TRAFFIC ENGINEERING LABORATORY MANUAL

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TRAFFIC ENGINEERING

LABORATORY MANUAL

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VISION OF THE INSTITUTE

To establish a unique identity of a pioneer technical Institute by developing a high-quality technical manpower and technological resources that aim at economic and social development of the nation as a whole and the region in particular keeping in view the global challenges.

MISSION OF THE INSTITUTE

M1. To create a strong and transformative technical educational environment in which fresh ideas, moral principles, research and excellence nurture with international standards.

M2. To prepare technically educated and broadly talented engineers, future innovators and entrepreneurs, graduates with understanding of the needs and problems of the industry, the society, the state and the nation.

M3. To inculcate the highest degree of confidence, professionalism, academic excellence and engineering ethics in budding engineers.

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To create a unique identity of the Department by achieving excellent standards of quality technical education keeping pace with the rapidly changing technologies and to produce Civil Engineers of global standards with the capability of accepting new challenges.

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M1. To promote academic growth in the field of Civil Engineering by offering state-of-theart undergraduate and postgraduate programmes.

M2. To provide knowledge base and consultancy services in all areas of Civil Engineering for industry and societal needs.

M3. To inculcate higher moral and ethical values among the students to become competent Civil Engineers with overall leadership qualities.

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PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1. To produce professionally competent Civil Engineers, capable of applying the knowledge of contemporary Science and Technology, to meet the challenges in the field of Civil Engineering and to serve the Society.

PEO2. To prepare the Civil Engineering graduates to work in industry, government or other organizations in different capacities involving individual and team work.

PEO3. To inculcate among the students the sense of ethics, morality, creativity, leadership, professionalism, self-confidence and independent thinking.

PEO4. To impart the training in problem visualization, surveying, analysis and planning for its solution.

PEO5. To impart training for development of laboratory and design skills, communication skills and skills for software and other modern tool usage among the students.

PEO6. To inculcate in the students the ability to take up the innovative research projects and to conduct investigations of complex Civil Engineering problems using research based methods, thus urging them for higher studies.

PREFACE

This manual titled "Traffic Engineering Laboratory Manual" is mainly designed to meet the requirements of Under Graduate (UG) and Post Graduate (PG) Engineering Students of National Institute of Technology Srinagar, Hazratbal, Jammu & Kashmir. It is intended to be used for performing various traffic engineering studies efficiently. An attempt has been made to make this manual student friendly as much as possible.

Traffic engineering is a practical area of study and many of its aspects are difficult to understand, analyze and simulate in classroom. This manual has been formulated to help in proper planning and organization of various traffic studies. It provides the guidelines to perform traffic studies efficiently and also gives detailed procedures to perform the whole experiment/ traffic study in a systematic manner. During the process of formulation of this manual, number of feedbacks from students and teachers were taken on a regular basis which were analyzed and incorporated with utmost care. Immense efforts were put in to answer the three basics questions often asked by the students:

"Why do we need to perform a particular traffic study?"

"Where do we need to perform it?"

"How do we perform it?"

The framework of this manual has been designed in such a manner that it becomes student friendly. Every experiment/ traffic study starts by defining its objectives followed by various equipments/facility required. The preliminary work required to be conducted in the laboratory, before a traffic survey is initiated, has also been included. Prior knowledge of theory is extremely important to perform any traffic survey. Keeping this in view, brief theoretical concepts have been included for each experiment/ study. Experimental procedures and observation sheets are designed such that these are concise and simple to use. Brief description on how the data can be analyzed and presented (both manually as well as using software[s]) is also included. Effort has been made to keep the textual content of the manual of the highest quality.

A chapter introducing the various softwares, routinely used for data analysis, traffic simulation and/or modeling, has also been included towards the end, in this manual. This has been done to make students familiar with the application of these softwares.

We (authors) hope that students of both UG and PG level will find this manual extremely useful. Moreover, we invite comments and/or criticisms that will help us to improve it further.

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IMPORTANCE OF TRAFFIC ENGINEERING: General Overview

The transportation system is often referred to as the nation's *"lifeblood circulation system."* Our complex system of roads and highways, railway tracks, airports and airlines, waterways and urban transit systems provide a facility for the movement of people and goods within and between our densest urban cities and the most remote outposts of the nation.

Traffic Engineering is a branch of Engineering that deals with planning, geometric design and traffic operations of roads, streets and highways, their networks, terminals, abutting lands and their relationship with other modes of transportation for the achievement of *safe*, *efficient* and *convenient* movement of persons and goods. It focuses mainly on the research, development, and application of scientific techniques necessary for designing and modeling of the mobility of goods and people from their places of origin to places of destination. Therefore, traffic engineers must have an appreciation for and understanding of planning, design, construction, operation, management, control and system optimization.

Basic Tenets

The transportation system should ensure to provide some basic tenets which are required to be followed at every stage of providing the facility for movement of people and goods. The focus should be on providing the system of mobility which is:

- *Safe*
- *Rapid*
- *Comfortable*
- *Convenient*
- *Economical*
- *Environmentally compatible*
- *Sustainable*

Importance

Traffic engineering provides valuable tools to understand the problems arisen due to the exponential growth of motor vehicles, severe congestion on roads, high accident rates, high vehicle operating costs (VOC), etc. and to evolve suitable measures to overcome the deficiencies.

1. Traffic engineering applies engineering principles that help solve transportation problems by considering the psychology and habits of the transportation system users.
2. Traffic Engineers are specialists at understanding and changing the technical aspects of road design to maximize traffic flow and reduce congestion.
3. Traffic engineers promote safer traffic conditions by providing roadway conditions that contribute to smooth and efficient traffic flow.
4. Safety goes hand in hand with smooth traffic operation. Disrupting the smooth flow of traffic increases the probability of accidents. Therefore, study for smooth flow of traffic is of paramount importance.
5. Erratic traffic operation may be caused by vehicles stopping or slowing in the roadway, passing and weaving maneuvers, or other surprise elements. Traffic engineering ensures the proper design and efficient operation of that on roads.
6. The road transport system has to be developed in a way that does not jeopardize the environment or public health and welfare of its participants.

The role of traffic engineers may be compared to that of the ***medical profession*** in protecting the public. As trained professionals, traffic engineers look at the symptoms of general traffic conditions and make a competent diagnosis. They take traffic counts, analyze accident statistics, study speed data, examine roadway conditions, conduct research and arrive at solutions.

Just as the doctors' decisions are accepted in matters regarding health, even though the medicine may be bitter or the needle painful, so should the decisions of professional traffic engineers be given due respect and consideration.

SCOPE & PURPOSE OF GUIDELINES

In order to facilitate the assessment of present and future traffic demands, for the development of need-based infrastructure, accurate information and continuous monitoring of traffic by appropriate methods are necessary. Implementing authorities must, therefore, ensure that sufficient and appropriate data is available to undertake necessary planning, design, construction, and maintenance of the country's road network, which is aimed at meeting the prevailing traffic flow, future traffic growth and loading without considerable deterioration in the quality of service.

The guidelines should, therefore, be prepared with the main aim to provide basic information, concept, and principles with respect to traffic data collection and analysis. This manual is only intended to provide guidance with respect to data collection and analysis and allows for variation in the methodologies adopted by different users, planners, developers, funding authorities, etc.

1. Guidelines for data collection be checked, for the measurement procedures vary with the geometry and other parameters.
2. Traffic engineering involves traffic counts in performing traffic studies. The distributions associated with these measurements/counts are linked to the type of statistical analysis techniques applied to these data. Probability distributions for both discrete outcomes that are countable/finite number of outcomes, and continuous outcomes, which include non-countable/infinite number of outcomes often found when taking measurements should be examined.
3. Diagrammatic presentation of data translates quite effectively the abstract ideas contained in numbers into more concrete and easily comprehensible form which is preferred over the tabular representation of data.

SAFETY GUIDELINES FOR CONDUCTING TRAFFIC SURVEYS

The various traffic surveys that are to be conducted especially on high-volume routes require rigid guidelines to ensure the safety of the staff as well as the equipment. Due to the volatile and unpredictable nature of the road users, all sensible precautions must be taken whenever performing any survey on roads to avoid potential hazards that may occur.

Road injuries do not happen without cause. The identification, isolation, and control of these causes are underlying principles of all injury prevention techniques.

As such, some general guidelines are being presented here which must be followed while collecting the data required for any traffic analysis:

1. Wear protective equipment and clothing.
2. Install appropriate warning signs prior to the survey.
3. Use traffic control and channeling devices wherever needed.
4. Use flags when traffic control and channeling devices do not provide adequate safety.
5. Use flashing amber warning lights on signals on either side of the survey site.
6. Choose an appropriate spot which is safe, like a footpath or a median.
7. Place the survey equipment at an appropriate place so that it does not compromise with the safety nor interfere with the normal traffic flow.
8. Always face traffic when working on the travelled way of a divided road or on shoulders of highways or use lookouts.
9. Do not make sudden movements that might confuse a motorist and cause him or her to take evasive action that could result in injury to the motorist as well as to surveyors.
10. Avoid interrupting traffic as much as possible.
11. Avoid working on wet pavement in an active traffic area, except for the emergency survey of a danger area which poses grave hazards to the public.
12. Always be alert for inattentive drivers even at signalized crossings.

GUIDELINES FOR SELECTING TRAFFIC SURVEY SITE

A specific location for the collection of traffic data using permanent or temporary methods and equipment(s) must be predetermined before going on site to conduct the traffic studies. Where an automatic counting system is to be used, the exact locations of loops should be decided while taking cognizance of the potential use of data collected.

The following guidelines should be kept in mind before deciding on the traffic survey site:

1. The road section should represent homogeneous traffic section along the road length and it should be away from junctions.
2. The location should be on a horizontal (flat) and geometrically straight road section (for good visibility without any kind of obstruction from trees/buildings).
3. Section of the road should have an uninterrupted traffic flow.
4. Sections should be so located that enumerators can take shelter in case of inclement weather and still observe traffic. A lighted location would be of advantage for counts conducted after daylight.
5. Sections should have very little pedestrian or animal traffic (unless the pedestrian counts are necessary).
6. Sections should meet the safety requirements at all times of the traffic survey.

In areas where trunk roads are in the vicinity of major city limits or town boundaries, the locations of counting sites using loops should be examined in more detail. Inductive loops at traffic signals may also be used for traffic counting in major cities and towns.

To ensure that adequate attention is given to sections of roads constituting a specific traffic flow, roads should be divided into uniform sections according to traffic characteristics.

