

## TRAFFIC STUDIES

- 2.1 Traffic Volume Studies
- 2.2 Traffic Speed Studies
- 2.3 Origin and Destination Studies
- 2.4 Traffic flow and Capacity Studies
- 2.5 Parking Studies
- 2.6 Crash Studies



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## TRAFFIC STUDIES WITH OBJECTIVES

- Done to analyze the traffic characteristics.
- Managing for physical system (signs, signals, markings), lighting fixtures, repair and maintenance, etc.
- Investigating trends over time including volume, speeds, crashes and needs assessments so that actions can be anticipated, identified and taken.
- Understanding the needs and choices of the public and industry for mobility including mode choice, routings, parking, trip making by time of day, goods delivery, motivation for ride sharing.
- Calibrating basic parameters or relations such as the perception-reaction time, friction coefficients, etc.
- Assessing potential impacts including traffic and environmental impact assessments, site developments and access requests.

Traffic engineer's responsibilities are dominated by 3 elements – evaluating performance, assessing potential impacts and managing the physical system.



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## TYPES OF TRAFFIC STUDIES

- **Traffic volume study**
- Speed study
  - Spot speed study
  - Speed and delay study
- Origin and Destination Study
- Traffic flow characteristics
- Traffic capacity study
- Parking study
- Crash study



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## TYPES OF TRAFFIC STUDIES – TRAFFIC VOLUME STUDY

- **Traffic volume study**
  - Traffic volume is the **number of vehicles** crossing a section of road **per unit time** at any selected period.
    - **Also known as flow.**
  - Traffic volume is used as a quantity measure of traffic flow.
    - **Units – veh/hrs, veh/day, etc.**
      - **However, the flow is expressed as PCU/hour or PCU/day for mixed traffic conditions.**
        - PCU – Passenger Car Unit



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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- Traffic volume study
  - Objective and use of traffic volume study
    - It is important for improvement and expansion of road.
    - It is used in planning, traffic operation/control of existing facilities and for planning new facilities.
    - It is used for structural design of pavements.
    - It is used to analyze traffic pattern.
    - It is used for design intersections, signal timing and other control devices.
    - Pedestrian traffic volume is used for planning and design of sidewalks, crosswalks, subways and pedestrian signals.



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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- Traffic volume study
  - Vehicle volume counts
    - **Short term counts (one hour or more)** – To determine peak hour traffic flow for use in measuring saturation flow.
    - **Full day count (24 hours)** – To determine hourly fluctuation of flow.
    - **Full week count** – To determine hourly and daily fluctuation of flow.
    - **Continuous count** – To monitor traffic in urban and non-urban locations. Provides data regarding daily, weekly, seasonally and yearly fluctuation. Can be used to find annual growth of traffic.



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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- **Traffic volume study**
  - Sub hourly volume and rate of flow
    - A facility may have adequate capacity to serve the peak hour demand, but short-term peaks of flow within the peak hour may exceed capacity thereby creating a breakdown.
    - Thus, the volumes observed for periods of less than one hour are generally expressed as equivalent hourly rates of flow.

$$\text{PHF} = \text{Hourly Volume} / \text{Maximum rate of flow}$$



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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- **Traffic volume study**
  - Common levels of measurement of vehicle flow
    - Average annual flow expressed in vehicle per year. Useful for estimating the total travel on road system and for determining the gross annual revenues from the road users.
    - **Annual Average Daily Traffic (AADT)** expressed in vehicle per day. It is 1/365 part of the yearly traffic flow usually used for road improvement, existing facilities, geometric standard, standard for pavement design and maintenance.
    - **Average Daily Traffic (ADT)** – If the flow is not measured for all 365 days but only for a few days then the average flow is known as ADT.



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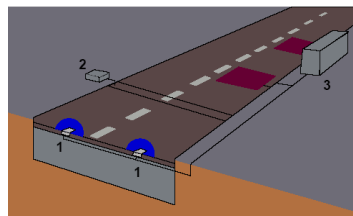
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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- Traffic volume study
  - Methods of Traffic Count
    - Manual Count
    - Manual Machine Counter
    - Automatic Devices
    - Photographic Method
    - Fixed Radar Method

Midlink Classified Count Data Sheet 2		Hour beginning	18	17	00
Pedal Cycles	////				
Two-Wheeled Motor Vehicles	///				
Cars and Taxis	HHH HHH HHH HHH				
Buses and Coaches	///				
Light Goods Vehicles	HHH //				



Type:1. Embedded magnetometers  
2. Pneumatic tube detectors  
3. Inductive detector loops



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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- Traffic volume study
  - Methods of Traffic Count
    - Manual Count
      - Carried out in peak-hours usually at intersections.
      - Five dash system is used.
      - Suitable for short term and non-continuous count.
      - Pedestrian Count can also be done.
      - Classified vehicular count can be done.
      - Enable to record unusual conditions.
      - Continuous counting not feasible.
      - Costly.

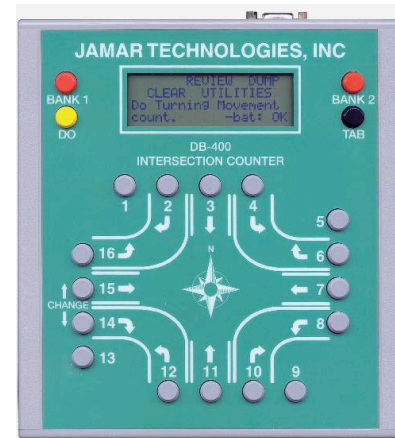
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Light Goods Vehicles	HHH //				



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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- Traffic volume study
- Methods of Traffic Count
  - Manual Machine Counter
    - Portable devices are used for short term count.
    - Counter could be added with printers.



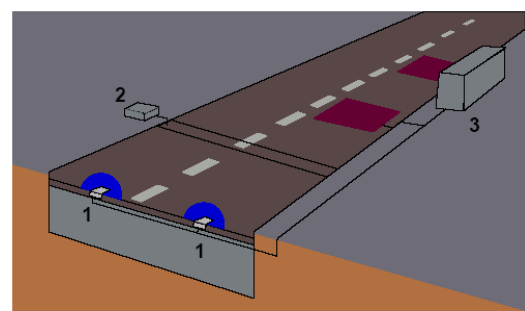
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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- Traffic volume study
- Methods of Traffic Count
  - Automatic Devices
    - Detector/impulse/simulation activates the counter.
    - Machine will be actuated with magnetic loop detector or road tube with air impulse switches.



Type:1. Embedded magnetometers  
 2. Pneumatic tube detectors  
 3. Inductive detector loops



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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- Traffic volume study
  - Methods of Traffic Count
    - Photographic Method
      - Photographs are taken with certain reference and or video equipment is used.



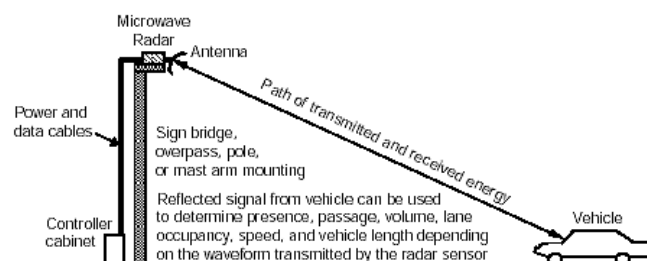
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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- Traffic volume study
  - Methods of Traffic Count
    - Fixed Radar Detector
      - Radar transmits/receives radio signal that counts vehicle (simple, reliable and accurate but high initial cost).



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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- **Traffic volume study**
  - Presentation and analysis of traffic data
    - **Average Annual Daily Traffic:** The average 24-hour traffic volume at a given location over a full 365-day year, i.e. the total number of vehicles passing the site in a year divided by 365. It is used for road improvement, geometric standard, standard for pavement design and maintenance.
    - **Trend Chart:** Extrapolation to estimate traffic of  $n^{\text{th}}$  year for future expansion and design, etc.
    - **Variation Chart:** Showing hourly, daily and seasonal variations to determine facilities and regulation required at peak hours.



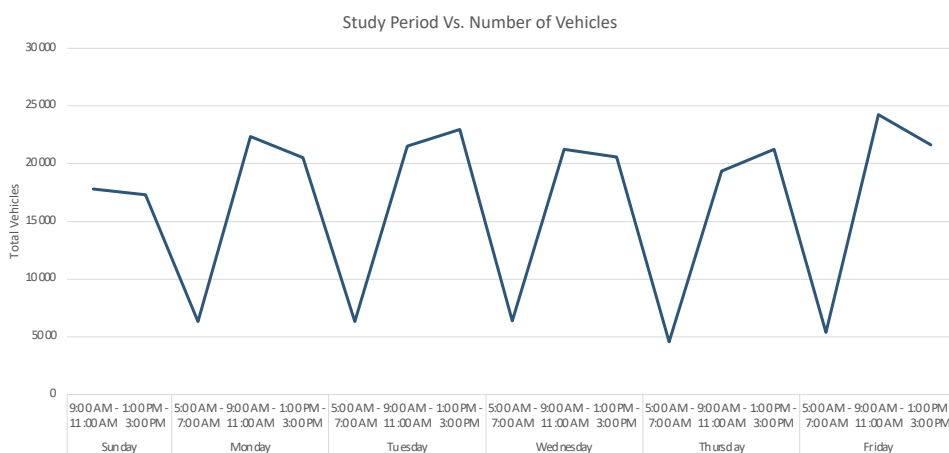
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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- **Traffic volume study**
  - Presentation and analysis of traffic data



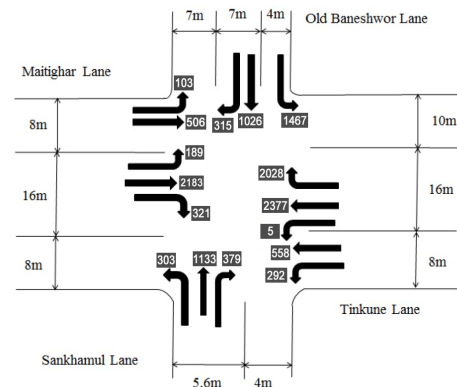
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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- **Traffic volume study**
  - **Presentation and analysis of traffic data**
    - **Volume flow at intersection shown by thick lines:**  
For intersection design and control measures.
    - **Traffic flow maps:** Thickness of line shows the traffic volume in scale to see traffic distribution at glance.
    - **30<sup>th</sup> Highest Hourly Volume:** That exceeds 29 times in a year and used as hourly volume for design purpose from both facility and economic point of view. A maximum of 29 hours of traffic congestion in a year is anticipated.



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## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- **Poisson distribution**
  - Known as counting distribution in traffic engineering.
  - The most widely used situation of Poisson distribution is the arrival pattern of vehicles, which is a random phenomenon.
  - If the  $\lambda$  is the average rate of arrival per second, the probability of arrival of  $x$  vehicles in any time interval  $t$  seconds is given by:

$$P(x) = \frac{(\lambda t)^x e^{-\lambda t}}{x!}$$

where,  $\lambda$  is the average rate of arrival per second.

- Poisson distribution is usually valid when  $n$  is sufficiently large say  $\gg 50$  and  $p$  is small say  $\ll 0.10$ .



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# NUMERICAL

Calculate the AWT, ADT, AAWT, AADT from the following data.

Month	No. of weekdays in month (days)	Total no. of days in month (days)	Total monthly volume (veh)	Total weekday volume (veh)
Jan	22	31	425000	208000
Feb	20	28	410000	220000
Mar	22	31	385000	185000
Apr	22	30	400000	200000
May	21	31	450000	215000
Jun	22	30	500000	230000
Jul	23	31	580000	260000
Aug	21	31	570000	260000
Sep	22	30	490000	205000
Oct	22	31	420000	190000
Nov	21	30	415000	200000
Dec	22	31	400000	210000



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# NUMERICAL

Month	No. of weekdays in month (days)	Total no. of days in month (days)	Total monthly volume (veh)	Total weekday volume (veh)	AWT	ADT
Jan	22	31	425000	208000	9455	13710
Feb	20	28	410000	220000	11000	14643
Mar	22	31	385000	185000	8409	12419
Apr	22	30	400000	200000	9091	13333
May	21	31	450000	215000	10238	14516
Jun	22	30	500000	230000	10455	16667
Jul	23	31	580000	260000	11304	18710
Aug	21	31	570000	260000	12381	18387
Sep	22	30	490000	205000	9318	16333
Oct	22	31	420000	190000	8636	13548
Nov	21	30	415000	200000	9524	13833
Dec	22	31	400000	210000	9545	12903
Total in Year	260	365	5445000	2583000		

Sample Calculations

AWT (Average Weekday Traffic) = Total weekday volume/No. of weekdays in month

ADT (Average Daily Traffic) = Total monthly volume/No. of days in month

AAWT = Total weekday volume in a year/Total weekdays in a year = 9935 vpd

AAAT = Total monthly volume in a year/Total no. of days in a year = 14918 vpd

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## NUMERICAL

A student recorded the following traffic counts of vehicles travelling on the roadside lane of a freeway. Compute a) the hourly volume b) the peak rate of flow for a 5 minute period and c) the peak rate of flow for a 15-min period for this lane.

Time	Count	Time	Count
8:35 – 8:40 AM	104	9:05 – 9:10 AM	101
8:40 – 8:45 AM	109	9:10 – 9:15 AM	105
8:45 – 8:50 AM	116	9:15 – 9:20 AM	130
8:50 – 8:55 AM	122	9:20 – 9:25 AM	103
8:55 – 9:00 AM	130	9:25 – 9:30 AM	107
9:00 – 9:05 AM	121	9:30 – 9:35 AM	105



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A student recorded the following traffic counts of vehicles travelling on the roadside lane of a freeway. Compute a) the hourly volume b) the peak rate of flow for a 5 minute period and c) the peak rate of flow for a 15-min period for this lane.

Time	Count	For 15 min count
8:35 – 8:40 AM	104	329
8:40 – 8:45 AM	109	347
8:45 – 8:50 AM	116	368
8:50 – 8:55 AM	122	373
8:55 – 9:00 AM	130	352
9:00 – 9:05 AM	121	327
9:05 – 9:10 AM	101	336
9:10 – 9:15 AM	105	338
9:15 – 9:20 AM	130	340
9:20 – 9:25 AM	103	315
9:25 – 9:30 AM	107	
9:30 – 9:35 AM	105	
<b>Sample Calculations</b>		
Hourly volume =		1353
Peak rate of flow for a 5 minute period =		1560
Peak rate of flow for a 15 minute period =		1492

Peak Hour Factor (PHF) = 0.91



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### TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

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$$PHF = \text{Hourly Volume} / \text{Maximum rate of flow}$$



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# NUMERICAL

A roadway has an average hourly volume of 360 veh/hr. assuming that the arrival of vehicles is Poisson distributed. Estimate the probabilities of having 0, 1, 2, 3, 4 and 5 or more vehicles arriving over a 20 sec interval. Plot the histogram of the Poisson distribution for  $\lambda = 360$  veh/hr.

### TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

- Poisson distribution**
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 where,  $\lambda$  is the average rate of arrival per second.
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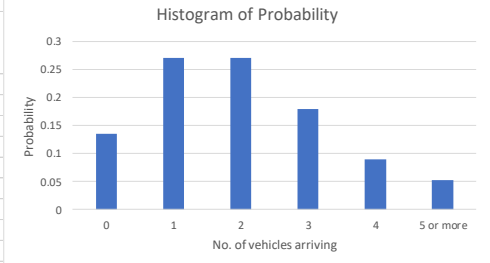


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# NUMERICAL

$\lambda$	= Arrival per unit time (one second)
	= (Total number of vehicles arriving during observation) / Total time of observation
	= 360/3600
	0.1 veh/secs
$t$	= selected time interval for observations = 20 seconds
$\lambda t$	= 0.10*20 = 2

	No. of vehicles arriving	Probability
$P(x=0)$	0	0.135335283
$P(x=1)$	1	0.270670566
$P(x=2)$	2	0.270670566
$P(x=3)$	3	0.180447044
$P(x=4)$	4	0.090223522
$P(x \geq 5)$	5 or more	0.052653017



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# NUMERICAL

It is observed that on an average a vehicle driver drives 4500 km during the course of a year. The probability of having a crash is 90 per 200 million vehicle kilometers. What is the probability of a driver having at least three crashes during his driving career extending to 22 years.

## TYPES OF TRAFFIC STUDIES - TRAFFIC VOLUME STUDY

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# NUMERICAL

It is observed that on an average a vehicle driver drives 4500 km during the course of a year. The probability of having a crash is 90 per 200 million vehicle kilometers. What is the probability of a driver having at least three crashes during his driving career extending to 22 years.

