traffic network
- Investigate traffic demand trends over time
- Understand the needs and choices of the public
- Calibrate basic traffic relationships
- Assess the effectiveness of improvements
- Assess the potential impacts of changes
- Evaluat facility or system performance

In short, traffic engineering is impossible without traffic data.

MANUAL TECHNIQUES

Traditional traffic counting method based on manual counts by observers:

- Technically reliable and flexible
- Expensive, boring, labour-intensive
    - Limited accuracy



Traffic Count Sheet

Traffic Counter:
Date:
Intersection:
Time:

	STREET:				STREET:		
	NORTHBOUND MOVEMENTS			PEDESTRIANS	SOUTHBOUND MOVEMENTS		
	Left Turn	Through	Right Turn	NB/SB	Left Turn	Through	Right Turn
CARS							
BUS							
TRUCK							
TOTALS							

	STREET:				STREET:		
	EASTBOUND MOVEMENTS			PEDESTRIANS	WESTBOUND MOVEMENTS		
	Left Turn	Through	Right Turn	EB/WB	Left Turn	Through	Right Turn
CARS							
BUS							
TRUCK							
TOTALS							

Traffic counts across street sections are straightforward:

- One counter per street often enough
- Traffic counts may or may not be lane-specific

Intersections are more complicated:

- Easy to lose track of movements through the phases
- Recommended:
    - 2 people

Traffic Count Sheet

Traffic Counter:
Date:
Intersection:
Time:

	STREET:				STREET:		
	NORTHBOUND MOVEMENTS			PEDESTRIANS	SOUTHBOUND MOVEMENTS		
	Left Turn	Through	Right Turn	NB/SB	Left Turn	Through	Right Turn
CARS							
BUS							
TRUCK							
TOTALS							

	STREET:				STREET:		
	EASTBOUND MOVEMENTS			PEDESTRIANS	WESTBOUND MOVEMENTS		
	Left Turn	Through	Right Turn	EB/WB	Left Turn	Through	Right Turn
CARS							
BUS							
TRUCK							
TOTALS							

Some techniques suggest taking a 1 minute break every 4 minutes.

- Estimation through interpolation.

(Over 4 minutes)

Intensity
(instantaneous veh/h)

Table 8.2: Data from an illustrative volume study

Period	Time (PM)	Actual Counts (vehs)		Expanded Counts (× 5/4 = 1.25)		Estimated Counts (vehs)		Estimated Flow Rates (vehs)	
		Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2	Lane 1	Lane 2
1	5:00	24		30.0		30	43	360	516
2	5:05		36		45.0	33	45	396	540
3	5:10	28		35.0		35	47	420	564
4	5:15		39		48.8	36	49	432	588
5	5:20	30		37.5		38	54	456	648
6	5:25		47		58.8	41	59	492	708
7	5:30	36		45.0		45	61	540	732
8	5:35		50		62.5	44	63	528	756
9	5:40	34		42.5		43	61	516	732
10	5:45		48		60.0	46	60	552	720
11	5:50	40		50.0		50	59	600	708
12	5:55		46		57.5	55	58	660	696

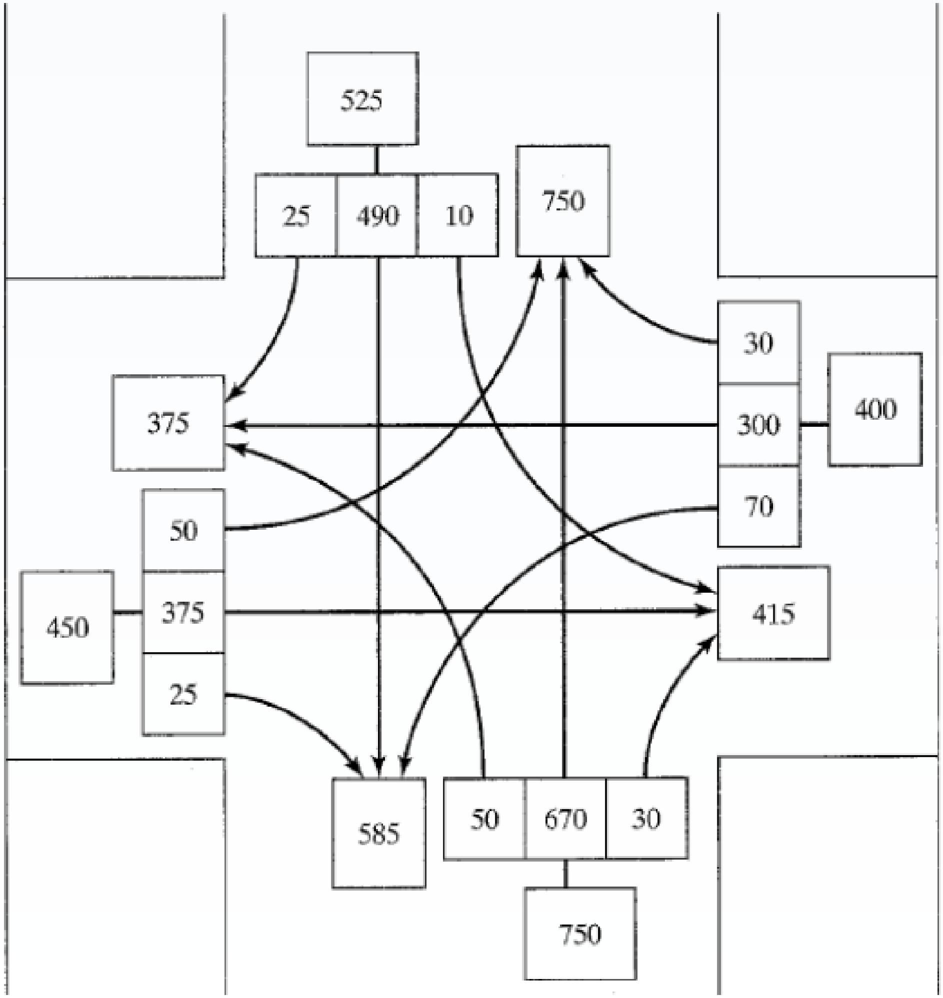
Interpolation

Balance departures and arrivals using queue length:

- Counting vehicle accumulation instantly at the beginning of the period

Time Period (PM)	Departure Count (vehs)	Queue Length (vehs)	Arrival Volume (vehs)
4:00–4:15	50	0	50
4:15–4:30	55	0	55
4:30–4:45	62	5	62 + 5 = 67
4:45–5:00	65	10	65 + 10 – 5 = 70
5:00–5:15	60	12	60 + 12 – 10 = 62
5:15–5:30	60	5	60 + 5 – 12 = 53
5:30–5:45	62	0	62 – 5 = 57
5:45–6:00	55	0	55
Total	**469**		**469**

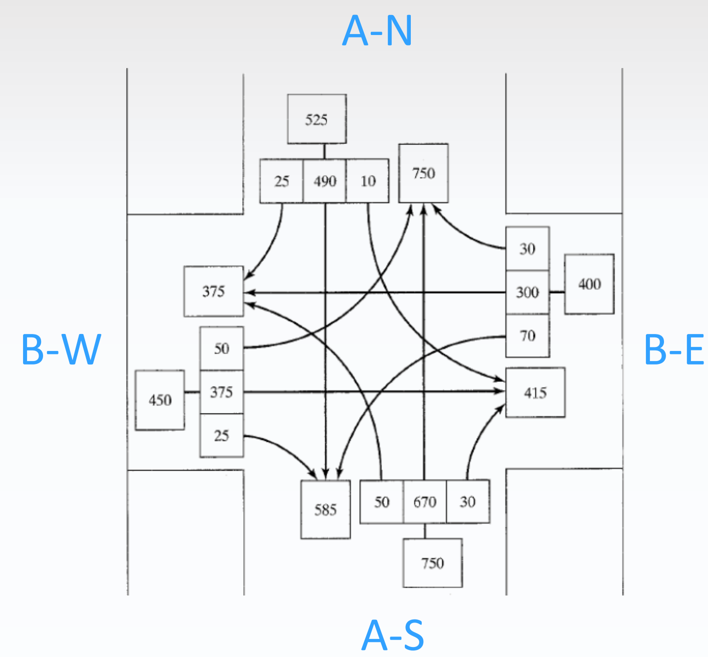
DATA PRESENTATION



OD NOTATION

Alternative presentation:

- Origin-destination (OD) matrix
- Typically used in practice



	A-N	A-S	B-W	B-E
A-N	0	490	25	10
A-S	670	0	50	30
B-W	25	50	0	375
B-E	30	70	300	0

AUTOMATED TECHNIQUES

Use of electronic sensors enables automated data collection:

- Embedded in the network or as temporary installation
- 24/7 data collection
- Cheap
- Moderate to very high accuracy

Electronic sensors are not perfect:

- Reliability issues
- “Black box” effect
- Growing concerns regarding privacy

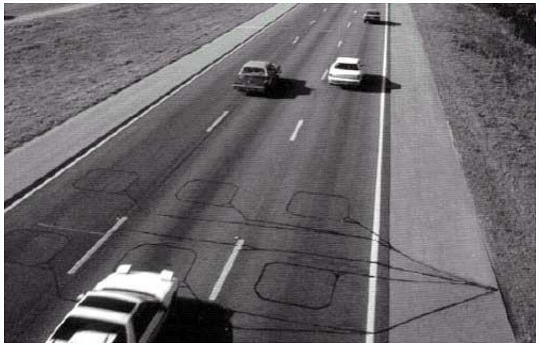
LOOP DETECTORS

Loop detectors are widely-used and one of the most ubiquitous traffic data collection systems:

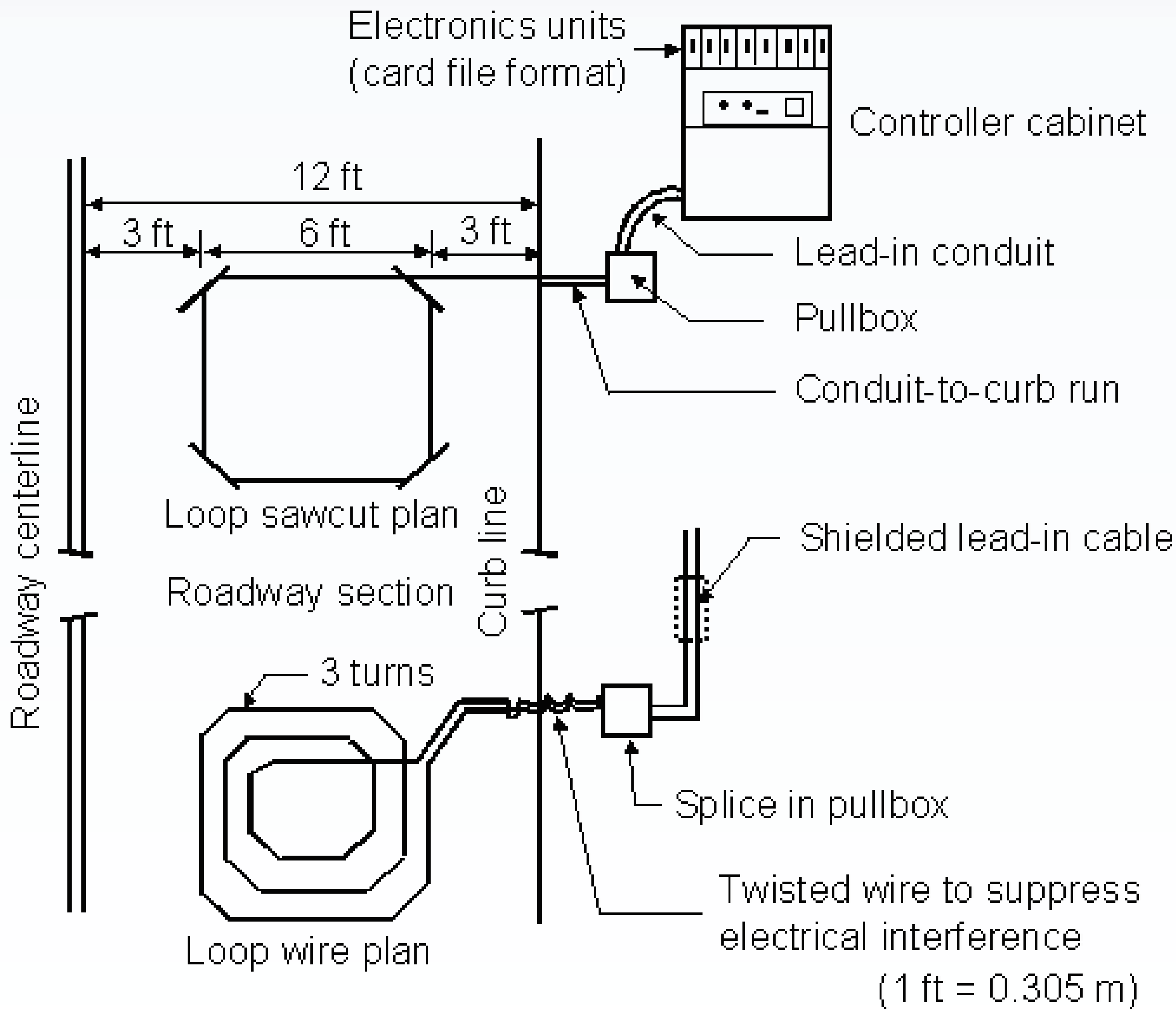
- Mature technology
- High accuracy
- Permanent and unobtrusive
- Long term counts
- Measures counts, occupation, and speed

Issues:

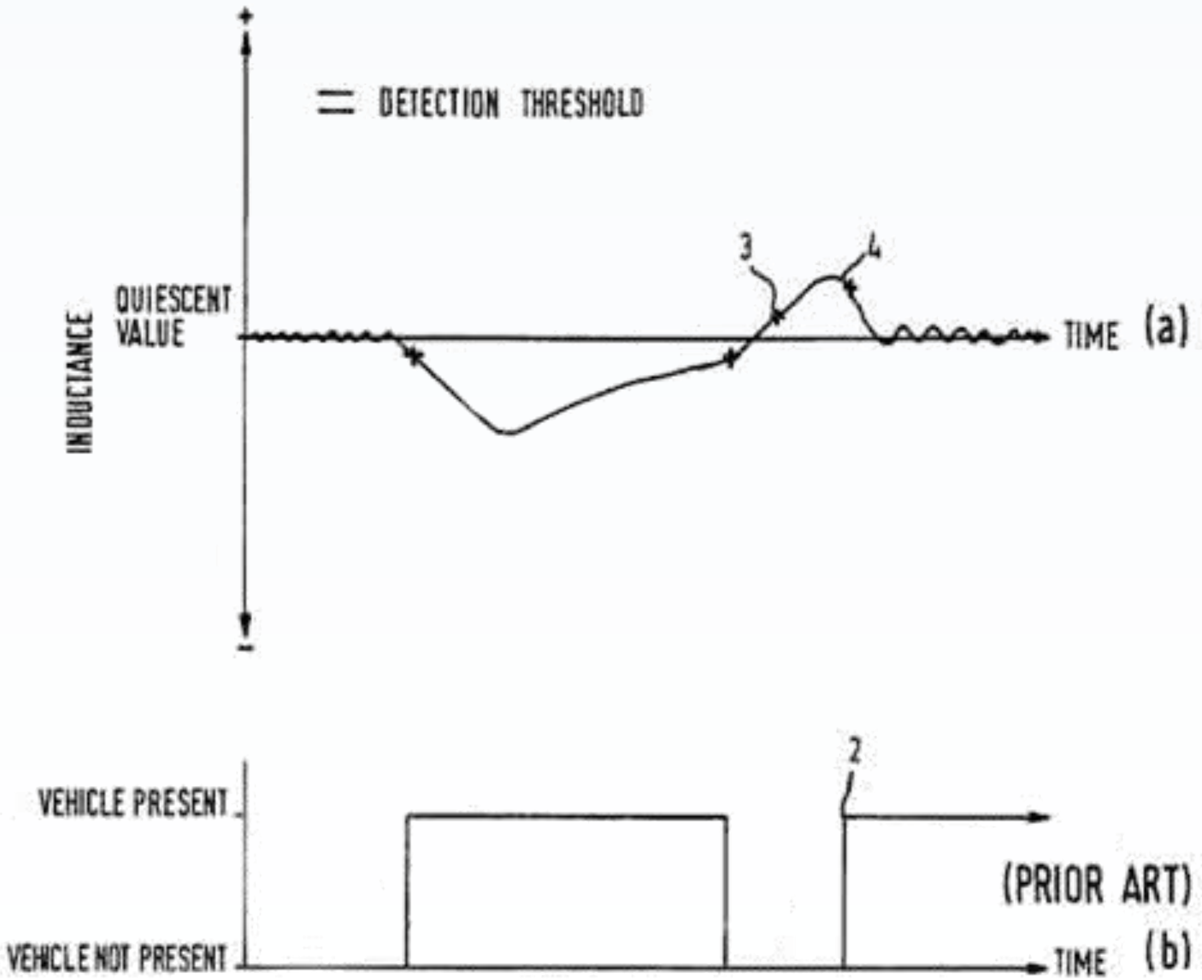
- Highly susceptible to damage
  - Particularly from weather and road work



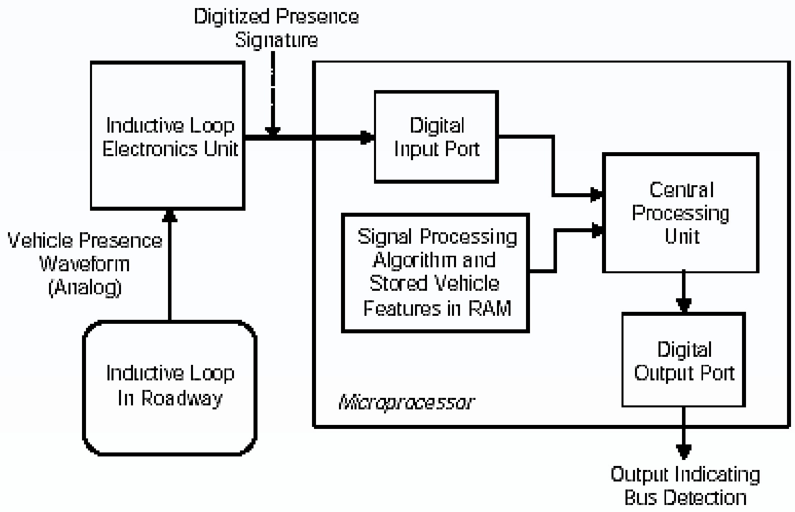
Installation:

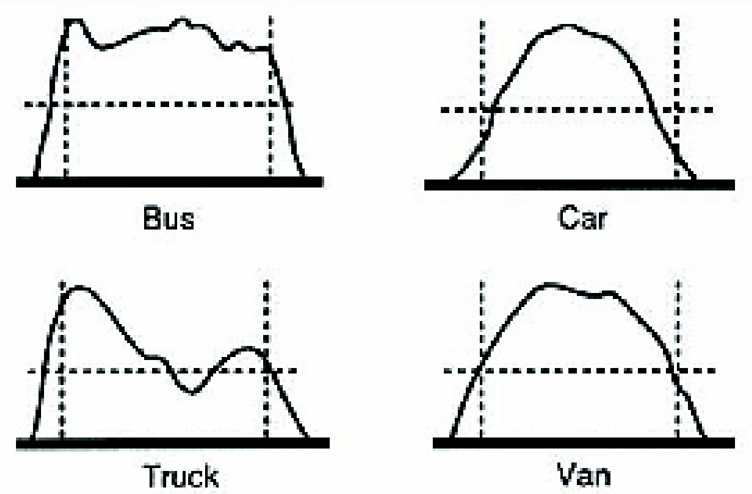


Current is induced as vehicle passes over the coil, producing a signal.

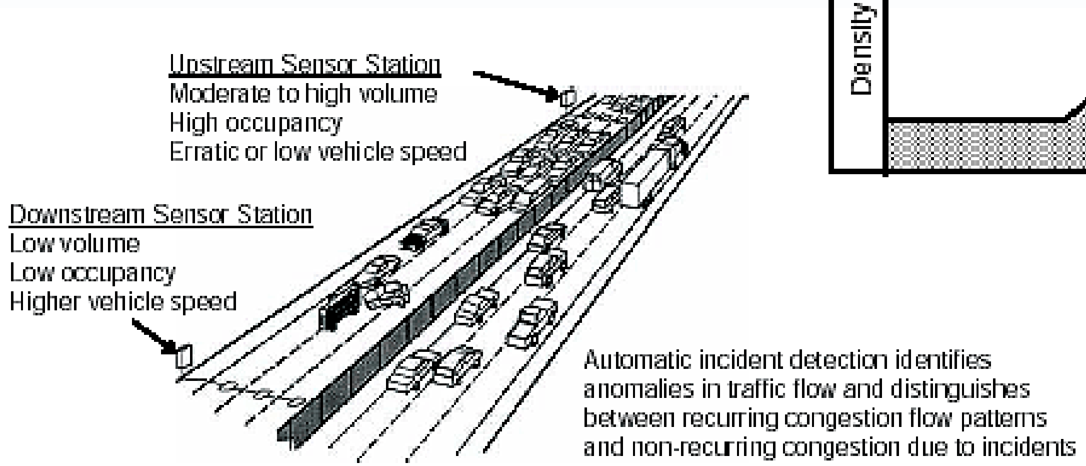


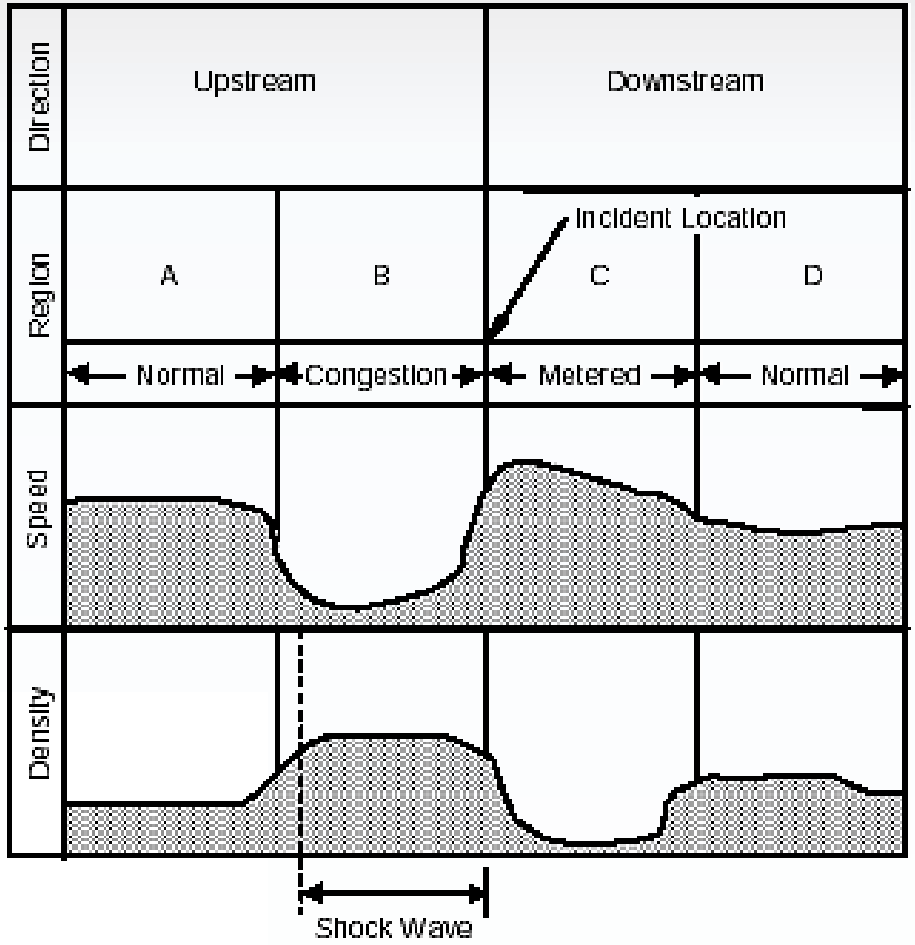
Vehicle type detection from serial detectors or induction profile:





Automatic incident detection using detectors:





DERIVED SYSTEMS

Magnetic induction also applied in:

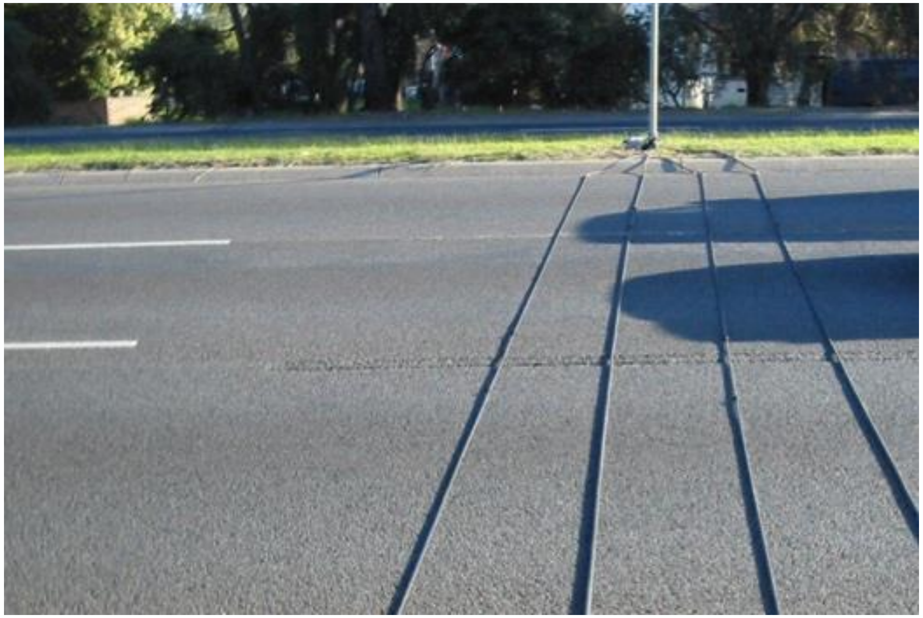
- Bicycle counters

- Magnetic plates (temporary counts)

PNEUMATIC TUBES

Pneumatic tubes are efficient for conducting temporary traffic studies.

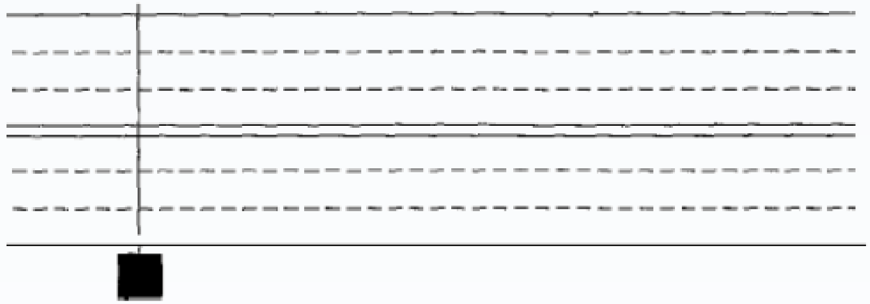
- Embedded sensors capable of detecting small changes in pressure inside the tube.
- With a pair of tubes or more, speed and vehicle classification is possible, in addition to counts.



Issues:

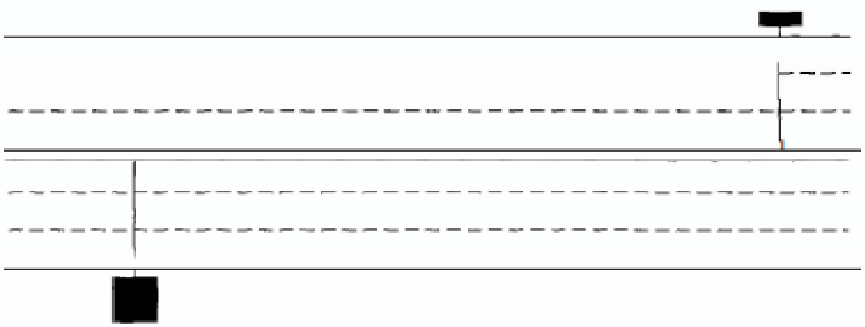
- Failure-prone
- Obtrusive

Total flow



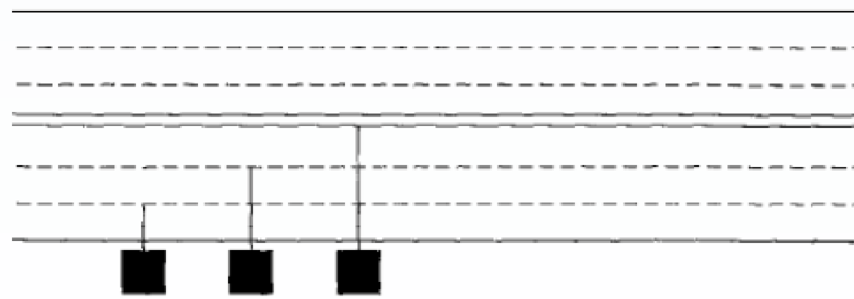
(a) Road Tube for Counting Total Two-Way Axle Counts

Directional Flow



(b) Road Tubes for Counting Directional Axle Counts

Lane Flow



(c) Road Tubes for Lane Axle Counts

ELECTROMAGNETIC DETECTORS

Microwave, RADAR, or LIDAR can be used to count cars and uses the Doppler effect to measure speed.