PRE & POST LABORATORY PREPARATION FOR TRAFFIC STUDIES

1. Properly study the theoretical concepts beforehand which are required for conducting the traffic survey.
2. Select the appropriate day for a particular traffic study by taking into account the basic criteria on which the traffic study is based. e.g., for a parking study, a weekday is selected rather than the weekend.
3. Enough knowledge and facts should be collected in advance for selecting the site of a traffic study.
4. The date and time should be selected keeping in view the weather forecast.
5. Plan the data collection observatories.
6. Design and Chart out the observation sheets required for the collection of raw data before the commencement of a traffic survey.
7. Also, keep the observation sheets designed in Step 6 ready for recording final observations and doing necessary calculations.
8. The equipment(s) required should be checked properly and synchronized a day before conducting the traffic survey.
9. After the completion of traffic survey, the raw data should be visualized carefully and checked for any errors or missing data.
10. While doing calculations and formulating the results, various cross-checks should be done, if possible.
11. Data should be properly presented by using various distributions and charts.
12. Proper software and/ or statistical tools must be used in carrying out the calculations and presentation of the data.

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TRAFFIC CONTROL DEVICES ITEMIZATION 1

TE Lab 1

OBJECTIVE: To identify, classify, and record various traffic control devices such as signs and signals installed along a street/ corridor.

EQUIPMENT AND FACILITIES REQUIRED

1. Traffic Control Devices Itemization (TCDI) observation sheet(s)
2. Vehicle (e.g. a car) fitted with Odometer
3. Measuring tape
4. A video recorder (optional)

NEED FOR THE STUDY

Traffic control devices are installed along travel routes to ensure safe, orderly, and predictable traffic movement. They provide guidance and warnings to road users. The purpose of road signs is to promote road safety and efficiency by providing for the orderly movement of all road users on all roads in both urban and non-urban areas. Road signs notify road users of regulations and provide warning and guidance needed for safe, uniform and efficient operation. Therefore it is very important to assess whether guidelines given by the Indian Roads Congress (IRC) are followed or not.

THEORY

IRC: 67-2012 titled "C*ode of Practice for Road Signs (Third Revision)*" contains the basic principles that govern the design and use of road signs for all categories of roads including expressways open to public travel irrespective of road agency having jurisdiction. Thus IRC: 67-2012 guidelines should be followed on all types of roads within India.

It is important that these principles be given primary consideration in the selection and application of each road sign. To be effective, a road sign should meet five basic requirements:

- Fulfill a need
- Command attention
- Convey a clear and simple meaning
- Command respect from road users
- Give adequate time for response

Design, placement, operation, maintenance, and uniformity are aspects that should be carefully considered in order to maximize the ability of a road sign to meet these five basic requirements.

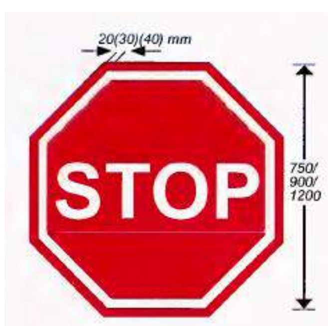
CLASSIFICATION OF ROAD SIGNS (as per IRC: 67-2012)

Mandatory/Regulatory Signs

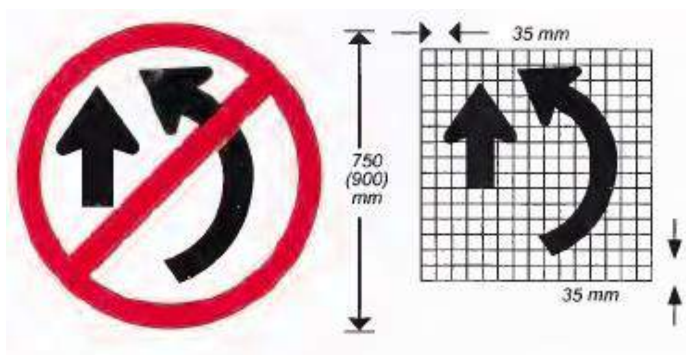
All Mandatory or Regulatory Signs are circular in shape. Mandatory/Prohibitory Signs are to indicate the prohibition upon certain kind of vehicle maneuver and vehicle type like "overtaking prohibited" or "U-turn prohibited" or "cycles prohibited" and restriction on parking like "parking prohibited" and limit on vehicle speed and size like "speed limit" and "maximum load limit". They are with red circular ring and diagonal bars with black symbols or arrows or letters on white background.

The red ring indicates prohibitory regulation, and the diagonal red bar prohibits the action or movement indicated by the black symbol.

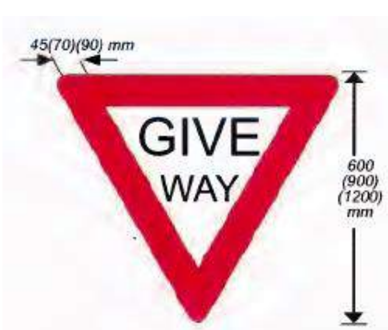
Mandatory signs giving positive instructions are circular with a white symbol on a blue background. They indicate what a driver must do compulsorily. For example, direction control signs are to compulsorily regulate certain movements wherever the restriction applies. The exceptions in shape are the octagonal red STOP sign and the triangular GIVEWAY or YIELD sign. These two signs provide an indication about the right of way to drivers. Mandatory and regulatory signs need to be complied with and any violation of the rules and regulations conveyed by these signs is a legal offence. Examples of these signs are shown in Fig. 1.1



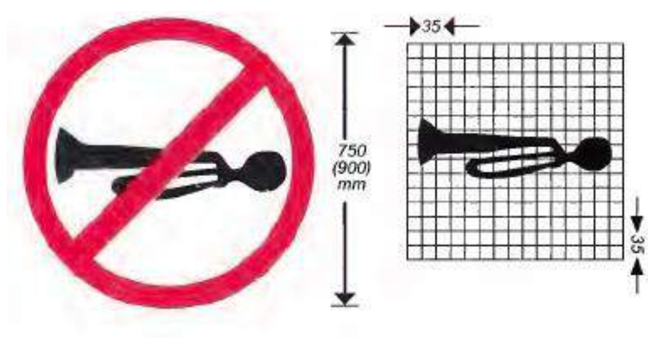
(a) STOP



(b) Overtaking prohibited



(c) Give Way



(d) Horn prohibited

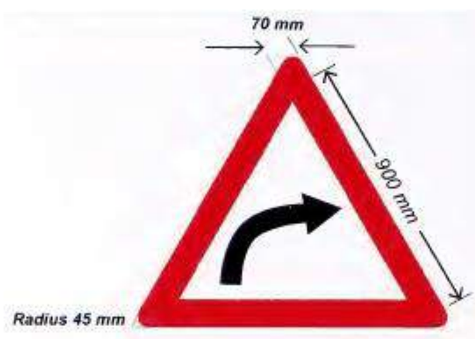
(e) Minimum Speed Limit

(f) Compulsory Cycle Track/Cycle Only

Fig. 1.1 Mandatory/Regulatory Signs

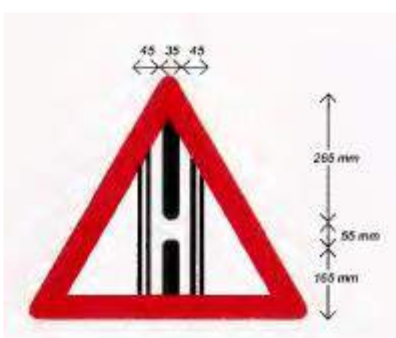
Cautionary/Warning Signs

Cautionary/Warning signs are triangular in shape with a red border and black symbol in the white background used to caution and alert the road users to potential danger or existence of certain hazardous conditions either on or adjacent to the roadway so that they take the desired action. These signs indicate a need for special caution by road users and may require a reduction in speed or some other manoeuvre. Some examples of these signs are Hairpin Bend, Narrow Bridge, Gap in Median, School Ahead, etc. An example is shown in Fig. 1.2



(a) Right Hand Curve

(b) Staggered Intersection



(c) Gap in Median

(d)Two way hazard marker

Fig. 1.2 Cautionary Warning Signs

Informatory/Guide Signs

All Informatory signs and Guiding signs for facilities are rectangular in shape. Informatory Signs for facilities indicates location and direction to facilities like "fuel station" or "eating place" or "parking" and shall be a symbol within a rectangular board with a blue background. Information signs in rectangular shape are also used with destination names and distances with arrows indicating the direction. The colour pattern of direction information sign is presented in Table 1.1. These are used to give such information to road users which will help them along the route in the most simple and direct manner. Examples of these are shown in Fig. 1.3.

Table 1.1 Colour Pattern for Direction Information Signs

Road Type	Background	Arrows/Border/Letters
Expressway	Blue	White
National Highway (NH)	Green	White
State Highway (SH)	Green	White
Major District Road (MDR)	Green	White
Village Road (ODR & VR)	White	Black
Urban/City Road	Blue	White

(a) Filling Station (Fuel Pump)

(b) Eating Place

(c) Hospital

Fig. 1.3 Information/Guide Signs

PROCEDURE

1. Select a section of road (preferably 5 to 10km) as a test section. The observations should be done during off-peak hours.
2. Take the starting point of the observations as Reduced Distance (RD) = 0.00 metres.
3. The vehicle is stopped at locations where traffic control devices are present or should be present. Make sure the vehicle is parked safe and properly delineated by means of traffic cones or so.

4. Take observations either directly recording different parameters associated with Traffic Control Devices Itemization (TCDI) or by means of videography. If the latter is adopted, then the observations are noted in the office and not in the field itself as in the former case.
5. Make a comparison of the observations with the IRC: 67-2012 guidelines.
6. Draw the road alignment showing various observations and recommendations using various symbols and colour codes.

ANALYSIS AND PRESENTATION

1. List the type(s) of traffic control devices, including color, shape, and message(s) that are installed along the survey route in the TCDI observation sheet(s).
2. Note RD for each observation.
3. Note the offset(s), horizontal and vertical clearance of each traffic control device. Compare the same with IRC: 67-2012 guidelines.
4. Describe the condition of signs installed along the survey route.
5. Describe whether or not the surveyed traffic control devices are consistent with IRC: 67-2012 standards.
6. Describe what improvements (additions or removals) are required to the traffic control devices along the survey route (add, remove, or replace) in a textual and pictorial manner.

Observation Sheet No. 1
(Traffic Control Devices Itemization)

Date________________________ Day_____________________ Weather_______________________ Page______________________

Name of the Observer(s):____

Origin____ Destination____

Starting Time____Ending Time____

S.No.	Reduced Distance (RD, m)	Traffic Sign Observed	Type (M/C/I)	Position/ Location	Offset Distance (m)	Clearance (m)		Remarks
						Horizontal	Vertical	

Note: M- Mandatory/ Regulatory sign; C- Cautionary/Warning sign; I- Information/Guide sign; m-metres

TRAFFIC VOLUME STUDIES 2

TE Lab 2

Traffic volume studies are conducted to determine the number, movements, and classifications of roadway vehicles at a given location.