Number of crashes = 90 per 200 million veh. Km			
Probability of having crash/km			
$\lambda$	= $90 / (200 * 10^6)$	0.00000045	crash/veh.km
t	= $22 * 4500$	99000	km driven by the driver
$\lambda t$	= $(4.5 * 10^{-7}) * 99000$	0.04455	
Average rate of occurrence of crash in the length of travel			
Probability of having at least three crashes per year			
$P(x \geq 3)$	= $1 - P(0) - P(1) - P(2)$		
P(0) =	0.956427778		
P(1) =	0.042608857		
P(2) =	0.000949112		
$P(x \geq 3) = 1 - P(0) - P(1) - P(2)$			

$P(x \geq 3) = 5.09 * 10^{-5}$



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## TRAFFIC STUDIES

2.1 Traffic Volume Studies

**2.2 Traffic Speed Studies**

2.3 Origin and Destination Studies

2.4 Traffic flow and Capacity Studies

2.5 Parking Studies

2.6 Crash Studies



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Speed studies**
  - Speed is the most important traffic characteristics that indicates the **rate of movement of traffic**.
  - Actual speed depends upon
    - Geometric features
    - Traffic conditions
    - Place
    - Time
    - Environment
    - Condition of driver



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- Speed studies
  - Objective of speed studies
    - Determining speed trend.
    - Planning traffic control measures like traffic signals, location of warning, regulatory and informatory signs, non passing zones, establishing restricted zones, etc.
    - Crash studies.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- Speed studies
  - Definitions
    - **Spot Speed:** Instantaneous speed of the vehicle as it passes a specified point on the highway.
    - **Average Speed:** Average of spot speed of all the vehicles passing a specified point on the highway.
      - **Time Mean Speed:** Average of several spot speeds observed on a particular location. (Arithmetic Mean). It represents the speed distribution of vehicles at a point on the road.
      - **Space Mean Speed:** Average speed of vehicles over a certain length of road at a given time. (Harmonic Mean). It is determined from the observed travel time of the vehicles over a relatively long stretch of the road. **It is simply the distance travelled divided by average travel times.**



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- Speed studies

### Time Mean Speed (TMS)

$$V_t = \frac{\sum v_i}{n}$$

where, n is the number of vehicles

$$V_t = \frac{\sum f_i v_i}{\sum f_i}$$

$$\sigma_t^2 = \frac{\sum (v_i - v_t)^2}{n-1}$$



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### Space Mean Speed (SMS)

$$V_s = \frac{L}{\sum_{i=1}^n \frac{t_i}{n}} = \frac{nL}{\sum_{i=1}^n t_i}$$

where, L = Length of road

$t_i$  = Travel time of observed vehicle

$$V_s = \frac{n}{\sum \frac{1}{v_i}} \text{ or } V_s = \frac{n}{\sum \frac{f_i}{v_i}}$$

$$\sigma_s^2 = \frac{\sum (v_i - v_s)^2}{n-1}$$

### Relationship between TMS and SMS

$$V_t = V_s + \frac{\sigma_s^2}{v_s}$$

Shows that, the TMS is always greater than the SMS.

$$V_s = V_t - \frac{\sigma_t^2}{v_t}$$

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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- Speed studies

- Definitions

- Travel Time:** Time taken to travel certain section of road.
- Delay:** Time lost during travel.
- Journey Speed:** It is the effective speed of vehicle between two points of observation inclusive of delays.

$$\text{Journey Speed} = \frac{\text{Total Length of Road}}{\text{Total Journey Time Including Delays}}$$

- Running Speed:** Average speed maintained by a vehicle over a given course while the vehicle is in motion.

$$\text{Running Speed} = \frac{\text{Length of Road}}{\text{Running Time}} = \frac{\text{Length of Road}}{\text{Journey Time} - \text{Delay}}$$



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## NUMERICAL

- Calculate the time mean speed and space mean speed from the following data:

Vehicle No.	Distance (m)	Travel time (s)
1	200	18.0
2	200	20.0
3	200	22.0
4	200	19.0
5	200	20.0

$$V_t = \frac{\sum v_i}{n}$$

$$V_s = \frac{L}{\sum_{i=1}^n \frac{t_i}{n}} = \frac{nL}{\sum_{i=1}^n t_i}$$

Vehicle No.	Distance (m)	Travel time (s)	Speed
1	200	18.0	11.11
2	200	20.0	10.00
3	200	22.0	9.09
4	200	19.0	10.53
5	200	20.0	10.00
Total	1000	99	50.73
Average	200	19.8	10.15
TMS = 10.15 m/sec			
SMS = 5*200/(99) =			10.10 m/sec



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## NUMERICAL

- Speed observations from a radar speed meter have been taken giving the speeds of the subsidiary streams composing the flow along with the volume of traffic of each subsidiary stream. The readings are as under.

Speed (kmph)	Volume of subsidiary stream (veh/hr)	Speed (kmph)	Volume of subsidiary stream (veh/hr)
5-8	1	33-36	90
9-12	7	37-40	88
13-16	2	41-44	50
17-20	8	45-48	36
21-24	25	49-52	24
25-28	48	53-56	10
29-32	85	57-60	9
Calculate time mean speed and space mean speed.		61-64	3



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# NUMERICAL

$$V_t = \frac{\sum f_i v_i}{\sum f_i} \quad V_s = \frac{n}{\sum \frac{1}{v_i}} \quad V_t = V_s + \frac{\sigma_s^2}{v_s} \quad V_s = V_t - \frac{\sigma_t^2}{v_t}$$

Speed (kmph)	Volume of subsidiary stream (veh/hr)	Speed (kmph)	Volume of subsidiary stream (veh/hr)
5-8	1	33-36	90
9-12	7	37-40	88
13-16	2	41-44	50
17-20	8	45-48	36
21-24	25	49-52	24
25-28	48	53-56	10
29-32	85	57-60	9
		61-64	3

Speed (kmph)	Volume of subsidiary stream (veh/hr) - fi	Midpoint (vi)	fi . vi	fi/vi	
5	8	1	6.5	6.5	0.15385
9	12	7	10.5	73.5	0.66667
13	16	2	14.5	29	0.13793
17	20	8	18.5	148	0.43243
21	24	25	22.5	562.5	1.11111
25	28	48	26.5	1272	1.81132
29	32	85	30.5	2592.5	2.78689
33	36	90	34.5	3105	2.6087
37	40	88	38.5	3388	2.28571
41	44	50	42.5	2125	1.17647
45	48	36	46.5	1674	0.77419
49	52	24	50.5	1212	0.47525
53	56	10	54.5	545	0.18349
57	60	9	58.5	526.5	0.15385
61	64	3	62.5	187.5	0.048
<b>Total</b>	<b>486</b>		<b>17447</b>	<b>14.8058</b>	
TMS =	17447/486	35.90	kmph		
SMS =	486/14.8058	32.82	kmph		
Variance about space =					
mean speed	(35.90-32.82)*32.82	100.91			



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# NUMERICAL

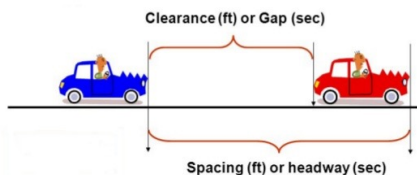
$$V_t = \frac{\sum v_i}{n}$$

$$V_s = \frac{n}{\sum \frac{1}{v_i}}$$

- The following speed data were collected during a two minute segment of a spot speed study (speed in kmph)

85    82    75    90    92    75    80    78  
 75    80    88    78    75    87    84

Estimate i) time mean speed ii) space mean speed iii) what will be the average density of the above traffic stream if the mean headway is 7.4 secs.



S.NO.	vi	1/vi	Mean headway	=7.4	secs
1	85	0.0118	Average spacing between the vehicles = = 7.4 * 81.22 / 3.60 = 166.95 Avg. density = 1000 / 166.95 = 6		m/veh veh/km
2	82	0.0122			
3	75	0.0133			
4	90	0.0111			
5	92	0.0109			
6	75	0.0133			
7	80	0.0125			
8	78	0.0128			
9	75	0.0133			
10	80	0.0125			
11	88	0.0114			
12	78	0.0128			
13	75	0.0133			
14	87	0.0115			
15	84	0.0119			
Total	1224	0.1847			
TMS =	1224/15 =	81.60	kmph		
SMS =	15/0.1846	81.22	kmph		



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# NUMERICAL

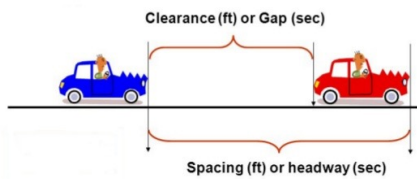
$$v_t = \frac{\sum v_i}{n}$$

$$v_s = \frac{n}{\sum \frac{1}{v_i}}$$

- The following speed data were collected during a two minute segment of a spot speed study (speed in kmph)

85	82	75	90	92	75	80	78
75	80	88	78	75	87	84	

Estimate i) time mean speed ii) space mean speed iii) what will be the average density of the above traffic stream if the mean headway is 7.4 secs.



**Spacing (Space Headway)** is defined as the distance between successive vehicles in a traffic lane measured from some common reference point on the vehicles.

**Headway (Time Headway)** is the time between successive vehicles as they pass a point along the lane also measured between common reference points on the vehicles.

Mean headway	= 7.4	secs
Average spacing between the vehicles =	Mean headway * Average speed	
	= 7.4 * 81.22 / 3.60	
	= 166.95	m/veh
Avg. density =	1000 / 166.95	
	6	veh/km



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# NUMERICAL

$$v_t = \frac{\sum v_i}{n}$$

$$v_s = \frac{n}{\sum \frac{1}{v_i}}$$

$$v_t = v_s + \frac{\sigma_s^2}{v_s}$$

$$v_s = v_t - \frac{\sigma_t^2}{v_t}$$

- Twenty six spot speed observations were taken and were as under:

50	45	47	60	55	58	61	42
40	52	54	42	40	52	53	43
57	60	62	40	42	43	50	49
60	59						

$$\sigma_t^2 = \frac{\sum (v_i - v_t)^2}{n-1}$$

$$\sigma_s^2 = \frac{\sum (v_i - v_s)^2}{n-1}$$

Estimate i) time mean speed ii) space mean speed and verify the relation between the two.



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## NUMERICAL

$$v_t = \frac{\sum v_i}{n}$$

$$v_s = \frac{n}{\sum \frac{1}{v_i}}$$

$$V_t = v_s + \frac{\sigma_s^2}{v_s}$$

$$V_s = v_t - \frac{\sigma_t^2}{v_t}$$

Estimate i) time mean speed ii) space mean speed and verify the relation between the two.

S.NO.	vi	1/vi	(vi - vs)^2				
1	50	0.0200	0.8836		TMS =	1316/26 =	50.62 kmph
2	45	0.0222	16.4836		SMS =	26/0.53 =	49.06 kmph
3	47	0.0213	4.2436				
4	60	0.0167	119.6836				
5	55	0.0182	35.2836				
6	58	0.0172	79.9236				
7	61	0.0164	142.5636				
8	42	0.0238	49.8436				
9	40	0.0250	82.0836				
10	52	0.0192	8.6436				
11	54	0.0185	24.4036				
12	42	0.0238	49.8436				
13	40	0.0250	82.0836				
14	52	0.0192	8.6436				
15	53	0.0189	15.5236				
16	43	0.0233	36.7236				
17	57	0.0175	63.0436				
18	60	0.0167	119.6836				
19	62	0.0161	167.4436				
20	40	0.0250	82.0836				
21	42	0.0238	49.8436				
22	43	0.0233	36.7236				
23	50	0.0200	0.8836				
24	49	0.0204	0.0036				
25	60	0.0167	119.6836				
26	59	0.0169	98.8036				
Total	1316	0.53	1495.05				

$$\sigma_t^2 = \frac{\sum (v_i - v_t)^2}{n-1}$$

$$\sigma_s^2 = \frac{\sum (v_i - v_s)^2}{n-1}$$



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- Types of Speed Studies
  - Spot Speed Study
  - Speed and Delay Study



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**
  - Spot Speed Study
    - Purposes of Spot Speed Study
      - To decide the speed trends.
      - To study the traffic capacity.
      - To plan traffic control and regulation measures.
      - To redesign existing highway geometric design.
      - For crash study.
      - To compare different types of drivers and vehicles under specified conditions.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**
  - Spot Speed Study
    - Methods of Spot Speed Measurement
      - Direct Timing Procedure
      - Enoscope
      - Pressure Contact Tubes
      - Radar Speed Meter
      - Photographic Method



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**
  - Spot Speed Study
    - Methods of Spot Speed Measurement
      - General Consideration for selecting site
        - The location at which measurements are taken is governed by the specific purpose for which the data are required.
        - Generally straight, level sections of highways should be selected so as to minimize the influence of geometric features of highways, roadside development and intersections.

Average Speed of Traffic-Stream (kmph)	Base Length (meter)
Less than 40	27
40 to 65	54
Greater than 65	81



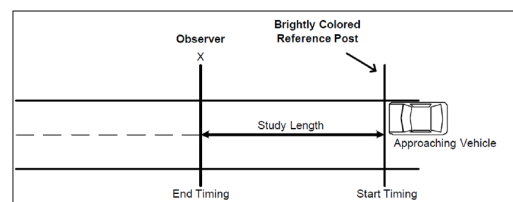
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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**
  - Spot Speed Study
    - Methods of Spot Speed Measurement
      - Direct Timing Procedure
        - Simplest method
        - Two reference points are marked on the pavement at a suitable distance apart and observer starts and stops stop watch as a vehicle crosses these two lines.
        - From the known distance and measured time intervals, spot speed is calculated.
        - **Large error may occur due to the parallax effect.**



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

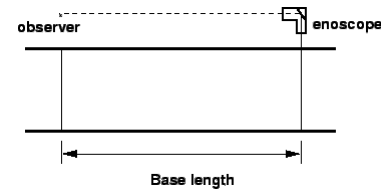
- Types of Speed Studies

- Spot Speed Study

- Methods of Spot Speed Measurement

- Enoscope

- It is a simple device consisting of L-shaped mirror box, open at both ends.
- It has a mirror set fixed at 45 degree to the arms of the instrument.
- An enoscope is placed in such a way that the image of the vehicle is seen by the observer when the vehicle crosses the section where the enoscope is fixed and at this instant the stop watch is stopped.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

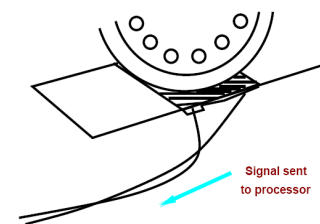
- Types of Speed Studies

- Spot Speed Study

- Methods of Spot Speed Measurement

- Pressure Contact Tubes

- Detectors are used to indicate the entering and leaving the base length.
- When vehicle passes tube laid at first reference point, an air impulse sent activates an electromagnetically controlled stopwatch in the hand of the observer.
- When the vehicle passes over the second tube, the stopwatch automatically stops.
- The disadvantage with the pressure contact tubes is that they are easily seen by drivers and this may affect their behavior.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

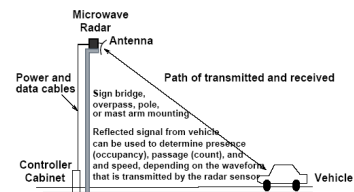
- Types of Speed Studies

- Spot Speed Study

- Methods of Spot Speed Measurement

- Radar Speed Meter

- Based on Doppler principle that the speed of a moving vehicle is proportional to the change in the frequency between the radio-wave transmitted to the moving body and radio-wave received back.
- The instrument is set up near the edge of the carriageway at a height of about 1 m above the ground level.



(a) Vehicle-Mounted Radar Unit  
(photo courtesy of Tribar Industries)



(b) Hand-Held Radar Unit  
(photo courtesy of Tribar Industries)



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- Types of Speed Studies

- Spot Speed Study

- Methods of Spot Speed Measurement

- Photographic Method

- Time lapse camera photography method has been used to determine the speeds of vehicles accurately in crowded streets.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- Types of Speed Studies

- Spot Speed Study

- Presentation and analysis of spot speed

- Tabular Presentation

- It is the grouping of spot speeds.
- To avoid excessive computations, the entire data are grouped into speed class intervals.

$$C_i = \frac{R}{1+3.322 \log n}$$

Where,

$C_i$  = class interval

R = range between the largest and the smallest speed

n = no. of observation



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

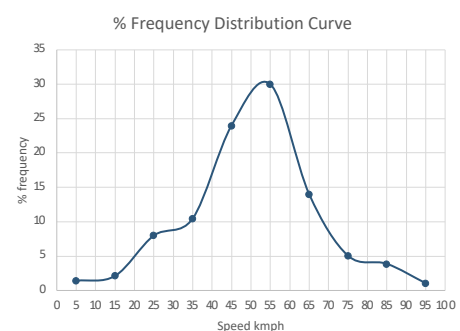
- Types of Speed Studies

- Spot Speed Study

- Presentation and analysis of spot speed

- Graphical Analysis

- Modal Speed:** This occurs most often peak of frequency distribution curve.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

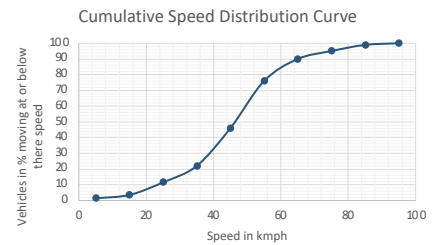
- Types of Speed Studies

- Spot Speed Study

- Presentation and analysis of spot speed

- Graphical Analysis

- Histogram and Cumulative frequency curves are used.
- Median Speed:** 50<sup>th</sup> Percentile Speed.
- 98<sup>th</sup> Percentile Speed:** The 98% vehicles move below this speed and it is taken as design speed for geometric design.
- 85<sup>th</sup> Percentile Speed:** The 85% of vehicles move below this speed and it is used to establish upper limit for traffic management. It is taken as safe speed in the road.
- 15<sup>th</sup> Percentile Speed:** It is used to determine minimum speed limit in major highways.



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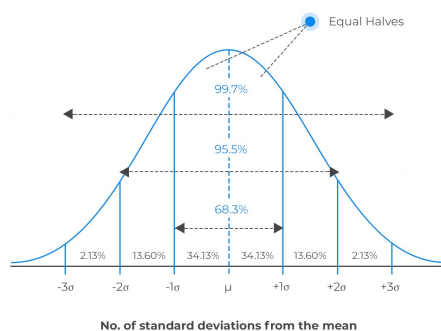
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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- Types of Speed Studies

- Spot Speed Study

- Applying the Normal Distribution to Analysis of Spot Speed data



$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

where  $-\infty < x < \infty$ ;  $-\infty < \mu < \infty$ ;  $\sigma > 0$

- $f(x)$  → Normal Probability Distribution
- $x$  → random variable
- $\mu$  → mean of distribution
- $\sigma$  → standard deviation of distribution
- $\pi$  → 3.14159
- $e$  → 2.71828

Standard normal distribution  $f(z)$

$$f(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}}$$

$$z = \frac{x - \mu}{\sigma}$$



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## NUMERICAL

Spot speed studies were carried out at a certain stretch of a highway and the consolidated data collected are given below. Determine (i) the upper and lower values of speed limit for regulation of mixed traffic flow (ii) the design speed for checking the geometric design elements of highway (iii) median speed (iv) dispersion speed (v) modal speed.