- Mature technology
- Relatively unobtrusive
- May or may not be permanent

Issues:

- Interference possible, particulary in high congestion
- Location-dependant
- Counts are only macroscopic in scope

TRAFFIC CAMERAS

Computer vision allows the automatic detection of vehicles and traveling speeds inside of camera space:

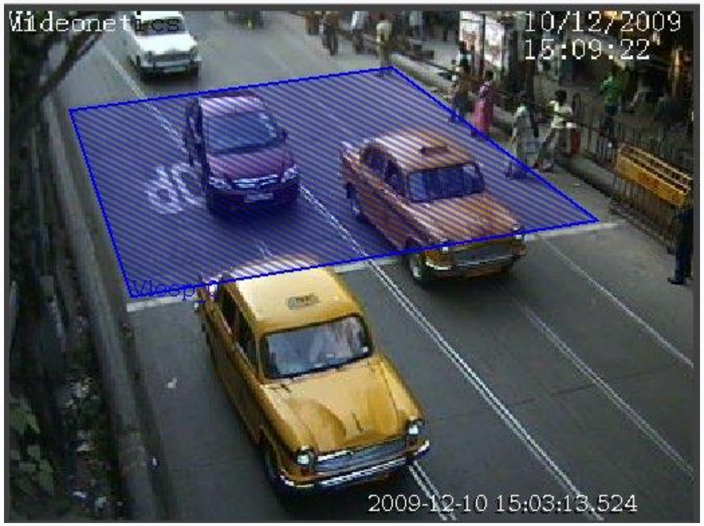
- Theoretically, can see everything a human sees and then some (infrared, night vision, etc.), and measure it to a very high accuracy, reliability, and resolution
- Counts, speeds, acceleration, size, class, gaps, location, occupation, infractions, incidents, at 30 times per second

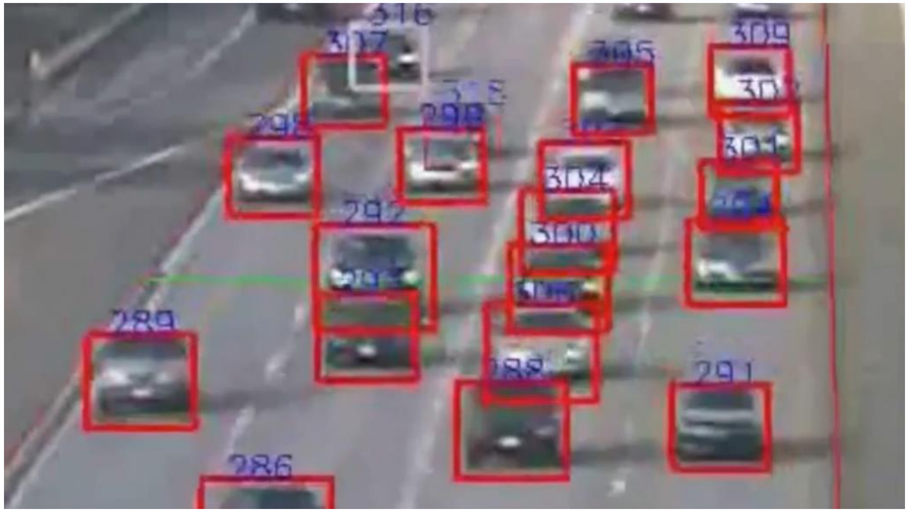
Issues:

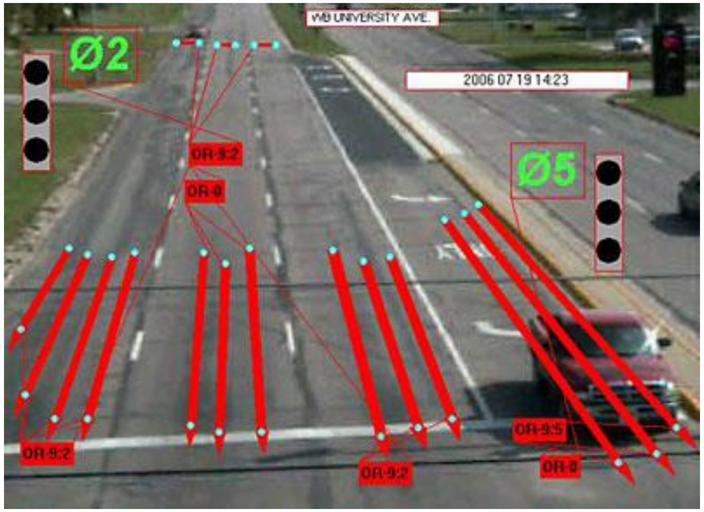
- Immature technology, AI challenge, marginally expensive
- Weather conditions can reduce visibility

Presence detection “roll-on-roll-off”

- Emulates the functionality of a virtual loop and is the most reliable, but least informative capturing mode.
- Adequate accuracy for current use
- Calibration required specific to the scene

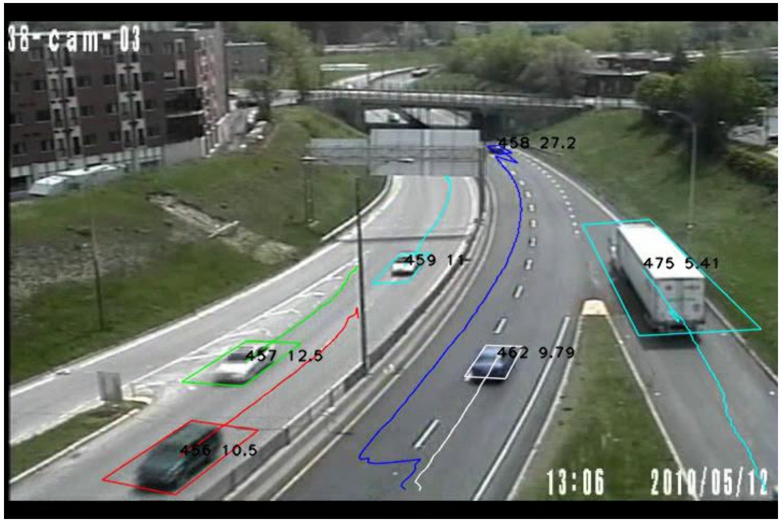


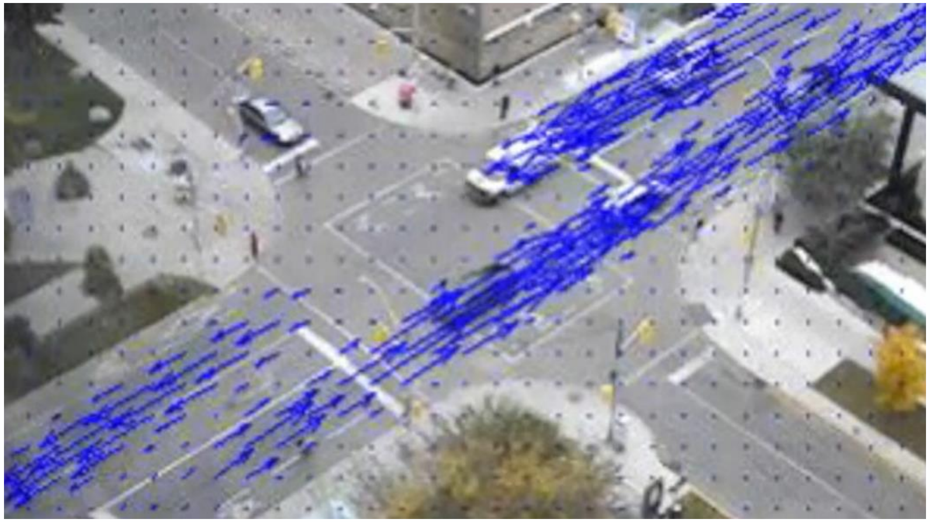




Trajectory tracking:

- Position, speed, acceleration 30 times per second for each vehicle.
- Microscopic in scope
- Intensive data management and processing requirements
- Specialised applications





Limitations with visibility and current AI:

GPS & CROWDSOURCING

The ubiquity of GPS systems and telecommunication in the first-world enable crowdsourcing traffic data:

- Cheap and efficient
- Currently in fashion

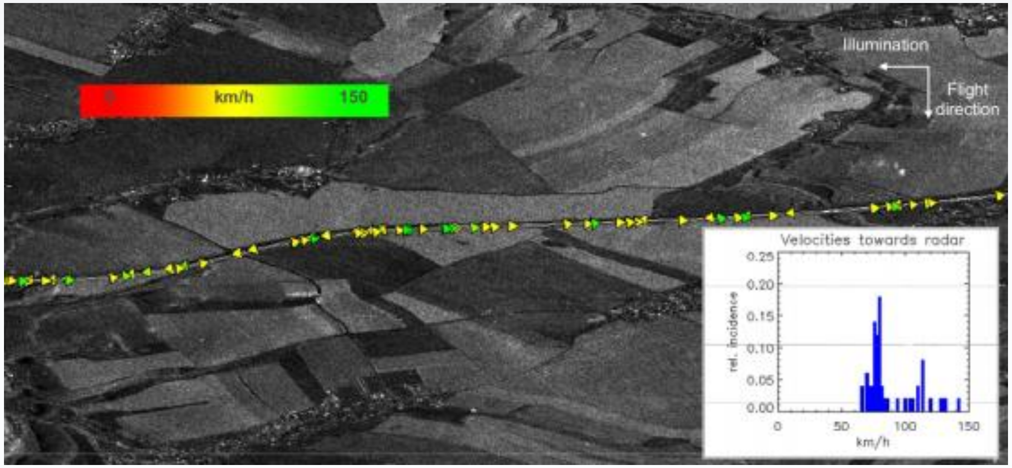
Limitations:

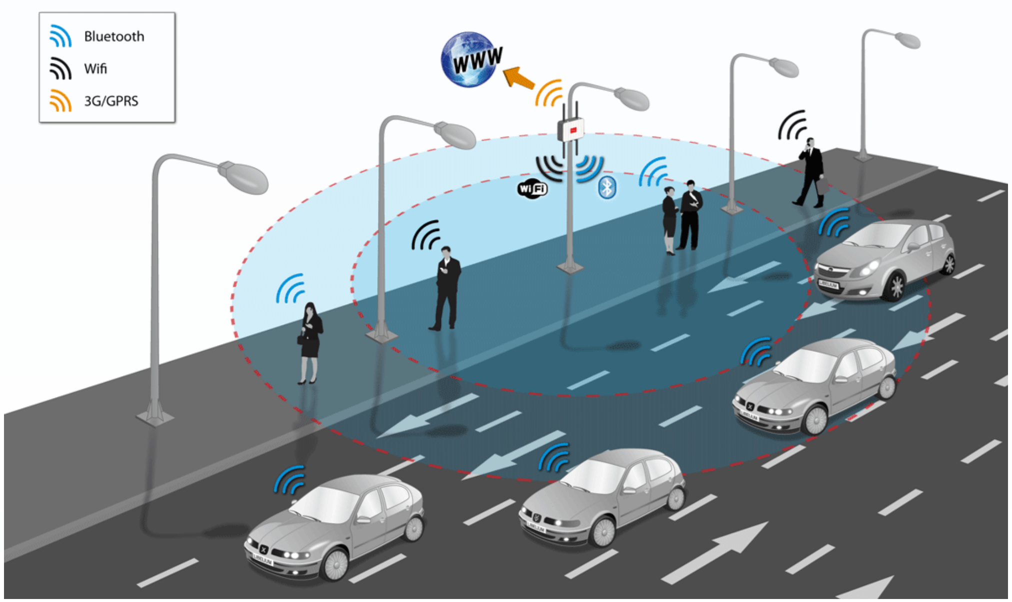
- Accuracy to only a few metres
- Very intrusive and/or limited participation
- Dependency on third-parties

OTHER DETECTORS

Many other detectors in niche or emerging applications:

- Satellite imaging
- Bluetooth MAC address detectors
- E-Z Pass





STUDY TYPES

- Volume studies
- Speed studies
- Travel time studies
- Delay studies
- Density studies
- Accident studies
- Parking studies
- Freight studies
- Transit studies
- Pedestrian studies
- Calibration studies
- Observation studies

DEFINITIONS

Volume:

- No. of vehicles passing a point in a specified time

Rate of flow:

- Rate at which vehicles pass a point, in vehicles per hour

Demand:

- No. of vehicles that desire to pass by a point

Supply/Capacity:

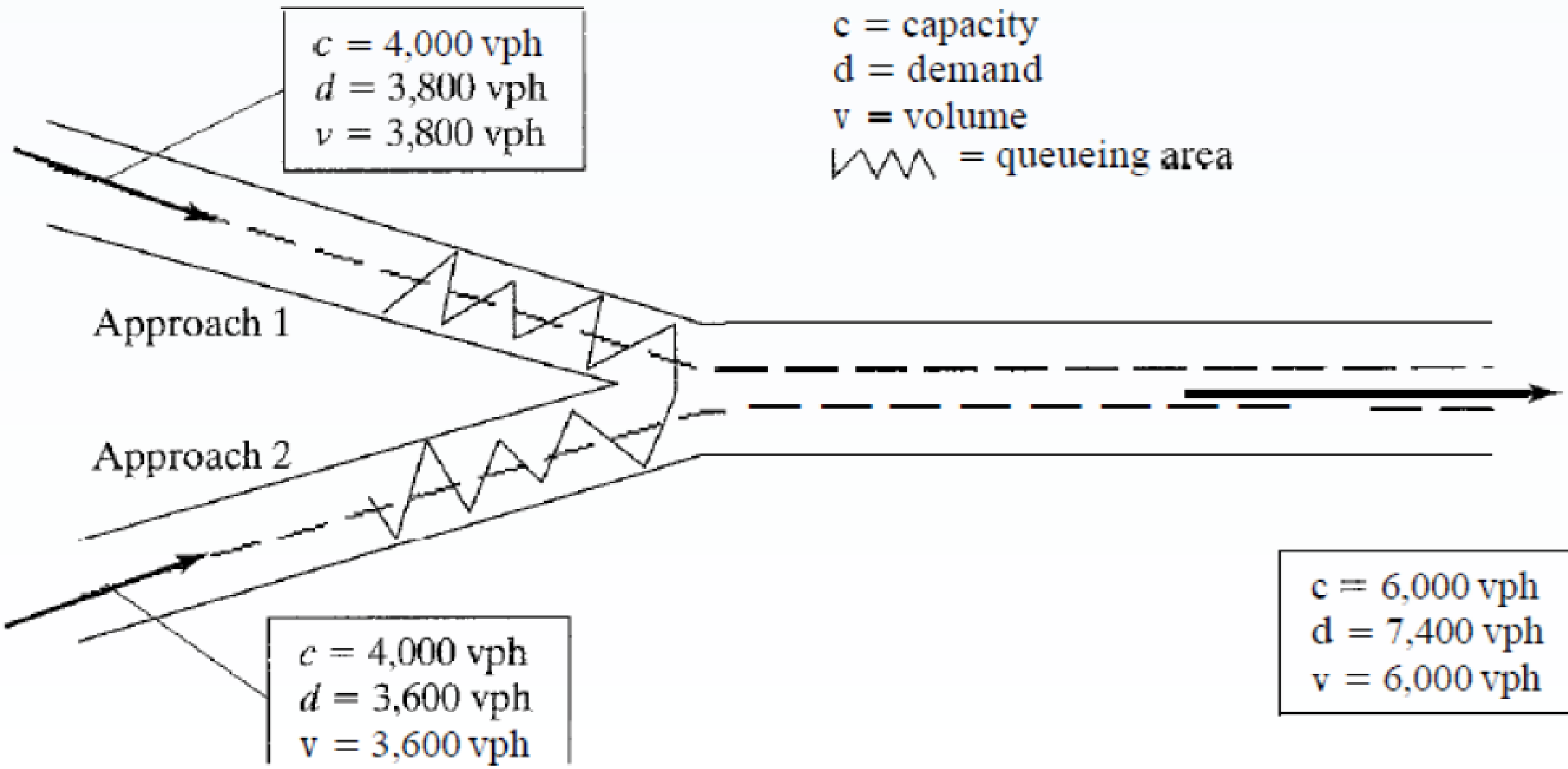
- Rate at which vehicles can traverse a point

Capacity:

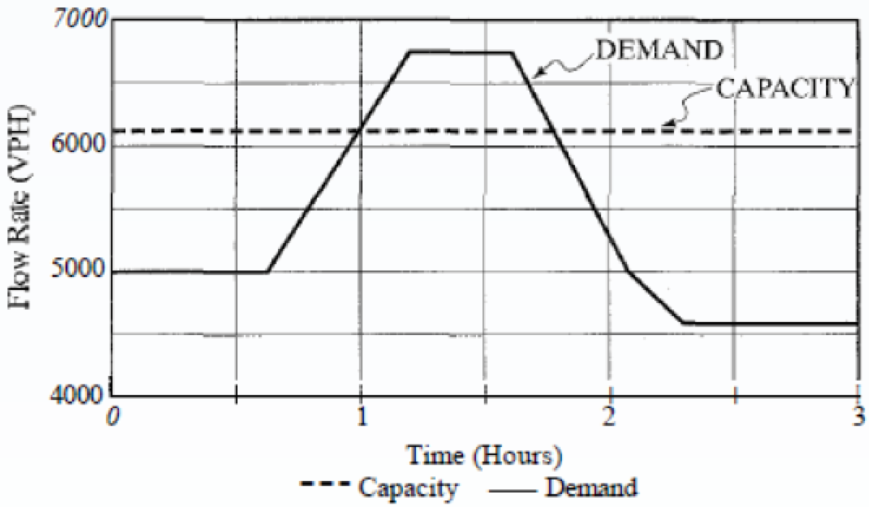
- Max. rate at which vehicles can traverse a point

EXAMPLE

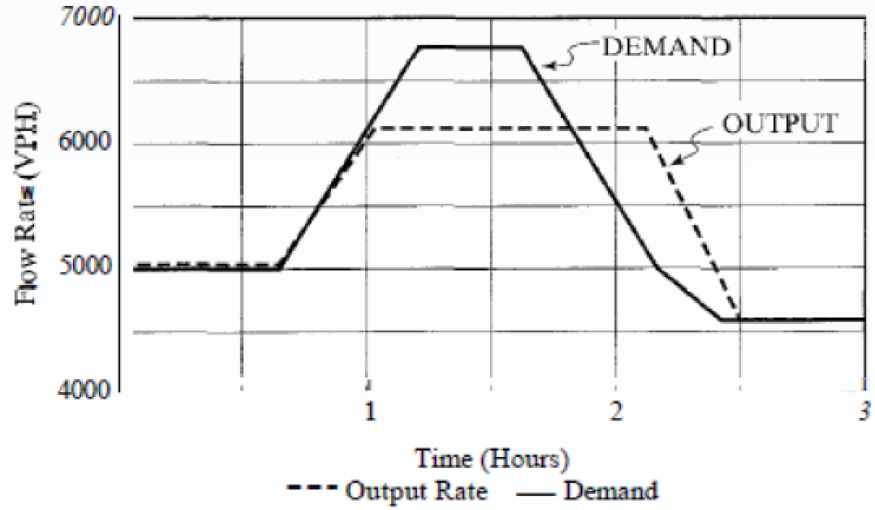
At what rate will the queue below grow?



DEMAND AND CAPACITY RELATIONSHIP



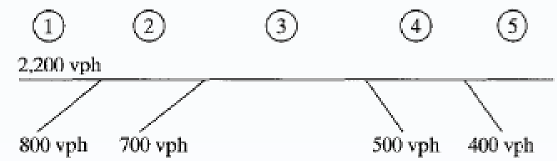
(a) Demand and capacity. as they would appear at the measurement point



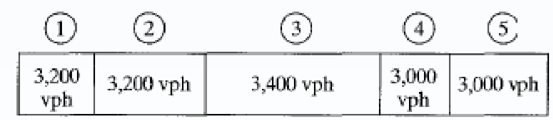
(b) Volume pattern distorted by capacity limit

EXAMPLE

Let's consider the scenario with the following true demand and capacity values.

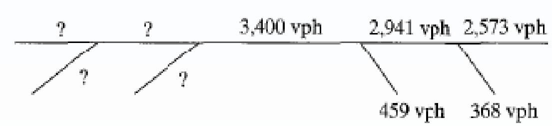


(a) True Demand



(b) Segment Capacities

Now if there was a person counting downstream, what can we say about <u>these counts</u> ?



(c) Observed Volumes

Segment	1	2	3	4	5
Volume (veh/h)	–	–	3,400	2,941	2,573
Demand (veh/h)	2,200	3,000	3,700	3,200	2,800
Capacity (veh/h)	3,200	3,200	3,400	3,000	3,000

(d) Volume, Demand, and Capacity for Freeway Segments

TEMPORAL PATTERNS

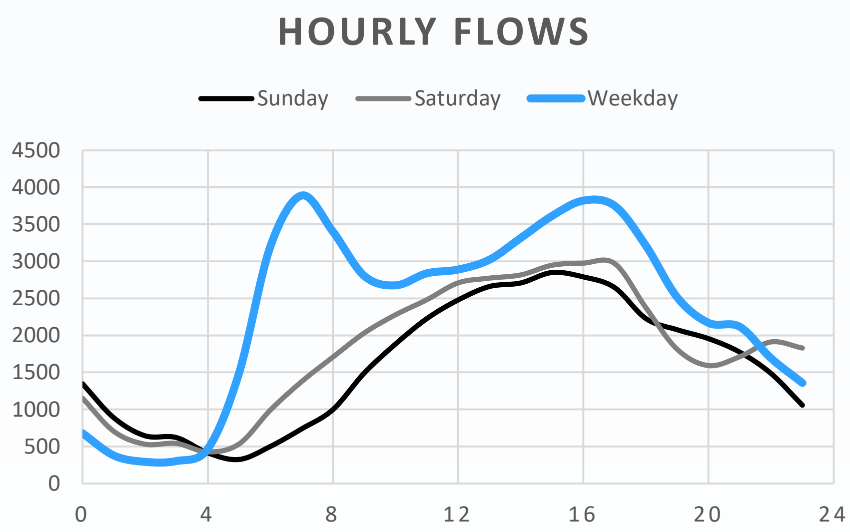
Traffic demand, and consequently flow, varies according to some temporal factors:

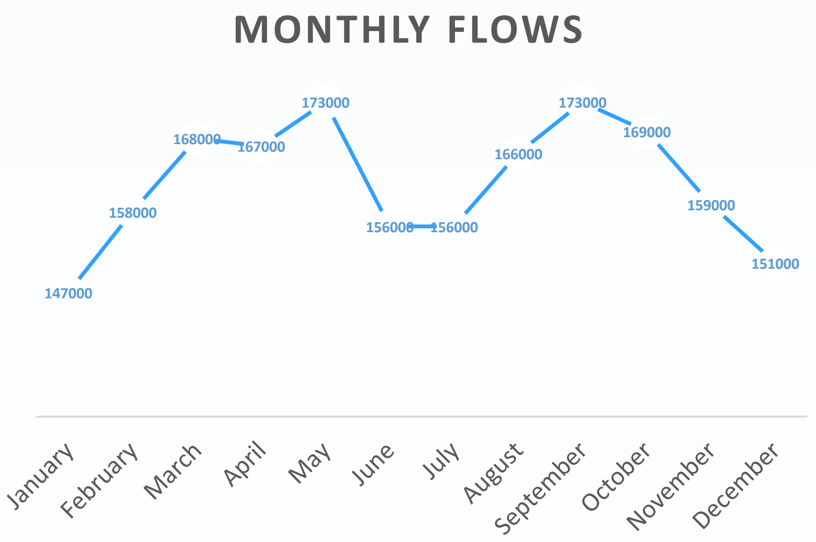
- Seasonal patterns
- Weekday patterns
- Hourly patterns
- Sometimes sub-hourly patterns
  - 10-15% in peak hour (traffic intensity)

Demand largely influenced by the traffic people are likely to put up with for non-negotiable travel times:

- Typically rush hour (7~9 AM and 4-6 PM)
- Heaviest traffic flow and thus the primary design period.