NEED FOR THE STUDY

These studies are useful for determining the following:

1. Magnitudes, classifications and the time and directional split of vehicular flows.
2. Proportions of vehicles in the traffic stream.
3. Hourly, daily, yearly and seasonal variation of vehicular flows.
4. Flow fluctuation on different approaches at a junction or different parts of a road network system.
5. The structural and geometric design of pavements, bridges and other highway facilities.
6. Intersection design.
7. Improvement of roadway operating conditions.
8. Traffic signal design.
9. Economic feasibility.

THEORY

Traffic Volume: It is defined as the number of vehicles passing a section of a lane or roadway during a given time interval.

Rate of Flow: It is the rate at which vehicles pass a point during a specified time period of less than one hour, expressed as an equivalent hourly rate.

Traffic volumes can be expressed as daily volumes, hourly volumes, and sub-hourly volumes.

1. ***Daily Volume:*** Traffic volume expressed as a number of vehicles per day is referred to as daily volume. It is used for determining pavement thickness.
2. ***Average Annual Daily Traffic:*** The average 24-hour volume at a given location over a full year (365 days), estimated as the number of vehicles passing a section in a year, is known as AADT.
3. ***Average Annual Weekday Traffic:*** The average 24-hour traffic volume at a given location occurring on weekdays over a full year is known as AAWT.
4. ***Average Daily Traffic:*** The average 24-hour volume at a given location over a defined time period of less than one year is known as ADT.

5. ***Average Weekday Traffic:*** An average 24-hour traffic volume occurring on weekdays for some period of time less than one year, such as for a month or a season.
6. ***Hourly Volume:*** Traffic volume expressed as a number of vehicles per hour is referred to as hourly volume.
7. ***Peak Hour Volume:*** It is the volume of traffic that uses the approach, lane or lane group in question during the hour of the day that observes the highest traffic volumes.
8. ***Directional Design Hourly Volume:*** It is the one-way volume in the predominant direction of travel in the design hour, expressed as a percentage of the two-way DHV.

$$\boldsymbol{DDHV = AADT \times K \times D}$$

where K is the proportion of daily traffic that moves in peak hour,
D is the proportion of peak hour traffic that moves in the peak direction.

9. ***Sub-Hourly Volume:*** It is the traffic volume expressed as a number of vehicles per hour when the study is conducted for less than an hour. In data collection and clustering, the time interval that represents instantaneous traffic is the 15-minute interval.
10. ***Peak Hour Factor (PHF):*** It is the ratio of the total hourly traffic volume to the maximum 15-minute traffic volume within the hour. It represents the flow variation within an hour.
11. ***PCU:*** A Passenger Car Unit is a measure of the impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single standard passenger car. This is also known as passenger car equivalent. Highway capacity is measured in PCU/hour daily.

Classified & Non-Classified Traffic Volume: Classified traffic volume takes into account the different categories of vehicles & non-classified don't consider the different types of vehicles.

Methods for Traffic Volume Survey:

1. Manual counting method.
2. Semi-automatic method.
3. Automatic method.

TE Lab 2.1

MANUAL METHOD FOR TRAFFIC VOLUME STUDY

OBJECTIVE: To conduct a traffic volume study and to determine different volume statistics for a particular road section.

EQUIPMENT AND FACILITIES REQUIRED

1. Observation sheets
2. A stopwatch
3. Video camera (in case of indirect methods)

THEORY

In this method, vehicles are counted manually. There are two methods of manual counting:

1. Direct method
2. Indirect method

Direct Method: In this method, data is recorded using hand tally on the observation sheets.

Advantages:

- By this method, traffic volume, as well as vehicle classification, can be obtained.
- Data can be used immediately after collection.

Disadvantages:

- This method is not practical for long duration counts and when the traffic flow is high.
- The counts cannot be cross-checked. So there is an increased probability of accumulation of errors.
- This method is very difficult when the volume is high and/or there are three or more than three traffic lanes.
- The counts cannot be recorded in bad weather.

Indirect Method: In this method, data is collected using a video camera. The video is captured for a particular duration of time and data is retrieved and entered into the observation sheets later by rewinding.

Advantages:

1. Besides traffic volume, several traffic parameters can be obtained from the recorded film.
2. Data can be cross-checked and quality can be ensured.
3. Applicable when the volume is high.
4. Suitable for non-lane-based traffic operation.

Disadvantages:

1. Data cannot be used immediately after collection.
2. This process is time-consuming and tedious.
3. Not suitable for very long duration counts.

PROCEDURE

1. First, a section of the road is to be selected according to the guidelines and all the necessary lab preparations are to be completed in advance.
2. Traffic volume is a unidirectional study. Therefore, it is more desirable to record traffic in each direction of travel and keep separate observers for each direction.
3. The number of observers required to count the vehicles depends upon the number of lanes and the type of information required.
4. The time slots and number of shifts could vary depending on members of the field team. For example, for all day counts, work in three shifts of 8 hours each could be organized.
5. Data is to be recorded on tally sheets/field data observation sheets. First, the observer records the date, location, weather condition, direction and time of the study. One or more sheets may be required for observing and recording the traffic data.
6. Observer counts the vehicles and records observations in the respective vehicle-type column with the help of hand tallies called Five-Dash system (vertical strokes for first four vehicles followed by an oblique for the fifth vehicle depicting a total of five) for each count interval, mostly 15 minutes.
7. Data is collected for each type of vehicle and filled in tally sheets for the whole time of the study.
8. Calculate the hourly volume (vehicles/hour). Volume can be expressed as Average Daily Traffic (ADT) and Annual Average Daily Traffic (AADT) depending on data recorded.
9. Also, determine the peak rate of flow and Peak Hour Factor (PHF) during both peak and off-peak periods for data recorded in the field.

OBSERVATIONS

$$\boldsymbol{PCU, vehicles = Number\ of\ vehicles \times PCU\ factor}$$

Observation Sheet 2.1

Classified Traffic Volume Count Study for Mid-Block Section

Name of the Road:	Day & date:
Section from: to:	Hour:
Location:	Weather:
Direction: Sheet No.:	Name of the observer(s):

	FAST MOVING VEHICLES								SLOW MOVING VEHICLES				
Vehicle Type / Time	Two-Wheeler	Three Wheeler	Four Wheeler	Bus		LCV	Truck		Cycle	Cycle Rickshaw	Animal Drawn		Others
				Mini	Full		2-Axle	Multi-Axle			Bullock cart	Horse	
00-15													
15-30													
30-45													
45-60													
TOTAL													
PCU Factor													
TOTAL PCU													

CALCULATIONS

$$volume = \frac{total\ no.of\ vehicles}{total\ time} PCU/hr$$

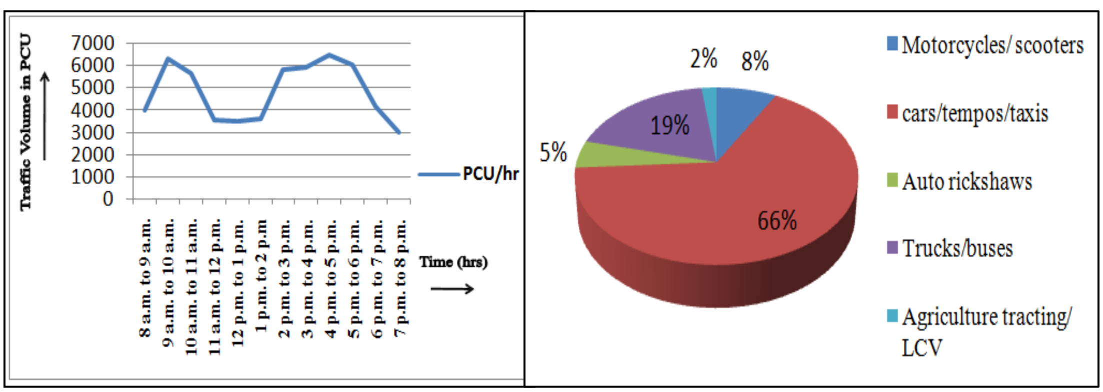
$$volume = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ PCU/hr$$

$$Peak\ hourfactor = \frac{total\ hourly\ volume}{4 \times maximum\ 15\ minute\ volume\ within\ the\ hour}$$

$$Peak\ hour\ factor = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ =$$

ANALYSIS AND PRESENTATION OF DATA

The data can be presented and analyzed by plotting line graphs and pie charts.



(a) (b)

Fig 2.1 Example plots showing data presentation.

(a) Determines the peak hour (b) Gives the composition of traffic

TE Lab 2.2

SEMI-AUTOMATIC METHOD FOR TRAFFIC VOLUME STUDY

OBJECTIVE: To conduct a traffic volume study using electronic traffic volume counting boards and to determine different volume statistics for a particular road section.

EQUIPMENT AND FACILITIES REQUIRED

1. Electronic counting boards
2. Batteries
3. Stopwatch
4. Cable Connector
5. Data Analyzer (Computer System)

THEORY

Portable traffic data equipment/semi-automated studies:

A large number of traffic studies are conducted using a variety of portable traffic data/ recording devices. The most common portable devices used in traffic studies are the mechanical and electronic counting boards.

- **Mechanical Counting Boards**

Mechanical count boards consist of counters mounted on a board that records each direction of travel. Common counts include pedestrian, bicycle, vehicle classification, and traffic volume counts. Typical counters are push-button devices with three to five registers. Each button represents a different stratification of the type of vehicle or pedestrian being counted.

- **Electronic Counting Boards**

Electronic counting boards are battery-operated, hand-held devices used in collecting traffic count data. They are similar to mechanical counting boards, but with some important differences. Electronic counting boards are lighter, more compact, and easier to handle. They have an internal clock that automatically separates the data by the time interval. The data which is recorded in the field is retrieved on a computer system through software. The software gives the tabular form of data. So there is no need to perform any calculations manually.

Important features of semi-automated methods

1. Counting is done by trained personnel.
2. Used when the effort and expense of automated equipment are not justified.
3. Used to gather data for determination of vehicle classification, turning movements, the direction of travel, pedestrian movements, or vehicle occupancy.
4. Usually used for counting period less than a day.