S.No.	Speed range, kmph	No. of vehicles observed
1	0 to 10	12
2	10 to 20	18
3	20 to 30	68
4	30 to 40	89
5	40 to 50	204
6	50 to 60	255
7	60 to 70	119
8	70 to 80	43
9	80 to 90	33
10	90 to 100	9



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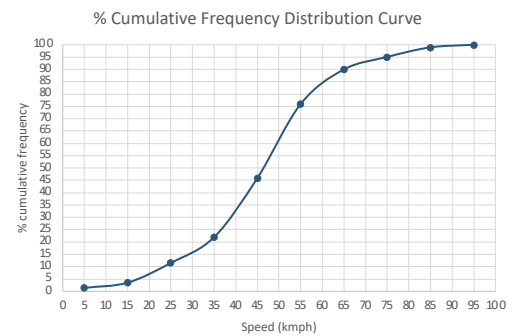
## NUMERICAL

Speed Group		Middle Speed	No. of vehicles in group n (frequency f)	Vehicles in group (%) (Frequency %)	Cumulative vehicles (%) (Cumulative frequency %)
Lower limit kmph	Upper limit kmph				
0	10	5	12	1.41	1.41
10	20	15	18	2.12	3.53
20	30	25	68	8.00	11.53
30	40	35	89	10.47	22.00
40	50	45	204	24.00	46.00
50	60	55	255	30.00	76.00
60	70	65	119	14.00	90.00
70	80	75	43	5.06	95.06
80	90	85	33	3.88	98.94
90	100	95	9	1.06	100.00
			850		



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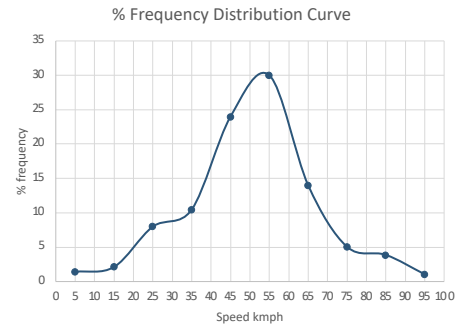


- Upper speed limit for regulation**  
= 85<sup>th</sup> percentile speed = 60kmph
- Lower speed limit for regulation**  
= 15<sup>th</sup> percentile speed = 28kmph
- Speed to check geometric design elements**  
= 98<sup>th</sup> percentile speed = 80kmph
- Median speed**  
= 50<sup>th</sup> percentile speed = 46kmph
- Dispersion Speed**  
= (85<sup>th</sup> – 15<sup>th</sup> percentile speed)  
= (60 – 28) kmph = 32 kmph

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# NUMERICAL

Speed Group		Middle Speed	No. of vehicles in group n (frequency f)	Vehicles in group (%) (Frequency %)	Cumulative vehicles (%) (Cumulative frequency %)
Lower limit kmph	Upper limit kmph				
0	10	5	12	1.41	1.41
10	20	15	18	2.12	3.53
20	30	25	68	8.00	11.53
30	40	35	89	10.47	22.00
40	50	45	204	24.00	46.00
50	60	55	255	30.00	76.00
60	70	65	119	14.00	90.00
70	80	75	43	5.06	95.06
80	90	85	33	3.88	98.94
90	100	95	9	1.06	100.00
			850		



Modal Speed = 53 kmph

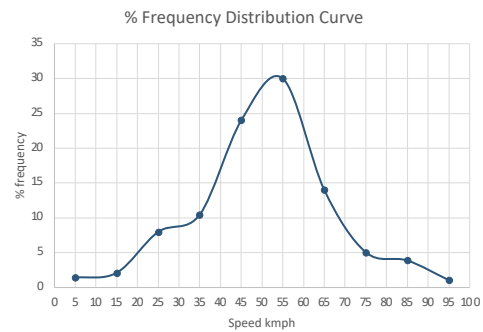
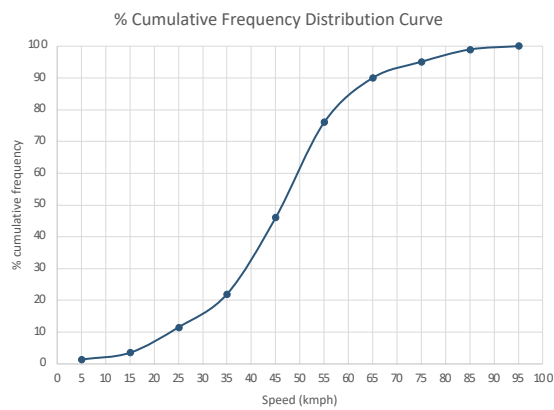


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# NUMERICAL



- Speed to check geometric design elements = 98<sup>th</sup> percentile speed = 80kmph
- Upper speed limit for regulation = 85<sup>th</sup> percentile speed = 60kmph
- Lower speed limit for regulation = 15<sup>th</sup> percentile speed = 28kmph
- Median speed = 50<sup>th</sup> percentile speed = 46kmph
- Dispersion Speed = (85<sup>th</sup> – 15<sup>th</sup> percentile speed) = (60 – 28) kmph = 32 kmph
- Modal Speed = 53 kmph



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## NUMERICAL

$$\mu = 28 \text{ minutes}$$

$$\sigma = 4 \text{ minutes}$$

An officer commutes daily from his suburban home to his downtown office. On an average the trip one way takes 28 minutes, with a standard deviation of 4 minutes. Assume the distribution of trip times to downtown to be normally distributed.

- What is the probability that a trip will take at least 32 minutes?
- If the working hour starts at 10:00 AM and he leaves his house at 9:40 AM what percentage of the time is he late at work?

### Probability of trip taking at least 32 minutes ( $x \geq 32$ )

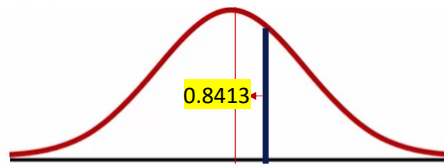
It is the area under the normal curve to the right of  $x = 32$

$$z = \frac{x - \mu}{\sigma} = \frac{32 - 28}{4} = \frac{4}{4} = 1$$

From z-table, for  $z = 1$ , we have  $\phi(1) = 0.8413$  which is the area to the left of the curve.

For the area to the right of the curve we deduct the value 0.8413 from the total area of curve, i.e. 1.

Therefore,  $P(x \geq 32) = 1 - 0.8413 = 0.1587$



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## CALCULATING PROBABILITIES USING CALCULATOR



**fx 991 ES Plus**

- Press Mode
- Select Mode 3: STAT
- Press AC
- Press Shift and then 1
- Select 5: Distr
- Select 1: P(
- Supply the z value obtained as input. Here P(1)
- Answer you will get is 0.8413

### fx 991 EX CLASSWIZ

- Press Mode
- Select 7: Distribution
- Select 2: Normal CD
- Normal CD
  - Lower: 0
  - Upper: 0
  - $\sigma$ : 1
  - $\mu$ : 0
- Replace values in Step 4 with your values as:
  - Normal CD
  - Lower: 0
  - Upper: 32
  - $\sigma$ : 4
  - $\mu$ : 28
- P = 0.8413



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## NUMERICAL

$$\begin{aligned}\mu &= 28 \text{ minutes} \\ \sigma &= 4 \text{ minutes}\end{aligned}$$

An officer commutes daily from his suburban home to his downtown office. On an average the trip one way takes 28 minutes, with a standard deviation of 4 minutes. Assume the distribution of trip times to downtown to be normally distributed.

- What is the probability that a trip will take at least 32 minutes?
- If the working hour starts at 10:00 AM and he leaves his house at 9:40 AM what percentage of the time is he late at work?

### Percentage of time he is late for work ( $x \geq 20$ )

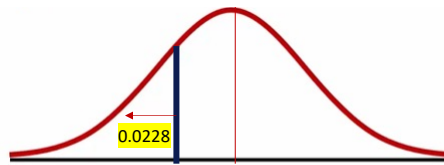
It is the area under the normal curve to the right of  $x = 20$

$$z = \frac{x - \mu}{\sigma} = \frac{20 - 28}{4} = \frac{-8}{4} = -2$$

From z-table, for  $z = -2$ , we have  $\phi(-2) = 0.0228$  which is the area to the left of the curve.

For the area to the right of the curve we deduct the value 0.0228 from the total area of curve, i.e. 1.

$$\text{Therefore, } P(x \geq 20) = 1 - 0.0228 = 0.9772 = 97.72 \%$$



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## NUMERICAL

$$\begin{aligned}\mu &= 51.7 \text{ kmph} \\ \sigma &= 8.3 \text{ kmph}\end{aligned}$$

The spot speeds at a particular locations are normally distributed with a mean of 51.7 kmph and a standard deviation of 8.3 kmph. What is the probability that a) the speed exceeds 65 kmph b) the speed lies between 40 kmph and 70 kmph c) What is the 98<sup>th</sup> percentile speed?

### Probability that the speed exceeds 65 kmph ( $x \geq 65$ )

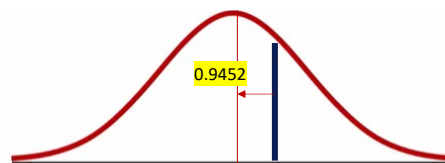
It is the area under the normal curve to the right of  $x = 65$  kmph

$$z = \frac{x - \mu}{\sigma} = \frac{65 - 51.7}{8.3} = \frac{13.3}{8.3} = 1.602$$

From z-table, for  $z = 1.602$ , we have  $\phi(1.602) = 0.9452$  which is the area to the left of the curve.

For the area to the right of the curve we deduct the value 0.9452 from the total area of curve, i.e. 1.

$$\text{Therefore, } P(x \geq 65) = 1 - 0.9452 = 0.0548 = 5.48 \%$$



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## NUMERICAL

$$\mu = 51.7 \text{ kmph}$$

$$\sigma = 8.3 \text{ kmph}$$

The spot speeds at a particular locations are normally distributed with a mean of 51.7 kmph and a standard deviation of 8.3 kmph. What is the probability that a) the speed exceeds 65 kmph b) the speed lies between 40 kmph and 70 kmph c) What is the 98<sup>th</sup> percentile speed?

### Probability that the speed exceeds lies between 40 and 70 kmph

It is the area under the normal curve in between 40 and 70 kmph

For  $x = 40$ kmph

$$z = \frac{40 - \mu}{\sigma} = \frac{40 - 51.7}{8.3} = \frac{-11.7}{8.3} = -1.409$$

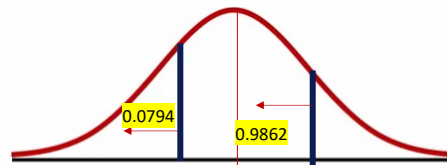
From z-table, for  $z = -1.409$ , we have  $\phi(-1.409) = 0.0794$  which is the area to the left of the curve from  $x = 40$ kmph

For  $x = 70$ kmph

$$z = \frac{70 - \mu}{\sigma} = \frac{70 - 51.7}{8.3} = \frac{18.30}{8.3} = 2.204$$

From z-table, for  $z = 2.204$ , we have  $\phi(2.204) = 0.9862$  which is the area to the left of the curve from  $x = 70$ kmph

Therefore,  $P(40 < x < 70) = 0.9862 - 0.0794 = 0.9068 = 90.68 \%$



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## NUMERICAL

$$\mu = 51.7 \text{ kmph}$$

$$\sigma = 8.3 \text{ kmph}$$

The spot speeds at a particular locations are normally distributed with a mean of 51.7 kmph and a standard deviation of 8.3 kmph. What is the probability that a) the speed exceeds 65 kmph b) the speed lies between 40 kmph and 70 kmph c) What is the 98<sup>th</sup> percentile speed?

### Calculating 98<sup>th</sup> percentile speed

$$\phi(z) = 0.98$$

From table, we have,  $z = 2.0537$

Now,

$$z = \frac{x - \mu}{\sigma} = \frac{x - 51.7}{8.3}$$

$$2.0537 = \frac{x - 51.7}{8.3}$$

$$x = 68.74 \text{ kmph}$$

### fx 991 EX CLASSWIZ

- 1: Press Mode
- 2: Select 7: Distribution
- 3: Select 3: Inverse Normal
- 4: Inverse Normal  
Area: 0  
 $\sigma$ : 1  
 $\mu$ : 0
- 5: Replace values in Step 4 with your values as:
 

Inverse Normal	Inverse Normal
Area: 0.98	Area: 0.98
$\sigma$ : 1	$\sigma$ : 8.3
$\mu$ : 0	$\mu$ : 51.7
6: xInv = 2.0537	xInv = 68.74



For,  $\phi(z) = 0.99$ ,  $z = 2.58$

For,  $\phi(z) = 0.98$ ,  $z = 2.0537$



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**
  - Spot Speed Study
  - Speed and Delay Study



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**
  - Speed and Delay Study
    - Spot speeds are most useful in measuring fluctuation in speed at particular locations.
    - But, they give no information regarding fluctuation in speed throughout a route as a whole.
    - This study gives the running speeds, overall speeds, variations in speed and delays between two specific stations on the road.
    - This study also furnishes information such as duration, location, frequency and causes of delay.
    - Carried out at major highways, high crash points, congestion point, at traffic signals and at points of future development.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**
  - Speed and Delay Study
    - Uses of Speed and Delay Study
      - Find the cost of journey.
      - Evaluate congestion, capacity, level of service and improvement needs.
      - Traffic planning studies.
      - Study of before and after improvement.
      - Delays study at intersection and for control device.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**
  - Speed and Delay Study
    - Classification of Delays
      - Fixed Delays are caused due to traffic signals, stop signals and level crossing.
      - Operational delays are caused due to interference by other components of traffic such as turning vehicles, parking and unparking of vehicles, pedestrians, insufficient capacity, crashes, etc.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**

- Speed and Delay Study

- Definitions

- **Travel Time:** Time taken to travel certain section of road.

- **Delay:** Time lost during travel.

- **Journey Speed:** Time taken to travel certain length of road.

$$\text{Journey Speed} = \frac{\text{Total Length of Road}}{\text{Total Time Including Delays}}$$

- **Running Speed:** Average speed maintained by a vehicle over a given length of road.

$$\text{Running Speed} = \frac{\text{Length of Road}}{\text{Journey Time} - \text{Delay}}$$



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**

- Speed and Delay Study

- Methods of carrying out Speed and Delay Study

- Floating car or riding check method.

- License Plate Method or Vehicle Number Method.

- Interview Method.

- Photographic Technique.

- Elevated Observations.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**
  - Speed and Delay Study
    - Methods of carrying out Speed and Delay Study
      - Floating car or riding check method.
        - In floating car method the speed and flow can be obtained by travelling in a car against and with the flow and noting down the journey time, the number of vehicles met with from the opposite direction.
        - A test vehicle is driven a number of times over a given stretch of road at approximately the average speed of the stream of traffic.
        - A number of test runs are made along the study stretch and a group of observers record the various details.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- **Types of Speed Studies**
  - Speed and Delay Study
    - Methods of carrying out Speed and Delay Study
      - Floating car or riding check method.
        - **First observer** is seated with two stopwatches. One of the stopwatches is used to record time at various control points at intersections. The other stopwatch is used to find the duration of individual delays.
        - **Second observer** records the time, location and causes of delays either on a tabular forms or by voice recording instruments.
        - **Third observer** records the number of vehicles overtaking the test vehicle and that overtaken by the test vehicle.
        - **Fourth observer** notes the number of vehicles travelling in the opposite direction in each.



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## TYPES OF TRAFFIC STUDIES – SPEED STUDIES

- Types of Speed Studies
  - Speed and Delay Study
    - Methods of carrying out Speed and Delay Study
      - Floating car or riding check method.

The average journey time  $T$  in minutes is calculated for all vehicles in a traffic stream in the direction of flow as follows:

$$T = t_w - \frac{n_y}{q}$$

$$q = \frac{n_a + n_y}{t_a + t_w}$$

where,

$t_a$  = average journey time in minutes when test vehicle is running against the stream.

$t_w$  = average journey time in minutes when the vehicle is travelling with the stream.

$q$  = flow of vehicles (volume per minute in one direction of stream)

$n_a$  = average number of vehicles counted in the direction of the stream when the test vehicle travels in the opposite direction.

$n_y$  = average number of vehicles overtaking the test vehicle minus the number of vehicles overtaken when the test vehicle is in the direction of flow.



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## NUMERICAL

Speed and delay studies by floating car method were conducted on stretch of city road of road 3 km length running north-south.

The data collected is given in tabular form. Find out the

i) Average value of volume ii) Journey speed and iii) Running speed of the traffic stream along either stream.

Trip No.	Direction of trip	Journey Time (min sec)	Total stopped delay in min sec	No. of vehicles overtaking	No. of vehicles overtaken	No. of vehicles from opposite direction
1	N-S	5'30"	1'30"	4	7	250
2	S-N	6'15"	1'90"	5	5	200
3	N-S	5'22"	1'30"	5	3	240
4	S-N	6'20"	2'15"	3	1	240
5	N-S	5'38"	1'10"	2	6	230
6	S-N	6'18"	1'20"	2	3	250
7	N-S	5'20"	1'40"	2	7	210
8	S-N	6'32"	1'50"	3	2	180
9	N-S	5'10"	1'30"	2	4	200



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## NUMERICAL

Road 3 km length

Find out the

i) Average value of volume

ii) Journey speed and iii) Running speed of the traffic stream along either stream.

$$q = \frac{n_a + n_y}{t_a + t_w}$$

$$T = t_w - \frac{n_y}{q}$$

### For S-N

**For S-N**  
 $n_y = 0.50$   
 $n_a = 226$   
 $t_w = 6.35$  mins  
 $t_a = 5.39$  mins

**Average Volume, q**  
 $q = 19.27$  veh/min

**Average Journey Time, T**  
 $T = 6.32$  mins

### For N-S

**For N-S**  
 $n_y = -2.4$   
 $n_a = 217.50$   
 $t_w = 5.39$  mins  
 $t_a = 6.35$  mins

**Average Volume, q**  
 $q = 18.30$  veh/min

**Average Journey Time, T**  
 $T = 5.53$  mins

**Average Journey Speed** = 28.46 kmph  
**Average Stopped Delay** = 1.97 mins  
**Average running time** = 4.35 mins  
**Average running speed** = 41.38 kmph

Direction	Journey Time		Stopped Delay		Number of Vehicles		
	Min		Min		Overtaking	Overtaken	From opposite direction
N-S	5.50		1.50		4	7	250
	5.37		1.50		5	3	240
	5.63		1.16		2	6	230
	5.33		1.66		2	7	210
	5.16		1.50		2	4	200
Total	26.99		7.33		15	27	1130
Mean	5.39		1.46		3	5.4	226

Direction	Journey Time		Stopped Delay		Number of Vehicles		
	Min		Min		Overtaking	Overtaken	From opposite direction
S-N	6.25		2.50		5	5	200
	6.33		2.25		3	1	240
	6.30		1.33		2	3	250
	6.53		1.83		3	2	180
	Total	25.41		7.91		13	11
Mean	6.35		1.97		3.25	2.75	217.50

**Average Journey Speed** = 32.54 kmph  
**Average Stopped Delay** = 1.46 mins  
**Average running time** = 4.07 mins  
**Average running speed** = 44.22 kmph

**Average Journey Speed**  
 = Distance/Avg. Journey Time  
 =  $3/5.53$   
 =  $3/(5.53/60)$   
 = 32.54 kmph

**Average Running Speed**  
 = Distance/Avg. Running Time  
 =  $3/4.07$   
 =  $3/(4.07/60)$   
 = 44.22 kmph

Avg. Running Time = Avg. Journey Time - Avg. Stopped Delay

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## NUMERICAL

The following tables gives the particulars collected for a section of road 1.5 km long during the course of a moving observer study.

