

VEB1072 Traffic Engineering



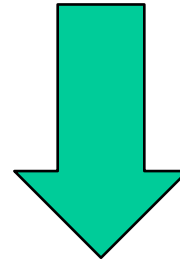
UNIVERSITI TEKNOLOGI PETRONAS

Lecture 3 Traffic Engineering Studies



Traffic Engineering Studies

Able to acquire, produce and apply the fundamental of traffic flow in solving complex traffic related problems. (CLO1)



Apply knowledge of mathematics, natural science, engineering fundamentals and an engineering specialisation as specified in WK1 to WK4 respectively to the solution of complex engineering problems. (PLO1)



Traffic Engineering Studies

LEARNING OUTCOMES

- Able to propose method of traffic data collection. (C6)
- Able to deduce and analyse traffic data. (C4)
- Able to present traffic data. (C4)



Traffic Characteristics

- Speed
- Volume
- Density



Traffic Studies



Common Traffic Studies

- Inventories Studies
- Administrative Studies
- Dynamic Studies



Dynamic Studies

- Speed
- Traffic Volume
- Travel Time and Delay
- Parking
- Accident



Speed Studies

- Spot Speed
- Journey Speed
- Running Speed



Speed Studies (Outcomes)

- Able to determine when and where to conduct spot speed study (An)
- Able to collect spot speed data (A)
- Able to reduce the collected data (An)
- Able to compare mean speeds (An)
- Able to present spot speed data (An)



Collection of Spot Speeds

- Collect during time period representative of desired outcome
- Usually cannot collect all vehicles
- Random sample



Collection of Spot Speeds

- Systematic Errors and Solutions
 - Error – looking for “fastest” vehicle
 - Solution – Sample every n^{th} vehicle
 - Error – too many heavy vehicle measurements
 - Solution – same as above – sample every n^{th} vehicle
 - Error – Inclusion of vehicle following platoon leader
 - Solution – Don’t include vehicles following too closely (60 m if < 65 kph, and 107 m otherwise) (200’ if < 40 mph, and 350’ otherwise)



Location, Time of Day and Duration

The objective and scope of the study dictate these.

Basic data collection	Like deciding speed limits Find locations where system characteristics change TWTh.
Speed trend analysis	Avoid external influences such as traffic lights, busy access roads. Mid blocks of streets, straight, level sections of highways. Off-peak, TWTh. 
Specific traffic engineering problems	All other specific purposes. Conduct at location of interest and time of day.

At least 1 hour and at least 30 data (if want to assume normal distribution)



Spot Speeds Collection Methods

1. Radar gun (meter)
2. Stopwatch
3. Pneumatic Road Tubes





Descriptive Statistics of Speed Data

Once data are collected, the first thing to do is to compute several descriptive statistics to get some ideas about the distribution of the speed data. (note that many statistical analyses used in traffic engineering assume data are normally distributed. So the goal is to check whether they are really normally distributed).

Typical descriptive statistics are:

- Average speed
- Variance and standard deviation
- Median speed
- Modal speed (or Modal speed range)
- The n^{th} percentile spot speed
- Pace. Usually a 10-kph interval that has the greatest number of observations.



Descriptive Statistics of Speed Data

	Data Grouped	Data Not Grouped
Average Speed	$u = \frac{\sum f_i u_i}{\sum f_i}$	$u = \sum \frac{u_j}{N}$
Standard Deviation	$s = \sqrt{\frac{\sum f(u_i - \bar{u})^2}{N - 1}}$	$s = \sqrt{\frac{\sum (u_j - \bar{u})^2}{N - 1}}$
Variance	S^2	

Average speed = arithmetic mean of all observed speeds

f_i = number of observation in each speed group

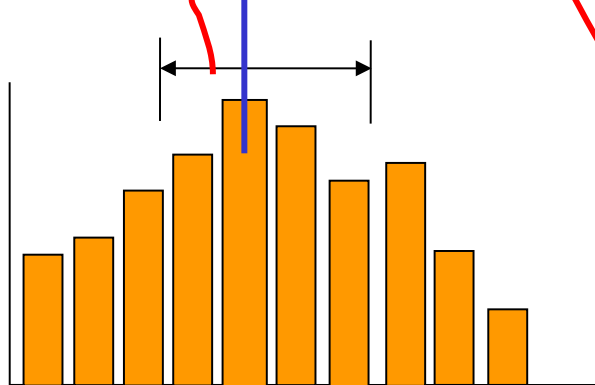
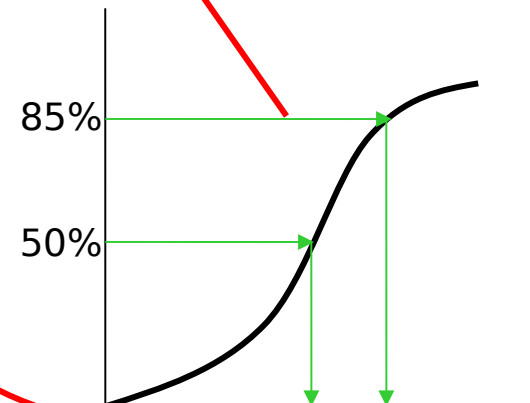
u_i = midvalue for the i^{th} speed group

N = number of observed values



Descriptive Statistics of Speed Data

Median Speed	The speed at the middle value in a series of spot speeds. Or 50 th -percentile speed
Modal Speed	The speed value that occurs most frequently in a sample of speeds
i th -percentile Speed	The spot speed below which i-percent of the vehicle travel, e.g. 85 th -percentile speed
Pace	The range of speed that has the greatest number of observations; usually 10-mph range





Presentation of Spot Speed Data

Vehicle	Speed (mph)
1	61
2	29
3	30
4	42
5	45
6	55
7	61
8	31
9	52
10	47
11	43
12	54
13	59
14	34
15	39
16	44

Raw Data for 16 vehicles

Data for 185 Vehicles		
Range (mph)	Midpoint (mph)	Vehicles
0 to 5	2.5	0
> 5 and <= 10	7.5	0
>10 and <= 15	12.5	0
>15 and <= 20	17.5	0
> 20 and <=25	22.5	0
> 25 and <= 30	27.5	1
> 30 and <= 35	32.5	10
> 35 and <= 40	37.5	6
> 40 and <=45	42.5	41
>45 and <=50	47.5	51
>50 and <= 55	52.5	53
>55 and <= 60	57.5	21
>60 and <=65	62.5	3
>65 and <70	67.5	0

Data for 185 Vehicles by 5 mph range



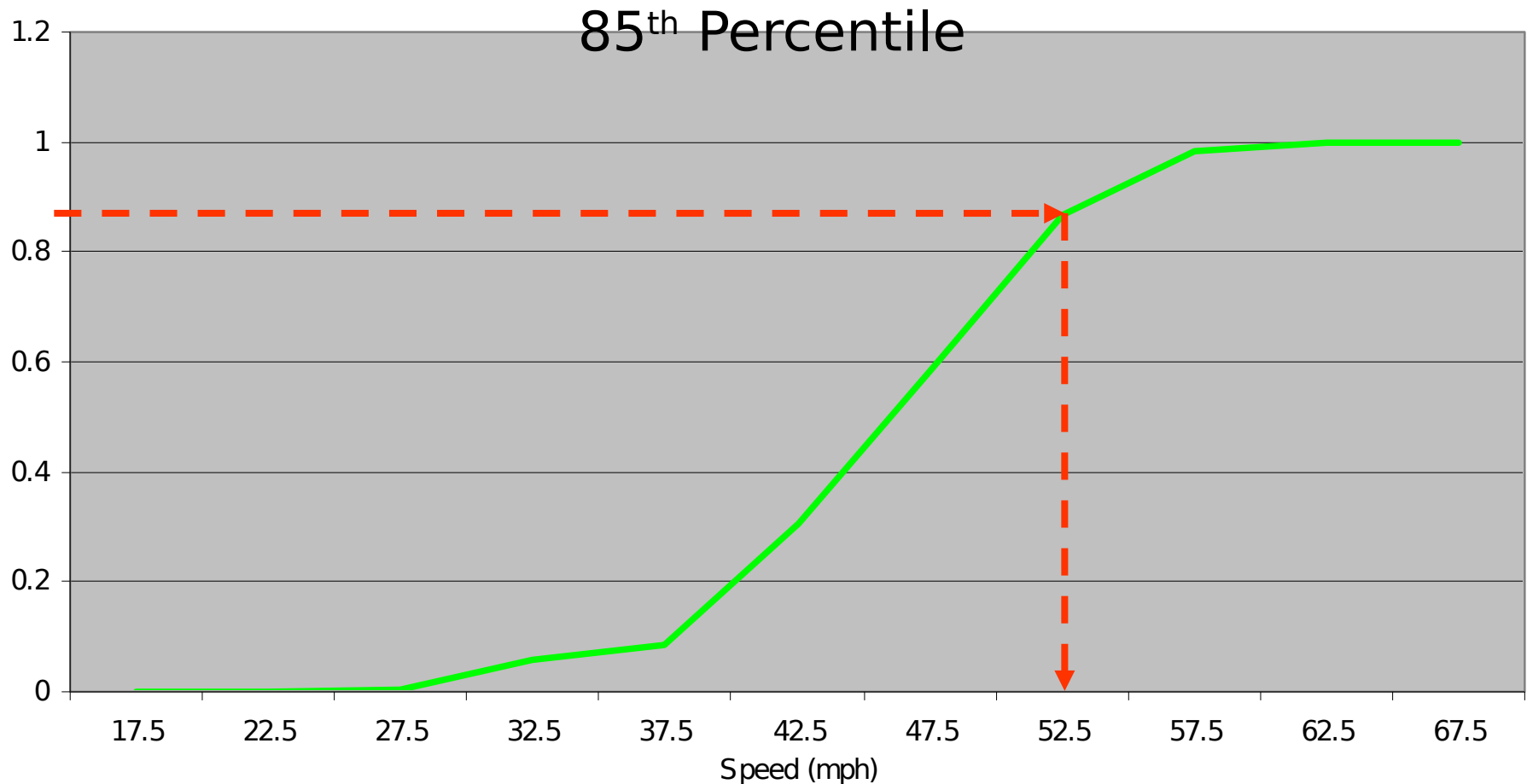
Frequency Distribution Table for Spot Speed