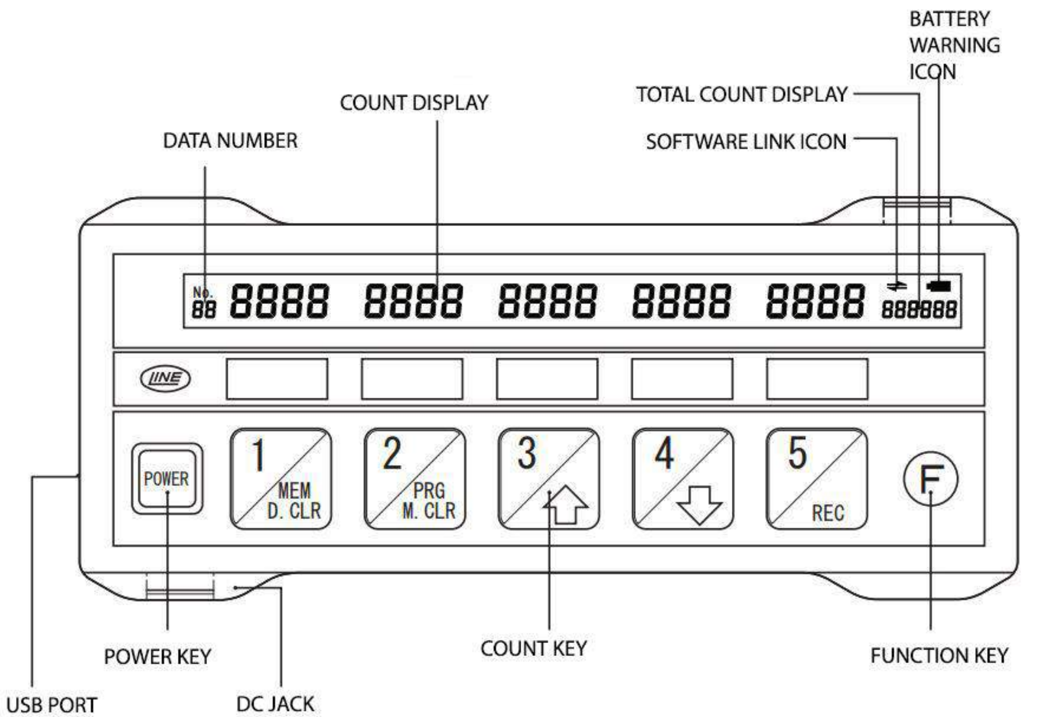


Fig 2.2 Line diagram showing various functions of electronic traffic volume counting board

Fig 2.3 Picture of an electronic traffic volume counting board

PROCEDURE

1. First, a section of the road is selected according to the guidelines and equipment to be used (electronic counting pads) is checked for its functioning and battery before the study.
2. Two observers, each having electronic counters, are positioned in both directions of the road.

3. Data is collected by the observer by pressing the button of the respective type of vehicle specified on counting pad.
4. The number of vehicles of each type, passing the section, is recorded for their respective time intervals, which are already fed. Data is separated according to the different time intervals by the internal clock of the equipment.
5. As counting pad can record only five/six different types of vehicles. Therefore, more than one counting pad can be used for getting classified volume for more than five/six types of vehicle types.
6. After recording observations for the whole study duration, data can be downloaded on a computer by connecting it to the electronic counting pad.
7. Using the tabular-form data obtained on a computer, calculate hourly volume, ADT, AADT and Peak Hour Factor for each direction.

CALCULATIONS

Since the data is retrieved in Microsoft Excel in the form a table, the calculations for computation of various parameters as in the TE Lab-2.1 are done using software tool only.

ANALYSIS AND PRESENTATION OF DATA

The analysis and presentation part is similar to that of TE Lab2.1

TE Lab 2.3

AUTOMATIC METHOD FOR TRAFFIC VOLUME STUDY

OBJECTIVE: To conduct a traffic volume study using pneumatic tubes and to determine different volume statistics for a particular road section.

EQUIPMENT AND FACILITIES REQUIRED

1. Pneumatic Tubes
2. Accessories (nails/bolts, hammer, holding strips, etc.)
3. Air switches
4. Data Analyzer (Computer System)

THEORY

Automatic recording

Today, thousands of permanent detectors are installed on freeways, at intersections and other locations. These detectors provide the opportunity to gather large amounts of data on the traffic system. The difficulty is that much of the data is only available in real time that is, it is not permanently stored in the retrievable form, and the variety of technologies in use makes it difficult to coordinate everything into a seamless system of critical information on the system.

Automatic count recording methods

Automatic counts are recorded using one of the following three methods:

1. Portable Counters
2. Permanent Counters
3. Videotape

- **Portable Counters:**

Portable counting is a form of manual observation. Portable counters serve the same purpose as manual counts but with automatic counting equipment. The period of data collection using this method is usually longer than when using manual counts. The portable counter method is mainly used for 24- hour counts. Pneumatic road tubes are used to conduct this type of automatic counts.

- **Permanent Counters:**

Permanent counters are used when long-term counts are to be conducted. The counts could be performed every day for a year or more. The data collected may be used to monitor and evaluate traffic volumes and trends over a long period of time. Permanent counters are not a cost-effective option in most situations. Few jurisdictions have access to this equipment.

- **Videotape**

Observers can record count data by videotaping traffic. Traffic volumes can be counted by viewing videotapes recorded with a camera at a collection site. A digital clock in the video image can prove useful in noting time intervals. Videotaping is not a cost-effective option in most situations. Not many jurisdictions have access to this equipment.

Pneumatic Tube-based counter

A pneumatic road tube is a closed-end tube in which air pressure is maintained. When stretched across a roadway, a vehicle (actually an axle) rolling over it creates an air pulse that travels through the tube, which is connected to some form of the data capture device. Such tubes are most often used for traffic counting, but they can also be used to measure speed.

Fig 2.4 Pneumatic tubes installed on road connected with the sensor

Pair of tubes can be used to measure speed, the recording devices measures the elapsed time between the actuation of the first and second tubes.

Although a variety of traffic counters are available to use with road tubes, the most common types record a total count at preset intervals, so that 5, 10, 15 and 60-minute counts can be automatically recorded.

Important features of automatic recording

1. Counting is done by sophisticated electronic devices, sensors, and detectors.
2. Used for gathering a large amount of traffic data.
3. Used when the effort and expense of automated equipment are justified.
4. Counting is usually done in 1-hour intervals for each 24-hour period.
5. Counting may be done continuously for a week, month or a year.
6. It is a fit-and-forget type of instrument.

PROCEDURE

1. First, a section of road is selected according to the guidelines where pneumatic tubes can be properly placed and they are checked for any cut, scratch, etc.
2. Pneumatic tubes are then placed on top of the leveled road surface at the selected section.
3. The tubes are held in place with the help of fastening strips. These strips are secured into the road pavement using nails/bolts by means of a hammer.
4. These are connected to air switches which in-turn, are connected to a traffic counting device.
5. The sensor is checked for proper working.
6. The traffic counting device is placed at an appropriate place where it is safe and secure (preferably off the road corridor).

Fig 2.5 Pneumatic tube installed on a road

7. When a vehicle passes over the tube, due to compression, change in air pressure is sent to the air switch which activates the traffic counting device. Air switches provide accurate axle counts and data is recorded by the counting device for every vehicle which passes. The internal mechanism of the air compressed records classified vehicle count. The direction is also recorded when a pair of tubes are placed on the road, depending on which tube is crossed first.
8. Data for the whole study duration is collected automatically, without the continuous involvement of the observer.
9. Data and results can be obtained by connecting the counting device to a computer using the software. From the recorded data, calculate hourly volume, ADT, AADT and Peak Hour Factor for each direction.

CALCULATIONS

Since the data is retrieved in Microsoft Excel in the form a table, the calculations for computation of various parameters as in the TE Lab-2.1 are done using software tool only.

ANALYSIS AND PRESENTATION OF DATA

The analysis and presentation part is similar to that of TE Lab2.1

SPOT SPEED STUDIES 3

TE Lab 3

Spot speed studies are conducted to document the distribution of vehicle speeds as they pass a point or short segment of the roadway. These studies are conducted under conditions of free flow/ uninterrupted flow facilities.

NEED FOR THE SPOT SPEED STUDY

Spot speed studies are used to determine vehicle speed percentiles, which are useful in making many speed-related decisions. Some are enlisted below:

1. Geometric design
2. Accidental analysis
3. Traffic control planning
4. Classification of roads as freeways, highways, arterials, collectors and local streets
5. Speed trends
6. Safety applications
7. Determination of existing traffic operations, evaluation of traffic control devices, and measurement of the effectiveness of traffic control devices, etc.

THEORY

Speed

Speed is the ratio of total distance travelled to the total time taken to traverse that distance. Units for speed are km/hr, m/s, feet/sec, miles/hr, etc. Speed is an important transportation consideration because it relates to safety, time, comfort, convenience and economics.

Study Components: There are basically three categories of speeds.

1. *Spot Speed*: It is the instantaneous speed of a vehicle at any specific location. It is determined by measuring the time required for a vehicle to traverse a specified distance along a road section.
2. *Running Speed*: It is determined by dividing the total distance by the total running time (only the time vehicle is in motion) for the route. In this, all spot-time delays are excluded.
3. *Journey Speed or Overall Speed*: It is obtained by dividing the total distance by the total time of travel including all delays.

Factors Affecting Spot Speed

Various factors which affect the spot speed are as follows:

1. Type of road
2. Traffic volume
3. Lane width
4. Sight distance
5. Gradient
6. Pavement unevenness
7. Roadside developments
8. Environmental conditions

Methods of the spot speed study

1. Pavement Marking method
2. Enoscope method
3. Radar/Speed gun method

TE Lab 3.1

SPOT SPEED STUDY BY PAVEMENT MARKING METHOD

OBJECTIVE: To conduct a spot speed study, develop a cumulative frequency speed distribution curve and calculate various statistical measures.

EQUIPMENT AND FACILITIES REQUIRED

1. Measuring tape
2. Flags/ Road markers
3. A stopwatch
4. Observation sheets
5. Computer system with statistical software e.g. MS Excel/ Sigma Plot (optional)

THEORY

The speed survey is done to determine the speed that drivers select, unaffected by the existence of congestion. This information is used to determine general speed trends, to help determine reasonable speed limits, and to assess safety. The speed of travel on the road is also used in classifying routes. Level of service based on speed is an indicator of the quality of traffic flow or mobility. The pavement marking method can be used to successfully complete a spot speed study using a small sample size taken over a relatively short period of time. It is a quick and inexpensive method for collecting speed data but a relatively inaccurate method. To calculate vehicle speed, we use the predetermined study length known as *trap length* and the elapsed time it takes for the vehicle to move through the test section in the following formula:

$$\boldsymbol{V = \frac{D}{T}}$$

where V = speed (m/s)
D = distance between two sections (m)
T = time elapsed between two sections (sec)

Using the recommended study lengths based on the average speed of the traffic stream, the speed calculations become straightforward and less confusing.