TYPICAL PATTERNS



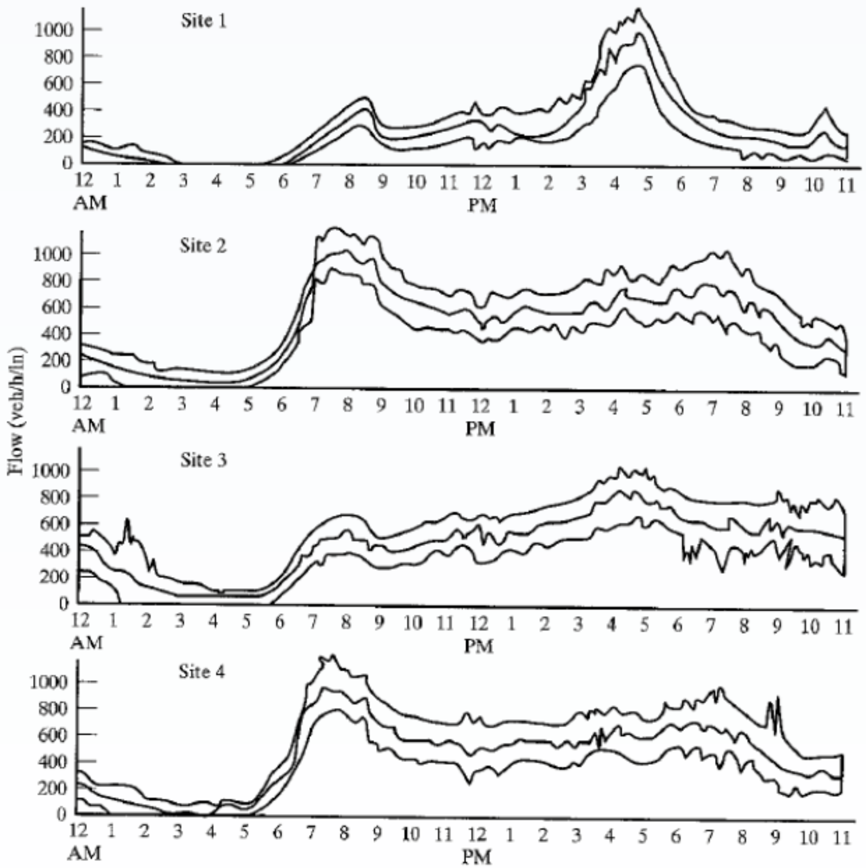


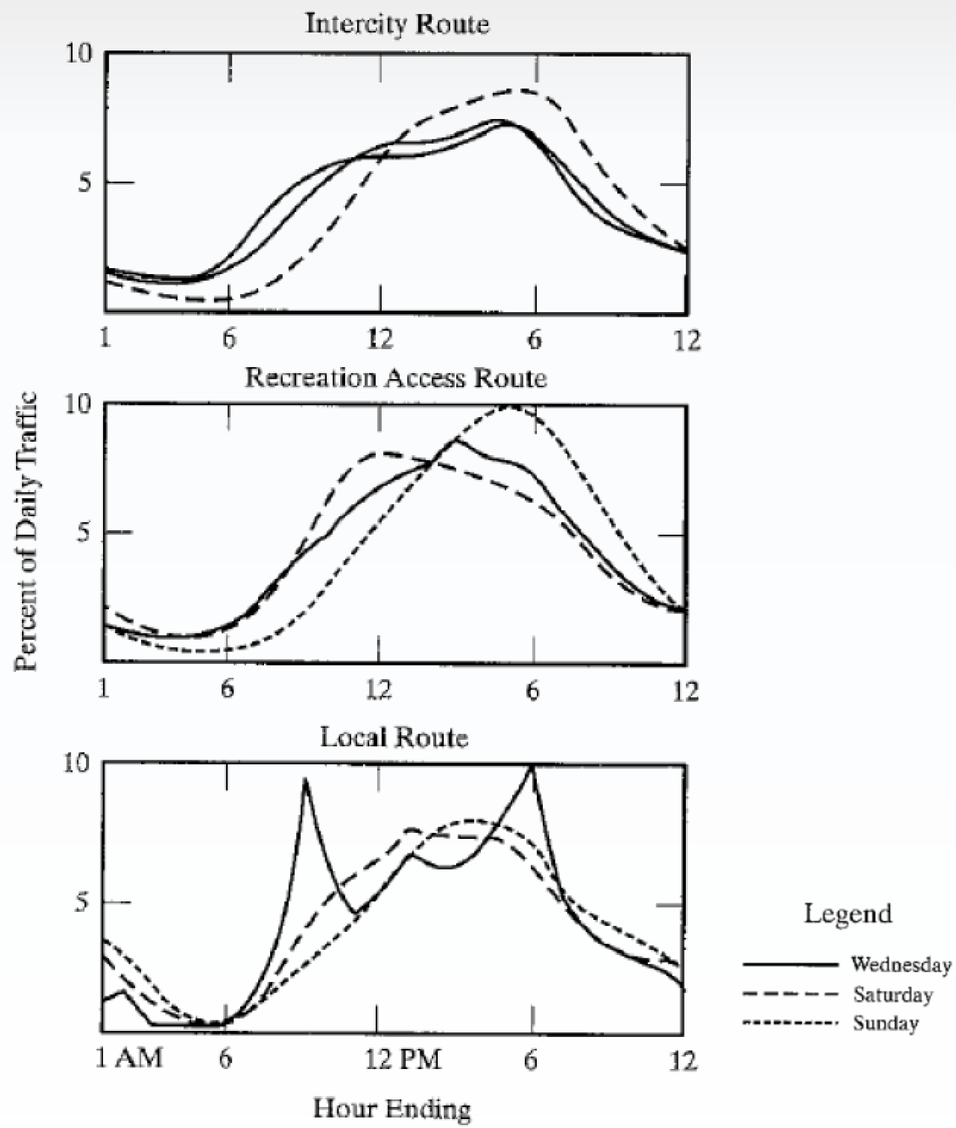
AVREAGE ANNUAL DAILY TRAFFIC (AADT)

Traditionally, Average Annual Daily Traffic (AADT) is the total volume of vehicle traffic of a highway, road, or intersection for a year divided by 365 days.

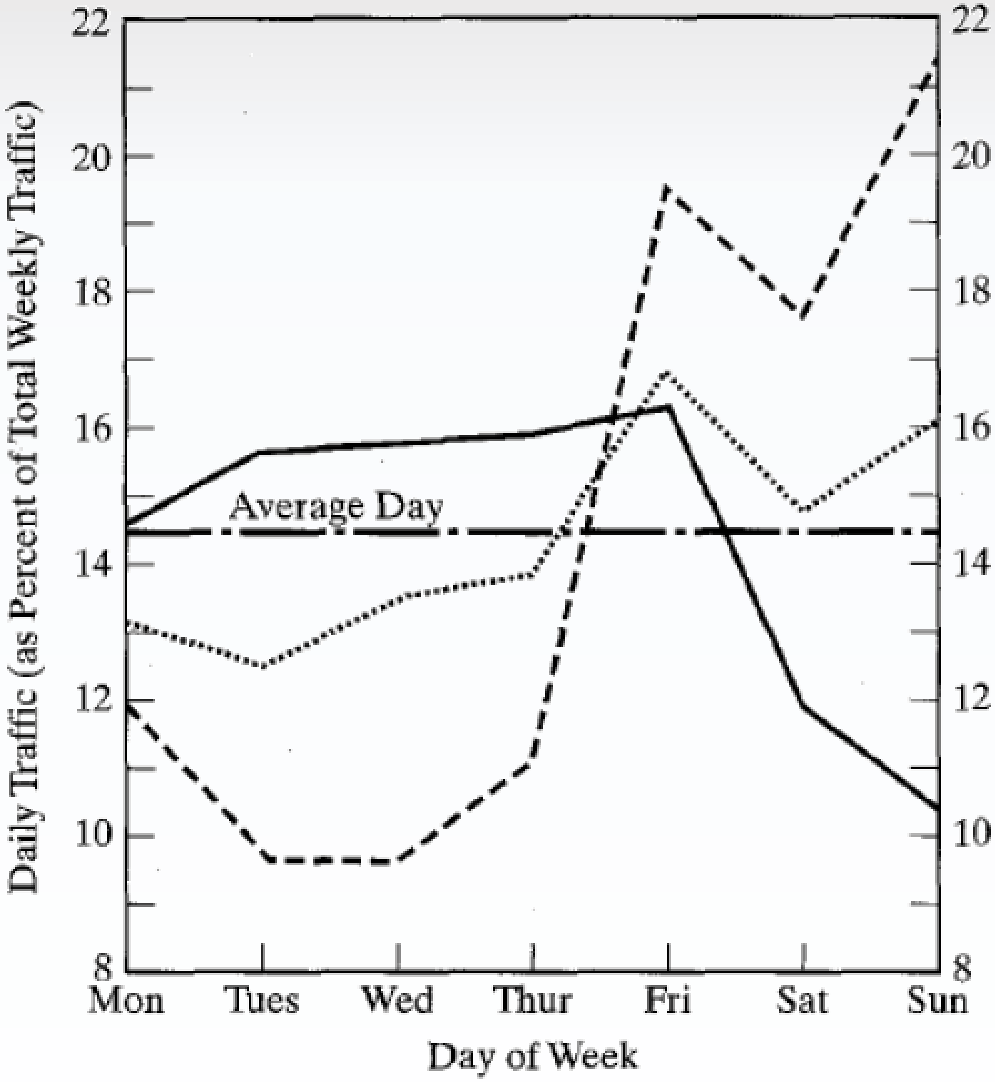
- Represents average conditions throughout the year, but not necessarily peak or even typical conditions (not a median)
- Primarily used in policy making, regional planning, and regional or long-term capacity studies.
  - Limited use for traffic design at the microscopic scale (traffic lights, road geometry, etc.)

Temporal variations vary also by location!

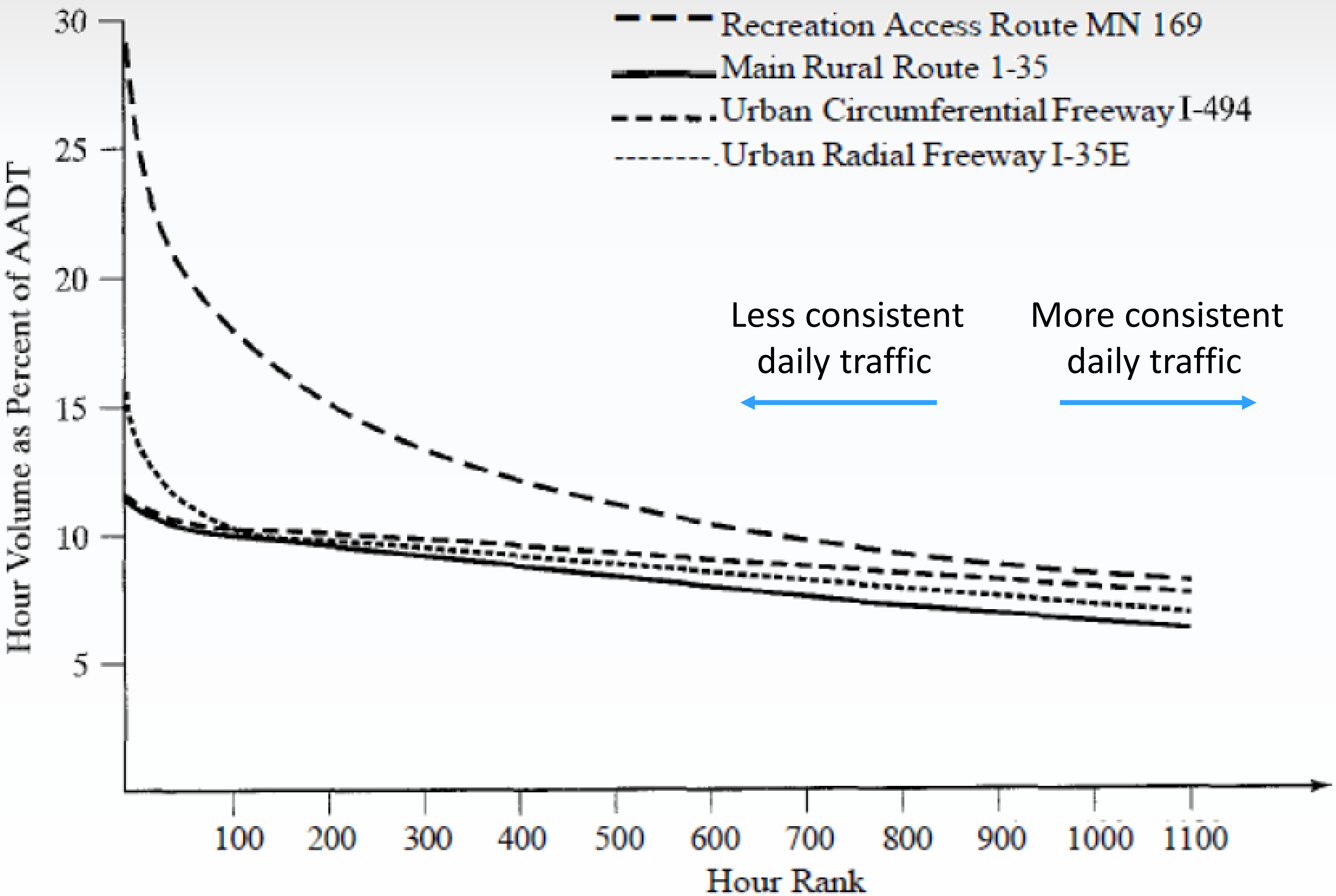




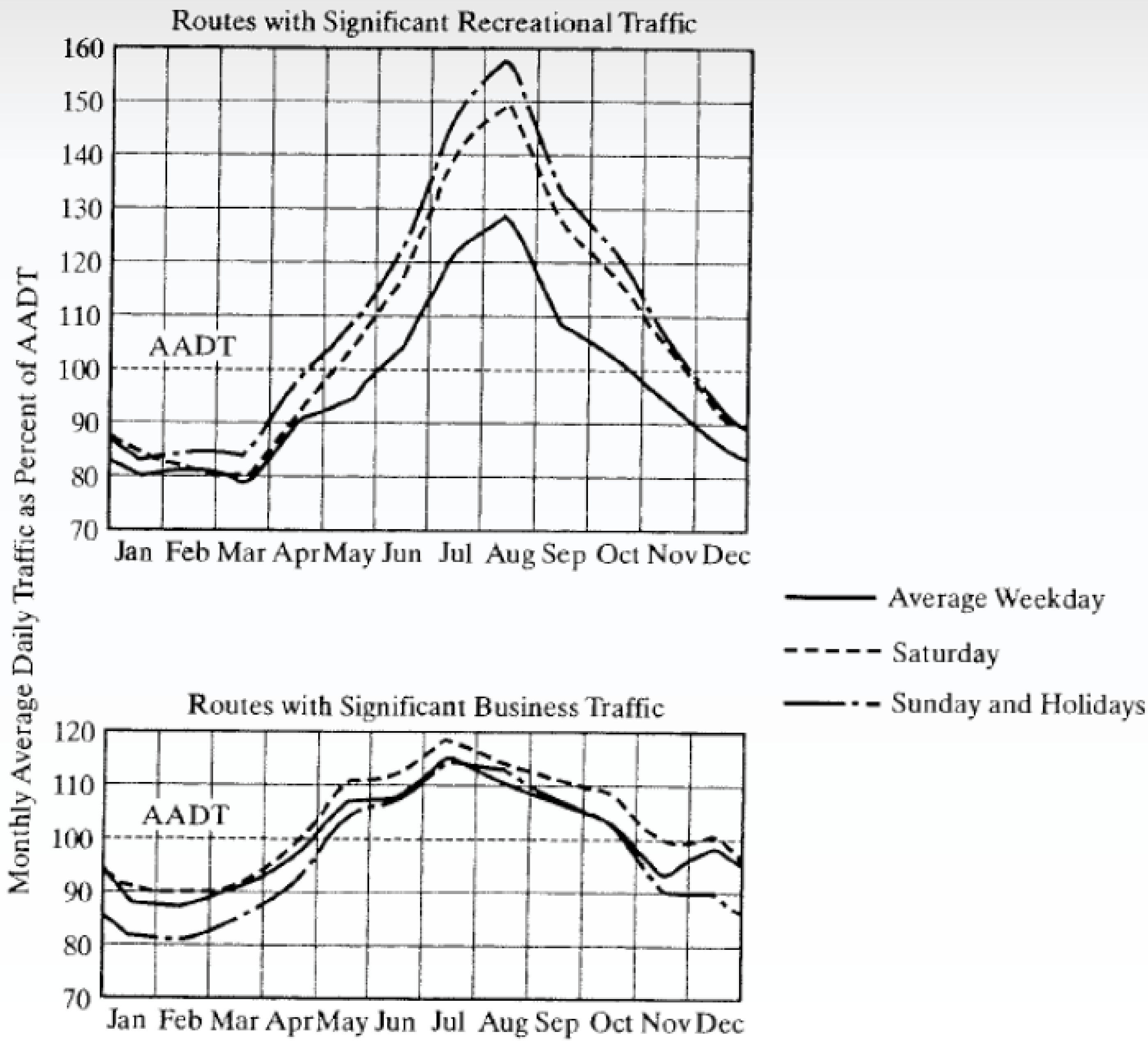
(a) Typical Variations for Rural Routes



··········Main rural route I-35, Southern Minnesota, AADT 10,823, 4 lanes, 1980.
- - - - Recreational access route MN 169, North-Central Lake Region, AADT 3,863, 2 lanes, 1981.
——— Suburban freeway, four freeways in Minneapolis-St. Paul, AADTs 75,000-130,000, 6-8 lanes, 1982.
—·— Average day.



Hour rank is the number of hours in the year with that corresponding amount of traffic.