Data for 185 Vehicles				
Range (mph)	Midpoint (mph)	Vehicles	Percent	Cummulative
0 to 5	2.5	0	0%	0
> 5 and <= 10	7.5	0	0%	0%
>10 and <= 15	12.5	0	0%	0%
>15 and <= 20	17.5	0	0%	0%
> 20 and <=25	22.5	0	0%	0%
> 25 and <= 30	27.5	1	0%	0%
> 30 and <= 35	32.5	10	5%	6%
> 35 and <= 40	37.5	6	3%	9%
> 40 and <=45	42.5	41	22%	31%
>45 and <=50	47.5	51	28%	58%
>50 and <= 55	52.5	53	29%	87%
>55 and <= 60	57.5	21	11%	98%
>60 and <=65	62.5	3	2%	100%
>65 and <70	67.5	0	0%	100%



Spot Speed Study

Cumulative Distribution Table for Spot Speed Data

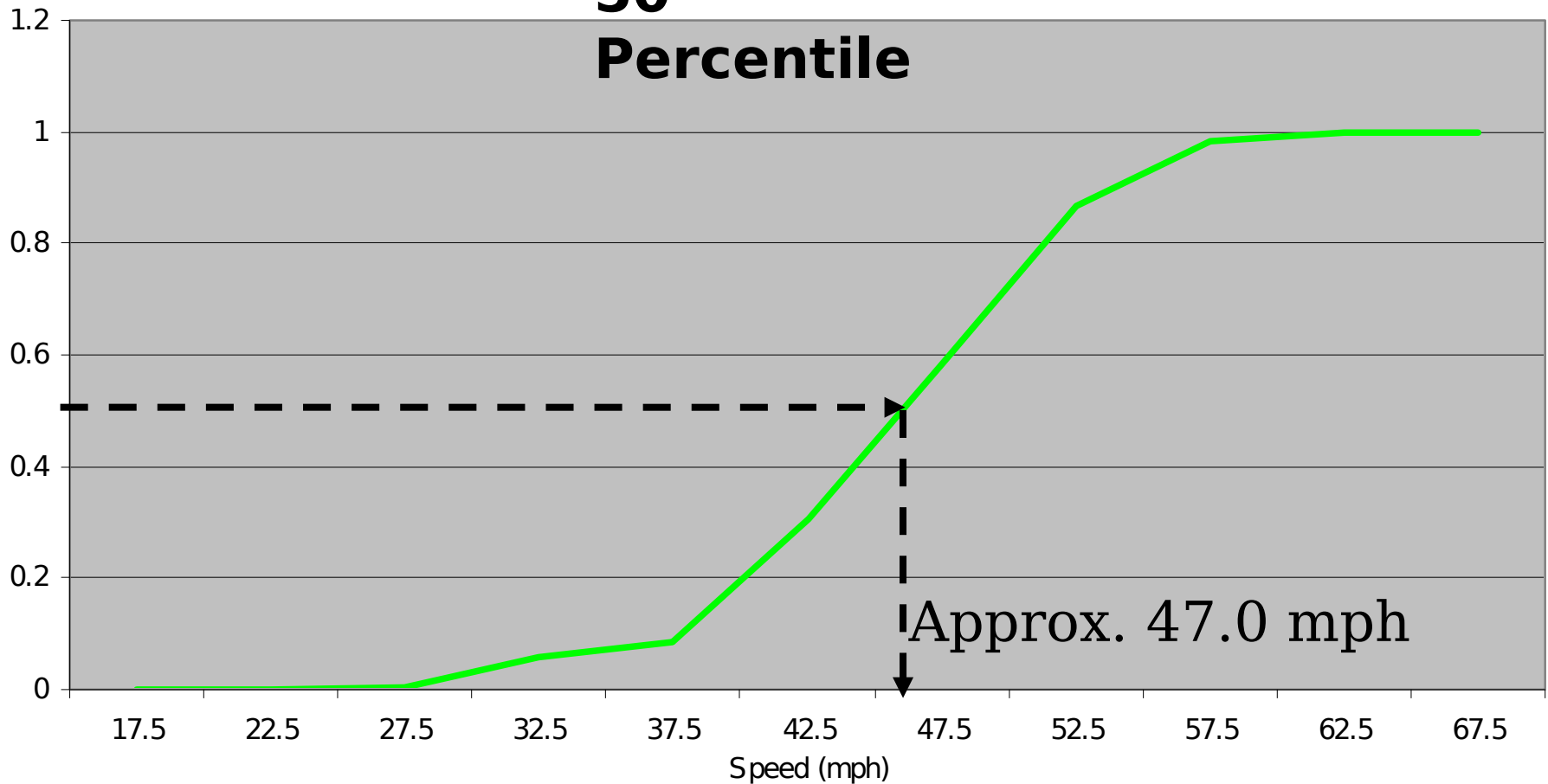




Spot Speed Study

Median Speed: 50% traveling above and 50% traveling below

**50th
Percentile**





Spot Speed Study

Pace: range in which most vehicles are found (i.e. 10 mph hour range)

Data for 185 Vehicles						
Range (mph)	Midpoint	Vehicles				
0 to 5	2.5	0				
> 5 and ≤ 10	7.5	0				
> 10 and ≤ 15	12.5	0				
> 15 and ≤ 20	17.5	0				
> 20 and ≤ 25	22.5	0				
> 25 and ≤ 30	27.5	1	11 veh			
> 30 and ≤ 35	32.5	10		16 veh		
> 35 and ≤ 40	37.5	6			56 veh	
> 40 and ≤ 45	42.5	41				97 veh
> 45 and ≤ 50	47.5	51	145 veh			
> 50 and ≤ 55	52.5	53		125 veh		
> 55 and ≤ 60	57.5	21			77 veh	
> 60 and ≤ 65	62.5	3				
> 65 and < 70	67.5	0				
		185				

Pace is 42.5 to 52.5 mph



Sample Size

Need to know a bit of statistical principles here...