Table 3.1 Recommended Trap length for spot speed studies

Traffic stream average speed (miles/hr)	**Recommended study length (feet)**
Below 25	88-100
25-40	176-200
Over 40	264-300

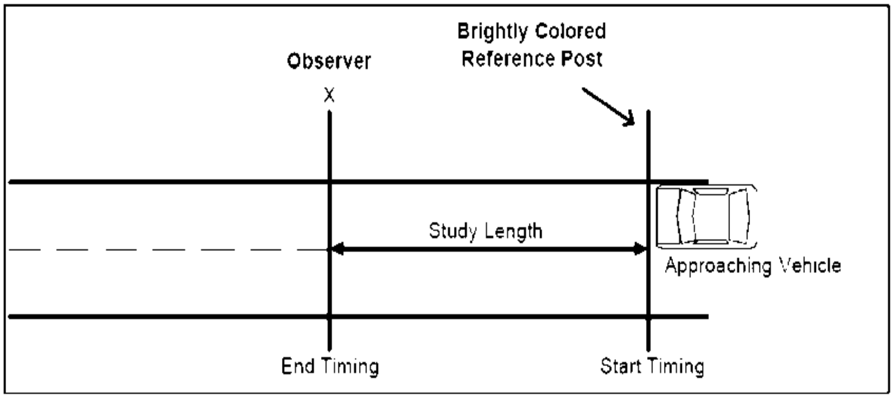


Fig.3.1 Trap length for conducting a speed study

Key parameters associated with roadway speeds

1. **Time Mean Speed (TMS)**: It is the average speed of all the vehicles passing a point on a highway or lane over some specified time period. It is taken as an arithmetic mean of all the speeds.

$$\boldsymbol{TMS} = \frac{\sum_i (\boldsymbol{d}/\boldsymbol{t_i})}{\boldsymbol{n}}$$

2. **Space Mean Speed (SMS)**: The average speed of all vehicles occupying a given section of highway or lane over some specified time period. Thus, it is the harmonic mean of speeds.

$$\boldsymbol{SMS} = \frac{\boldsymbol{d}}{\sum_i \boldsymbol{t_i}/\boldsymbol{n}}$$

where d = *distance traversed*
t_i = *time for "i^{th}" vehicle to traverse a particular section*
n = *number of observed vehicles*

3. **85th Percentile Speed**: The speed at or below which 85% of a sample of free-flowing vehicles is travelling.
4. **Median (50th Percentile Speed)**: The speed that equally divides the distribution of spot speeds. 50% of observed speeds are higher than the median whereas 50% of observed speeds are lower than the median.
5. **Design Speed**: 98th percentile speed is taken as design speed.
6. **Mode**: The mode is defined as the single value of speed that is most likely to occur, i.e. for which frequency is maximum.
7. **Pace**: It is defined as the 10 km/h increment in speed in which the highest percentage of drivers is observed. It is also found graphically using the

frequency distribution curve. The pace is a traffic engineering measure not commonly used for other statistical analyses.

PROCEDURE

1. Select the site as per guidelines and then obtain appropriate trap length. Using the recommended study lengths based on the average speed of the traffic stream, the speed calculations become easy and less tedious.
2. Record observations on spot speed study data entry form. On the spot speed data form, the observer records the date, location, weather conditions, start time, and end time. Spot speed study is a unidirectional study. First, choose one direction and then proceed to observations.
3. As the front of the vehicle (or only the lead vehicle in a group) crosses the starting section of the study length, the observer there signals the observer at the end section who starts the stopwatch. The observer stops the stopwatch when the vehicle reaches the end station. Therefore, the time elapsed between the two sections is obtained.
4. Repeat the procedure for recording time of vehicles moving in the opposite direction.
5. Calculate vehicle speeds by using the predetermined study length and the elapsed time it took the vehicle to move through the test section in the following formula:

$$\boldsymbol{V = \frac{D}{T}}$$

where V = speed (m/s)

D = distance between two sections (m)

T = time elapsed between two sections (sec)

6. Choose appropriate bin limits and generate a frequency distribution table.
7. Perform calculations using Table 3.2.
8. Generate a frequency distribution curve and cumulative frequency distribution curve either manually or using software such as MS Excel/ Sigma Plot.
9. Compute various statistical metrics like mean, mode, standard deviation, etc. either using statistical formulae or using the generated graphs. Also determine the speed percentiles such as 15^{th}, 50^{th}, $85^{th,}$ and 98^{th} percentile speeds.
10. Compute the confidence bounds with 95% and 99.7% confidence respectively and hence compute the sample size required to achieve a tolerance of "x, km/hr" as an error.

OBSERVATIONS

Observation Sheet 3.1

Spot speed study data entry form

Date:	Day:	Weather:	Page:
Name of the road:			
Name of the observer(s):			
Study/trap length:			
Direction From:	Towards:		
Total number of vehicles observed:			
Vehicle No.	Time taken to cover study length (s)	Speed (m/s)	Speed (km/hr)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

NOTE: Different observers can observe different types of vehicles and thus we can have classified spot speeds.

CALCULATIONS

Table 3.2 Cumulative Frequency Distribution Sheet

<table>
<tr><td colspan="2">Date:</td><td colspan="2">Day:</td><td colspan="2">Weather:</td><td colspan="2">Page:</td></tr>
<tr><td colspan="8">Name of the road:</td></tr>
<tr><td colspan="8">Name of the observer(s):</td></tr>
<tr><td colspan="8">Study/trap length:</td></tr>
<tr><td colspan="8">Direction From: Towards:</td></tr>
<tr><td colspan="8">Total number of vehicles observed:</td></tr>
<tr><td>Speed interval (Km/hr)</td><td>Mid value of speed interval, V_i (km/hr)</td><td>Frequency, f_i</td><td>Cumulative frequency, $\sum f_i$</td><td>% Frequency, $\%f_i$</td><td>% Cumulative frequency $\%\sum f_i$</td><td>$f_i \times V_i$</td><td>$f_i(V_i - V_m)^2$</td></tr>
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</table>

ANALYSIS OF DATA

Plot frequency distribution curve and cumulative frequency distribution curve and report the following results.

1. Median speed =________________km/hr
2. Modal speed = ________________km/hr
3. Pace = ___________________ km/hr
4. %Vehicles in pace =_______________
5. Mean Speed = $V_{mean} = \frac{\sum f_i \times V_i}{n}$ = ------------- =____________ km/hr
6. Standard Deviation, $\sigma_s = \sqrt{[\frac{f_i(V_i - V_m)^2}{n-1}]}$ =----------------=___________km/hr
7. Percentile Speeds: 15th Percentile Speed = __________________________

   50th Percentile Speed = __________________________

   85th Percentile Speed = _________________________

   98th Percentile Speed = __________________________
8. Confidence bounds, μ = $V_{mean} \pm Z\sigma_s$

Note: For 95% confidence, Z=1.96 & for 99.7% confidence, Z=3.0

9. Sample size required for x% confidence with accepted error of S_e,

   $n_s = \frac{Z^2 \sigma_s^2}{S_e^2}$ =-------------------- = __________

PRESENTATION OF DATA

Some graphical illustrations have been shown below. These graphs have been generated with the set of an example spot speed study using MS Excel.

Table 3.3 Frequency of speeds obtained from a sample survey

Speed Range, kmph	20-25	26-30	31-35	36-40	41-45	46-50	51-55
Frequency	0	2	6	18	25	19	16
Speed Range, kmph	56-60	61-65	66-70	71-75	76-80	81-85	Total
Frequency	17	12	7	4	3	1	130