Routes with Significant Recreational Traffic
160
150
140
130
120
110
100
90
80
70
AADT
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Monthly Average Daily Traffic as Percent of AADT
Average Weekday
Saturday
Sunday and Holidays
Routes with Significant Business Traffic
120
110
100
90
80
70
AADT
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

PEAK-HOUR FLOW

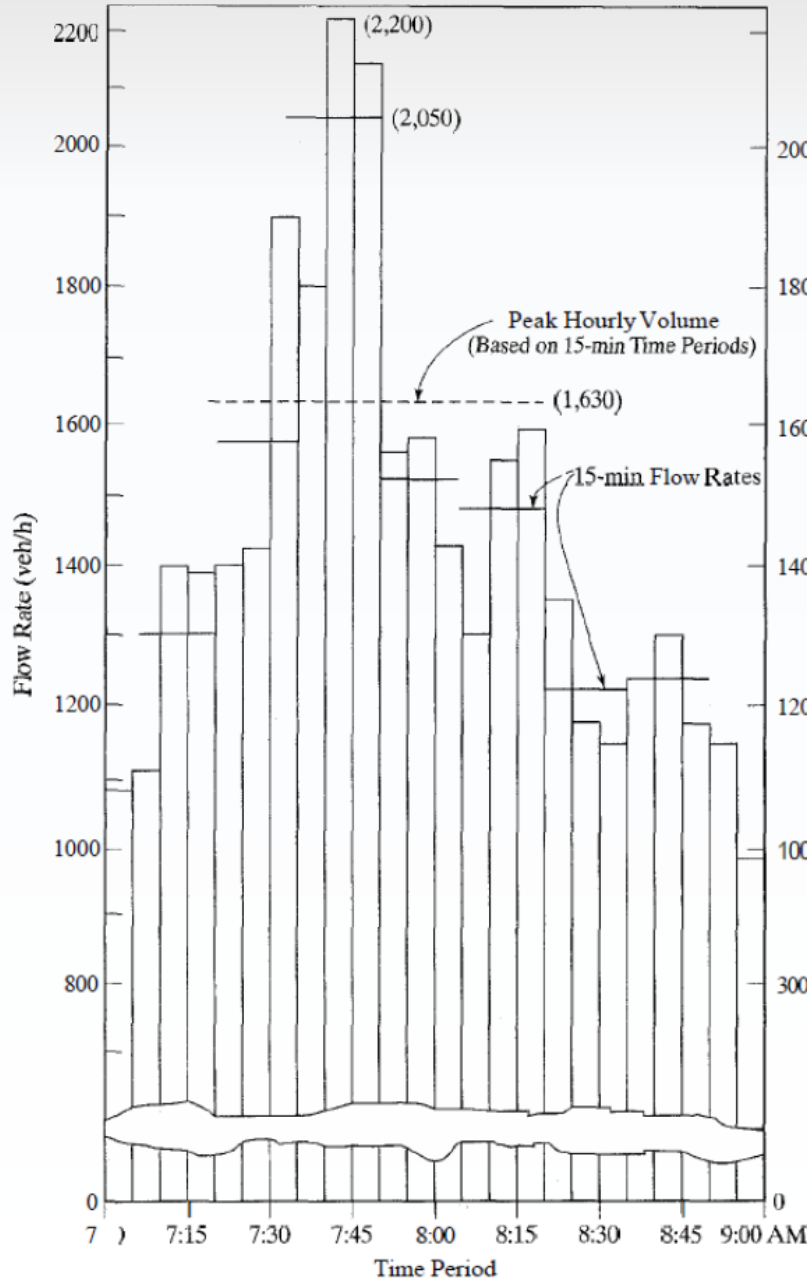
The HCM provides a standardised way of reporting peak-hour flows using a peak-hour factor (PHF):

$$PHF = \frac{V}{4v_p}$$

where v_p = Peak 15-minute volume

V = Peak hourly volume

This effectively assumes that the 15-minute traffic-intensity lasts for an entire hour.



(2,200)
(2,050)
Peak Hourly Volume
(Based on 15-min Time Periods)
(1,630)
15-min Flow Rates
Flow Rate (veh/h)
2200
2000
1800
1600
1400
1200
1000
800
300
0
7
7:15
7:30
7:45
8:00
8:15
8:30
8:45
9:00 AM
Time Period

SMALL NETWORK COUNTS

Two types of counts:

- Continuous counts
  - Taken 365 days a year at permanent sites
  - Useful for discovering seasonal and long term trends
- Control counts
  - Collected over entire time of a given study (e.g. 1-24 days)
  - Samples specific points of interest, selected appropriately
- Coverage counts
  - Collected for a short time (e.g. 8 hours) at all points of interest

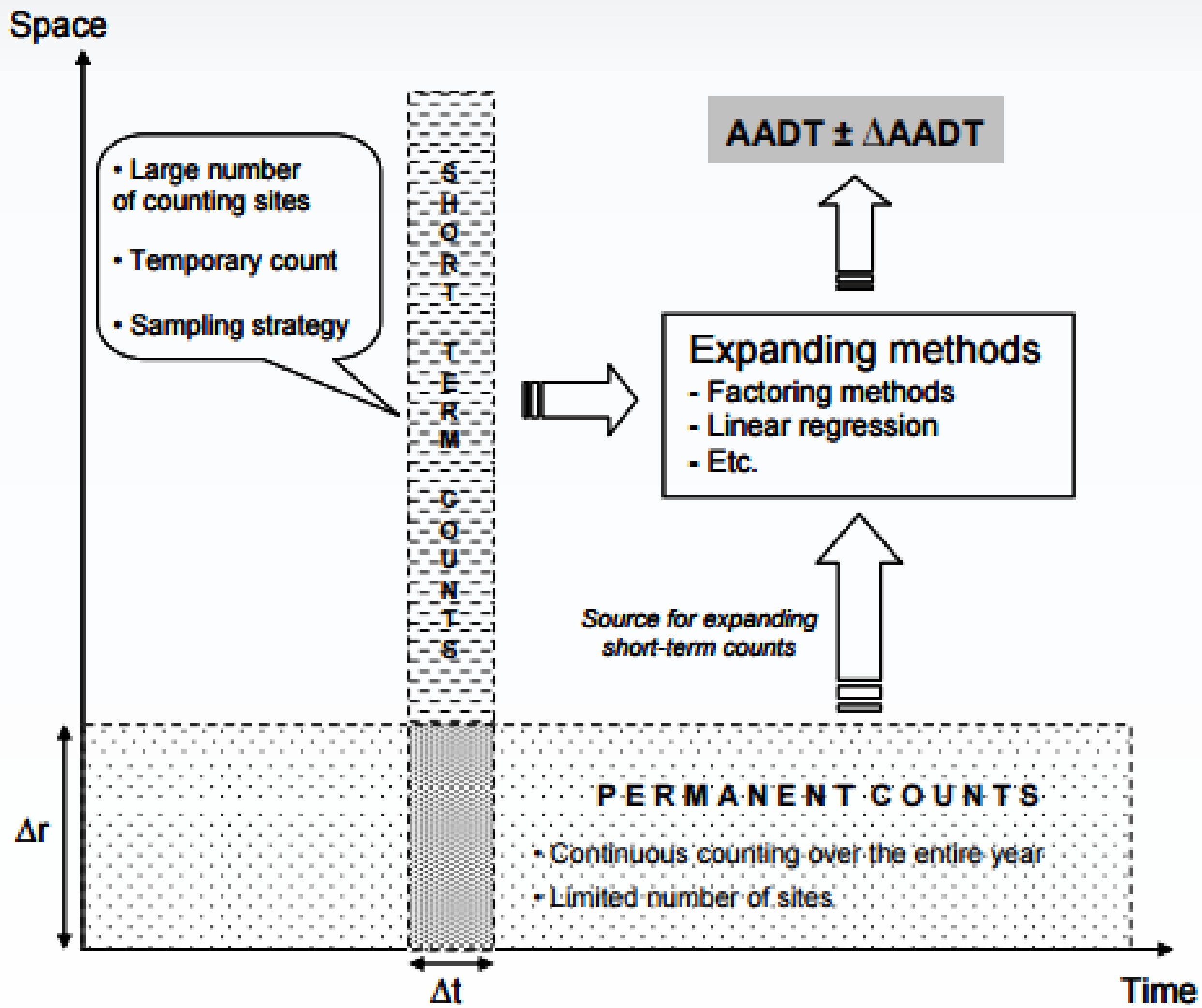


Figure 4: Schematic view of the main procedure for estimating AADT

http://ftp.jrc.es/EURdoc/JRC47967.TN.pdf

Control-site study:

- data

Control-Count Data Location A		Coverage-Count Data		
Time (PM)	Count (vehs)	Location	Time (PM)	Count (vehs)
12–1	825	1	12–1	840
1–2	811	2	1–2	625
2–3	912	3	2–3	600
3-4	975	4	4–5	390
4–5	1,056	5	5–6	1,215
5–6	1,153	6	6–7	1,440
6–7	938			
7–8	397			

Control-site study:

- 8-hour flow

Time (PM)	Count (vehs)	Proportion of 8-Hour Total
12–1	825	825/7,067 = 0.117
1–2	811	811/7,067 = 0.115
2–3	912	912/7,067 = 0.129
3–4	975	975/7,067 = 0.138
4–5	1,056	1,056/7,067 = 0.149
5–6	1,153	1,153/7,067 = 0.163
6–7	938	938/7,067 = 0.133
7–8	397	397/7,067 = 0.056
Total	**7,067**	**1.000**

Control-site study:

- Estimated peak volume

Location	Time (PM)	Count (Vehs)	Estimated 8-Hr Volume (Vehs)	Estimated Peak Hour Volume (Vehs)
1	12–1	840	840/0.117 = 7,179	× 0.163 = 1,170
2	1–2	625	625/0.115 = 5,435	× 0.163 = 886
3	2–3	600	600/0.129 = 4,651	× 0.163 = 758
4	4–5	390	390/0.149 = 2,617	× 0.163 = 427
5	5–6	1,215	1,215/0.163 = 7,454	× 0.163 = 1,215
6	6–7	1,440	1,440/0.133 = 10,827	× 0.163 = 1,765

Coverage-count study:

- data

Contrail-Count Data Location A		Coverage-Count Data		
Day	8-Hour Count (vehs)	Coverage Location	Day	8-Hour Count (Vehs)
Monday 1	7,000	1	Monday 1	6,500
Tuesday	7,700	2	Tuesday	6,200
Wednesday	7,700	3	Wednesday	6,000
Thursday	8,400	4	Thursday	7,100
Friday	7,000	5	Friday	7,800
Monday 2	6,300	6	Monday 2	5,400

(a) Data for a Six-Day Study

Coverage-count:

- Adjustment factors using control data (below)

Day	8-Hour Count (Vehs)	Adjustment Factor
Monday 1	7,000	7,350/7,000 = 1.05
Tuesday	7,700	7,350/7,700 = 0.95
Wednesday	7,700	7,350/7,700 = 0.95
Thursday	8,400	7,350/8,400 = 0.88
Friday	7,000	7,350/7,000 = 1.05
Monday 2	6,300	7,350/6,300 = 1.17
Total	44,100	
Average	44,100/6 = 7,350	

Coverage-count:

- Adjusted 8-hour counts for covered sites

Station	Day	8-Hour Count (Vehs)	Adjusted 8-Hour Count (Vehs)
1	Monday 1	6,500	× 1.05 = 6,825
2	Tuesday	6,200	× 0.95 = 5,890
3	Wednesday	6,000	× 0.95 = 5,700
4	Thursday	7,100	× 0.88 = 6,248
5	Friday	7,800	× 1.05 = 8,190
6	Monday 2	5,400	× 1.17 = 6,318

ESTIMATING AADT

Using a similar approach to control-site traffic volume studies, AADT can be estimated from relatively small traffic counts using expansion factors.

- The general principle is to perform linear interpolation on the counts adjusting for temporal effects at the time t when the counts where performed.

$$Q_{AADT} = \frac{Q_{count}}{Adj_{hour_t} \times Adj_{weekday_t} \times Adj_{month_t}}$$

- Larger counts and appropriate expansion factor selection yields more accurate estimates.
- Check your units! Q_{count} is typically veh/h, Q_{AADT} is veh/day. Average/expand multiple counts as necessary.

For example, $Adj_{weekday_t}$ is the expansion factor that corrects for the day of the week at which counts were made.

$$Adj_{weekday_t} = \frac{Prop.\ of\ flow}{count(t_{weekday})}$$

$$Adj_{weekday_t} = \frac{Prop.\ of\ flow}{7}$$

t	Prop. of flow	$Adj_{weekday_t}$
Sunday	10.11%	0.7077
Monday	14.47%	1.013
Tuesday	15.21%	1.0646
Wednesday	15.40%	1.0779
Thursday	15.91%	1.1138
Friday	16.02%	1.1212
Saturday	12.88%	0.9018