### Journey North Bound

Trip No.	Journey Time (mins)	Stopped time (mins)	Vehicles met with in the opposing direction			Vehicles in the same direction	
			Car	Bus	Truck	Overtaking vehicles	Overtaken vehicles
1	2.25	0.62	30	1	6	2	1
2	2.10	0.38	20	0	1	5	2
3	2.85	1.22	12	2	4	4	2
4	2.12	0.42	15	1	6	2	1
5	2.01	1.23	4	3	7	3	3
6	2.20	0.52	30	2	3	1	2

### Journey South Bound

Trip No.	Journey Time (mins)	Stopped time (mins)	Vehicles met with in the opposing direction			Vehicles in the same direction	
			Car	Bus	Truck	Overtaking vehicles	Overtaken vehicles
1	2.23	0.87	13	2	2	3	2
2	2.13	1.23	10	1	5	7	1
3	3.11	0.45	32	0	3	5	5
4	3.01	0.49	30	3	2	4	6
5	2.85	0.62	20	2	5	6	3
6	2.28	0.98	23	0	6	2	4

Assuming the equivalency factor of 1, 3 and 2 for each car, bus and truck respectively, calculate the flow in PCU per hour in both directions of traffic. Also calculate the journey speed and running speed in both directions.

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# NUMERICAL

Road 1.5 km long

Equivalency factor of 1, 3 and 2 for each car, bus and truck respectively

$$\begin{aligned} \text{PCU for S-N} &= (111*1) + (9*3) + (27*2) \\ &= 192 \\ \text{PCU for N-S} &= (128*1) + (8*3) + (23*2) \\ &= 198 \end{aligned}$$

## Journey North Bound

Trip No.	Journey Time (mins)	Stopped time (mins)	Vehicles met with in the opposing direction			Vehicles in the same direction	
			Car	Bus	Truck	Overtaking vehicles	Overtaken vehicles
1	2.25	0.62	30	1	6	2	1
2	2.1	0.38	20	0	1	5	2
3	2.85	1.22	12	2	4	4	2
4	2.12	0.42	15	1	6	2	1
5	2.01	1.23	4	3	7	3	3
6	2.2	0.52	30	2	3	1	2
<b>Total</b>	<b>13.53</b>	<b>4.39</b>	<b>111.00</b>	<b>9.00</b>	<b>27.00</b>	<b>17.00</b>	<b>11.00</b>
PCU =			192.00				
<b>Average</b>	<b>2.26</b>	<b>0.73</b>	<b>32.00</b>			<b>2.83</b>	<b>1.83</b>

## Journey South Bound

Trip No.	Journey Time (mins)	Stopped time (mins)	Vehicles met with in the opposing direction			Vehicles in the same direction	
			Car	Bus	Truck	Overtaking vehicles	Overtaken vehicles
1	2.23	0.87	13	2	2	3	2
2	2.13	1.23	10	1	5	7	1
3	3.11	0.45	32	0	3	5	5
4	3.01	0.49	30	3	2	4	6
5	2.85	0.62	20	2	5	6	3
6	2.28	0.98	23	0	6	2	4
<b>Total</b>	<b>15.61</b>	<b>4.64</b>	<b>128.00</b>	<b>8.00</b>	<b>23.00</b>	<b>27.00</b>	<b>21.00</b>
PCU =			198.00				
<b>Average</b>	<b>2.60</b>	<b>0.77</b>	<b>33.00</b>			<b>4.50</b>	<b>3.50</b>

$$q = \frac{n_a + n_y}{t_a + t_w}$$

$$T = t_w - \frac{n_y}{q}$$

For S-N

For S-N

$$n_y = 1$$

$$n_a = 33$$

$$t_w = 2.26 \text{ mins}$$

$$t_a = 2.60 \text{ mins}$$

Average Volume, q

$$q = 6.99 \text{ pcu/min}$$

Average Journey Time, T

$$T = 2.12 \text{ mins}$$

Average Journey Speed = 42.45 kmph

Average Stopped Delay = 0.73 mins

Average running time = 1.39 mins

Average running speed = 64.75 kmph

For N-S

For N-S

$$n_y = 1$$

$$n_a = 32$$

$$t_w = 2.60 \text{ mins}$$

$$t_a = 2.26 \text{ mins}$$

Average Volume, q

$$q = 6.79 \text{ pcu/min}$$

Average Journey Time, T

$$T = 2.45 \text{ mins}$$

Average Journey Speed = 36.73 kmph

Average Stopped Delay = 0.77 mins

Average running time = 1.68 mins

Average running speed = 53.57 kmph



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# NUMERICAL

ABCD is a street running north to south comprising of 3 adjacent sections. The table below gives the length of each section:

Section	AB	B	BC	C	CD
Length (m)	500	Intersection	600	Intersection	450

Again the following table gives the details of observations (average of test runs) by the moving observer team:

## Moving observer travelling south

Section	Time taken to traverse (min)	Vehicles met with in opposing direction	Vehicles in the same direction	
			Vehicles overtaking	Vehicles overtaken
AB	2.53	25	4	3
B	0.25	-	-	-
BC	2.87	31	2	2
C	0.17	-	-	-
CD	2.30	28	3	4

## Moving observer travelling north

Section	Time taken to traverse (min)	Vehicles met with in opposing direction	Vehicles in the same direction	
			Vehicles overtaking	Vehicles overtaken
DC	2.20	50	2	1
C	0.20	-	-	-
CB	2.67	55	3	4
B	0.30	-	-	-
BA	2.42	45	1	1

Calculate the flow and running speeds in each section in both directions and the overall journey speeds in each direction.



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# NUMERICAL

ABCD is a street running north to south comprising of 3 adjacent sections. The table below gives the length of each section:

Section	AB	B	BC	C	CD
Length (m)	500	Intersection	600	Intersection	450

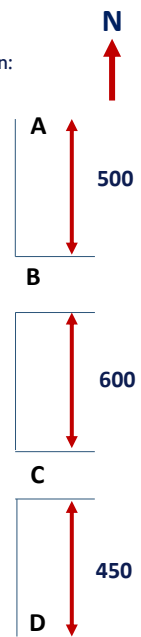
Again the following table gives the details of observations (average of test runs) by the moving observer team:

### Moving observer travelling south

Section	Time taken to traverse (min)	Vehicles met with in opposing direction	Vehicles in the same direction	
			Vehicles overtaking	Vehicles overtaken
AB	2.53	25	4	3
B	0.25	-	-	-
BC	2.87	31	2	2
C	0.17	-	-	-
CD	2.30	28	3	4

### Moving observer travelling north

Section	Time taken to traverse (min)	Vehicles met with in opposing direction	Vehicles in the same direction	
			Vehicles overtaking	Vehicles overtaken
DC	2.20	50	2	1
C	0.20	-	-	-
CB	2.67	55	3	4
B	0.30	-	-	-
BA	2.42	45	1	1



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# NUMERICAL

### Moving observer travelling south

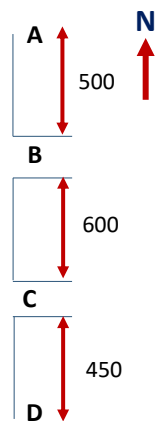
Section	Time taken to traverse (min)	Vehicles met with in opposing direction	Vehicles in the same direction	
			Vehicles overtaking	Vehicles overtaken
AB	2.53	25	4	3
B	0.25	-	-	-
BC	2.87	31	2	2
C	0.17	-	-	-
CD	2.30	28	3	4

### Moving observer travelling north

Section	Time taken to traverse (min)	Vehicles met with in opposing direction	Vehicles in the same direction	
			Vehicles overtaking	Vehicles overtaken
DC	2.20	50	2	1
C	0.20	-	-	-
CB	2.67	55	3	4
B	0.30	-	-	-
BA	2.42	45	1	1

$$q = \frac{n_a + n_y}{t_a + t_w}$$

$$T = t_w - \frac{n_y}{q}$$



### Flow in North Bound Direction

#### In section DC

$n_y = 1$   
 $n_a = 28$   
 $t_w = 2.20$  mins  
 $t_a = 2.30$  mins  
 $q = 6.44$  veh/mins  
 $T = 2.04$  mins

#### In section CB

$n_y = -1$   
 $n_a = 31$   
 $t_w = 2.67$  mins  
 $t_a = 2.87$  mins  
 $q = 5.41$  veh/mins  
 $T = 2.85$  mins

#### In section BA

$n_y = 0$   
 $n_a = 25$   
 $t_w = 2.42$  mins  
 $t_a = 2.53$  mins  
 $q = 5.05$  veh/mins  
 $T = 2.42$  mins

### Flow in South Bound Direction

#### In section AB

$n_y = 1$   
 $n_a = 45$   
 $t_w = 2.53$  mins  
 $t_a = 2.42$  mins  
 $q = 9.29$  veh/mins  
 $T = 2.42$  mins

#### In section BC

$n_y = 0$   
 $n_a = 55$   
 $t_w = 2.87$  mins  
 $t_a = 2.67$  mins  
 $q = 9.92$  veh/mins  
 $T = 2.87$  mins

#### In section CD

$n_y = -1$   
 $n_a = 50$   
 $t_w = 2.30$  mins  
 $t_a = 2.20$  mins  
 $q = 10.88$  veh/mins  
 $T = 2.39$  mins



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Calculate flow, running speed and overall journey speed in each directions.

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## NUMERICAL

Moving observer travelling south

Section	Time taken to traverse (min)	Vehicles met with in opposing direction	Vehicles in the same direction	
			Vehicles overtaking	Vehicles overtaken
AB	2.53	25	4	3
B	0.25	-	-	-
BC	2.87	31	2	2
C	0.17	-	-	-
CD	2.30	28	3	4

Moving observer travelling north

Section	Time taken to traverse (min)	Vehicles met with in opposing direction	Vehicles in the same direction	
			Vehicles overtaking	Vehicles overtaken
DC	2.20	50	2	1
C	0.20	-	-	-
CB	2.67	55	3	4
B	0.30	-	-	-
BA	2.42	45	1	1

Running Speed in North Bound Direction

In section DC	In section CB	In section BA
T = 2.04 mins Distance = 450m <u>Running Speed</u> $\frac{450/1000}{2.04/60}$ = 13.23kmph	T = 2.85 mins Distance = 600m <u>Running Speed</u> $\frac{600/1000}{2.85/60}$ = 12.63kmph	T = 2.42 mins Distance = 500m <u>Running Speed</u> $\frac{500/1000}{2.42/60}$ = 12.40kmph

Running Speed in South Bound Direction

In section AB	In section BC	In section CD
T = 2.42 mins Distance = 500m <u>Running Speed</u> $\frac{500/1000}{2.42/60}$ = 12.40kmph	T = 2.87 mins Distance = 600m <u>Running Speed</u> $\frac{600/1000}{2.87/60}$ = 12.54kmph	T = 2.39 mins Distance = 450m <u>Running Speed</u> $\frac{450/1000}{2.39/60}$ = 11.30kmph

$q = \frac{n_a + n_y}{t_a + t_w}$   
 $T = t_w - \frac{n_y}{q}$

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Calculate flow, running speed and overall journey speed in each directions.

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## NUMERICAL

Moving observer travelling south

Section	Time taken to traverse (min)	Vehicles met with in opposing direction	Vehicles in the same direction	
			Vehicles overtaking	Vehicles overtaken
AB	2.53	25	4	3
B	0.25	-	-	-
BC	2.87	31	2	2
C	0.17	-	-	-
CD	2.30	28	3	4

Moving observer travelling north

Section	Time taken to traverse (min)	Vehicles met with in opposing direction	Vehicles in the same direction	
			Vehicles overtaking	Vehicles overtaken
DC	2.20	50	2	1
C	0.20	-	-	-
CB	2.67	55	3	4
B	0.30	-	-	-
BA	2.42	45	1	1

Journey Speeds in North Bound Direction

Journey Time Traveling North from D to A

= 2.42 + 0.20 + 2.85 + 0.30 + 2.04 = 7.81 mins

Journey Speed in North Bound Direction

=  $\frac{(450 + 600 + 500)/1000}{(\frac{7.81}{60})}$  = 11.91kmph

Journey Speeds in South Bound Direction

Journey Time Traveling South from A to D

= 2.42 + 0.25 + 2.87 + 0.17 + 2.39 = 8.10 mins

Journey Speed in South Bound Direction

=  $\frac{(500 + 600 + 450)/1000}{(\frac{8.1}{60})}$  = 11.48kmph

$q = \frac{n_a + n_y}{t_a + t_w}$   
 $T = t_w - \frac{n_y}{q}$

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Calculate flow, running speed and overall journey speed in each directions.

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**T is calculated taking into consideration the average time of test vehicle  $t_w$  because:**

We tend to move our test vehicle at the average speed of the stream which is always not possible. The average  $t_w$  so obtained is the average speed of the test vehicle in the stream. If  $t_w$  had been the average speed of the stream then there wont be any case of overtaking and overtaken leading  $n_y$  to be zero. However, it is not always true. Thus the obtained average time needs to be corrected as  $T = t_w - \frac{n_y}{q}$  which is affected by other interfering vehicles (No. of overtaking vehicles, no. of vehicles overtaken and so on).



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## TRAFFIC STUDIES

- 2.1 Traffic Volume Studies
- 2.2 Traffic Speed Studies
- 2.3 Origin and Destination Studies**
- 2.4 Traffic flow and Capacity Studies
- 2.5 Parking Studies
- 2.6 Crash Studies



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## TYPES OF TRAFFIC STUDIES – ORIGIN AND DESTINATION STUDY (O AND D STUDY)

- **Origin and Destination Study (O and D Study)**
  - Origin and destination survey provides the basic data for determining the desired direction of flow.
  - Carried out to
    - Determine the pattern of the journeys that people make.
    - Determine the amount of travel there are between various locations.
    - Determine the relationship between the amount and type of travel and the traffic generating factors.



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## TYPES OF TRAFFIC STUDIES – ORIGIN AND DESTINATION STUDY (O AND D STUDY)

- **Origin and Destination Study (O and D Study)**
  - Purpose of the Study is to get information about
    - Why people travel - Purpose of the trip
    - When people travel – Time and Direction
    - How the people travel – Mode of travel
    - Where do people travel – Origin and Destination
    - Where and why people stop – To determine concentration of vehicles warranting need of parking facilities.



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## TYPES OF TRAFFIC STUDIES – ORIGIN AND DESTINATION STUDY (O AND D STUDY)

- **Origin and Destination Study (O and D Study)**
  - Uses
    - To provide expressways along the maximum desire lines of travel.
    - To plan public transportation system in the cities.
    - To evaluate the existing facilities and plan for improvement.
    - To locate intermediate stops for public transportation.
    - To establish over and under bridge site according to the traffic demand.
    - To locate new bridges as per traffic demands.
    - To locate terminals and to plan terminal facilities.



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## TYPES OF TRAFFIC STUDIES – ORIGIN AND DESTINATION STUDY (O AND D STUDY)

- **Origin and Destination Study (O and D Study)**
  - Methods of Carrying out O-D Study
    - Drivers Interview
    - License Plate Method
    - Return Post Card Method
    - Home Interview
    - Tag on Car Method



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## TYPES OF TRAFFIC STUDIES – ORIGIN AND DESTINATION STUDY (O AND D STUDY)

- **Origin and Destination Study (O and D Study)**
  - Methods of Carrying out O-D Study
    - Drivers Interview
      - Interview stations are established on all the roads originating from the city.
      - With the help of traffic police, vehicles are stopped and answers to prescribed questionnaire collected at the spot from the drivers.
      - The questionnaire includes place and time of origin and destination, route, purpose of trip, type of vehicle, number of passengers in the vehicle, stoppage location, etc.



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## TYPES OF TRAFFIC STUDIES – ORIGIN AND DESTINATION STUDY (O AND D STUDY)

- **Origin and Destination Study (O and D Study)**
  - Methods of Carrying out O-D Study

Field Data Collection Sheet Registration Plate No. Survey			
Survey Station: _____	Surveyor: _____		
Date: _____	Day: _____		
Registration No.	Time	Vehicle Type	Others

Image Source: Dr. Pradeep K. Shrestha

- License Plate Method
  - Registration numbers of the vehicles entering or leaving the area are recorded at the station setup for the purpose.
  - The observers with synchronized watches records the passes time and vehicle registration number as the vehicle passes the observer.
  - Vehicle's origin is assumed to be where it was first observed while its destination is assumed to be its last observation point.
  - Large number of stations are required to take observation so as to get the information of the routes followed by the vehicles hence large number of study personnel is required to take simultaneous observations.



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## TYPES OF TRAFFIC STUDIES – ORIGIN AND DESTINATION STUDY (O AND D STUDY)

- Origin and Destination Study (O and D Study)
  - Methods of Carrying out O-D Study
    - Return Post Card Method
      - Road users are distributed post – cards on which the questionnaire to be filled in, along with the request to answer them and also the purpose of study is printed.
      - Cards may be directly mailed to the vehicle owners or distributed through such stations where vehicles have to stop.

Field Data Collection Sheet Post Card Questionnaire Survey	
Survey Station: _____	Surveyor: _____
Date: _____	Day: _____
Time: _____	Vehicle Type: _____
Vehicle Occupancy: _____	Destination: _____
Types of Goods Carried: _____	



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Image Source: Dr. Pradeep K. Shrestha

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## TYPES OF TRAFFIC STUDIES – ORIGIN AND DESTINATION STUDY (O AND D STUDY)

- Origin and Destination Study (O and D Study)
  - Methods of Carrying out O-D Study
    - Home Interview
      - About 10 % population is interviewed by trained personnel.
      - Detailed information regarding the trips made by the members is obtained.
      - The data collected may be useful for the planning of mass transportation requirements of the passengers.



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## TYPES OF TRAFFIC STUDIES – ORIGIN AND DESTINATION STUDY (O AND D STUDY)

- Origin and Destination Study (O and D Study)
  - Methods of Carrying out O-D Study
    - Tag on Car Method
      - Pre-coded cards are tied to the vehicles at observation station when it enters the study area.
      - The tag is removed from the car as soon as it leaves the cordoned area.
      - On the removed card, the time of entry, time of leaving, station, direction of travel, etc. are marked.

**Field Data Collection Sheet**  
Tag on Vehicle Survey

Survey Station: _____	Surveyor: _____
Date: _____	Day: _____
Time while starting: _____	Vehicle Type: _____
Survey Station: _____	Surveyor: _____
Date: _____	Day: _____
Time while Removing: _____	Vehicle Type: _____



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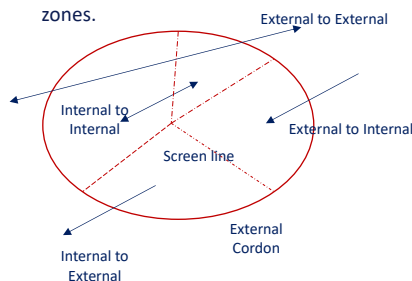
Image Source: Dr. Pradeep K. Shrestha

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## TYPES OF TRAFFIC STUDIES – ORIGIN AND DESTINATION STUDY (O AND D STUDY)

- Origin and Destination Study (O and D Study)
  - Presentation of O-D Data
    - Tabular Format
      - Origin and Destination tables are developed which show number of trips between different zones.