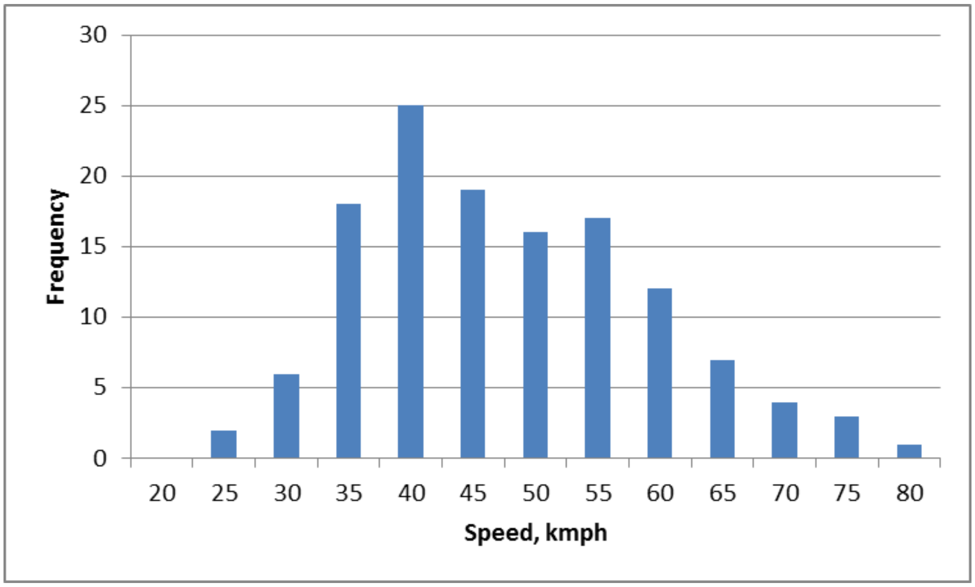

Fig 3.2 Frequency distribution of speeds

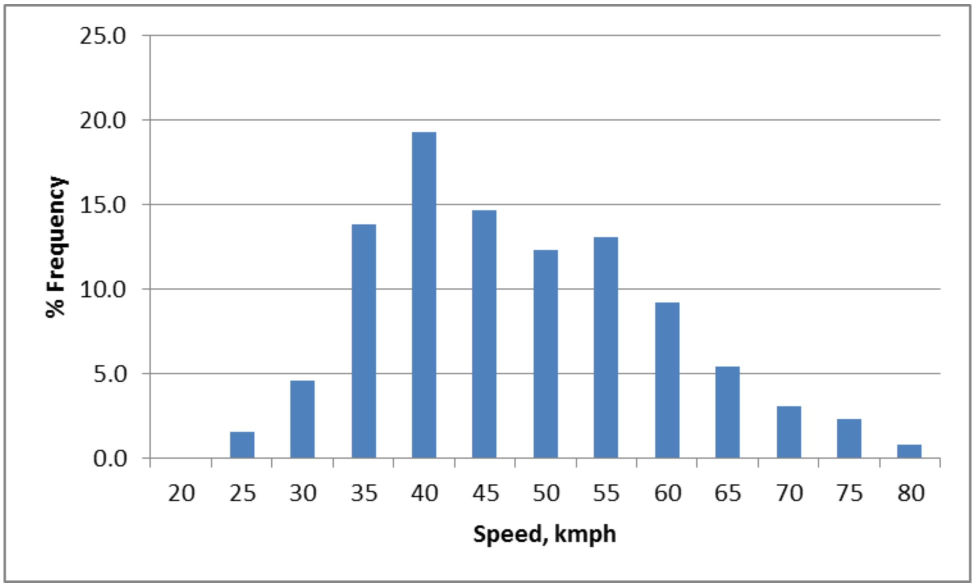

Fig 3.3 Percent frequency distribution of speeds

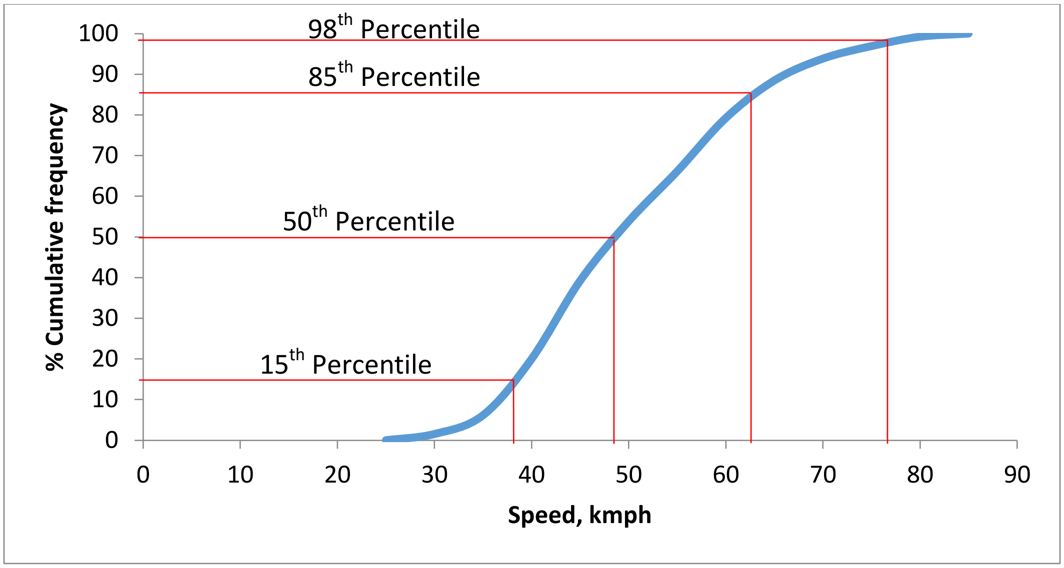

Fig 3.4 Percent Cumulative frequency distribution of speeds

Students are expected to use the data collected during spot speed surveys. The data should be analyzed and presented in both tabular as well as graphical forms using both the manual method and using the software. Hence inferences should be drawn from each.

TE Lab 3.2

SPOT SPEED STUDY USING ENOSCOPE

OBJECTIVE: To conduct a spot speed study using Enoscope, develop cumulative frequency speed distribution curve and calculate various statistical measures.

EQUIPMENT AND FACILITIES REQUIRED

1. Measuring tape
2. Mirror Box (Enoscope)
3. A stopwatch
4. Observation sheets
5. Computer system with statistical software e.g. MS Excel/ Sigma Plot (optional)

THEORY

Enoscope, also known as the Mirror Box, is an L-shaped box, open at both ends, with a mirror set at a 45° angle to the arms of the instrument. The instrument bends the line of sight of the observer so that it is perpendicular to the path of the vehicle. The method can be used with one Enoscope or with two Enoscopes.

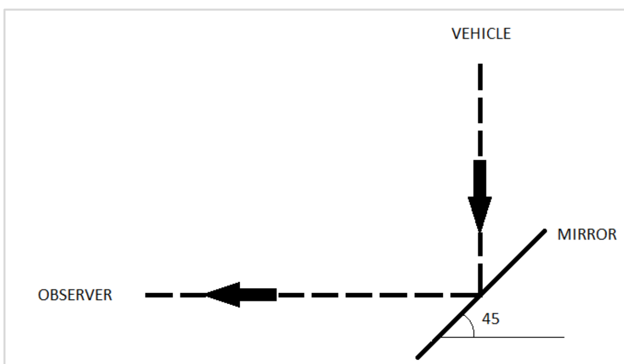

Fig3.5 Working principle of Enoscope

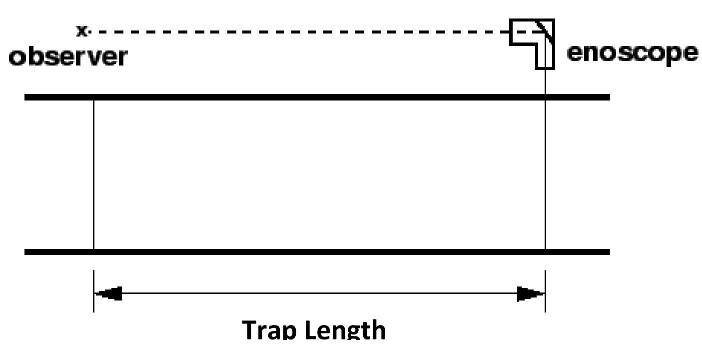

Fig 3.6 Trap length for speed study using one Enoscope

PROCEDURE

1. Select appropriate trap length at an appropriate site. Using the recommended study lengths based on the average speed of traffic stream, two reference points are marked on the road.
2. Record observations on spot speed study data form. First, note down the date, location, weather condition, time and choose the direction of movement of the vehicles for which time is to be noted first.
3. Enoscope is placed directly opposite to the first reference point and observer stands opposite to another reference point such that observer and Enoscope are in the same line of sight.
4. Start the stopwatch when the image of the passing vehicle is seen through the Enoscope by the observer and stop the stopwatch as soon as it passes the observer. Therefore, the time elapsed is obtained.
5. Repeat the procedure for recording time of vehicles moving in the opposite direction.
6. If two Enoscopes are used then observer stands mid-way between two reference points and notes the time taken.
7. Now calculate vehicle speeds by using the formula:

$$\boldsymbol{V = \frac{D}{T}}$$

where V = speed (m/s)
D = distance between two sections (m)
T = time elapsed between two sections (sec)

8. Choose appropriate bin limits and generate a frequency distribution table.
9. Perform calculations using Table 3.2.
10. Generate a frequency distribution curve and cumulative frequency distribution curve either manually or using software such as MS Excel/ Sigma Plot.
11. Compute various statistical metrics like mean, mode, standard deviation, etc. either using statistical formulae or using the generated graphs. Also determine the speed percentiles such as 15^{th}, 50^{th}, $85^{th,}$ and 98^{th} percentile speeds.
12. Compute the confidence bounds with 95% and 99.7% confidence respectively and hence compute the sample size required to achieve a tolerance of "x, km/hr" as an error.

OBSERVATIONS

Refer to observation sheet 3.1

CALCULATIONS

Refer to Table 3.2

ANALYSIS OF DATA

Same as in TE Lab 3.1.

PRESENTATION of DATA

Same as in TE Lab 3.1. Refer to Fig 3.2, Fig 3.3 and Fig 3.4

TE Lab 3.3

SPOT SPEED STUDY USING RADAR/ SPEED GUN

OBJECTIVE: To conduct a spot speed study using Speed/ Radar Gun, develop cumulative frequency speed distribution curve and calculate various statistical measures.

EQUIPMENT AND FACILITIES REQUIRED

1. Speed/Radar Gun
2. Observation sheets
3. Computer system with statistical software e.g. MS Excel/ Sigma Plot (optional)

THEORY

The speed gun or radar meters are used for measurement of spot speeds much rapidly as compared to previously discussed methods. It measures speed directly by measuring the difference in the frequency between the emitted and reflected radar wave emitted on an oncoming vehicle. The principle of radar meter is that when it is targeted to a vehicle moving with some speed, the difference between the frequencies of the emitted and reflected beams is used to calculate the speed. This is normally referred to as the *Doppler Effect* which states that the difference in frequency is proportional to the speed of the oncoming vehicle. Using this principle, the instrument is programmed to calculate the speed of the vehicle.

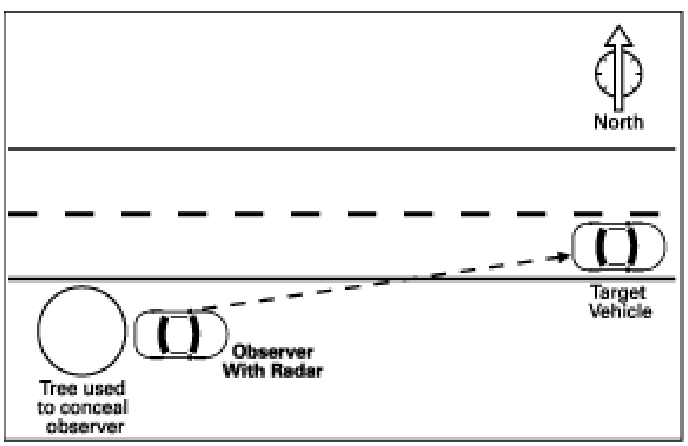

Fig 3.7 Radar Speed Meter Study Layout

Fig 3.8 Radar Gun

This is a recent advancement in speed studies; it automatically records speed and employs a radar transmitter-receiver unit. The apparatus transmits high-frequency electromagnetic waves as a narrow beam towards the moving vehicle, the beam changes its frequency depending upon the vehicle's speed and is returned to the receiver unit. Upon calibration, spot speed of the vehicle is obtained.

These meters are widely used by engineers, traffic police and other departments. These have certain practical limitations. They are:

1. In some situations, there is a possibility of recording wrong input like when a test sample is obstructed by other vehicles, the triggered radar beam bounds back by hitting the obstacle but not the test sample.
2. Accurate measurements from radar meter are obtained only when the radar wave is reflected directly along the axis of the movement. But in some cases, it is practically difficult.

PROCEDURE

1. Select the proper location and placement of radar meter. The radar meter is so kept that the angle between the direction of travel of the vehicle and the axis of transmission of a radio wave is as low as possible, within 20°. The instrument is set up near the edge of carriageway about 1m high above the ground level.
2. After setting up the instrument, the observer records the date, location, weather conditions, time and direction on spot speed study form.
3. Choosing a particular direction of movement of vehicles, radar speed meter is started by pressing on-button. Radar speed meter directs radio wave of a certain frequency at the moving vehicle and speed of the vehicle is proportional to change in frequency of radio wave transmitted and received.
4. Radar speed meter is pre-calibrated to display vehicle speed in km/hr with an accuracy of at least 1.5 to 3 km/hr.
5. A slash/tally is recorded on the data form corresponding to speed observed for each selected vehicle under vehicle-type classification.
6. Perform calculations using Table 3.2.
7. Generate a frequency distribution curve and cumulative frequency distribution curve either manually or using software such as MS Excel/ Sigma Plot.
8. Compute various statistical metrics like mean, mode, standard deviation, etc. either using statistical formulae or using the generated graphs. Also determine the speed percentiles such as 15^{th}, 50^{th}, 85^{th} and 98^{th} percentile speeds.
9. Compute the confidence bounds with 95% and 99.7% confidence respectively and hence compute the sample size required to achieve a tolerance of "x, km/hr" as an error.
10. Repeat the procedure for vehicles moving in the other direction also.