It is based on the normal distribution curve.

$$N = \left(\frac{Z\sigma}{d} \right)^2$$

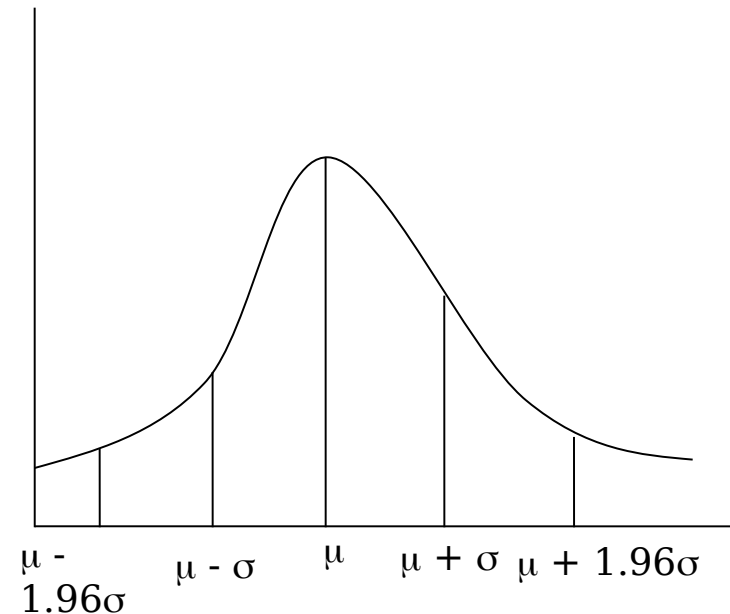
N = minimum sample size

Z = number of standard deviation for confidence level

(see Table 4.1)

σ = standard deviation (kph)

d = limit of acceptable error in average speed estimate (precision level)



At 95% confidence level, Z = 1.96



Number of Standard Deviation (Z)

Confidence Level (%)	Constant (Z)
68.3	1.00
86.6	1.50
90.0	1.64
95.0	1.96
95.5	2.00
98.8	2.50
99.0	2.58
99.7	3.00



Comparison of Means

$$S_d = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}$$

n_1 = sample size for study 1

n_2 = sample size for study 2

S_d = square root of the variance of the difference in means

S_1^2 = variance about the mean for study 1

S_2^2 = variance about the mean for study 2



Example : Calculating if Action Helped to Reduce Speed

- Speeds are collected before and after the use of a speed display monitor on an arterial street. Did the monitor have a significant impact on slowing down traffic.

- Data

	Before	After
Ave. Speed	62.5	59.6
Std. Dev	8.4	12.6
Num.	850	850



- Apply statistical test
 - Null hypothesis – no difference

between two speeds



Statistical Test

- Standard deviation of the means

$$S_d = \sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}$$

$$S_d = \sqrt{\frac{8.4^2}{850} + \frac{126^2}{850}} = 0.52$$

$$62.5 - 59.6 = 2.9 \text{ kph}$$

$$1.96 * 0.52 = 1.02 < 2.9$$

They are statically different – is this significant?



Dynamic Studies

- Speed
- Traffic Volume
- Travel Time and Delay
- Parking
- Accident



Volume Studies (Outcomes)

- Able to explain various types of volume count (C)
- Able to present volume count data (A)
- Able to determine the number of count stations (A)
- Able to adjust periodic counts (An)



Volume Studies

- Measure traffic (vehicles, pedestrian) volumes at one or more locations during specific time period.



Terminology

- **Average Annual Daily Traffic (AADT)**
The average of 24-hour counts collected every day in the year.
- **Average Daily Traffic (ADT)**
The average of 24-hour counts collected over a number of days greater than 1 but less than a year.
- **Peak Hour Volume (PHV)**
The maximum number of vehicles that pass a point on a highway during a period of 60 consecutive minutes.
- **Vehicle Classification (VC)**
Records volume with respect to the types of vehicles.
- **Vehicle Miles/Kilometers of Travel (VMT, VKT)**
A measure of travel along a section of road. A product of roadway in miles or kilometers to which the volume is applicable.
- **Hourly Flow Rate**
An hourly volume expanded from a count taken in a period shorter than 60 minutes. Typical one is peak hourly flow rate which is 4 times the peak 15-minute count.



Average Annual Daily Traffic (AADT)

- Estimation of highway user revenues
- Computation of accident rates in terms of accident per 100 million vehicle-kilometers
- Establishment of traffic volume trends
- Evaluation of the economic feasibility of highway projects
- Development of freeway and major arterial street systems
- Development of improvement and maintenance programs



Average Daily Traffic (ADT)

- Planning of highway activities
- Measurement of current demand
- Evaluation of existing traffic flow



Peak Hour Volume (PHV)

- Functional classification of highway
- Design of the geometric characteristics of a highway such as number of lanes, intersection signalization or channelization
- Capacity analysis
- Development of programs related to traffic operations such as one-way street systems or traffic routing
- Development of parking regulation



Vehicle Classification (VC)

- Design of geometric characteristics, two-axle trucks or three-axle trucks. VC is used in requirements of maximum grades, lane widths, etc.
- Capacity analysis with respect to passenger car equivalents or trucks
- Adjustment of traffic count obtained by machines
- Structural design of highway pavements, bridges, etc.



VEHICLE CLASSIFICATION

CLASS	VEHICLE TYPE
Motorcars , Taxis & Small MPV's <div>1</div>	 Small MPV's :- Proton Ixora, Proton Alza, Honda Stream, Toyota Wish, Naza Ria, etc.
Small Vans, Big MPV's & Utilities (Light 2 axles) <div>2</div>	 Big MPV's :- Toyota Alphard/Vellfire, etc.
Lorries & Large Vans (Heavy 2 axles) <div>3</div>	 Large Vans :- 12 Seater and Above
Lorries with 3 axles (Heavy 3 axles and above) <div>4</div>	
Buses <div>5</div>	
Motorcycles & Scooters <div>6</div>	 Including 3 Wheel Motorcycle



Vehicle Kilometers of Travel (VKT, VMT)

- Used mainly as a base for allocating resources for maintenance and improvement of highways.



Volume Count Methods

- **Manual Method**
 - Labor-intensive and expensive
 - Subject to limitations of human factors
 - Cannot be used for long periods of counting

- **Automatic Method**
 - Junior Counter (Golden River Traffic)
 - Marksman 400 (Golden River Traffic)
 - Hi-Star NC-90A (Nu-metrics)



Types of Volume Counts

Cordon counts	When vehicle accumulation within an area is needed
Screen line counts	When changes in traffic flow from one area to another is needed
Intersection counts	When turning movements are needed
Pedestrian volume counts	When pedestrian demand is needed
Periodic volume counts	When traffic volume characteristics are needed : Continuous, control, and coverage counts



Periodic Volume Counts

➤ Continuous or Permanent Counts

- these counts are carried out continuously by using mechanical counters

➤ Control counts

- these counts are taken at a strategically located stations to estimate seasonal and monthly variations of traffic

➤ Coverage Counts

- these counts are used to estimate ADT using expansion factors developed from control counts