		Destination Zones								
		Internal			External					
		1	2	3			71	72	73	
Origin Zones	Internal	1								
		2								
		3								
External	Internal									
External	Internal	71								
		72								
		73								



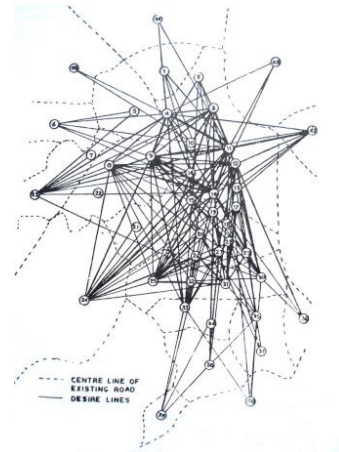
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## TYPES OF TRAFFIC STUDIES – ORIGIN AND DESTINATION STUDY (O AND D STUDY)

- **Origin and Destination Study (O and D Study)**
  - Presentation of O-D Data
    - Graphical Representation
      - Data may be presented in graphical form by desire lines. Desire lines are straight lines joining the origin and destination points.
      - The thickness of desire lines is drawn proportional to the number of trips.
      - In this method, points of similar specific traffic needs are joined just in the same way as in done to draw contour lines.



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## TRAFFIC STUDIES

- 2.1 Traffic Volume Studies
- 2.2 Traffic Speed Studies
- 2.3 Origin and Destination Studies
- 2.4 Traffic flow and Capacity Studies**
- 2.5 Parking Studies
- 2.6 Crash Studies



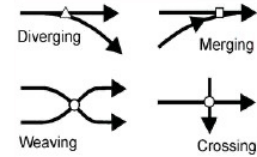
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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- The theory of traffic flow can be defined as mathematical study of the movement of vehicles over road network.



- In traffic flow characteristics diverging, merging, crossing and weaving maneuvers are involved.
- Diverging and merging from left side do not cause any problem but diverging to and merging from right cause conflicts and difficulties to traffic moving on straight path.
- Traffic or a vehicle moving from one traffic lane to the adjacent lane and then again coming back to the original traffic lane involves both merging and diverging maneuvers.
- When vehicle moves obliquely first merging with a vehicle moving in the same direction at relatively smaller angle and then diverging from the traffic stream, the maneuver is termed as weaving. Weaving action consists of both merging and diverging maneuvers.



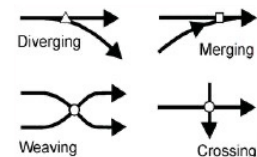
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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- In the case of two-way roads, crossing and overtaking operations are involved.
- Traffic stream characteristics are influenced by varieties of vehicles and road users, geometric standards, intersections and other regulatory devices of the road.
- Traffic flow characteristics study consists of both lateral and longitudinal distribution of vehicles in the traffic stream.
- This study is useful in geometric design features as volume, capacity, number of lanes, carriage width, traffic regulation measures, traffic control methods, intersection design.



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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- **Basic parameters of unidirectional uninterrupted traffic flow**
  - Speed – Average speed of the vehicles moving in that stream.
  - Density – Average number of vehicles per unit length of the stream.



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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- **Types of traffic facilities**
  - Uninterrupted flow facilities
  - Interrupted flow facilities



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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- **Types of traffic facilities**

- Uninterrupted flow facilities

- These are the facilities on which no external factors cause periodic interruption to the traffic stream.
    - Exists primarily on freeways and other limited access facilities where there are no traffic signals, STOP or YIELD signs or surface intersections to interrupt the flow.
    - May exist on long section of rural highway between signalized intersection.
    - Breakdowns are the result of internal interactions in the traffic stream, not external causes.



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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- **Types of traffic facilities**

- Interrupted flow facilities

- Due to external devices that periodically interrupt traffic flow.
    - Principal device is traffic signal, STOP and YIELD signs.
    - Must deal with the constant stopping and restarting of a traffic stream.
    - Flow depends not only on the interactions among vehicles and the roadway environment but also on signal timing.
    - Flow occurs in platoons.



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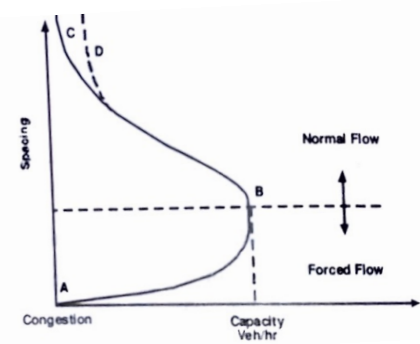
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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- **Uninterrupted Traffic Flow Model**

- As vehicles speed and spacing increases, the speed approaches free speed.
- Drivers adopt their own speed when uninfluenced by other vehicles in traffic stream (Point C).
- Point A represents the maximum traffic density that occurs when traffic has come to complete stop.
- The dashed curve represents the normal flow behavior if all drivers were to have the same free speed (D).
- About half the capacity flow (Point B) in the forced region, each vehicle adopts its minimum spacing and clearance.



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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- **Other Additional Parameters of Traffic Flow**

- Transverse and longitudinal distribution of vehicles on the various routes.
- The gap ahead of each vehicle determines the longitudinal distribution of vehicles in one way traffic stream.
- Spacing (Space Headway) is defined as the distance between successive vehicles in a traffic lane measured from some common reference point on the vehicles.
- Headway (Time Headway) is the time between successive vehicles as they pass a point along the lane also measured between common reference points on the vehicles.
- The number of headways per unit time is dependent on the rate of traffic flow and is therefore a direct measure of traffic volume.



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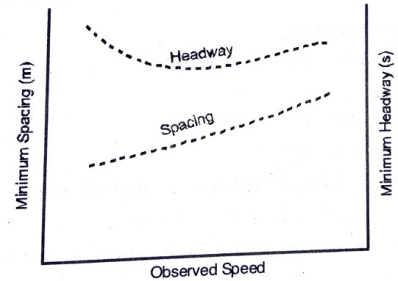
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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- Other Additional Parameters of Traffic Flow

- With increase in speed of traffic stream, the minimum space headway increases whereas the minimum time headways first decreases and after reaching a minimum value at optimum speed of the stream increases.



- Lane occupancy is a measure used in freeway surveillance.

$$R = \frac{\text{Sum of length of vehicles}}{\text{Length of roadway section}} = \frac{\sum L_i}{D}$$

- Lane occupancy can also be described as the ratio of the time that vehicles are present at a detection station in a traffic lane compared to the time of sampling.

$$LO = \frac{\text{Total time vehicle detector is occupied}}{\text{Total Observation Time}} = \frac{\sum t_o}{T}$$



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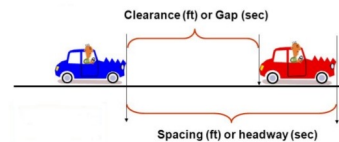
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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- Other Additional Parameters of Traffic Flow

- Clearance and gap corresponds to parameters of spacing and headway.
- The difference between spacing and clearance is the average length of a vehicle.
- The difference between headway and gap is the time equivalence of the average length of a vehicle ( $L/v$ ).



$$g = h - \frac{L}{v}$$

$$C = g * v$$

- Where,
- $g$  = mean gap (s)
  - $L$  = mean length of vehicle
  - $C$  = mean clearance
  - $h$  = mean headway
  - $v$  = mean speed

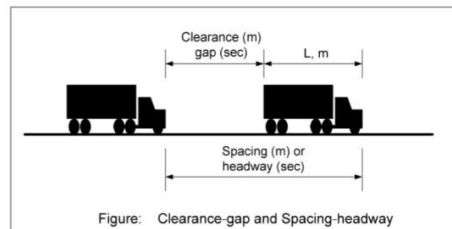


Figure: Clearance-gap and Spacing-headway



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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- Analysis of Speed, Flow and Density Relationship

It is hypothesized that a linear relationship exists between the speed of traffic on an interrupted traffic lane and the traffic density (veh/km).

$$V = A - Bk$$

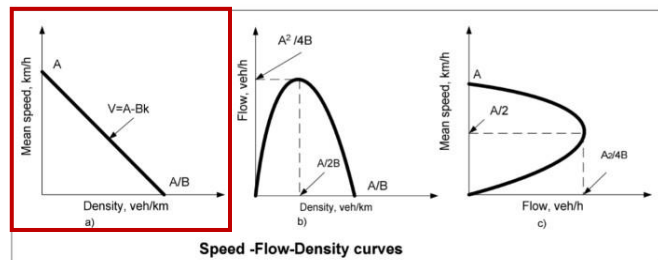
Where,

V = Mean speed of vehicles

k = average density of vehicles

A and B = empirically determined parameters

- Speed will be maximum, referred to as the free flow speed, and when the density is maximum, the speed will be zero.
- Corresponding to the zero density, vehicles will be flowing with their desire speed, or free flow speed.
- When the density is jam density, the speed of the vehicles becomes zero.



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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

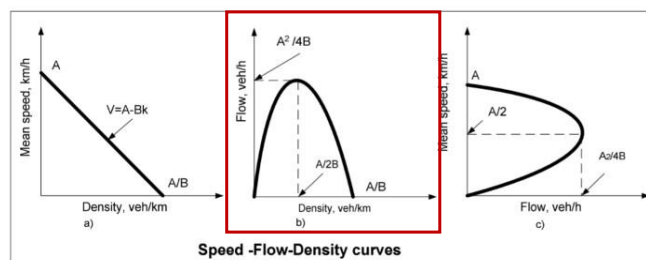
- Analysis of Speed, Flow and Density Relationship

We have, the flow of an uninterrupted traffic stream as the product of the density and the speed.

$$q = k V = Ak - Bk^2$$

$$q = \frac{A}{B}V - \frac{V^2}{B}$$

- The flow and density varies with time and location.
- The relation between the density and the corresponding flow on a given stretch of road is referred to as one of the fundamental diagram of traffic flow.



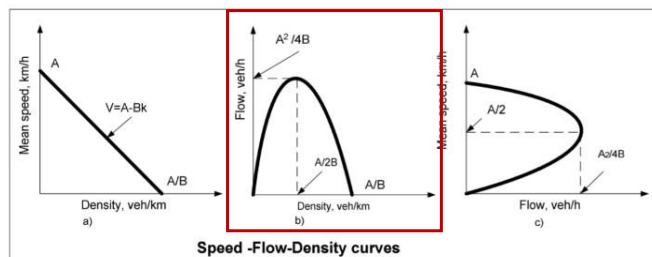
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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- Analysis of Speed, Flow and Density Relationship

Characteristics of an ideal flow-density relationship are listed below as:

- When the density is zero, flow will also be zero, since there is no vehicle on the road.
- When the number of vehicles gradually increases, the density as well as flow increases.
- When more and more vehicles are added, it reaches a situation where vehicles can't move. This is referred to as jam density or the maximum density. At jam density, flow will be zero because the vehicles are not moving.
- There will be some density between zero density and jam density when the flow is maximum.



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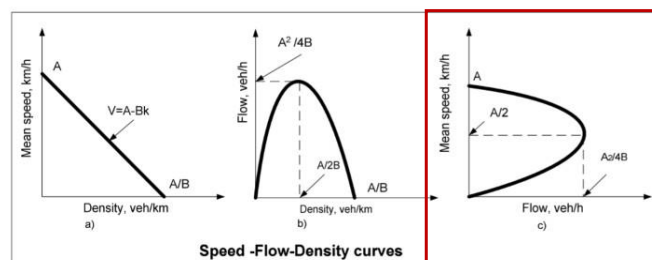
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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- Analysis of Speed, Flow and Density Relationship

- The relationship between the speed and flow can be postulated as follows
  - The flow is zero either because there are no vehicles or there are too many vehicles so that they cannot move.
  - At maximum flow, the speed will be in between zero and free flow speed.
  - It is possible to have two different speeds for a given flow.



$$q = \frac{A}{B}V - \frac{V^2}{B}$$



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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- Analysis of Speed, Flow and Density Relationship

- We have,

$$q = kV = Ak - Bk^2$$

For  $q_{max}$

$$\frac{dq}{dk} = 0$$

$$A - 2Bk = 0$$

$$k = \frac{A}{2B}$$

$$q_{max} = \frac{A^2}{4B}$$

- At zero density, mean free speed = A
- At zero speed, jam density = A/B

**Capacity flow:**

The value of maximum speed is called the free mean speed and is represented by  $V_f$ . The maximum density at zero speed is called jam density and is represented by  $K_j$ . The maximum flow  $q_{max}$  or  $q_c$  which is called capacity flow takes place when the speed is  $\frac{V_f}{2}$  and density is  $\frac{K_j}{2}$ .

Therefore,  $q_{max} = \frac{V_f * K_j}{4}$



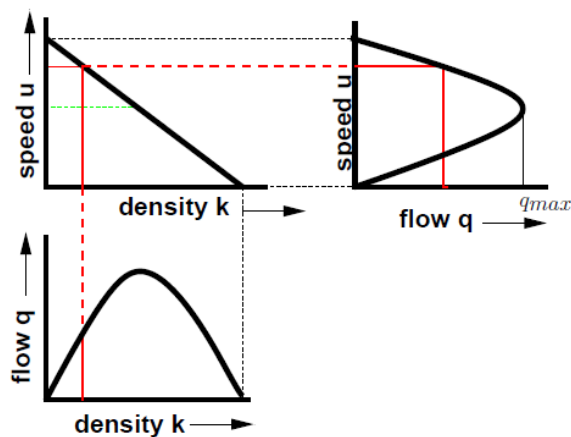
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## TYPES OF TRAFFIC STUDIES – TRAFFIC FLOW CHARACTERISTICS

- Analysis of Speed, Flow and Density Relationship



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## NUMERICAL

$$V = A - BK$$

A study of freeway flow at a particular site has resulted a calibrated speed density relationship as  $V = 57.5 (1 - 0.008K)$   
 For this relationship, determine a) free flow speed b) jam density c) speed flow relationship d) flow density relationship and e) capacity.

**$V = 57.5 (1 - 0.008K)$**

$V = 57.5 - 0.46K$  .....a)

Comparing equation a) with  $V = A - BK$

$A = 57.5, B = 0.46$

**For free flow speed**

$K = 0$

$V = 57.5$  kmph

**For Jam Density**

$V = 0$

$K = \frac{57.5}{0.46} = 125$  veh/km

**Speed-flow relationship**

$q = K V$

$q = (125 - 2.17V) V = 125 V - 2.17 V^2$

**Flow-density relationship**

$q = K V$

$q = K (57.5 - 0.46K) = 57.5K - 0.46K^2$

**Capacity**

$$q_{\max} = \frac{V_f}{2} * \frac{K_j}{2}$$

$$q_{\max} = \frac{57.5}{2} * \frac{125}{2}$$

$q_{\max} = 1797$  veh/hr

Also,  $q_{\max} = \frac{A^2}{4B} = \frac{57.5^2}{4 * 0.46} = 1797$  veh/hr



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## NUMERICAL

Assuming a linear speed-density relationship, the mean free speed is observed to be 85 kmph near zero density and the corresponding jam density is 140 veh/km. a) Write down the speed-density and flow-density equations. B) Draw the V-K, V-q and q-K diagrams. C) Compute speed and density corresponding to the flow of 1000 veh/hr.

**$V = V_f - \frac{V_f}{K_j} K$**

Where,

V is the mean speed at density K

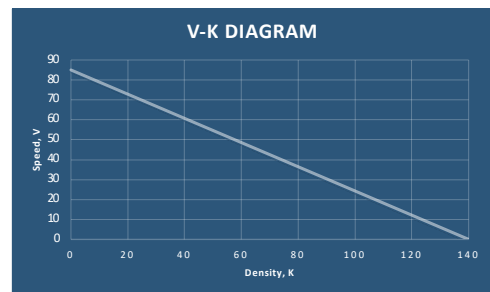
$V_f$  is the free speed

$K_j$  is the jam density

**Speed-density equation**

$V = 85 - \frac{85}{140} K$

$V = 85 - 0.607 K$  .....a)



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## NUMERICAL

Assuming a linear speed-density relationship, the mean free speed is observed to be 85 kmph near zero density and the corresponding jam density is 140 veh/km. a) Write down the speed-density and flow-density equations. B) Draw the V-K, V-q and q-K diagrams. C) Compute speed and density corresponding to the flow of 1000 veh/hr.

$$V = V_f - \frac{V_f}{K_j} K$$

Where,

V is the mean speed at density K

V<sub>f</sub> is the free speed

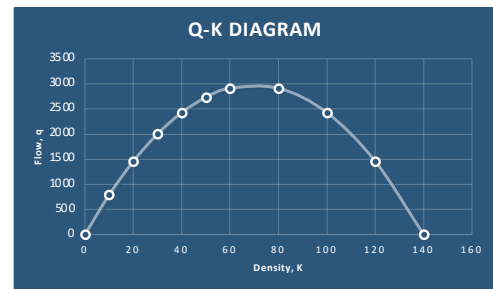
K<sub>j</sub> is the jam density

### Flow – density equation

$$q = KV$$

$$q = K (85 - 0.607 K)$$

$$q = 85K - 0.607K^2 \dots\dots\dots b)$$



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## NUMERICAL

Assuming a linear speed-density relationship, the mean free speed is observed to be 85 kmph near zero density and the corresponding jam density is 140 veh/km. a) Write down the speed-density and flow-density equations. B) Draw the V-K, V-q and q-K diagrams. C) Compute speed and density corresponding to the flow of 1000 veh/hr.

$$V = V_f - \frac{V_f}{K_j} K$$

Where,

V is the mean speed at density K

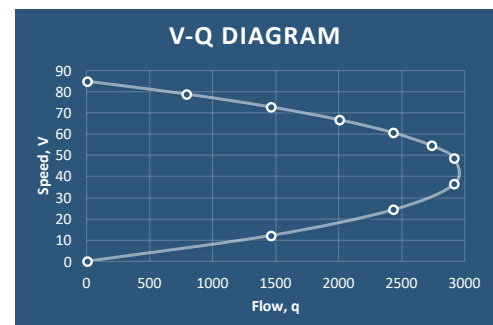
V<sub>f</sub> is the free speed

K<sub>j</sub> is the jam density

### Velocity – Flow equation

From a) and b)

$$q = 140 V - 1.647 V^2 \dots\dots\dots c)$$



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## NUMERICAL

Assuming a linear speed-density relationship, the mean free speed is observed to be 85 kmph near zero density and the corresponding jam density is 140 veh/km. a) Write down the speed-density and flow-density equations. B) Draw the V-K, V-q and q-K diagrams. C) Compute speed and density corresponding to the flow of 1000 veh/hr.

$$V = V_f - \frac{V_f}{K_j} K$$

Where,

V is the mean speed at density K

$V_f$  is the free speed

$K_j$  is the jam density

For q = 1000 veh/hr

From b)

K = 127.06 veh/km or 12.96 veh/km

From a)

For K = 127.06 veh/km

V = 7.87 kmph

For K = 12.96 veh/km

V = 77.133 kmph

From c)

V = 77.133 kmph or V = 7.87 kmph



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## TRAFFIC STUDIES

2.1 Traffic Volume Studies

2.2 Traffic Speed Studies

2.3 Origin and Destination Studies

**2.4 Traffic flow and Capacity Studies**

2.5 Parking Studies

2.6 Crash Studies



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- Traffic capacity is the **ability of roadway to accommodate traffic volume**.
- **Traffic volume** or traffic flow is the number of vehicles moving in a specified direction on a given lane or roadway that pass a given point or cross section during specified unit of time. Traffic volume is expressed as vehicles per hour or PCU/hour.

$$\text{Traffic Volume} = \text{Traffic Density} * \text{Mean speed of traffic flow.}$$

- **Traffic density** is the number of vehicles occupying a unit length of lane of roadway at a given instant, usually expressed as vehicles per kilometer.
- **Highway capacity or capacity** of a traffic lane is the ability of the roadway or traffic lane to allow maximum traffic flow or traffic volume per unit time. **It is usually expressed as vehicles per hour per lane.**
- Traffic volume represents an actual rate of flow and responds to variations in traffic demand while capacity indicates a capability or maximum rate of flow within a certain level of service that can be carried by the roadway. **The capacity of roadway depends on a number of prevailing roadway traffic conditions.**



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- **Types of Highway Capacity**

Highway Capacity Manual (HCM) classifies capacity into three types as:

- Basic Capacity
- Possible Capacity
- Practical Capacity



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- Types of Highway Capacity

- Basic Capacity

- It is defined as the maximum number of passenger cars passing a specified point on the road in one hour duration **under nearly ideal roadway and traffic conditions which can possibly be attained.**
    - Two roads having the same physical features **will have the same basic capacity** irrespective of traffic conditions as they are assumed to have ideal conditions.
    - It is also known **as theoretical capacity.**



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- Types of Highway Capacity

- Possible Capacity

- It is defined as the maximum number of vehicles which can pass a given point in one hour under the prevailing roadway and **traffic conditions.**
    - The possible capacity is generally much lower than the basic capacity as the prevailing roadway and traffic conditions are seldom ideal.
    - During congestion – traffic come to a stand-still condition and in such a situation the possible capacity of the road may approach to **zero.**
    - When the prevailing roadway and traffic conditions approach the ideal condition, **the possible capacity would also approach the basic capacity.**
    - Possible capacity varies from zero to basic capacity.
    - **Neither basic capacity nor possible capacity is used for design** as they represent two extreme cases of roadway and traffic conditions.