OBSERVATIONS

Observation Sheet 3.2

Spot speed study(using speed/radar gun) data entry form

<table>
<tr><td colspan="2">Date:</td><td colspan="2">Day:</td><td colspan="2">Weather:</td><td>Page:</td></tr>
<tr><td colspan="7">Name of the road:</td></tr>
<tr><td colspan="7">Name of the observer(s):</td></tr>
<tr><td colspan="5">Direction From:</td><td colspan="2">Towards:</td></tr>
<tr><td colspan="7">Total number of vehicles observed:</td></tr>
</table>

Vehicle No.	Speed (km/hr)	Vehicle No.	Speed (km/hr)	Vehicle No.	Speed (km/hr)

Observation Sheet 3.3

Spot speed study (using speed/radar gun) data entry form

Date:	Day:	Weather:	Page:
Name of the road:			
Name of the observer(s):			
Direction From:		Towards:	
Total number of vehicles observed:			

Speed Range (km/hr)		Tally Mark		Number		Total
		Car/Jeep	Bus/ Truck	Car/Jeep	Bus/ Truck	

CALCULATIONS

Refer to Table 3.2

ANALYSIS OF DATA

Same as in TE Lab 3.1.

PRESENTATION of DATA

Same as in TE Lab 3.1. Refer to Fig 3.2, Fig 3.3 and Fig 3.4

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PARKING STUDIES 4

TE Lab 4

Parking Studies are conducted to collect the required information about the capacity and use of existing parking facilities. These studies may be restricted to a particular attractor such as a shopping mall or may encompass an entire region such as a Central Business District.

NEED FOR THE STUDY

1. To determine the demand at an existing or new parking area.
2. To study the existing parking regulations and safety aspects of the parking area.
3. To study the efficiency of parking lots.

THEORY

Parking Systems

- On-street parking
- Off-street parking

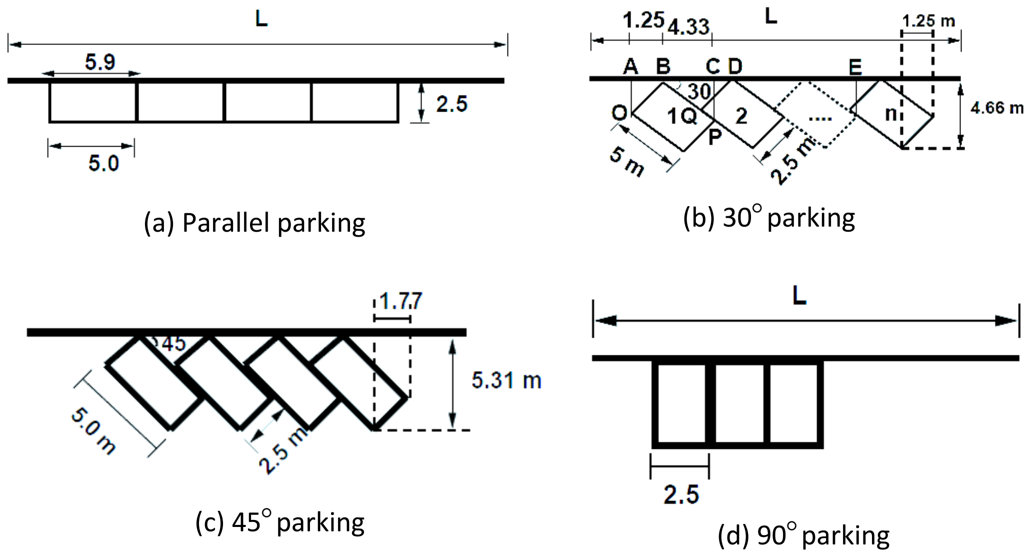
On-street parking: In case of on-street parking, the vehicles are parked on the sides of the street itself.

Ill effects of on-street parking:

1. Loss of street space leading to traffic congestion.
2. Maneuvers associated with parking and un-parking can cause accidents.
3. Parked cars obstruct the movement of fire-fighting vehicles and greatly impede their operations.

Table 4.1 Common systems of on-street parking and the spaces available.

S.No.	Parking system	Length of parking space available for parking 'n' number of vehicles (m)
1	Parallel parking	L = n/5.9
2	30° angle parking	L = 0.58 + 5n
3	45° angle parking	L = 3.54n + 1.77
4	60° angle parking	L = 2.89n+2.16
5	Right angle parking	L = 2.5n



(a) Parallel parking

(b) 30° parking

(c) 45° parking

(d) 90° parking

Fig. 4.1 Illustrations of various on-street parking systems

Parallel parking consumes the maximum kerb length and right angle parking consumes the minimum curb length. But parallel parking makes the least use of the width of the street. From the point of view of maneuverability, angle parking seems to be better than parallel parking which usually involves a backing motion. As regards safety, it has been noticed that angle parking is more hazardous than parallel parking. It is recommended that in general, parallel parking should be favored on streets. On exceptionally wide (wider than 20m) and low volume streets, consideration might be given for angle parking.

Off-street parking

In the case of off-street parking, the vehicles are parked not on streets but at places which are meant only for parking.

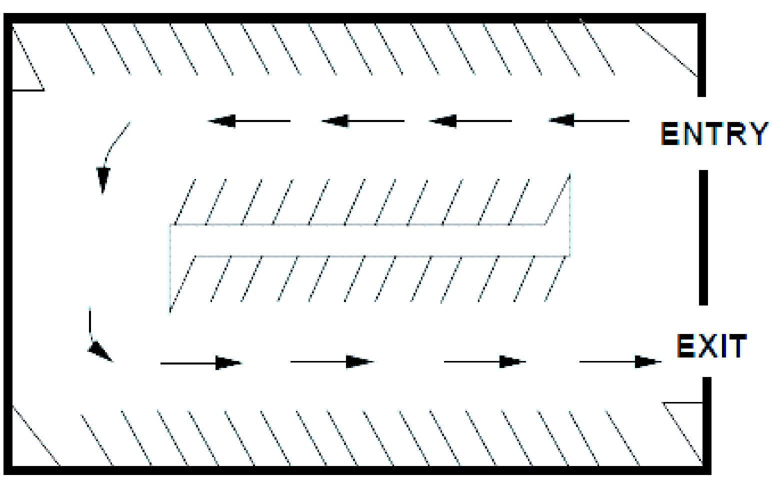


Fig. 4.2 Illustrations of off-street parking system

As per IRC, the standard dimensions of a car are taken as 5m x 2.5m and that for a truck as 3.75m x 7.5m.

Parking Statistics

1. **Parking accumulation:** It is defined as the number of vehicles parked at a given instant of time. It is expressed by the accumulation curve (graph obtained by plotting the number of bays occupied with respect to time).

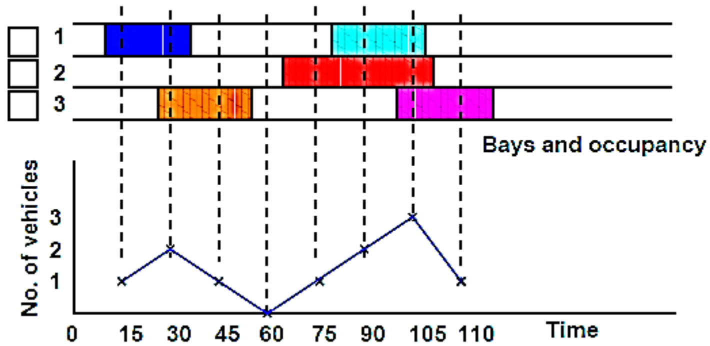


Fig. 4.3 Parking bays and accumulation curve

2. **Parking volume:** It is the total number of vehicles parked at a given duration of time. This does not account for the repetition of vehicles. The actual volume of vehicles entered in the area is recorded.

$$\boldsymbol{Parking\ Volume, PV = n_t}$$

where n_t = *total number of vehicles parked at a location during* $'t'$ *duration of time*

3. **Parking load:** It is given by the area under the accumulation curve. 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 as vehicle hours.

$$\boldsymbol{Parking\ Load, PL = \sum_{i=0}^{t}(n_{i\times}t_i)}$$

where $n_i = i^{th}$ *number of vehicle parked at a location for* $'t_i'$*duration of time*

4. **Average parking duration:** It is the ratio of total vehicle hours to the number of vehicles parked.

$$\boldsymbol{Parking\ Duration, PD = \frac{PL}{PV}}$$

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

$$\boldsymbol{Parking\ Turnover, PT = \frac{PV}{N_b}}$$

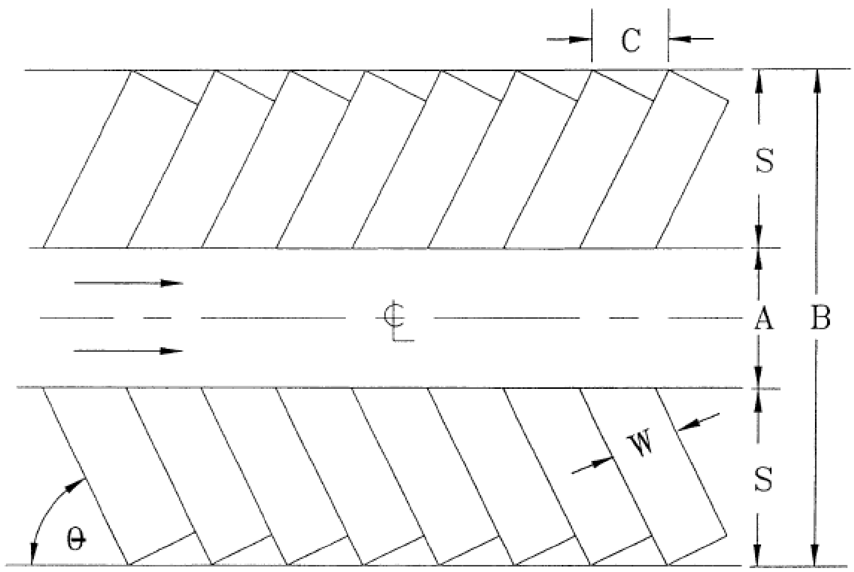
where $\boldsymbol{N_b}$ = *number of bays available*

6. **Parking index or Occupancy or Efficiency:** It is defined as the ratio of a number of bays occupied in a time interval to the total space available. It gives an aggregate measure of how effectively the parking space is utilized.

$$\boldsymbol{Parking\ Index, PI = \frac{PL}{PC} \times 100}$$

where $\boldsymbol{PC}$ *= Parking capacity*

Parking Geometrics



C= Curb Length; $\boldsymbol{\theta}$ *= Parking angle; W = Stall width;*
S = Stall length; A = Aisle; B = Bay width

Figure 4.4 General parking stall geometrics

Parking Surveys

Parking surveys are conducted to obtain different parking statistics.

1. **In-out survey:** In this survey, the occupancy count in the selected parking lot is taken at the beginning. Then the number of vehicles that enter the parking lot for a particular time interval is counted. The number of vehicles that leave the parking lot is also taken. The final occupancy in the parking lot is also taken. One person is enough to study the parking lot. But parking duration and turn over are not obtained.