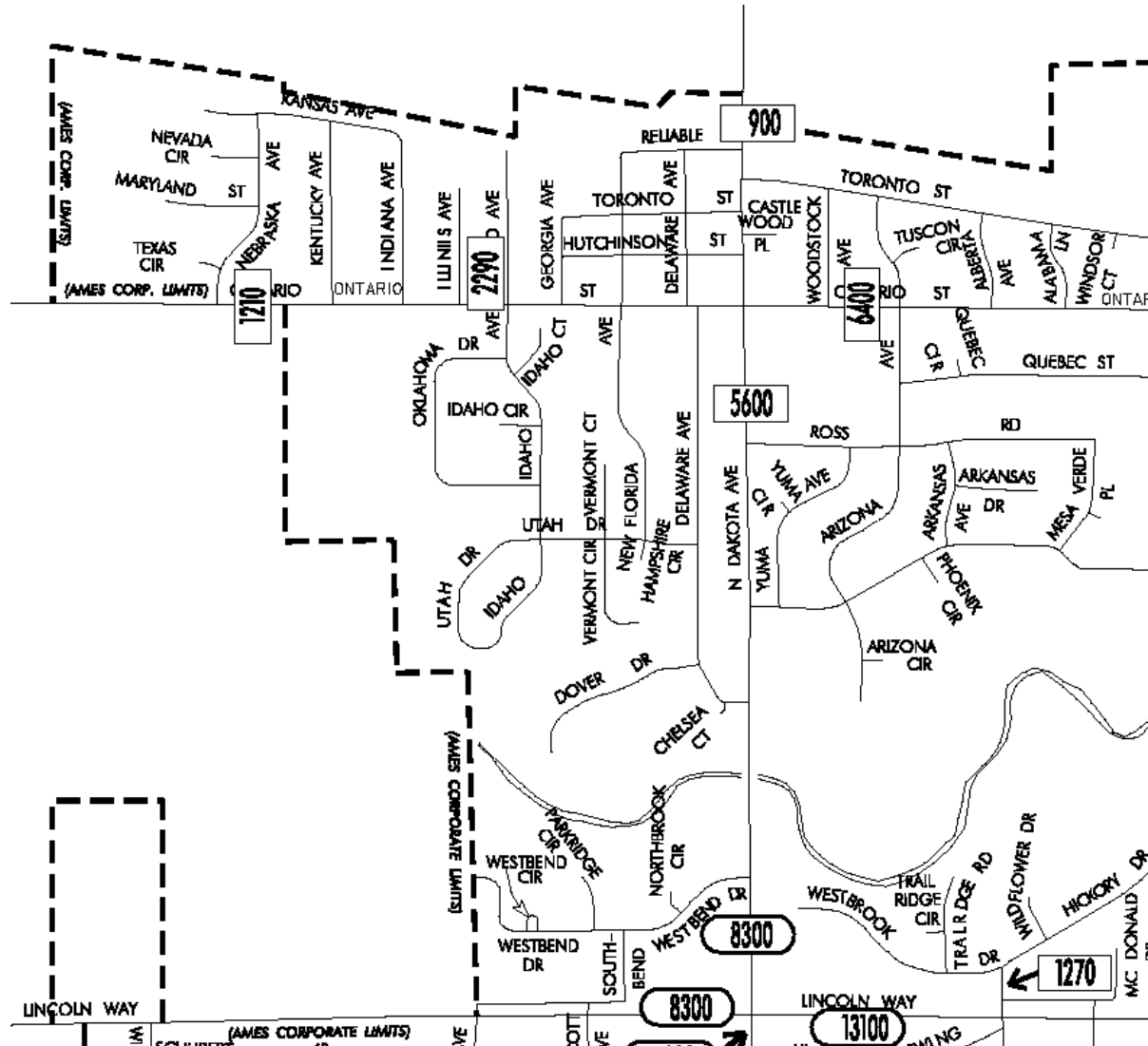


Traffic Volume Data Presentation

- Traffic Flow Maps
- Intersection Summary Sheets
- Time-Based Distribution Charts
- Summary Tables



Traffic Count Map

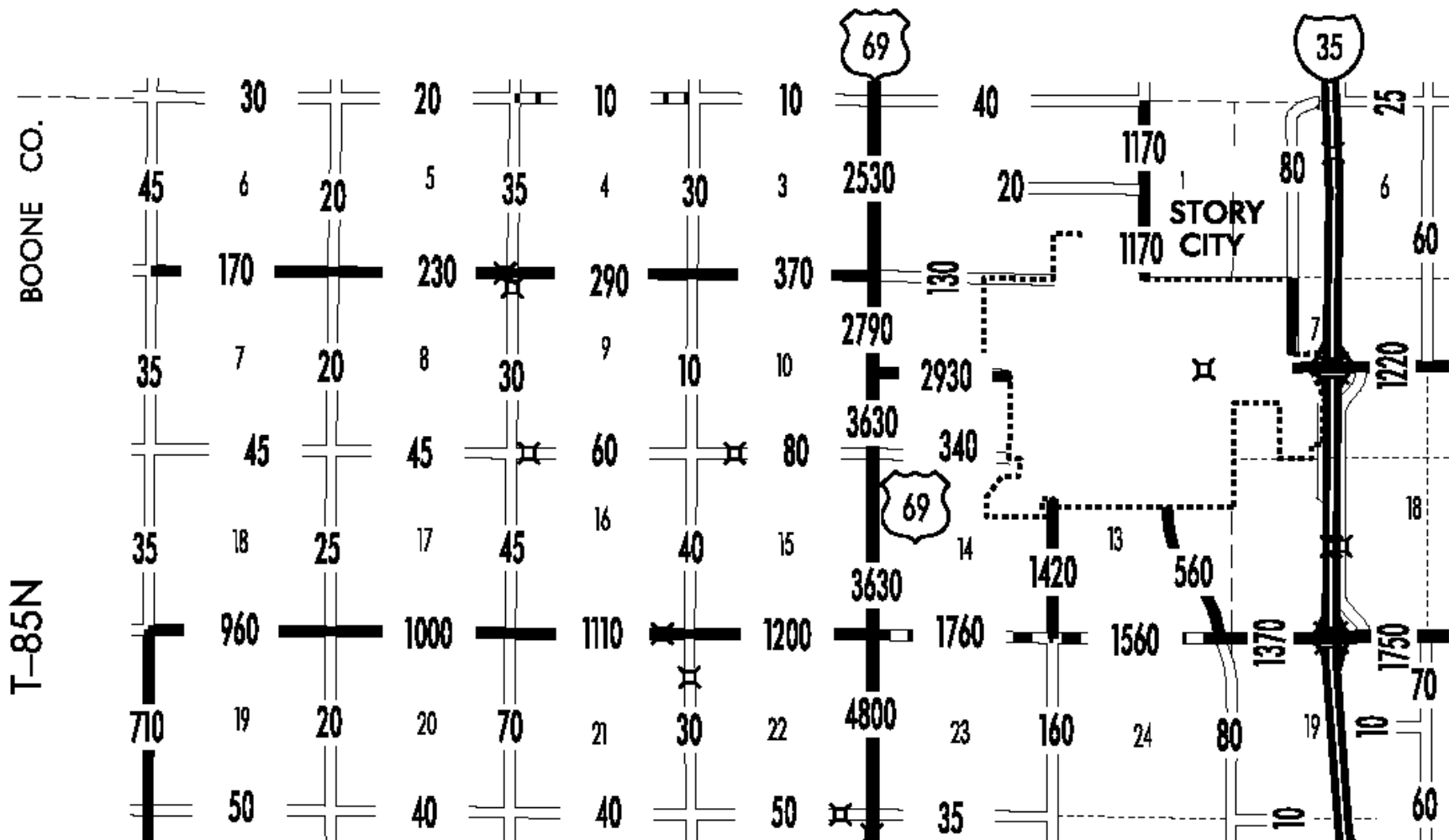




Traffic Flow Map

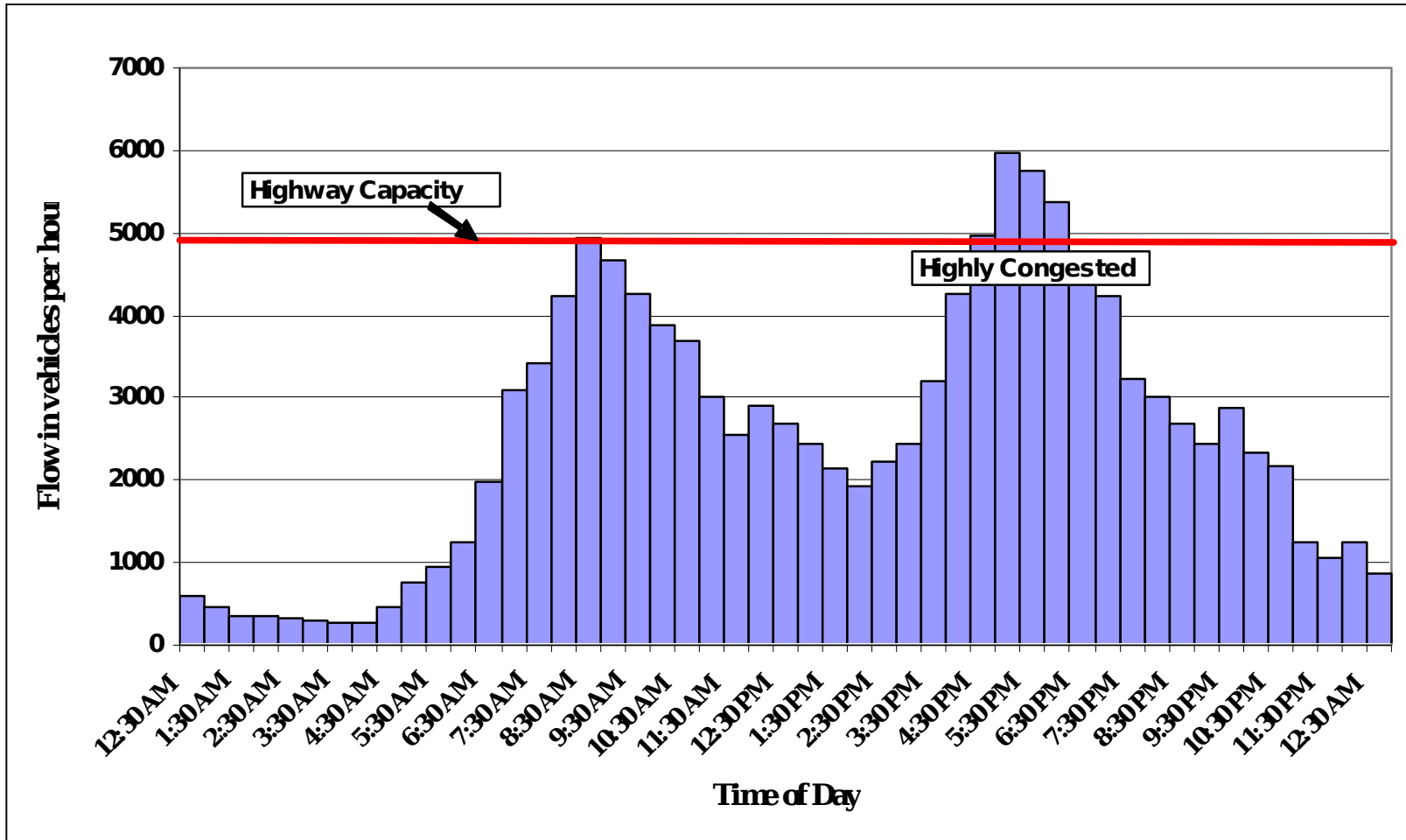
HAMILTON CO.