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- **Types of Highway Capacity**

- **Practical Capacity**

- The maximum number of vehicles that can pass a given point on a lane or roadway during one hour without the traffic density being so great as to cause unreasonably delay, hazard or restriction to drivers' freedom to maneuver under prevailing roadway and traffic conditions.
    - This capacity is also called design capacity.



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- **Importance of Highway Capacity**

Listed below are the application of traffic capacity.

- Design features governed by the capacity are highway type, number of lanes required, width of lane, intersection geometrics, etc.
  - To study adequacy or deficiency of highway network, present traffic volume is compared with the capacity of the existing facility.
  - Improvements and changes in geometric features, junctions, traffic control devices, traffic management measures can be planned effectively if capacity of facility is known.



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

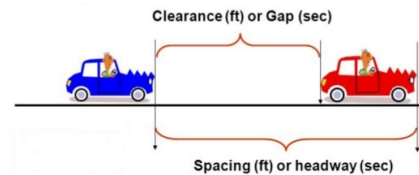
- Determination of Theoretical Maximum Capacity

Basic or theoretical capacity

$$C = \frac{1000 V}{S}$$

Where, C = capacity of single lane, vehicle per hour per lane  
 V = speed, kmph  
 S = average center to center spacing of vehicles (space headway), m when they follow one behind the other as a queue or 'space headway', m

**Average Spacing** = Average length of vehicles + Average Clear Gap between the vehicles in the stream.



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Traffic Volume = Traffic Density \* Mean speed of traffic flow.

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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- Determination of Theoretical Maximum Capacity

The value of spacing, the headway distance is known from the actual observations or can be calculated from the considerations of perception time, braking distance and length of vehicles.

$$S = L + 0.278 * V * t + \frac{V^2}{254 * f} m$$

Where, S = spacing of vehicle, m  
 L = length of vehicle, m  
 V = speed, kmph  
 f = frictional factor  
 t = perception time, seconds

$$S = L + V * t + \frac{V^2}{2 * g * f} m$$

Where, S = spacing of vehicle, m  
 L = length of vehicle, m  
 V = speed, m/s  
 f = frictional factor  
 t = perception time, seconds



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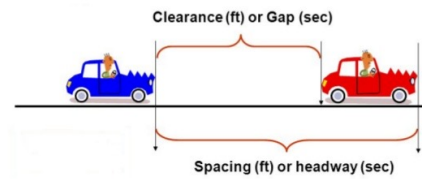
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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- Determination of Theoretical Maximum Capacity

The maximum theoretical capacity of the traffic lane may be obtained if the minimum time headway  $h_t$  is known and it is commonly known as saturation flow rate.

$$C = \frac{3600}{h_t} \text{ veh/hr}$$



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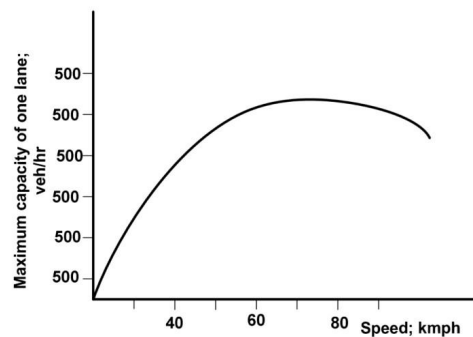
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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- Speed Capacity Relationship

- Peak value of the maximum theoretical capacity is related at an optimum speed.
- As speed increased further, the maximum capacity of the lane starts decreasing due to increasing in headway.



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- **Design Capacity and Level of Service**

- The Highway Capacity Manual (HCM) has introduced the concept of Level of Service (LOS) to denote the level of facility one can derive from a road under different operating characteristics and traffic volumes.
- Level of Service (LOS) is **the qualitative measures** describing the operational conditions within a traffic stream, and their perception by motorists or passengers.



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- **Evaluation of Level of Service (LOS)**

The following factors may be considered to evaluate Level of Service (LOS).

- Speed and travel time, including the operating speed and overall travel time.
- Traffic interruption or restrictions, with due consideration to the number of stops per mile, delays involved and the speed changes necessary to maintain pace in the traffic stream.
- Driving comfort and convenience reflecting the roadway and traffic conditions.
- Freedom to maneuver to maintain the desired operating speed.
- Economy with due consideration of operating cost of vehicles.
- In order to simplify the LOS concept, two factors are considered by the HCM as: **the ratio of service volume to capacity** ( $q/q_c$ ) and the operating travel speed.



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- Level of Service (LOS)

LOS A	LOS B	LOS C	LOS D	LOS E	LOS F
<ul style="list-style-type: none"> <li>Free flow with low volume and high speed.</li> </ul>	<ul style="list-style-type: none"> <li>Reasonably free flow</li> </ul>	<ul style="list-style-type: none"> <li>Provides flow with speed still at near free flow speed</li> </ul>	<ul style="list-style-type: none"> <li>Speed begins to decline slightly with increasing flow.</li> </ul>	<ul style="list-style-type: none"> <li>Flow at low speeds.</li> </ul>	<ul style="list-style-type: none"> <li>Forced flow at low speeds.</li> </ul>
<ul style="list-style-type: none"> <li>Traffic density is low.</li> </ul>	<ul style="list-style-type: none"> <li>Ability to maneuver within the traffic stream – slightly restricted.</li> </ul>	<ul style="list-style-type: none"> <li>Ability to maneuver within the traffic stream – noticeably restricted.</li> </ul>	<ul style="list-style-type: none"> <li>Density begins to increase somewhat quickly with freedom to maneuver – more limited.</li> </ul>	<ul style="list-style-type: none"> <li>Highest density values.</li> <li>Maneuverability is extremely limited.</li> </ul>	<ul style="list-style-type: none"> <li>Breakdown in vehicular flow at points of recurring congestion such as merge, weave or diverging locations.</li> </ul>
<ul style="list-style-type: none"> <li>Average spacing of 161m.</li> </ul>	<ul style="list-style-type: none"> <li>Average spacing of 100.50 m.</li> </ul>	<ul style="list-style-type: none"> <li>Average spacing of 67m.</li> </ul>	<ul style="list-style-type: none"> <li>Average spacing of 50m.</li> </ul>	<ul style="list-style-type: none"> <li>Average spacing of 33.5m.</li> </ul>	



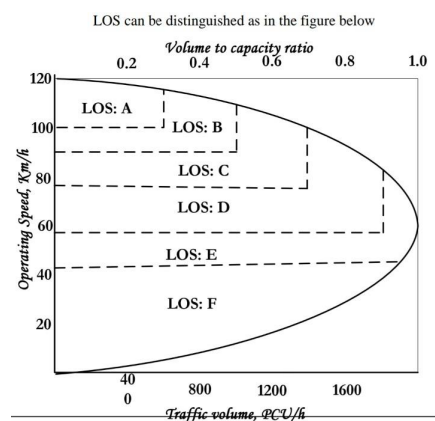
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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- Level of Service (LOS)



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- **Factors Affecting Capacity and LOS**

- **Roadway Factors**

- Lane Width
    - Lateral Clearance
    - Width of the shoulder
    - Surface Condition
    - Alignment
    - Existence of Road Intersection

- **Traffic Factors** – One-way or Two-way traffic, number of traffic lanes, vehicular and traffic characteristics, driver characteristics, single type traffic or mixed traffic, traffic volume, flow speed, etc.



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- **Passenger Car Unit (PCU)**

- Different classes of vehicles with different vehicular characteristics as cars, buses, trucks, auto rickshaw, motor cycles, bicycles, etc. use the common roadway facilities without segregation and result in heterogeneous traffic flow or mixed traffic flow.
  - It is rather difficult to estimate the traffic volume and capacity of roadway facilities under mixed traffic flow, unless the different vehicle classes are converted to one common standard vehicle unit.
  - It is common practice to consider the passenger car as the standard vehicle unit to convert other vehicle class and this unit is called as Passenger Car Unit (PCU).
  - **The PCU is considered as a measure of the relative space requirement of a vehicle class compared to that of a passenger car under a specified set of roadway, traffic and other condition.**



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- **Factors Affecting PCU Values**

- Vehicle characteristics such as dimension, power, speed, acceleration and braking characteristics.
- Transverse and longitudinal gap or clearance between moving vehicles, which depends upon the speeds, driver characteristics and vehicle classes at the adjoining spaces.
- Traffic stream characteristics such as composition of different vehicle classes mean speed and speed distribution of the mixed traffic stream, volume to capacity ratio, etc.
- Roadway characteristics such as road geometrics including gradient, curve access control, presence of intersections and the types of intersections.
- Regulation and control of traffic such as speed limit, one-way traffic and presence of different traffic control devices.
- Environment and climatic conditions.



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## TYPES OF TRAFFIC STUDIES – HIGHWAY CAPACITY

- **Factors Affecting PCU Values**

Factors considered for a simple analysis of PCU values of different vehicle classes are:

- Average speed of the vehicle class under the prevailing roadway and traffic conditions.
- Average length and width of the vehicle class.
- Average transverse and longitudinal gaps.

S.N.	PCU Equivalent suggested by IRC		PCU Equivalent by NRS 2070	
	Vehicle Class	Equivalent Factor	Vehicle Type	Equivalent Factor
1.	Passenger car, tempo, auto rickshaw and tractor	1.0	Car, autorickshaw, SUV, Light van and Pick up	1.0
2.	Bus, Truck, agricultural trailer unit	3.0	Light (Mini) Truck, Tractor, Rikshaw	1.5
3.	Motorcycle, scooter and pedal cycle	0.5	Truck, Bus, Minibus, Tractor with Trailer	3.0
4.	Cycle rickshaw	1.5	Bicycle, Motorcycle	0.5
5.	Horse drawn vehicles	4.0	Non-motorized carts	6.0
6.	Small bullock cart and hand cart	6.0		
7.	Large bullock cart	8.0		



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## NUMERICAL

$$\text{Theoretical Capacity (C)} = \frac{1000 V}{S}$$

$$\text{Average Spacing (S)} = L + 0.278 * V * t + \frac{V^2}{254 * f}$$

Calculate the theoretical maximum traffic capacity of a traffic lane at a speed of 70 kmph. Average length of vehicle may be assumed as 6.1m. Given average reaction time = 0.75 seconds and  $f = 0.38$ .

solution:

$$\begin{aligned} \text{Average Spacing (S)} &= L + 0.278 * V * t + \frac{V^2}{254 * f} \\ &= 6.10 + 0.278 * 70 * 0.75 + \frac{70^2}{254 * 0.38} \\ &= 71.93 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{Theoretical capacity (C)} &= \frac{1000 V}{S} \\ &= \frac{1000 * 70}{71.46} = 980 \text{ vphpl} \end{aligned}$$



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## NUMERICAL

$$\text{Theoretical Capacity (C)} = \frac{1000 V}{S}$$

$$\text{Average Spacing (S)} = \text{Average Gap} + \text{Average Length of Vehicle}$$

Estimate the theoretical maximum traffic capacity of a traffic lane at a speed of 65kmph. Assume coefficient of friction ( $f$ ) as 0.38, total reaction time ( $t$ ) as 0.68 secs and average length of vehicle as 6.1 m. Assume the average space gap between vehicles to follow the relation  $S_g = 0.278 Vt + \frac{V^2}{254f}$ .

solution:

$$\begin{aligned} \text{Average Spacing (S)} &= \text{Average Gap} + \text{Average Length of Vehicle} \\ &= 0.278 Vt + \frac{V^2}{254f} + 6.10 \\ &= 0.278 * 65 * 0.68 + \frac{65^2}{254 * 0.38} + 6.10 \\ &= 62.16 \text{ m} \end{aligned}$$

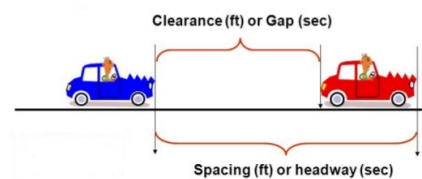
$$\text{Theoretical Capacity (C)} = \frac{1000 V}{S} = \frac{1000 * 65}{62.16} = 1046 \text{ vphpl}$$



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## NUMERICAL

$$\text{Basic Capacity (C)} = \frac{1000V}{S}$$

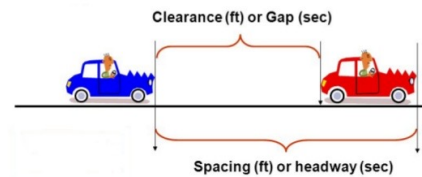
$$\text{Average Spacing (S)} = \text{Average Space Gap} + \text{Average Length of Vehicle}$$

Calculate the theoretical capacity of a traffic lane with one way traffic flow at a stream speed of 35 kmph. Assume the average space gap between vehicles to follow the relation  $S_g = 0.278Vt$  where  $V$  is the stream speed in kmph,  $t$  is the average reaction time of 0.85 secs. Assume average length of vehicles as 5.50 m.

solution:

$$\begin{aligned} \text{Average Spacing (S)} &= \text{Average Gap} + \text{Average Length of Vehicle} \\ &= 0.278Vt + 5.50 \\ &= 0.278 * 35 * 0.85 + 5.50 \\ &= 13.77 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{Basic Capacity (C)} &= \frac{1000V}{S} \\ &= \frac{1000 * 35}{13.77} \\ &= 2542 \text{ vphpl} \end{aligned}$$



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## NUMERICAL

$$\text{Traffic Density (k)} = \frac{1000}{\text{Average Spacing}}$$

The mean free speed on a roadway is found to be 70 kmph. Under stopped condition the average spacing between vehicles is 7.0m. Determine the capacity flow.

solution:

$$\text{Jam density (k}_j) = \frac{1000}{\text{Average Spacing between the Vehicles}} = \frac{1000}{7} = 143 \text{ veh/km/lane}$$

$$\begin{aligned} \text{Capacity flow (q}_{\max}) &= \frac{V_f}{2} * \frac{k_j}{2} \\ &= \frac{V_f * k_j}{4} \\ &= \frac{70 * 143}{4} \\ &= 2503 \text{ veh/hr/lane} \end{aligned}$$



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# TRAFFIC STUDIES

- 2.1 Traffic Volume Studies
- 2.2 Traffic Speed Studies
- 2.3 Origin and Destination Studies
- 2.4 Traffic flow and Capacity Studies
- 2.5 Parking Studies**
- 2.6 Crash Studies



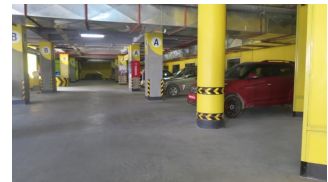
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# TYPES OF TRAFFIC STUDIES – PARKING STUDY

- Parking is the act of stopping a vehicle and leaving it in unoccupied for more than a brief time.



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Objective of Parking Study

- To obtain information regarding supply of land demand for parking facilities.
- To determine vehicle terminal facilities.
- For improvement and regulation of existing facilities.



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Components required for Planning and Designing Parking Facilities

- Characteristics of vehicles
- Behavior of Drivers
- Parking Operation
- Parking generating characteristics of different land use served.



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### III Effects of Parking

- **Congestion**
  - Loss of street space leads to the decrement in highway capacity.
  - Journey time increases, operational cost increases.
- **Crash**
  - Opening of doors of parked vehicles.
  - Moving out of a parked position and bringing a car to the parking location from the mainstream traffic creates problem.
- **Obstruction to Fire Fighting Operations**
  - Fire brigades don't get adequate space for movement.
- **Environment**
  - Noise and fume during starting operations.



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Types of Parking Survey

- Parking Space Inventory
- Parking Usage Survey by Patrol
- Questionnaire type parking usage survey
- Cordon Count
- Photographic Method



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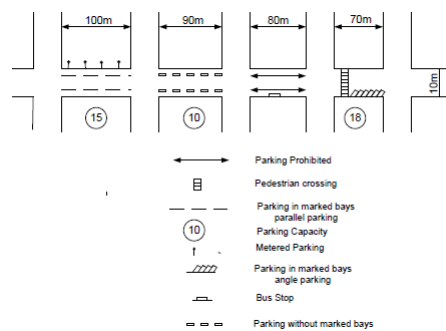
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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Types of Parking Survey

- **Parking Space Inventory**

Sketch plan of parking space will be prepared indicating length of kerb, no. of parking space, street with location of bus stops, taxi stands, pedestrian crossing (location), traffic signs and unused land.