EXAMPLE

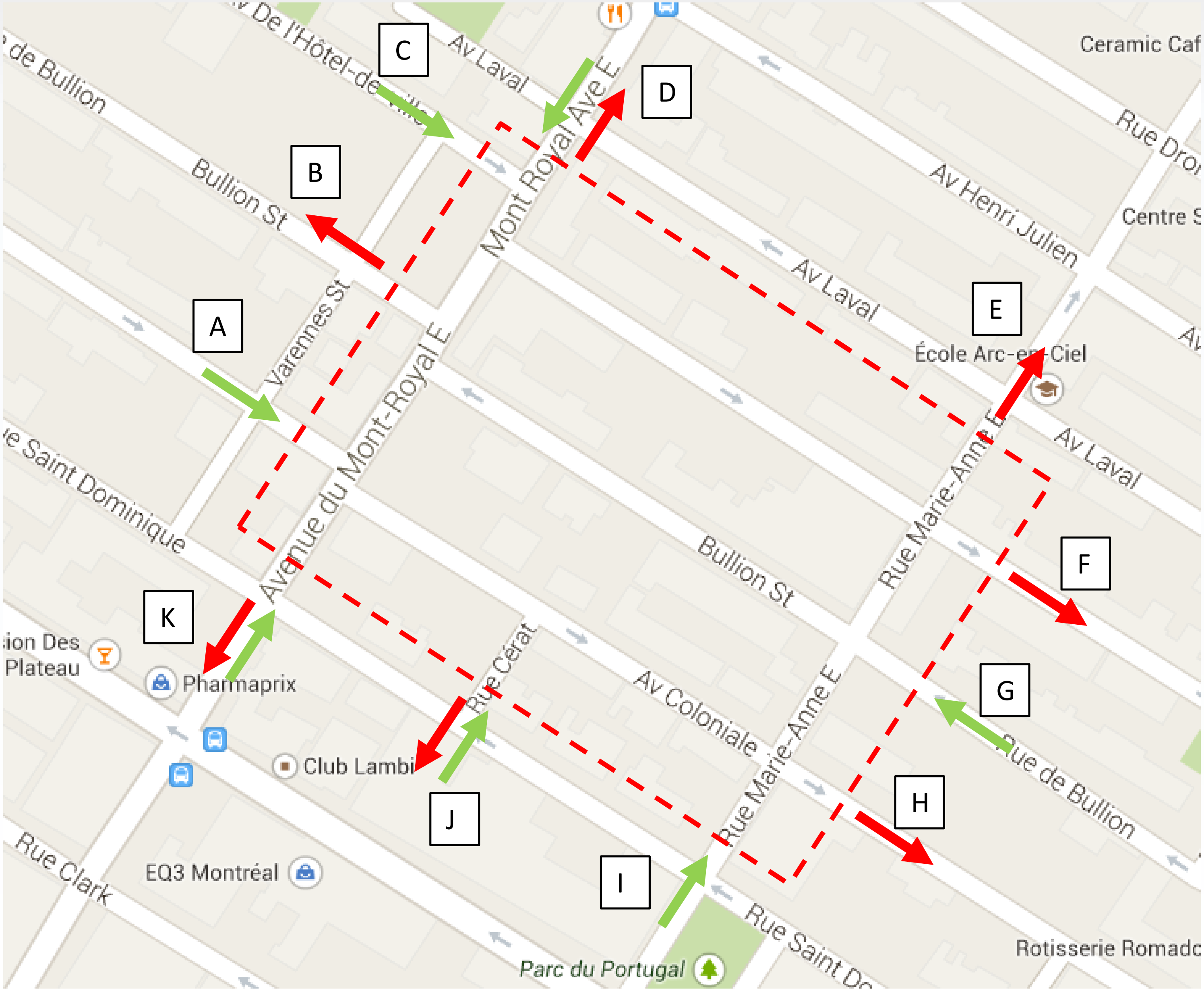
Calculate the AADT from the following traffic counts (nearest hour): 340 veh counted two hours ago and 450 veh counted one hour ago. Use expansion factors from the provided Excel sheet.

TRIP ASSIGNMENT IN A SMALL NETWORK

In a small network, we assume origins and destinations inside the network are not significant and that these trips balance each other out over the course of the study.

Two main options exist:

- Origin-destination matrix between all inflows and outflows
  - Increased study complexity and data collection needs
  - Better results in larger networks
- Inflow counts + turning ratios
  - Simpler and more efficient
  - Trip assignment is not dynamic and does not respond to saturation


A
B
C
D
E
F
G
H
I
J
K
Bullion St
Av Laval
Mont Royal Ave E
Avenue du Mont-Royal E
Varennes St
Rue Saint Dominique
Rue Cérat
Av Coloniale
Rue Marie-Anne E
Av Henri Julien
Rue de Bullion
Rue Clark
École Arc-en-Ciel
Pharmaprix
Club Lambi
EQ3 Montréal
Parc du Portugal
Rotisserie Romado
Ceramic Caf
Centre S
Plateau

ORIGIN-DESTINATION MATRIX

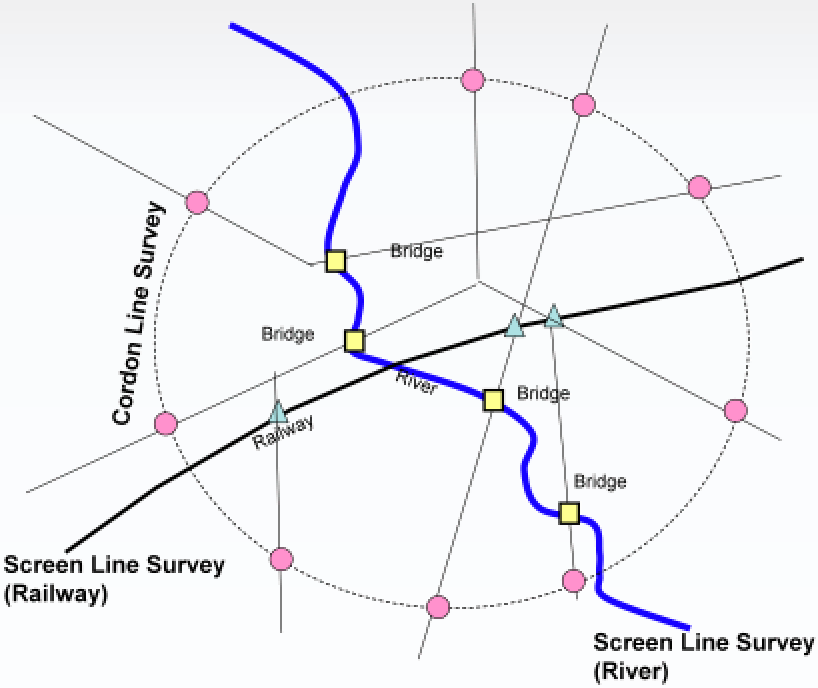
The origin destination matrix (OD-matrix) is a table that lists all trips from one point to another.

Destination

Origin	A	B	…	K
A	-	598	…	372
B	0	-	…	…
…	…	…	…	…
K	0	197	…	-

This topic is covered in greater detail in CIVE 540 - Urban Transportation Planning…

ALTERNATIVE APPROACHES



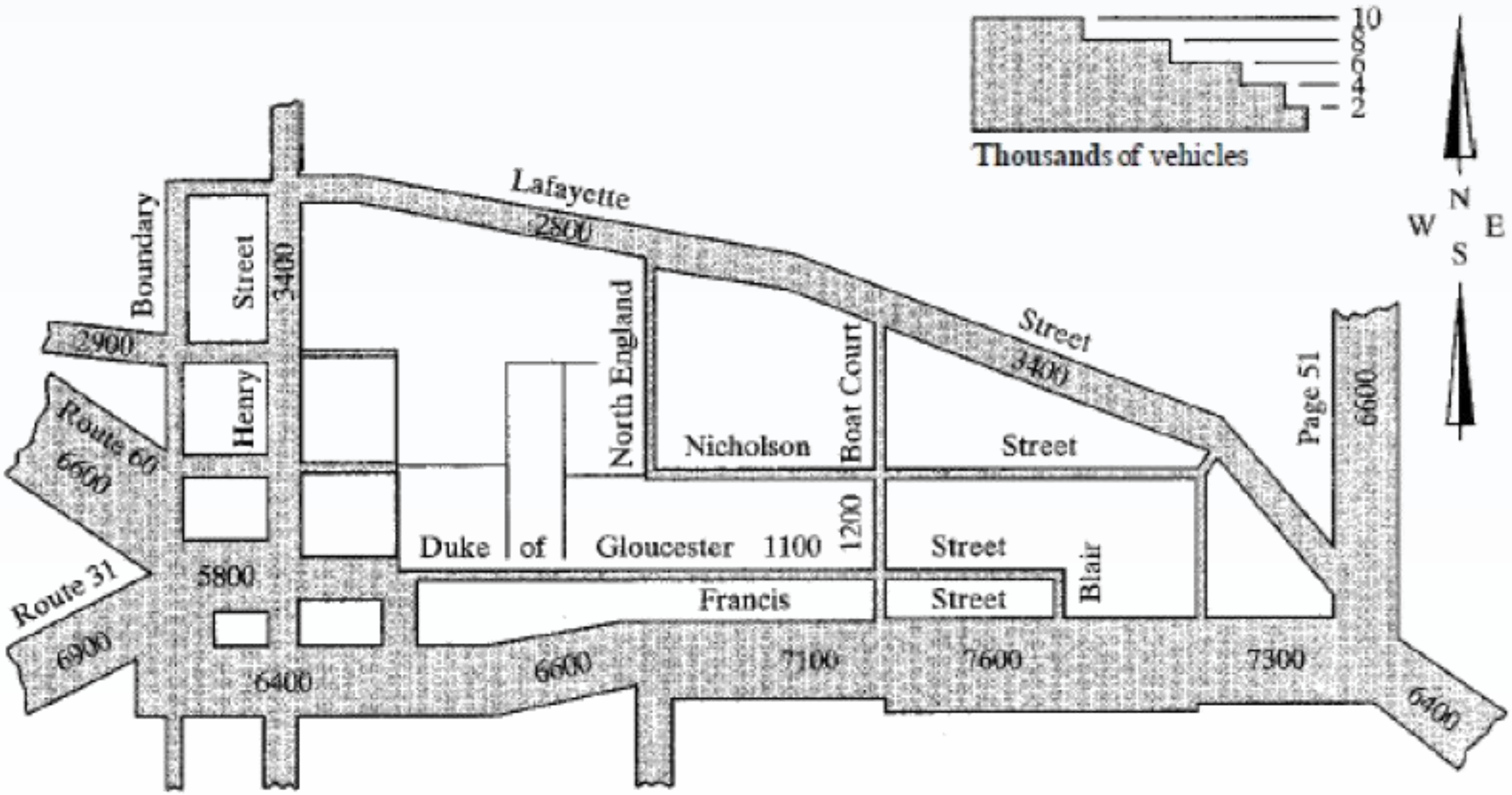
Cordon counts

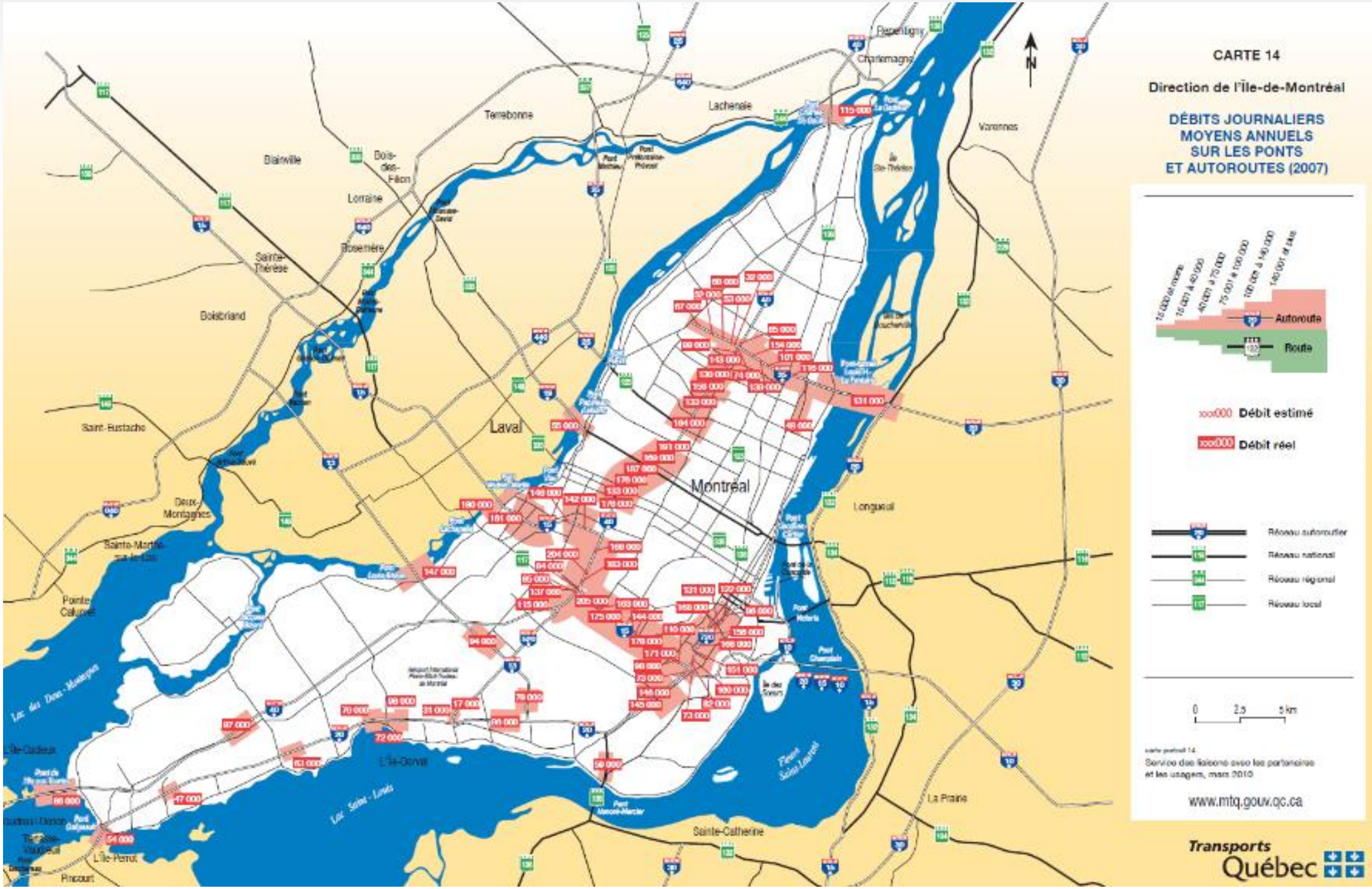
- Imaginary boundary areas

Screen-line

- Divide the region using physical barriers like a river, rail, road etc.
- Counts vehicle crossings over this line

MAP FLOW REPRESENTATION




CARTE 14
Direction de l'Île-de-Montréal
DÉBITS JOURNALIERS MOYENS ANNUELS SUR LES PONTS ET AUTOROUTES (2007)
Autoroute
Route
Débit estimé
Débit réel
Montréal
Laval
Longueuil
Terrebonne
Blainville
Lorraine
Boisbriand
Saint-Eustache
Deux-Montagnes
Lachenale
Varennes
Repentigny
Charlemagne
Sainte-Catherine
La Prairie
L'Île-Perrot
L'Île-Bizard
Pincourt
www.mtq.gouv.qc.ca
Transports Québec

SPEED, TIME AND DELAY STUDIES

Besides capacity, other indicators of performance for traffic facilities include:

- speed
- travel time
- delay

Highway Capacity Manual (HCM):

- Average travel speed is used for arterials and two-lane rural highways
- Control delay is the measure of effectiveness for signalized and STOP-controlled intersections
- Freeways use density as a primary measure, while also measuring speed

SPEED

Specifically free-flow-speed:

- Usually measured under unsaturated conditions
- To assess desirable speed limits or effectiveness of speed limits
  - Posted speed limits play a very small role
  - A large aspect related to desired speed has to do with human psychology…
- Assess safety
  - Stopping-sight-distance
  - Horizontal and vertical curves
  - Exposure to vehicle-vehicle conflicts and vulnerable road users (pedestrians, cyclists)

What speed would you drive at in the following scenario?