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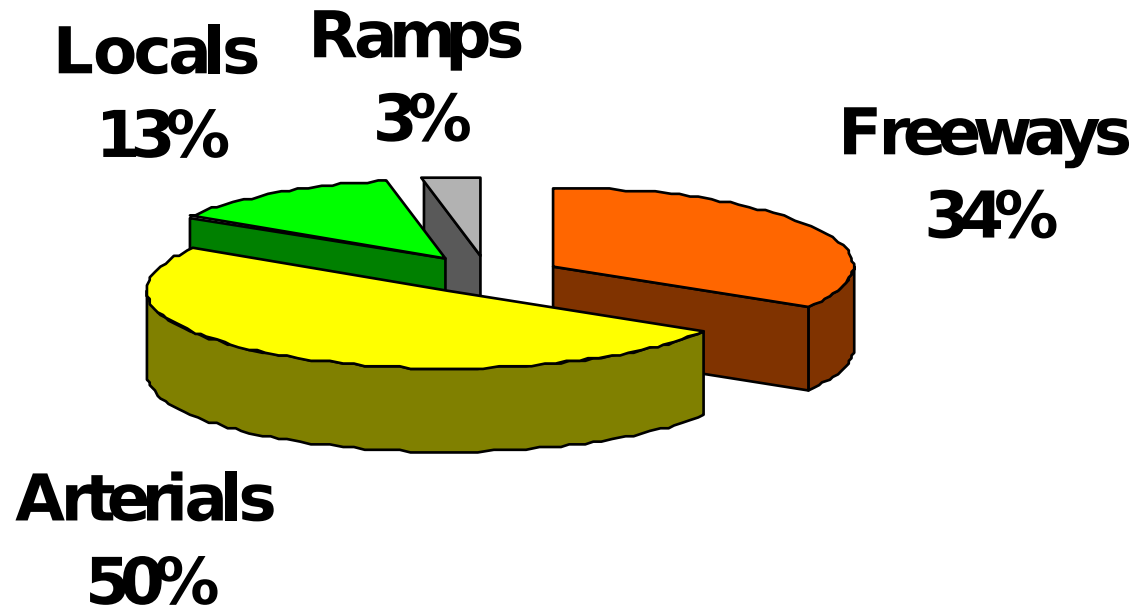


Time-Based Distribution Charts





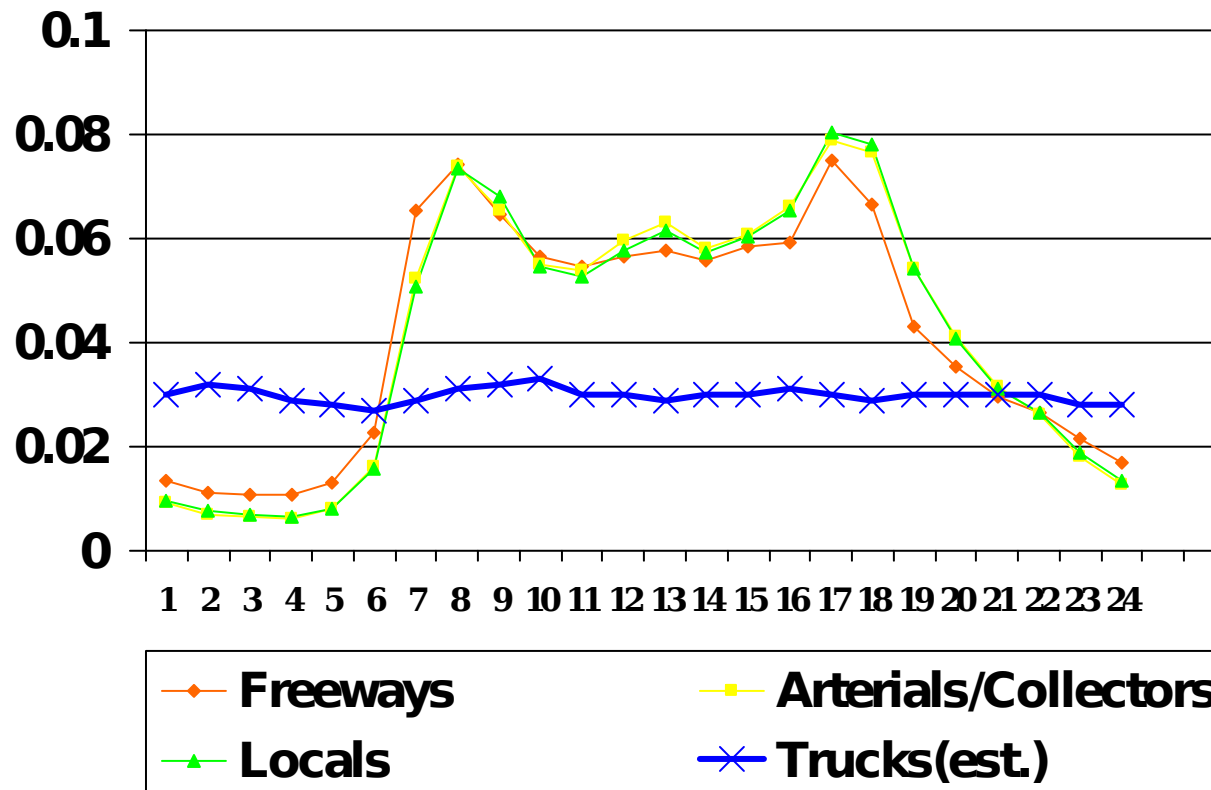
Default VMT(VKT) Distribution



Source: Everett, 2000



Hourly Distribution of VMT(VKT)



Source: Everett, 2000



Traffic Counting

- Most basic measurement unit in traffic engineering is counting
- Count provides estimates of:
 - Volume and flow rate
 - Demand
 - Capacity
- **Volume:**
 - number of vehicles, pedestrians, etc. passing a point during a specific period of time
 - for vehicles, usually expressed as veh/hour (vph) or veh/hour/lane (vphpl)



Traffic Counting

- **Demand:**
 - number of vehicles, pedestrians, etc. that desire to travel past a point during a specific period
 - Frequently higher than volume during certain peak times
 - Trips are diverted or not made when there are constraints in the system
- **Capacity:**
 - maximum number of vehicles that can pass a point during a specific period of time
 - A characteristic of the roadway or facility



Characteristics of Traffic Flow

- Highly variable
 - Time of day
 - Day of week
 - Season
 - Road characteristics
 - Direction



Determination of Number of Count Station

Common precision level
for volume counts : 95
– 5

Which means 95% confidence level and the precision level (tolerance) expressed as 5% of the estimated mean volume.



Determination of Number of Count Station

$$n = \frac{t_{\alpha/2, N-1}^2 (S^2 / d^2)}{1 + (1/N)(t_{\alpha/2, N-1}^2)(S^2 / d^2)}$$

Where,

n = minimum number of count location required

t = value of the student's t distribution with $(1-\alpha/2)$ confidence level ($N-1$ degree of freedom)

N = total number of links (population) from which a sample is to be selected

α = significance level

S = estimate of the spatial standard deviation of the link volumes

d = allowable range of error



Adjustment of Periodic Counts

- Hourly Expansion Factor (HEF)
- Daily Expansion Factor (DEF)
- Monthly Expansion Factor (MEF)

From continuous count stations.



Expansion Factors

- Ratios developed from data for continuous and control counters and used to estimate ADTs, AADTs, and PHVs from coverage counts at similar locations



Hourly Expansion Factor (HEF)

$$HEF = \frac{\text{Total volume for 24-hr period}}{\text{Volume for particular hour}}$$

Are use to expand counts of durations shorter than 24 hours to 24-hour volume by multiplying the hourly volume for each hour during the count period by HEF for that hour and finding the mean of these products.