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Types of Parking Survey

- **Parking Usage Survey by Patrol**

- Objective of survey is to obtain data on the extent of usage of parking spaces.
- The survey will include counts of parked vehicles at regular intervals through a period, covering both the morning and evening peak period and the parking accumulation and turnover.
- Method consists of marking periodic observations of parked vehicles on each patrol.



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Types of Parking Survey

- Questionnaire Type Parking Usage Survey
  - Questioning to drivers.
  - Type of vehicle.
  - Origin and Destination.
  - Type of parking used, pricing paid.



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Types of Parking Survey

- Cordon Count
  - Cordon line is fixed for designed area and entering and leaving vehicles are counted. The difference between vehicles gives the number of vehicles parked.
  - The counting can be manual or automatic.



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Types of Parking Survey

- Photographic Method
  - Photograph at certain interval are taken and analyzed.



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Parking Facilities

- On-Street Parking
- Off-Street Parking



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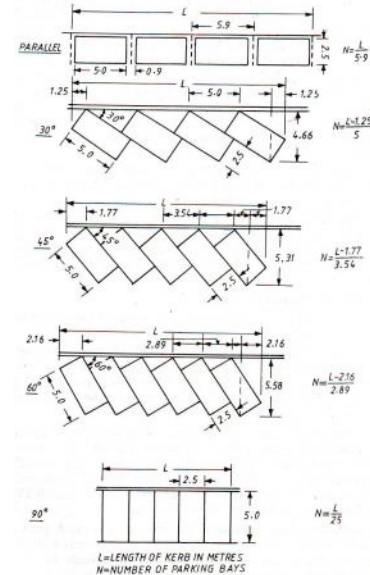
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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Parking Facilities

- **On-Street Parking**
  - Controlled by police or controlled by meters and a certain time fee is collected from those who park the vehicles for certain duration of parking times.
  - Parallel parking where the width of kerb parking space and width of street is limited.
  - Angle parking – 30°, 60°, 90°. 90° is used to accommodate maximum vehicles and 45° is considered suitable from all prospects.



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Parking Facilities

- **On-Street Parking**
  - **On Street Parking Should be Prohibited at**
    - **Near Intersection** – Capacity of intersection is greatly reduced if vehicles are allowed to park in approaches. Visibility is also adversely affected and safety is reduced.
    - **Narrow Streets** – In busy streets of the central area, it is generally desirable to prohibit parking on two-way streets less than 5.75m wide and one-way street less than 4.0m wide.
    - **Pedestrian Crossing** – Desirable to prohibit parking within about 8m from the pedestrian crossing.
    - **Structures** – Parking should be prohibited at bridges, tunnels and underpass that have width less than highway.
    - **Entrance driveway** – Vehicles should be prohibited from parking in front of entrance driveways leading to houses and buildings.



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Parking Facilities

- **Off-Street Parking**
  - Separate parking facilities away from the kerb.
  - No congestion and delay on roads as in on-street parking.
  - One has to walk longer distance.
  - No off-street parking facilities at very close intervals.
  - Self-Parking System
  - Attendant Parking System – Vehicles are left at entrance and parked as well as delivered by the attendants.
  - **Basic Traffic Operation is: Entrance → Acceptance → Storage → Delivery → Exit**



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Parking Facilities

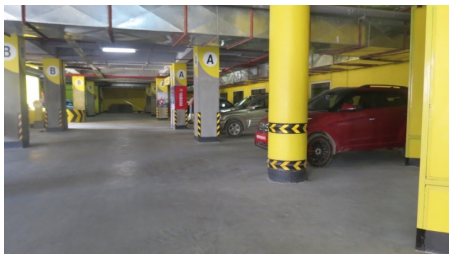
- **Off-Street Parking**
  - Types of Off-Street Parking



Surface Car Parks



Mechanical Car Parks



Underground Car Parks



Multi storey car Parks



Roof Parks



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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Peripheral Parking Schemes

- **Park and Walk** – Park outside of the town and walk down to the town centre.
- **Park and Ride** – Vehicles are parked outside the town and local transportation are taken by going to the town.
- **Meet and Ride** – Dropping in the car in the morning near a bus stop from where one goes to work in a bus. The reverse operation takes place in the evening.
- Commercial traffic and bus/truck terminals.



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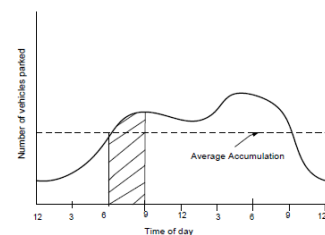
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## TYPES OF TRAFFIC STUDIES – PARKING STUDY

### Definition of Common Terms

- **Parking Accumulation** – The number of vehicles parked at a given instant of time. Normally this is expressed by accumulation curve. Accumulation curve is a graph obtained by plotting the number of bays occupied with respect to time.
- **Parking Volume** – Parking volume is the total number of vehicles parked at a given duration of time. This does not account for repetition of vehicles.
- **Parking Load** – The area under the parking accumulation curve during a specified period is the parking load. It can also be obtained by simply multiplying the number of vehicles occupying the parking area at each time interval with the time interval. It is expressed in vehicle hours.



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# TYPES OF TRAFFIC STUDIES – PARKING STUDY

## Definition of Common Terms

- **Average Parking Duration** – It is the ratio of total vehicle hours to the number of vehicles parked.

$$\text{Parking Duration} = \frac{\text{Parking Load}}{\text{Parking Volume}}$$

- **Parking Turnover** – It is the ratio of number of vehicles parked in a duration to the number of parking bays available. This can be expressed as number of vehicles per bay per time duration.

$$\text{Parking Turnover} = \frac{\text{Parking Volume}}{\text{Number of Bays Available}}$$

- **Parking Index** – Parking index is also called occupancy or efficiency. It is defined as the ratio of number of bays occupied in a time duration to the total space available. It gives an aggregate measure of how effectively the parking space is utilized. Parking index can be found out as follows.

$$\text{Parking Index} = \frac{\text{Parking Load}}{\text{Parking Capacity}} * 100 \text{ where Parking Capacity} = \text{Number of bays} * \text{Number of hours}$$



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# EXPLANATION

Figure shows the duration for which each of the bays are occupied (shaded portion). Now the accumulation graph can be plotted by simply noting the number of bays occupied at time interval of 15, 30, 45 etc. minutes is shown in the figure.

**Parking Volume** – Parking volume is the total number of vehicles parked at a given duration of time. This does not account for repetition of vehicles.

- Parking Volume = 5 vehicles

**Parking Load** - It can also be obtained by simply multiplying the number of vehicles occupying the parking area at each time interval with the time interval. It is expressed in vehicle hours.

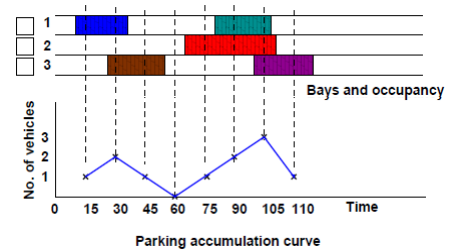
- Parking Load =  $(1+2+1+0+1+2+3+1) * \frac{15}{60} = 2.75 \text{ veh hour.}$

**Average Parking Duration** – It is the ratio of total vehicle hours to the number of vehicles parked.

- Parking Duration =  $\frac{\text{Parking Load}}{\text{Parking Volume}} = \frac{2.75}{5} = 0.55 \text{ hours} = 33 \text{ minutes}$

**Parking Turnover** – It is the ratio of number of vehicles parked in a duration to the number of parking bays available. This can be expressed as number of vehicles per bay per time duration.

- Parking Turnover =  $\frac{\text{Parking Volume}}{\text{Number of Bays Available}} = \frac{5/2}{3} = 0.83 \text{ veh/hr/bay}$



**Parking Index** – Parking index is also called occupancy or efficiency. It is defined as the ratio of number of bays occupied in a time duration to the total space available.

- Parking Index =  $\frac{\text{Parking Load}}{\text{Parking Capacity}} * 100 = \frac{2.75}{3*2} * 100 = 45.83\%$



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## NUMERICAL

From an in-out survey conducted for a parking area consisting of 40 bays, the initial count was found to be 25. Table gives the result of the survey. The number of vehicles coming in and out of the parking lot for a time interval of 5 minutes is as shown in the table 1. Find the accumulation, total parking load, average occupancy and efficiency of the parking lot.

Time	In	Out	Accumulation	Parking Load	Occupancy
5	3	2	26	2.17	65
10	2	4	24	2.00	60
15	4	2	26	2.17	65
20	5	4	27	2.25	67.50
25	7	3	31	2.58	77.50
30	8	2	37	3.08	92.50
35	2	7	32	2.67	80
40	4	2	34	2.83	85
45	6	4	36	3.00	90
50	4	1	39	3.25	97.50
55	3	3	39	3.25	97.50
60	2	5	36	3.00	90
<b>Total</b>				<b>32.25</b>	<b>9.6750</b>

**Accumulation:**  
 For first 5 mins interval = 25 + (3-2) = 26  
 For second 5 mins interval = 26 + (2-4) = 24

**Parking Load:**  
 For first 5 mins interval =  $26 \times \frac{5}{60} = 2.17$  veh-hrs  
 For second 5 mins interval =  $24 \times \frac{5}{60} = 2.00$  veh-hrs

**Total Parking Load** = 32.25 veh-hrs

**Occupancy:**  
 For first 5 mins interval =  $\frac{26}{40} \times 100 = 65\%$   
 For second 5 mins interval =  $\frac{24}{40} \times 100 = 60\%$

**Average Occupancy** = 9.6750 / 12 = 0.80625 = 80.625%

**Efficiency** =  $\frac{\text{Parking Load}}{\text{Parking Capacity}} \times 100 = \frac{32.25}{40} \times 100 = 80.625\%$



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## NUMERICAL

The parking survey data collected from a parking lot by license plate method is shown in the table below. Find accumulation, average occupancy, average turnover, parking volume, parking load, average parking duration, parking capacity and efficiency of the parking lot.

Bay	Time			
	12:00 – 12:15	12:15 – 12:30	12:30 – 12:45	12:45 – 13:00
1	4780	8910	-	1020
2	3023	3023	3023	3023
3	5550	1825	1825	1825
4	1957	1957	4624	8045
5	6095	6095	-	1556
6	-	4345	-	5560
7	-	9676	9676	9676
8	2965	2965	2965	-
9	2560	2560	1910	7852
10	3145	-	1570	1570



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## NUMERICAL

Find accumulation, average occupancy, average turnover, parking load, average parking duration, parking capacity and efficiency of the parking lot.

Bay	Time				Time				Turnover
	12:00 – 12:15	12:15 – 12:30	12:30 – 12:45	12:45 – 13:00	12:00 – 12:15	12:15 – 12:30	12:30 – 12:45	12:45 – 13:00	
1	4780	8910	-	1020	1	1	0	1	3
2	3023	3023	3023	3023	1	1	1	1	1
3	5550	1825	1825	1825	1	1	1	1	2
4	1957	1957	4624	8045	1	1	1	1	3
5	6095	6095	-	1556	1	1	0	1	2
6	-	4345	-	5560	0	1	0	1	2
7	-	9676	9676	9676	0	1	1	1	1
8	2965	2965	2965	-	1	1	1	0	1
9	2560	2560	1910	7852	1	1	1	1	3
10	3145	-	1570	1570	1	0	1	1	2
Accumulation (vehicles)					8	9	7	9	20
Occupancy					0.8	0.9	0.7	0.9	2
Parking Load (vehicle hours)					2	2.25	1.75	2.25	

Average Occupancy =  $\frac{0.80+0.90+0.70+0.90}{4} = 0.825 = 82.50\%$

Average Turnover =  $\frac{\text{Sum of Turnover}}{\text{Total number of bays}} = \frac{20}{10} = 2$

Parking Capacity = No. of bays \* No. of hours = 10 \* 1 = 10 vehicle hours

Total Parking Load = 2+2.25+1.75+2.25 = 8.25 veh-hours

Parking Volume = Sum of turnover in all bays = 20 vehicles

Efficiency =  $\frac{\text{Parking Load}}{\text{Parking Capacity}} = \frac{8.25}{10} = 0.825 = 82.50\%$

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Average Duration =  $\frac{8.25 * 60}{20} = 24.75$  minutes

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## TRAFFIC STUDIES

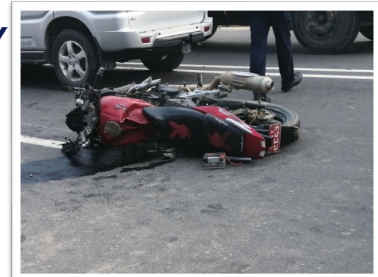
- 2.1 Traffic Volume Studies
- 2.2 Traffic Speed Studies
- 2.3 Origin and Destination Studies
- 2.4 Traffic flow and Capacity Studies
- 2.5 Parking Studies
- 2.6 Crash Studies

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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

- Crash is an event occurring suddenly, unexpectedly and inadvertently under unforeseen circumstances.
- Crash may occur due to mistake, carelessness and deliberate action of road users.
- It may occur due to vehicle failure and also due to road surface characteristics.



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

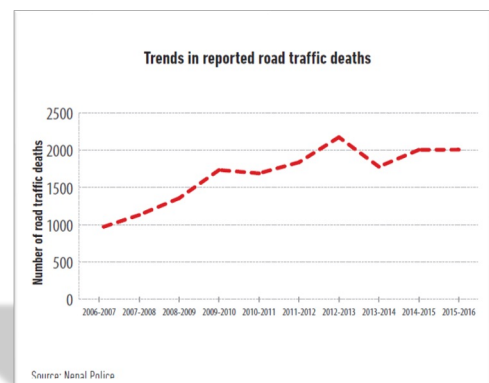
### Objective of Crash Studies

- To evaluate existing facilities and to give support to proposed design.
- To know the basic cause of crashes and find out remedial solutions.
- To economically justify proposed designs.
- To compute financial losses due to crashes.

#### DATA

Reported road traffic fatalities (2015)	2 006 <sup>a</sup> (80% M, 20% F)
WHO estimated road traffic fatalities (2016)	4 622 (95% CI 3 928 - 5 317)
WHO estimated rate per 100 000 population (2016)	15.9

<sup>a</sup> Nepal Police. Died within 30 days of crash



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Elements Involved

- Vehicles
- Road Users
- Road Geometrics
- Environment



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Causes of Crashes

- **Road Users:** Excessive speed and rash driving, violation of rules and regulations by both drivers and pedestrians, failure to perceive traffic situation or sign or signal in adequate time, carelessness, fatigue, alcohol, sleep, etc. Passenger tempting to run in and out of a running vehicle also leads to crashes.



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Causes of Crashes

- **Vehicle defects:** Failure of brakes, steering system, tyre burst, lightning system.
- **Road condition:** Skidding road surface, pot holes, ruts.



To help deal with his grief, Prakash's devastated father Dadarao Bilhore decided he would do something about Mumbai's roads, which like much of India's, are notoriously shoddy. (AFP)



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Causes of Crashes

- **Road design:** Defective geometric design like inadequate sight distance, inadequate width of shoulders, improper curve design, improper traffic control devices and improper lighting.
- **Environmental factors:** Unfavorable weather conditions like mist, snow, smoke and heavy rainfall which restrict normal visibility and makes driving unsafe.



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Causes of Crashes

- **Other Causes:** Improper location of advertisement boards, gate of level crossing not closed when required, animals on road, etc.



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Crash Studies and Records

- Crash Data Collection
- Crash Reporting
- Crash Records
- Statistical Analysis of Crashes



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Crash Studies and Records

- **Crash data collection**

Recording of details of crashes as date, time, persons involved in the crash, crash classification, description and details of the location of crashes, primary causes of crash, crash cost, nature of crashes, etc. are made.

- **Crash Reporting**

- Reporting of the crash to the police authorities to take legal actions need to be done.
- Crash report is prepared with all the facts which might be useful in subsequent analysis, claim for compensation, etc.



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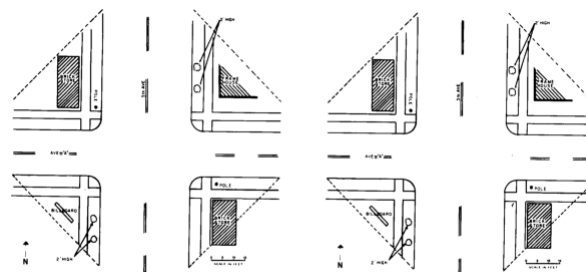
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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Crash Studies and Records

- **Crash Records**

- Crash records are maintained in the form of location files, spot maps, collision diagram and condition diagram.
- All important physical and environmental conditions of a crash are shown in condition diagram.
- It most show all geometric feature of the site, the location and description of all controls (signs, signals, markings, lighting, etc.) and all relevant features of the road side environments such as location of objects, driveway, land uses and so on.



Condition Diagram



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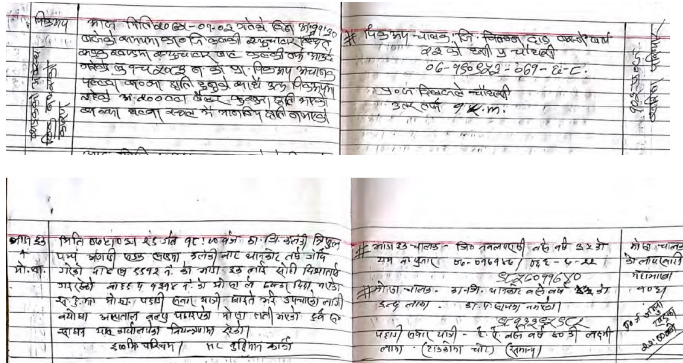
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# TYPES OF TRAFFIC STUDIES – CRASH

## Crash Studies and Records

- Crash Records



## Crash Data Entry Screen

Crash Data Entry Screen

DCC 130 130 - Thru-Thru - Same Dir.

130 Vehicles approaching from same direction and are both going straight ahead resulting in a rear end crash.

Number of data records required to capture all the details of this crash: 1

1 Report No. [ ]

2 Computer No. [ ]

3 Police Station: [Click here to add Police Details](#) 27018

4 Police Station: Kaski Traffic Police Station Number: 27018  
 District: Kathmandu District Number: 27  
 Zone: Bagmati Zone Number: 4  
 Region: Central Region Region Number: 2

5 No. of Vehicles: Enter Number -> [ ]

6 No. of Drivers Involved: Enter Number -> [ ]

7 No. of Passenger Casualties: Enter Number -> [ ]

8 No. of Pedestrian Casualties: Enter Number -> [ ]

9 Accident Severity: Select -> [ ]

10 to 13 Date & Day from Crash Form  
 The Gregorian calendar (or Western) is today's internationally-accepted civil calendar. The reason for its use is its consistency from one year to the next. Enter date equals to check. Enter day and date, in the same as values in far left column. Check that the days do match. If not check Date. It is important to check that the information on the Crash Form, day and date, is the same as values in far left column. So type the date here and check that the day is the same as entered from form.