What speed would you drive at in the following scenario?

Route 10@ MP 125.3
LOCATION

July 10,2003
DATE

1:00 - 400 PM
TIME

Good - Clear, Dry
WEATHER CONDITIONS

Asphaltic concrete-good.
ROADWAY SURFACE CONDITIONS

SPEED GROUP Lower limit (mph)	SPEED GROUP Upper limit (mph)	TIME GROUP Lower limit (secs)	TIME GROUP Upper limit (secs)	PASSENGER CARS	TRUCKS	OTHER	TOTALS PC	TOTALS Trucks	TOTALS Other	TOTALS Total
30	32									
32	34									
34	36			II	II	I	2	2	1	5
36	38			III	II		3	2	0	5
38	40			卌	I	I	5	1	1	7
40	42			卌 卌	III		10	3	0	13
42	44			卌 卌 卌 III	III		18	3	0	21
44	46			卌 卌 卌 卌 卌 IIII	IIII		29	4	0	33
46	48			卌 卌 卌 卌 卌 卌 卌 卌 卌 II	II	II	42	2	2	46
48	50			卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌 卌	II		60	2	0	62
50	52			卌 卌 卌 卌 卌 卌 卌 II			37	0	0	37
52	54			卌 卌 卌 卌 III			23	1	0	24
54	56			卌 卌 III		I	13	0	1	14
56	58			卌 II	I	I	7	1	1	9
58	60			卌			5	0	0	5
60	62			II			2	0	0	2
62	64									
64	66									
66	68									
68	70									

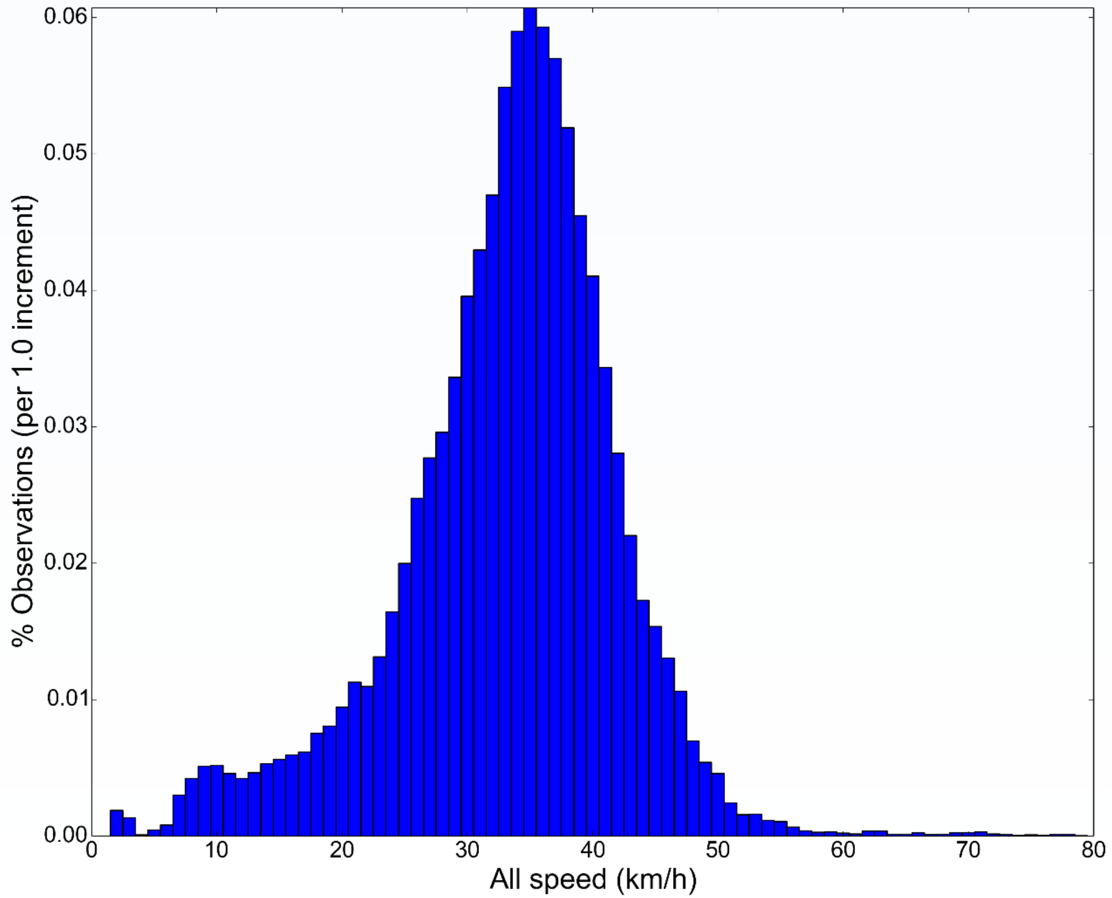
METHOD OF MEASUREMENT
x Radar
___ Time over measured course length of ___ ft
___ Stop watch/manual
___ Road tubes w/timer
___ Electronic contact w/timer

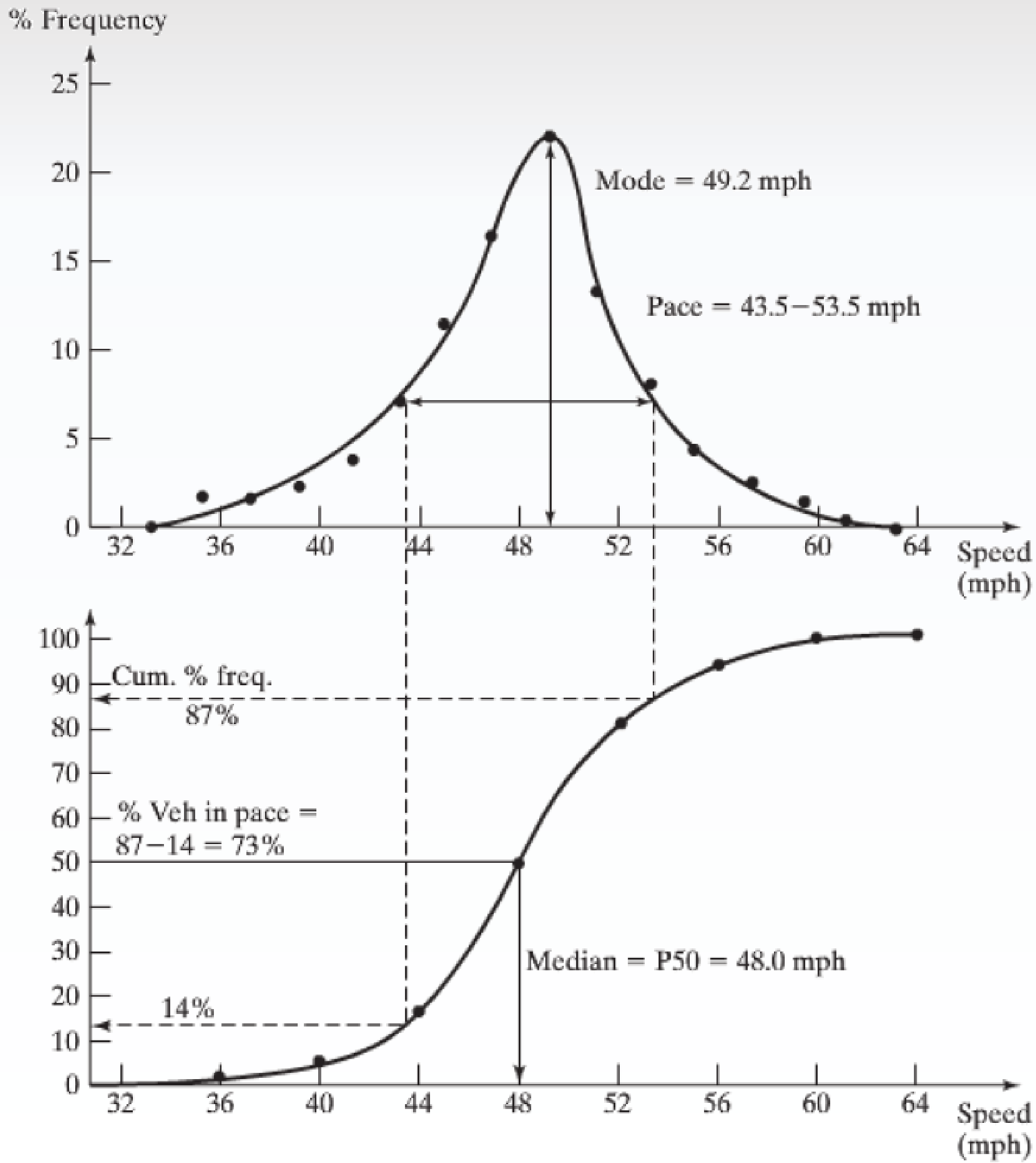
Signature ___ 7/10/03

SPEED VARIATION

Different desired speed limits for different drivers

- Mean
- Median
- Mode
- Std. Deviation
- Percentile
  - 85th percentile typical safety metric
- Dispersion

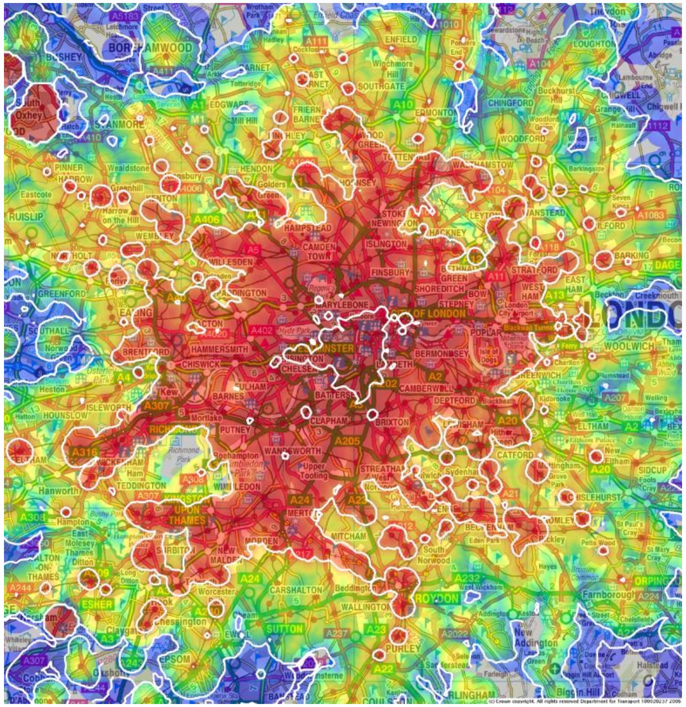



% Frequency
25
20
15
10
5
0
32
36
40
44
48
52
56
60
64
Speed (mph)
Mode = 49.2 mph
Pace = 43.5−53.5 mph
100
90
80
70
60
50
40
30
20
10
0
Cum. % freq.
87%
% Veh in pace =
87−14 = 73%
Median = P50 = 48.0 mph
14%
32
36
40
44
48
52
56
60
64
Speed (mph)

TRAVEL TIME

Purpose:

- To identify locations that result in longer travel times
- Measure arterial level of service
- Input for traffic assignment
- Economic evaluation of transportation improvements
  - $$\sum Reductions\ in\ travel\ time \times opportunity\ cost$$
- To prepare contour maps and depict traffic congestion



Travel time is commonly measured as you'd expect:

- Moving with traffic and recording time from a particular origin to a particular destination.

A few measuring philosophies:

- Floating car technique: you maintain the relative position in the traffic stream (i.e. the no. of cars overtaking you = no. of cars you overtake)
- Maximum car technique: the driver goes at the maximum safe speed (without crossing speed limit)
- Average car technique: the driver is instructed to drive at the average traffic stream speed

- Floating car approach is used in two lane highways where passing is rare (and we can actually count the events)
- Maximum car technique provides you with the lower end of the travel time distribution (typically 85th percentile)
- Some techniques do not provide average travel times (maximum car technique)
- All test cars should follow same technique
- Not too many test cars used (why?)
- Not easy to ensure no. of vehicles you overtake is same as no. of vehicles that overtake you especially in multi lane highways or in urban congestion

Alternative travel time collection technique:

- Recorders collect license plate numberss and timestamp from where they stand
- Then these are matched with different recorders throughout a city
  - Tie-in with origin-destination survey
- This can also be done with Bluetooth and crowdsourcing data collection systems.
- Issues?

Special case:

- If a vantage point permits observation over an entire route, travel times can be observed externally easily.

Table 9.4: A Sample Travel Time Field Sheet

Site: Lincoln Highway *Run No.* 3 *Start Location:* Milepost 15.0

Recorder: William McShane *Date:* Aug 10, 2002 *Start Time:* 5:00 PM

Checkpoint	Cum. Dist. Along Route (mi)	Cum. Trav. Time (min:sec)	Per Section			
			Stopped Delay (s)	No. of stops	Section Travel Time (min:sec)	Special Notes
MP 16	1.0	1:35	0.0	0	1:35	
MP 17	2.0	3:05	0.0	0	1:30	
MP 18	3.0	5:50	42.6	3	2:45	Stops due to signals at: MP17.2 MP17.5 MP18.0
MP 19	4.0	7:50	46.0	4	2:00	Stops due to signal MP18.5 and double-parked cars.
MP 20	5.0	9:03	0.0	0	1:13	
MP 21	6.0	10:45	6.0	1	1:42	Stop due to School bus.
MP 22	7.0	12:00	0.0	0	1:15	
Section Totals	**7.0**		**88.6**	**8**	**12:00**	

REFERENCE SOURCES

- Traffic Engineering by Roger P. Roess, Elena S. Prassas & William R. McShane Prentice Hall, 4th ed., 2011.
- Fundamentals of Traffic Engineering, Homburger et al., 16th edition
- Rail Transportation http://www.tc.gc.ca/eng/railsafety/guideline-rtd10-325.htm
- Mannering, F.L.; Kilareski, W.P. and Washburn, S.S. (2003). *Principles of Highway Engineering and Traffic Analysis*, Fourth Edition. Chapter 5
- http://courses.washington.edu/cee320w/schedule.htm (graphs in slides)

That's all for today!