Daily Expansion Factor (DEF)

$$DEF = \frac{\text{Average total volume for week}}{\text{Average volume for particular day}}$$

Are used to determine weekly volume from counts of 24-hr duration by multiplying the 24-hr volume by the DEF



Monthly Expansion Factor (MEF)

$$MEF = \frac{AADT}{ADT \text{ for particular month}}$$

The AADT for a given year may be obtained from the ADT for a given month by multiplying this volume by the MEF



HEF for a Rural Primary Road (example)

Hour	Volume	HEF	Hour	Volume	HEF
0600-	294	42.00	1800-	743	16.62
0700	426	29.00	1900	706	17.49
0700-	560	22.05	1900-	606	20.38
0800	657	18.80	2000	489	25.26
0800-	722	17.10	2000-	396	31.19
0900	667	18.52	2100	360	34.31
0900-	660	18.71	2100-	241	51.24
1000	739	16.71	2200	150	82.33
1000-	832	14.84	2200-	100	123.50
1100	836	14.77	2300	90	137.22
1100-	961	12.85	2300-	86	143.60
1200	892	13.85	0000	137	90.14
1200-			0000-		
1300			0100		
1300-			0100-		
1400			0200		
1400-			0200-		
1500			0300		

total daily volume =
12,350



DEF for a Rural Primary Road (example)

Day of Week	Volume	
Sunday	7,895	
Monday	10,714	
Tuesday	9,722	
Wednesday	11,413	
Thursday	10,714	
Friday	13,125	
Saturday	11,539	

*Total weekly volume =
75,122*



DEF for a Rural Primary Road (example)

Day of Week	Volume	DEF
Sunday	7,895	9.515
Monday	10,714	7.012
Tuesday	9,722	7.727
Wednesday	11,413	6.582
Thursday	10,714	7.012
Friday	13,125	5.724
Saturday	11,539	6.510

*Total weekly volume =
75,122*



MEF for a Rural Primary Road (example)

Month	ADT	
January	1350	
February	1200	
March	1450	
April	1600	
May	1700	
June	2500	
July	4100	
August	4550	
September	3750	
October	2500	
November	2000	
December	1750	

*Total yearly ADT volume =
28,450*

*Mean average daily volume =
2370*



MEF for a Rural Primary Road (example)

Month	ADT	MEF
January	1350	1.756
February	1200	1.975
March	1450	1.635
April	1600	1.481
May	1700	1.394
June	2500	0.948
July	4100	0.578
August	4550	0.521
September	3750	0.632
October	2500	0.948
November	2000	1.185
December	1750	1.354

*Total yearly ADT volume =
28,450*

*Mean average daily volume =
2370*





Dynamic Studies

- Speed
- Traffic Volume
- Travel Time and Delay
- Parking
- Accident



Travel Time & Delay Studies (Outcomes)

- Able to collect data for travel time and delay studies (A)
- Able to evaluate types of travel time studies (E)



Travel Time and Delay (what?)

- Studies to estimate the average running times (and delays) of vehicle through a road section



- Indicate the level of service
- Identify problem locations



The Use of Travel Time and Delay Studies

- Identify problem locations
- Specifically looks at delay
- Measure Level Of Service (LOS)
- Input to traffic assignment models
- Economic analysis of reduced travel time
- Measure of congestion
- Before and after studies to assess improvements



Definition of Terms

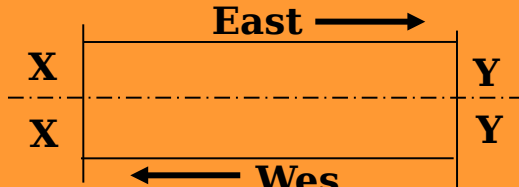
Travel time	The time taken by a vehicle to traverse a given section of a highway
Running time	The time a vehicle is actually in motion while traversing a given section of a highway
Delay	The time lost by a vehicle due to causes beyond the control of the driver
Operational delay	That part of the delay caused by the impedance of other traffic
Stopped-time delay	That part of the delay during which the vehicle is at rest
Fixed delay	That part of delay caused by control devices such as traffic signals
Travel-time delay	The difference between the actual travel time and the travel time traversed at an average speed equal to that for an uncongested traffic flow



Test Methods

(1) Method Requiring a Test Vehicle

$$N = \left[\frac{t_{\alpha} \times \sigma}{d} \right]^2$$

Floating-car technique	The test car “floats” with the traffic. Attempts to pass as many vehicles as those that pass the test vehicle
Average-speed technique	Drive the test car at a speed that, in the opinion of the driver, is the average speed of the traffic stream
Moving-vehicle technique	<p>Make a round trip on a test section and collect five pieces of information: T_e, T_w, N_e, O_w and P_w</p> 



Test Methods

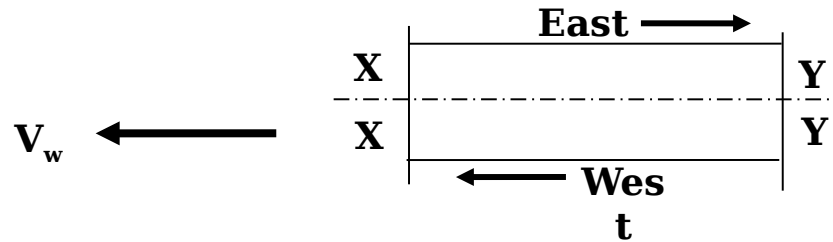
(2) Method Not Requiring a Test Vehicle

License-plate observation	Each observer located at strategic points record last 3 or 4 digits of license plates. Need to synchronize the observer's watch.
Interviews	Ask the drivers!

License-plate method → *not good for a grid network.*
Why?



Moving-Vehicle Technique



V_w = The volume in the westbound direction

T_e = Time taken to travel east from X-X to Y-Y in minutes

T_w = Time taken to travel west from Y-Y to X-X in minutes

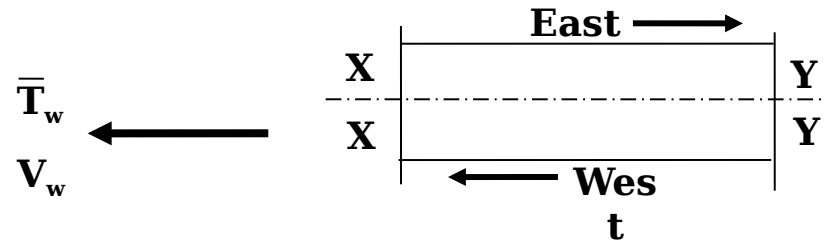
N_e = Number of vehicles traveling west in the opposite lane while the test car is traveling east

O_w = Number of vehicles that overtake the test car while it is traveling west from Y-Y to X-X (westbound vehicles)

P_w = Number of vehicles that the test car passes while it is traveling west from Y-Y to X-X (westbound test car)



Moving-Vehicle Technique



Westbound Volumes, V_w

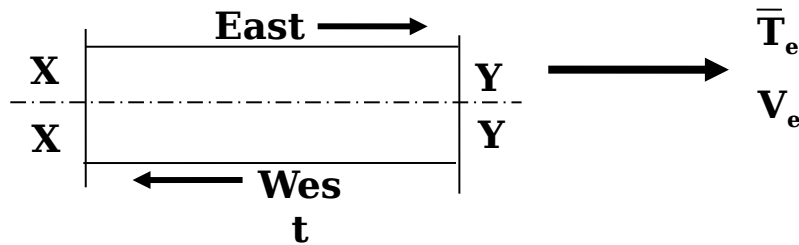
$$V_w = \frac{60(N_e + O_w - P_w)}{T_e + T_w}$$

Westbound Average Travel Time, $\bar{T}_w$

$$\bar{T}_w = T_w - \frac{60(O_w - P_w)}{V_w}$$



Moving-Vehicle Technique



V_e = The volume in the eastbound direction

T_e = Time taken to travel east from X-X to Y-Y in minutes

T_w = Time taken to travel west from Y-Y to X-X in minutes

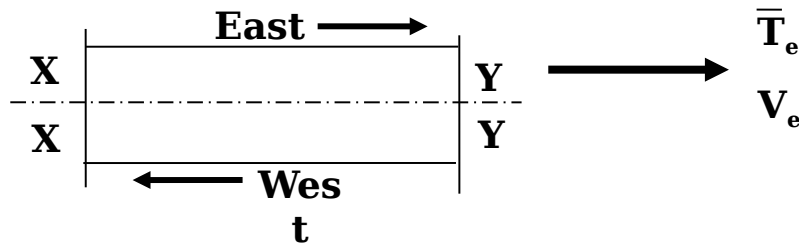
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P_e = Number of vehicles that the test car passes while it is traveling east from X-X to Y-Y (eastbound test car)



Moving-Vehicle Technique



Eastbound Volumes, V_e

$$V_e = \frac{60(N_w + O_e - P_e)}{T_e + T_w}$$

Eastbound Average Travel Time, $\bar{T}_e$

$$\bar{T}_e = T_e - \frac{60(O_e - P_e)}{V_e}$$





Average Speed Technique

Driving the test car along the length of the test section at a speed that in the opinion of the driver is the average speed of the traffic stream

1. Identify the test section
2. Measure travel time (stopwatch #1)
3. Recording the time at which the test car arrives at specific locations
4. Measure the time test car is stopped (stopwatch #2)



Average Speed Technique

Street Name: 29 North
Weather: Clear

Date: July 7, 1994
Non-peak

Time: 2:00–3:00 p.m.