14 Time (24 hours) hhmm: Enter Time -> [ ]

15 Junction Type: Select -> [ ]

16 Traffic Control: Select -> [ ]

17 Collision Type: Select -> [ ]

139 139 - Other - Rear End 139 Vehicles approaching from same direction and resulting in a rear end crash.



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# TYPES OF TRAFFIC STUDIES – CRASH STUDY

## Statistical Analysis of Crashes

- Helps to evaluate the effectiveness of various measures adopted to decrease the occurrence of the crashes.
- The crash rate is expressed in terms of the number of vehicles and population or in terms of vehicle movements (vehicle-km) and population.
- Crash prone sections of different roads may be evaluated by finding the crash density per unit length of road.



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Crash Prevention (3Es)

- Engineering Measures
- Enforcement Measures
- Education Measures
- Encouragement
- Emergency Care



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Crash Prevention

- Engineering Measures
  - **Road Design** – Geometric elements of the road (sight distance, width of the pavement, horizontal and vertical alignment, etc) are checked and adjusted if necessary. Pavement maintenance need to be carried from time to time to meet the required design standards.
  - **Road Lighting** – Proper lightning facilities particularly at intersections, bridge sites and placers where there is restriction to traffic movements need to be set up.
  - **Maintenance of Vehicle** – Periodic maintenance of vehicles are required. Maintenance of brakes, steering and other lightning system and accessories.



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Crash Prevention

- **Enforcement Measures**
  - **Speed Control** – Checking of spot speed at certain locations need to be done and legal actions must be taken against those who violates the rule.
  - **Training and Supervision** – Necessary training to the road users and strict test while issuing of driving license and testing of driving skill while renewing need to be done.
  - **Medical Check** – Test of vision and reaction time at prescribed intervals.
  - **Observation of Law and Regulations**



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Crash Prevention

- **Education Measures**
  - **Road Users** – Educate road users about road rules, the way of using roadway facilities through awareness, public campaign, posters and advertisements.
  - **Safety Drive** – Traffic safety week where the road users are properly directed by the help of traffic police and transport staff need to be imposed. Proper driver training courses also should be made available.



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Analysis of a particular traffic crash

- Moving vehicle collides with a stationary vehicle.
- Two approaching vehicles from different direction collide at an intersection.
- Head on collision of vehicle approaching from opposite directions.
- Moving vehicle collide with stationary object like tree, electric pole, parapet or any other rigid structure.



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Assumptions made while analyzing any particular crash

- When skid marks at the site of crashes are visible they are measured to find out actual braking distance and assumed that 100% skid has taken place. When skid marks are not visible it is assumed as a free collision, without brake being applied.
- Impact of the colliding vehicles may be direct or oblique.
- Friction coefficient of the pavement surface is either determined or suitably assumed depending upon the conditions of the surface.
- When two colliding vehicles of masses  $m_1$  and  $m_2$  with speed of  $v_1$  and  $v_2$  collide, it is assumed that both are perfectly plastic and both move together with common velocity  $v'$  after collision.

$$m_1v_1 + m_2v_2 = (m_1 + m_2) v'$$

It means coefficient of restitution is zero.

If both vehicles are assumed perfectly elastic, the coefficient of restitution will be unity, i.e.  $v_1 - v_2 = v_2' - v_1'$ .

In case coefficient of restitution is  $e$ , then:  $e(v_1 - v_2) = v_2' - v_1'$ .



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Working out speed from skid distance

- Skid distance 'S' for a vehicle of weight 'W' to slow down from  $v_1$  to  $v_2$  m/secs speed is obtained equating loss of kinetic energy to the work done against frictional force.

$$\frac{1}{2}m(v_1^2 - v_2^2) = f * W * S$$

$$\frac{1}{2g} W (v_1^2 - v_2^2) = f * W * S$$

$$S = \frac{v_1^2 - v_2^2}{2gf}$$

If the skid distance 'S' is measured from skid marks, the initial speed of the vehicle,  $v_1$  can be worked out as:

$$v_1 = \sqrt{v_2^2 + 2gfs} \dots\dots\dots a)$$

If vehicle comes to stop after skid distance S, then  $v_2$  will become zero. Therefore, initial speed,  $v_1$  can be calculated as:

$$v_1 = \sqrt{2gfs} \dots\dots\dots b)$$



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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Collision of moving vehicles with parked vehicles

- Suppose vehicle 1 moving with speed  $v_1$  m/secs skid through a distance  $s_1$  after the effective application of brakes, collides with a parked vehicle 2 and two vehicles skids together through a distance  $s_2$  before coming to stop. The problem is to estimate initial speed  $v_1$  m/secs.
- Before collision the vehicles 1 of weight  $W_1$  moving with moving with initial speed  $v_1$  m/sec applies brake, skids through a distance  $s_1$  and attains speed  $v_2$  m/secs just before actual collision takes place.

$$v_1^2 = v_2^2 + 2gfs_1 \dots\dots\dots a)$$

- At collision with stationary vehicle 2 of weight  $W_2$ , both start moving together at speed  $v_3$  m/secs. Here it is assumed that perfectly plastic impact has taken place. The relationship between  $v_2$  and  $v_3$  is given by momentum equation.

$$\frac{W_1}{g} * v_2 = \frac{W_1 + W_2}{g} * v_3$$

$$v_2 = \frac{W_1 + W_2}{W_1} * v_3 \dots\dots\dots b)$$

Substituting the value of  $v_2$  in equation a), we have,  $v_1^2 = (\frac{W_1 + W_2}{W_1})^2 * v_3^2 + 2gfs_1 \dots\dots\dots c)$

- After collision vehicle 1 and 2 skid through distance  $s_2$  before coming to stop (velocity  $v_3$  reducing to  $v_4 = 0$ ),  $v_3^2 = 2gfs_2$

Substituting the value of  $v_3^2$  in equation c),  $v_1^2 = (\frac{W_1 + W_2}{W_1})^2 * (2gfs_2) + 2gfs_1 \rightarrow v_1 = \sqrt{(\frac{W_1 + W_2}{W_1})^2 * (2gfs_2) + 2gfs_1}$

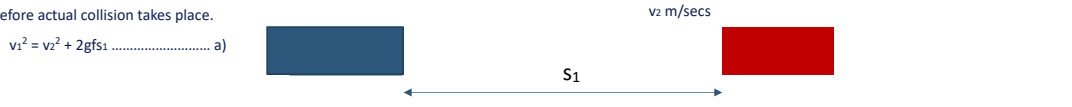


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# TYPES OF TRAFFIC STUDIES – CRASH STUDY

## Collision of moving vehicles with parked vehicles

- Suppose vehicle 1 moving with speed  $v_1$  m/sec skid through a distance  $s_1$  after the effective application of brakes, collides with a parked vehicle 2 and two vehicles skids together through a distance  $s_2$  before coming to stop. The problem is to estimate initial speed  $v_1$  m/sec.
- Before collision the vehicles 1 of weight  $W_1$  moving with moving with initial speed  $v_1$  m/sec applies brake, skids through a distance  $s_1$  and attains speed  $v_2$  m/sec just before actual collision takes place.



- At collision with stationary vehicle 2 of weight  $W_2$ , both start moving together at speed  $v_3$  m/sec. Here it is assumed that perfectly plastic impact has taken place.
- The relationship between  $v_2$  and  $v_3$  is given by momentum equation.



Substituting the value of  $v_2$  in equation a), we have,  $v_1^2 = (\frac{W_1+W_2}{W_1})^2 * v_3^2 + 2gfs_1$  ..... c)

- After collision vehicle 1 and 2 skid through distance  $s_2$  before coming to stop (velocity  $v_3$  reducing to  $v_4 = 0$ ),  $v_3^2 = 2gfs_2$

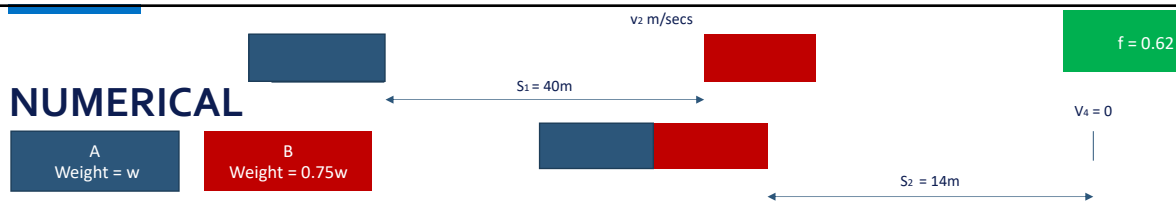
Substituting the value of  $v_3^2$  in equation c),  $v_1^2 = (\frac{W_1+W_2}{W_1})^2 * (2gfs_2) + 2gfs_1 \rightarrow v_1 = \sqrt{(\frac{W_1+W_2}{W_1})^2 * (2gfs_2) + 2gfs_1}$

When vehicle 1 does not apply brakes, the value of  $s_1$  becomes zero.



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## NUMERICAL



A vehicle skids through a distance of 40m before colliding with another parked vehicle the weight of which is 75 percent of the former. After collision both the vehicles skid through 14m before stopping. Compute the initial speed of the moving vehicle. Assume coefficient of friction is 0.62.

solution:

Let the original speed of vehicle  $v_1$  m/sec which reduces to  $v_2$  m/sec after the application of brakes and skids  $s_1 = 40m$ . After collision, both vehicles start to move with the velocity  $v_3$  m/sec and finally stops at  $v_4 = 0$ , after skidding  $s_2 = 14m$ .

$v_1 = \sqrt{(\frac{W_1+W_2}{W_1})^2 * (2gfs_2) + 2gfs_1}$   
 $v_1 = 31.75$  m/sec

### After Collision

Loss in KE = Work done against frictional force

$$\frac{1}{2} (m_A + m_B) (v_3^2 - v_4^2) = f * (W_A + W_B) * S_2$$

$$\frac{1}{2g} (W_A + W_B) (v_3^2 - 0^2) = 0.62 * (W_A + W_B) * 14$$

$$v_3^2 = 2 * g * 0.62 * 14$$

$$v_3 = 13.05$$
 m/sec

### At Collision

Momentum before Impact = Momentum after Impact

$$m_A v_2 = (m_A + m_B) v_3$$

$$v_2 = 1.75 * 13.05$$

$$v_2 = 22.84$$
 m/sec

### Before Collision

Loss in KE = Work done against frictional force

$$\frac{1}{2} m_A (v_1^2 - v_2^2) = f * W_A * S_1$$

$$\frac{1}{2g} W_A (v_1^2 - v_2^2) = f * W_A * S_1$$

$$v_1^2 = v_2^2 + 2g * f * S_1 = 22.84^2 + 2 * 9.81 * 0.62 * 40 = 1008.24$$

$$v_1 = 31.75$$
 m/sec



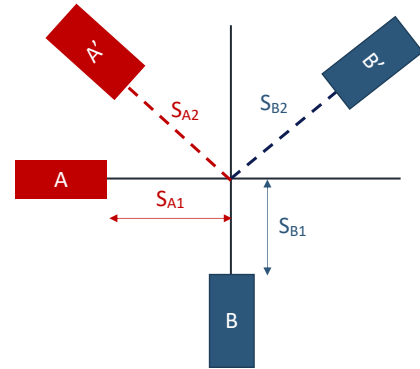
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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Two vehicles approaching from right angled collide

- Two vehicles A and B on approaching an intersection are assumed to skid on application of brakes; they collide with each other and skid further in different direction as shown in figures.
- The direction of the skidding vehicles after collision in this case depends upon the initial speeds of two vehicles and their weight.
- If  $S_{A2}$  and  $S_{B2}$  are the skid distance of the vehicles after collision, the speed of vehicles  $V_{A3}$  and  $V_{B3}$  just after collision may be found out by:
 
$$V_{A3} = \sqrt{2gf \cdot S_{A2}} \text{ m/sec}$$

$$V_{B3} = \sqrt{2gf \cdot S_{B2}} \text{ m/sec}$$
- The momentum of the vehicles just after collision may be found using the speed values from above equations and these resolved in the original direction of motion of two vehicles.
- As per assumption, the momentum before collision is taken equal to the momentum after collision.



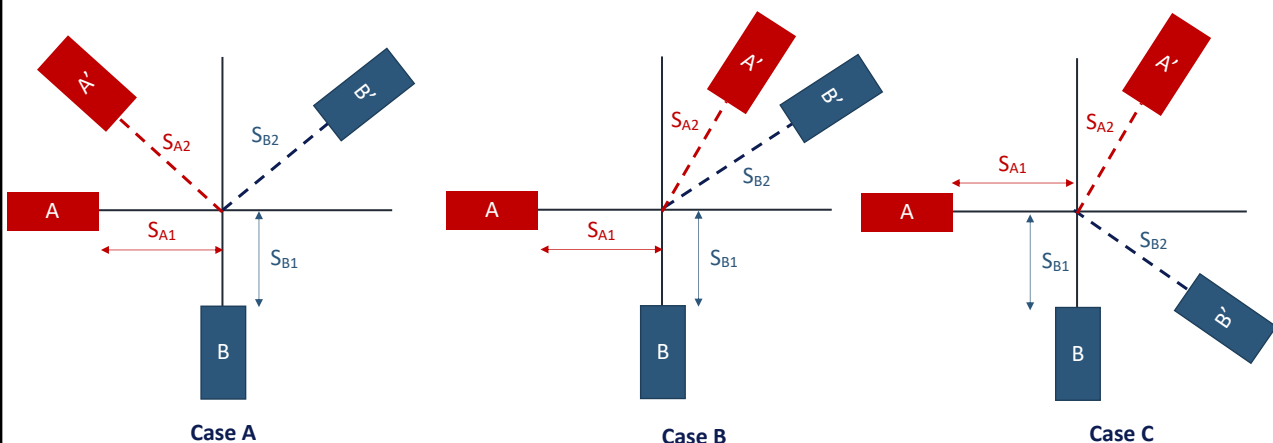
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## TYPES OF TRAFFIC STUDIES – CRASH STUDY

### Two vehicles approaching from right angled collide



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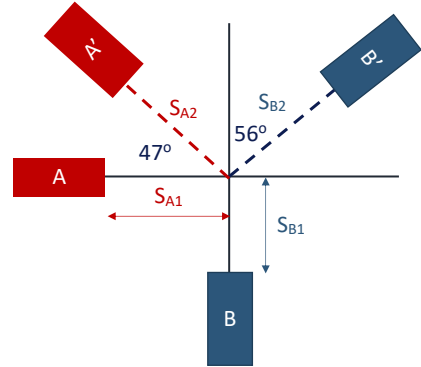
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## NUMERICAL

Two vehicles A and B approaching at right angles, A from West and B from South, collide with each other. After the collision, vehicle A skids in a direction 47° North of West and vehicle B 56° East of North. The initial skid distance of the vehicles A and B are 32 and 18 m respectively before collision. The skid distances after collision are 14m and 33m respectively. If the weights of vehicles A and B are 4 and 6 tonnes respectively, calculate the original speeds of vehicles. The average skid resistance of the pavement is found to be 0.52.

**solution:**

Let the initial speeds of vehicles A and B before the application of brakes be  $v_{A1}$  and  $v_{B1}$ . The speed just before collision after skidding through the distance  $S_{A1} = 32\text{m}$  and  $S_{B1} = 18\text{m}$  be  $v_{A2}$  and  $v_{B2}$  respectively. The speed of the vehicles just after collision be  $v_{A3}$  and  $v_{B3}$  and the final speed of the vehicles when come to stop is zero, after skidding through the distance  $S_{A2} = 14\text{m}$  and  $S_{B2} = 33\text{m}$ . Given  $f = 0.52$



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## NUMERICAL

**After Collision**

Loss in KE of each vehicle = Work done against skid resistance

**For vehicle A**

$$\frac{1}{2} m_A (v_{A3}^2 - v_{A4}^2) = f \cdot W_A \cdot S_{A2}$$

$$\frac{1}{2g} W_A v_{A3}^2 = f \cdot W_A \cdot S_{A2}$$

$$v_{A3} = 11.95 \text{ m/sec}$$

**For vehicle B**

$$\frac{1}{2} m_B (v_{B3}^2 - v_{B4}^2) = f \cdot W_B \cdot S_{B2}$$

$$\frac{1}{2g} W_B v_{B3}^2 = f \cdot W_B \cdot S_{B2}$$

$$v_{B3} = 18.35 \text{ m/sec}$$

$m_A = 4 \text{ tons}, m_B = 6 \text{ tons}$   
 $S_{A1} = 32\text{m}, S_{A2} = 14\text{m}, S_{B1} = 18\text{m}, S_{B2} = 33\text{m}$

**At Collision**

Momentum before collision = Momentum after collision

**Resolving along E-W direction**

$$m_A v_{A2} = m_B v_{B3} \sin 56^\circ - m_A v_{A3} \cos 47^\circ$$

$$v_{A2} = 14.67 \text{ m/sec}$$

**Resolving along N-S direction**

$$m_B v_{B2} = m_A v_{A3} \sin 47^\circ + m_B v_{B3} \cos 56^\circ$$

$$v_{B2} = 16.09 \text{ m/sec}$$

**Before Collision**

Loss in KE of each vehicle = Work done against skid resistance

**For vehicle A**

$$\frac{1}{2} m_A (v_{A1}^2 - v_{A2}^2) = f \cdot W_A \cdot S_{A1}$$

$$\frac{1}{2g} W_A (v_{A1}^2 - v_{A2}^2) = f \cdot W_A \cdot S_{A1}$$

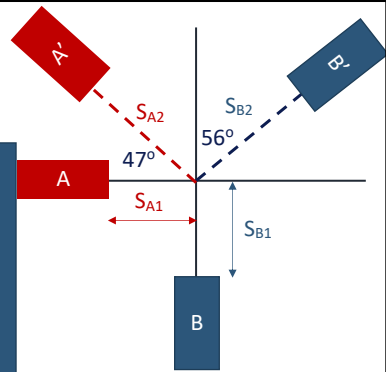
$$v_{A1} = 23.27 \text{ m/sec}$$

**For vehicle B**

$$\frac{1}{2} m_B (v_{B1}^2 - v_{B2}^2) = f \cdot W_B \cdot S_{B1}$$

$$\frac{1}{2g} W_B (v_{B1}^2 - v_{B2}^2) = f \cdot W_B \cdot S_{B1}$$

$$v_{B1} = 21.03 \text{ m/sec}$$



$v_{A1} = 23.27 \text{ m/sec}$   
 $v_{B1} = 21.03 \text{ m/sec}$



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