Cross Streets	Distance (ft)	Travel Time (sec)	Segment Speed (mi/h)	Stop Time (sec)	Reason for Stoppage	Speed Limit (mi/h)	Ideal Travel Time (sec)	Segment Delay (sec)	Net Speed (mi/h)
	0	0.0	–	0.0		–	0.0	0.0	–
Ivy Road	1584	42.6	25.4	20.1	Signal	40	27.0	15.6	17.2
Massie Road	1320	27.7	32.5	0.0		40	22.5	5.2	32.5
Arlington Blvd.	792	19.7	27.4	8.9	Signal	40	13.5	6.2	18.9
Wise Street	1320	32.1	28.0	15.4	Signal	40	22.5	9.6	18.9
Barracks Road	2244	49.8	30.7	9.2	Signal	40	38.3	11.5	25.9
Angus Road	1584	24.4	44.3	0.0		45	24.0	0.4	44.3
Hydraulic Road	1584	42.6	25.4	19.5	Signal	45	24.0	18.6	17.4
Seminole Court	1848	41.5	30.4	15.6	Signal	45	28.0	13.5	22.1
Greenbrier Drive	1320	37.4	24.1	11.8	Signal	45	20.0	17.4	18.3
Premier Court	1584	23.6	45.8	4.9	Signal	45	24.0	–0.4	37.9
Fashion Square I	1056	19.7	36.5	0.0		45	16.0	3.7	36.5
Fashion Square II	1056	20.2	35.6	14.1	Signal	45	16.0	4.2	21.0
Rio Road	17292	381.3	30.9	119.5			275.8	105.5	23.5
Totals									



Dynamic Studies

- Speed
- Traffic Volume
- Travel Time and Delay
- Parking
- Accident



Parking Studies (Outcomes)

- Able to outline the methodology of parking studies (An)
- Able to determine space requirement for a parking garage (A)



Types of Parking Facilities

- On-street parking facilities
 - Parking bays alongside the curb

- Off-street parking facilities
 - Private vs. public
 - Surface lots vs. garage
 - Self-parking vs. attendant-parking



Definition of Parking Terms

Space-hour	A unit of parking. The use of a single parking space for a period of 1 hour.
Parking volume	The total number of vehicles that park in a study area during specific length of time.
Parking accumulation	The number of parked vehicles in a study area at any specified time.
Parking load	The area under the accumulation curve between two specific times. (space-hour)
Parking duration	The length of time a vehicle is parked at a parking bay
Parking turnover	The rate of use of a parking space. Divide the parking volume for a specified period by the number of parking spaces.



Four Steps of Parking Studies

- Inventory of existing parking facilities
- Collection of data on parking accumulation, parking turnover and parking duration
- Identification of parking generators
- Collection of information on parking demand

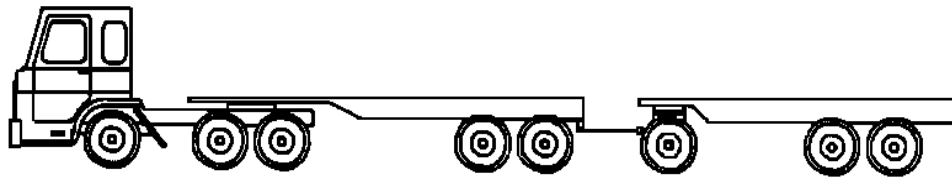
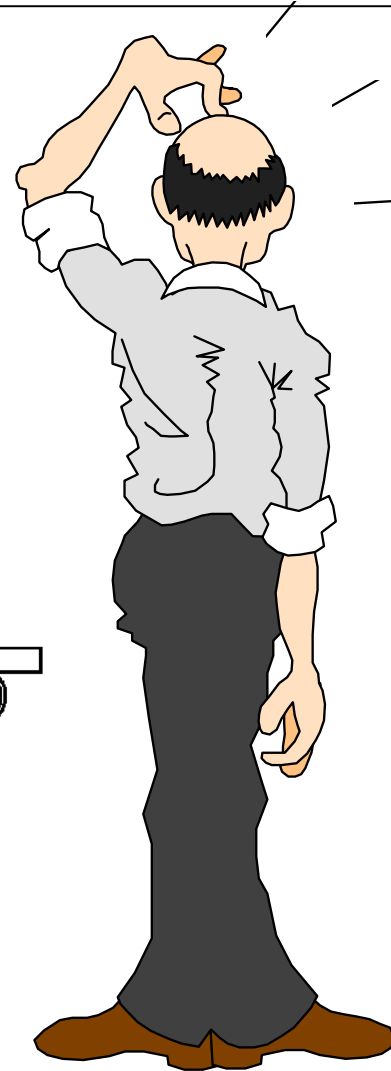


Inventory of Existing Parking Facilities

- Type and number of parking spaces
- Times of operation and limit on duration of parking
- Type of ownership
- Parking fees
- Restrictions on use
- Other restrictions (near bus stop, fire hydrant)
- Probable degree of permanency



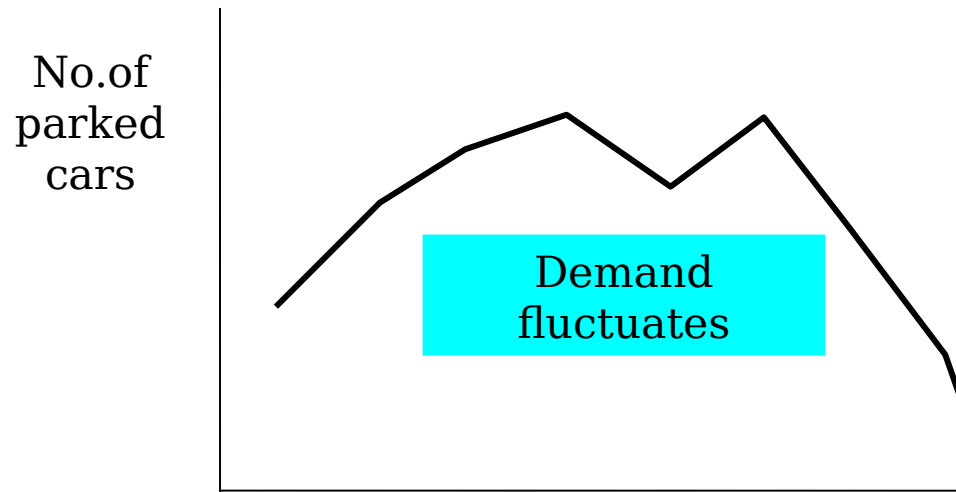
Questions?





Collection of Parking Data

- Accumulation – checked about every 2-hr basis



- Turnover and (max. permissible) duration

$$T = (\text{no. of different vehicles parked}) / (\text{No. of parking spaces})$$



Identification of Parking Generators

Special distribution, size of parking generator (trip attraction facilities), and available transportation modes affect the level of parking demand.



Parking Demand Survey

- Interview drivers on a typical weekday between 0800 and 1000
- Or, give drivers a survey form

Trip origin

Trip

Vehicle
type

Arrival &
departure

Destination
after
parking

If you get
30% back,
you are
really
fortunate!



Analysis of Parking Data

- Number and duration for vehicles legally parked
- Number and duration for vehicles illegally parked
- Space-hour of demand for parking
- Supply of parking facilities



Parking Demand Estimation

$$D = \sum_{i=1}^N (n_i t_i)$$

Class N (= 2 here)	Average Duration t_i	No. of Vehicles n_i
Commuter	9 hrs	120
Shopper	2 hrs	80

D = Space vehicle-hours demand for a specific period of time (usually the duration the parking facility is open)

N = Number of classes of parking duration ranges (commuters, shoppers, business meetings, etc. “Class” means grouping of purpose and parking durations).

t_i = Midparking (meaning “average” here) duration of the i th class.

n_i = Number of vehicles parked for the i th duration range (meaning “class”)



HEF for a Rural Primary Road (example)

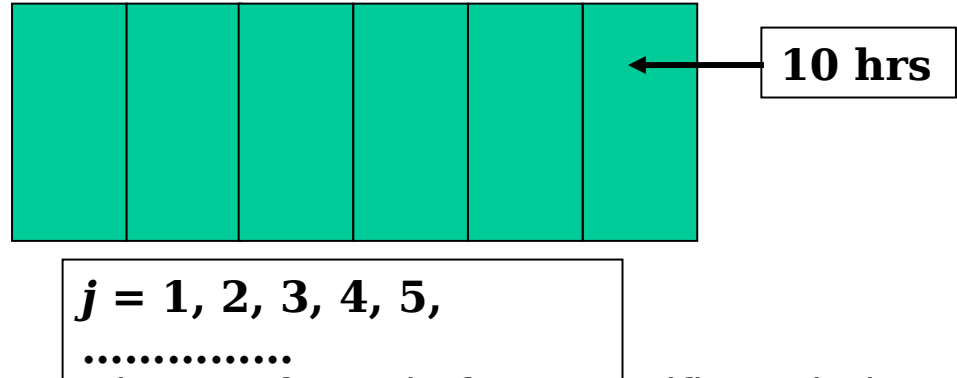
Hour	Volume		Hour	Volume	
0600-	294		1800-	743	
0700	426		1900	706	
0700-	560		1900-	606	
0800	657		2000	489	
0800-	722		2000-	396	
0900	667		2100	360	
0900-	660		2100-	241	
1000	739		2200	150	
1000-	832		2200-	100	
1100	836		2300	90	
1100-	961		2300-	86	
1200	892		0000	137	
1200-			0000-		
1300			0100		
1300-			0100-		
1400			0200		
1400-			0200-		
1500			0300		

total daily volume =
12350



Parking Supply Estimation

$$S = f \sum_{j=1}^M t_j$$



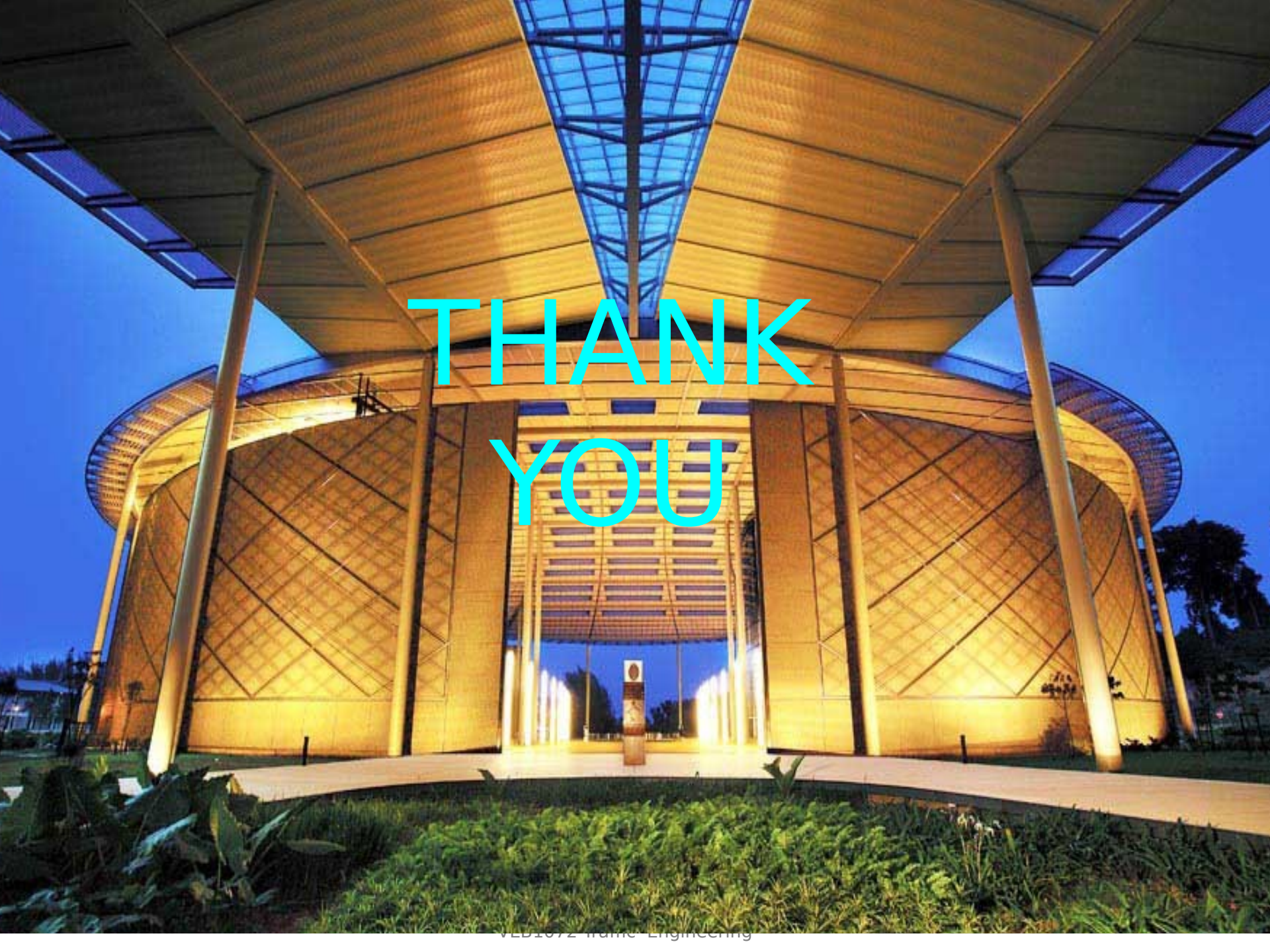
S = Practical number of space-hours of supply for a specific period of time

M = Number of parking spaces available

t_j = Total length of time in hours when the j th space can be legally parked on during the specific period

f = Efficiency factor to take into account the time lost during turnovers





THANK
YOU



Example 1

A traffic engineer, wishing to determine a representative value of the ADT on 250 highway links having similar volume characteristics, conducted a preliminary study from which the following estimates were made:

Mean volume = 45750 veh/day

Standard deviation = 3750 veh/day

Determine the minimum number of stations for which the engineer should obtain 24-hour volume counts for a 95-5 precision level.



Example 1

$$n = \frac{t_{\alpha/2, N-1}^2 (S^2 / d^2)}{1 + (1/N)(t_{\alpha/2, N-1}^2)(S^2 / d^2)}$$

$\alpha = 100 - 95 = 5$ (assume limit of acceptable error is 10% of mean volume)

$S = 3750$

$M = 45750$ therefore $d = (0.1)(45750) = 4575$

$V = N - 1 = 250 - 1 = 249$

$(t_{\alpha/2, N-1}) = 1.96$

$$n = \frac{(1.96)^2 (3750^2 / 4575^2)}{1 + (1/250)(1.96^2)(3750^2 / 4575^2)} = 2.57 = 3$$



Example 2

A traffic engineer urgently needs to determine the AADT on a rural primary road that has the volume distribution characteristics shown. The data collected on a Tuesday during the month of May are as follows:

07:00 – 08:00	400
08:00 – 09:00	535
09:00 – 10:00	650
10:00 – 11:00	710
11:00 – 12:00	650

Determine the AADT of the road.



Example 2

Estimate the 24-hour volume for Tuesday

$$\frac{(400 \times 290) + (535 \times 2205) + (650 \times 1880) + (710 \times 1710) + (650 \times 1852)}{5} = 11959$$

Adjust the 24-hr volume for Tuesday to an average volume for the week

$$\text{Total 7-day volume} = 11959 \times 7.727 = 92407$$

$$\text{Average 24-hr volume} = \frac{92407}{7} = 13201$$

$$\text{Since the data were collected in May, AADT} = 13201 \times 1.394 = 18402$$



Example 3

- A four-hour traffic count at a roadway segment shows that the consecutive sixteen 15-minute volumes are: 15, 18, 20, 23, 25, 10, 15, 35, 45, 55, 68, 75, 60, 45, 40 and 30 vehicles. Based on these data, estimate the peak hour volume and the peak hour factor (PHF)

Time		15-min Vol	Hourly Vol
1 st	7:00	15	
2 nd	7:15	18	
3 rd	7:30	20	
4 th	7:45	23	76
5 th	8:00	25	86
6 th	8:15	10	78
7 th	8:30	15	73
8 th	8:45	35	85
9 th	9:00	45	105
10 th	9:15	55	150
11 th	9:30	68	203
12 th	9:45	75	243
13 th	10:00	60	258
14 th	10:15	45	235
15 th	10:30	40	207
16 th	10:45	30	162

- PHVhr = 258 veh
- $P_{15min} = 75$ veh
- $PHF = (PHVhr / 4 \times P_{15min}) = 258 / (4 \times 75) = 0.86$