2. **License plate method of survey:** In this case of survey, every parking stall is monitored at a continuous interval of 15 minutes or so and the license plate number is noted down. This will give the data regarding the duration for which a particular vehicle was using the parking bay. This will help in calculating the fare based on the duration for which the vehicle was parked. But this method is very labor intensive.

TE Lab 4.1

PARKING STUDY BY IN-OUT SURVEY

OBJECTIVE: To identify various elements that relate to a parking study by examining an existing parking area using in-out survey.

EQUIPMENT AND FACILITIES REQUIRED

1. Observation sheets
2. A stopwatch
3. Measuring tape/ Electronic Distance Measuring (EDS) Device
4. A marker like chalk, lime(in case the parking bays are not marked)

PROCEDURE

1. Choose a parking lot whose parking characteristics are to be determined. For good results, a working day should be selected to carry out the study of the parking lot.
2. Record the date, time and weather conditions and note it down on observation sheet.
3. The occupancy count in the selected parking lot is taken and reported as the initial count.
4. Number of vehicles that enter the parking lot for a particular time interval is counted.
5. The number of vehicles that leave the parking lot is also taken.
6. Data is to be recorded for the whole time of the study (usually one hour). As it is not a labour intensive work, one observer is sufficient.
7. Tabulate the data and calculate accumulation, total parking load, average occupancy, and efficiency of the parking lot. Since we don't collect any data regarding the time duration, therefore parking duration and turn over cannot be obtained.
8. Calculate accumulation, total parking load, average occupancy, and efficiency of the parking lot.

OBSERVATIONS

Observation Sheet 4.1

In-Out field survey sheet

Day:	Date:	Weather:	Page:
Name of the observer(s):			
Location:			
Time Start:		Finish:	
Initial Count:	Total No. of bays:		
Time	Number of vehicles entering the stall	Number of vehicles leaving the stall	
05			
10			
15			
20			
25			
30			
40			
45			
55			
60			

CALCULATIONS

Table 4.2 Calculation of accumulation, occupancy, and parking load

Day:	Date:		Weather:		Page:
Name of the observer(s):					
Location:					
Time Start:				Finish:	
Initial Count:			Total No. of bays:		
Time (1)	Number of vehicles entering the stall (2)	Number of vehicles leaving the stall (3)	Accumulation (4)	Occupancy (5)	Parking load (6)
05					
10					
15					
20					
25					
30					
40					
45					
55					
60					
Total parking load					

Notes: Accumulation can be found out as the initial count plus number of vehicles that entered the parking lot till that time minus the number of vehicles that just exited for that particular time interval.

Occupancy for that time interval is accumulation in that particular interval divided by total number of bays.

Parking load is obtained by multiplying accumulation with the time interval i.e. col. (4)× time interval

ANALYSIS AND PRESENTATION

This method is quick but not exhaustive. It is usually done to have a gross idea of the parking spaces available. Sketch out the plan observed for a parking lot. The calculated indices should be compared with the exhaustive data (if available) and recommendation about the improvements should be given accordingly.

TE Lab 4.2

PARKING STUDY BY LICENSE PLATE METHOD

OBJECTIVE: To identify various elements that relate to a parking study by examining an existing parking area using License Plate Method.

EQUIPMENT AND FACILITIES REQUIRED

1. Observation sheets
2. A stopwatch
3. Measuring tape/ Electronic Distance Measuring (EDS) Device
4. A marker like chalk, lime(in case the parking bays are not marked)

PROCEDURE

1. Choose a parking lot whose parking characteristics are to be determined. For good results, a working day should be selected to carry out the study of parking lot.
2. Record the date, time and weather conditions and note it down on observation sheet.
3. Identify the total number of lanes and stalls (bays) in the parking lot and differentiate each and every stall and lane by naming them accordingly. If stalls are not marked, then mark them using lime, chalk, etc. having dimensions 5m×2.5m (as per IRC) for simplification.
4. Fill in the inventory of parking facilities (as given in observation sheet no. 4.1)to have ample information about the parking lot.
5. Observer monitors every parking stall and notes the license plate number of vehicles present in each and every stall at continuous intervals of 15 minutes or so.
6. Data is to be recorded for the whole time of the study (full day) in the same manner. As it is labour-intensive work, a number of observers are preferred.
7. After tabulating the data, determine the turnover for each stall in the parking lot which gives information regarding the duration for which a particular vehicle has used the parking stall.
8. Plot the accumulation curve (number of vehicles vs time) and calculate Parking Load, Parking Volume, Average Parking Duration, and Parking Turnover.
9. The Parking Index or Efficiency is also to be determined which gives an idea about the true benefits of parking lot available.
10. Sketch out the plan of the parking lot.

OBSERVATIONS

Observation Sheet 4.2

Inventory of parking facilities

Day:	Date:	Weather:	Page:	
Name of the observer(s):				
Location:				
Time Start:		Finish:		
S.No.	Type of observation	Possibility	Observation	Comment
1.	Parking Charges	Paid/ Free		
2.	Parking lot markings	Present/ absent		
3.	Entry and Exit Gates	Open/ Controlled		
4.	Space for 2-wheelers	Present/ absent		
5.	Space for bicycles	Present/ absent		
6.	Parking angle	Parallel, 30,45, or so		
7.	Curb Length	In metre/ feet		
8.	Stall length	In metre/ feet		
9.	Stall width	In metre/ feet		
10.	Aisle width	In metre/ feet		
11.	Bay width	In metre/ feet		
12.	Aisle	Divided/ undivided		
13.	Signs boards	Present/ absent		
14.	Adjoining land-use Northbound Southbound Eastbound Westbound	Industrial/ commercial/ domestic/ agricultural/ wasteland or so		
15.	Local jurisdiction	Government/ private		
16.	Intelligent Transport Systems	Present/ Absent		
17	Proximity to destination(s)	In metre/ feet		
18	Pedestrian crosswalks	Present/ Absent		
19.	Distance from the nearest parking lot	In miles/kilometres		
20.	Peak demand days/hours	Monday/ Tuesday/ 9:00 am to 5:00 pm or so		

Note: This form is not exhaustive and should be taken as a reference. The number and type of observations can vary from one place to another and thus the form should be designed accordingly.

Observation Sheet 4.3

License-Plate field survey sheet

Day:		Date:		Weather:	Page:
Name of the observer(s):					
Location:					
Time Start:				Finish:	
Lane	Bay No.	Time, minutes			
		0-15	15-30	30-45	45-60

CALCULATIONS

Table 4.3 Calculation of accumulation, occupancy and turn over for each bay

Day:			Date:				Weather:			Page:
Name of the observer(s):										
Location:										
Time	Start:								Finish:	
Lane (1)	Bay No. (2)	Time/ Observed license plate numbers				Time/ Accumulation				Turn Over (11)
		0-15 (3)	15-30 (4)	30-45 (5)	45-60 (6)	0-15 (7)	15-30 (8)	30-45 (9)	45-60 (10)	
		∑Accumulation								
		∑Occupancy								

Notes: Turn over in Col. 11 is computed as the number of vehicles present in that bay for that particular hour.
Accumulation for a time interval is the total number of vehicles in the respective bay(s) for that time interval.
Occupancy for that time interval is accumulation in that particular interval divided by total number of bays.

$$Parking\ Load, PL = \sum_{i=0}^{t} (n_{i\times} t_i)$$

$= \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$ vehicle hours

$$Parking\ Volume, PV = n_t$$

$= \_\_\_\_\_\_\_\_\_\_\_\_$

$$Average\ Parking\ Duration, PD = \frac{PL}{PV}\ hr$$

$= \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ hr$

$$Parking\ Turnover, PT = \frac{PV}{N_b}$$

$= \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$

$$Parking\ Index, PI = \frac{PL}{PC} \times 100$$

$= \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \%$

ANALYSIS AND PRESENTATION

Select two to three different locations. Compare the data and various parking statistical indices of each. Sketch out the plan(s) observed for each parking lot showing all the features e.g. angle of parking, entry and exit gates, possible manoeuvres, aisle width, curb length, etc. Improvements in the respective parking lots may also be given through sketches.

TRAFFIC STREAM PARAMETERS STUDY 5

TE Lab 5

OBJECTIVE: To determine fundamental/ macroscopic characteristics i.e. flow, density and speed of a traffic stream and their interdependencies thereof by Moving Observer Method.

EQUIPMENT AND FACILITIES REQUIRED

1. An observation sheet/ Counting pads
2. A test vehicle (e.g. a car)
3. Stop watches
4. A team of at least 3 to 4 members

NEED FOR THE STUDY

1. The traffic stream parameters provide information regarding the nature of traffic flow, which helps the analyst in detecting any variation in flow characteristics.
2. To gather the information such as amount, location, duration, frequency and the causes of the delay in the traffic stream.
3. To determine the spots of congestion, causes and in arriving at suitable remedial measures.
4. To find the travel time, average journey time, and benefit-cost analysis.
5. To rate the efficiency of a road.

THEORY

For a complete description of traffic stream modeling, one would require flow, speed, and density. Fundamental equation of traffic flow is used for this purpose which is as follows:

$$\boldsymbol{q} = \boldsymbol{u} \times \mathbf{k}$$

where q = flow of traffic stream, vehicles/hour
u = speed of traffic stream, km/hr
k = density of traffic stream, vehicles/km

If we know any two parameters, the third can be computed. In field, moving car or moving observer method of traffic stream measurement has been developed to provide simultaneous measurement of traffic stream variables. It has the advantage of obtaining the complete state with few observers, and a vehicle. In this method, the observer moves in the traffic stream unlike other methods.

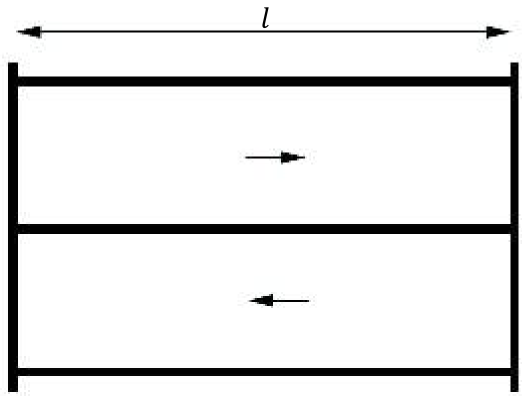


Fig.5.1 Illustration of moving observer method

The first parameter i.e. flow or volume of the traffic stream is computed using the following formula:

$$\boldsymbol{Flow\ of\ vehicles}, \qquad \boldsymbol{q} = \frac{\boldsymbol{n_a - n_y}}{\boldsymbol{t_a + t_y}}$$

where q *= flow of vehicles in one direction of the stream.*

n_a *= average no. of vehicles counted in the direction of the stream when the test vehicles travels in the opposite direction.*

n_y *= average no. of vehicles overtaking the test vehicle minus the no. of vehicles overtaken in the direction of flow.*

t_a *= average journey time when the test vehicle is travelling with the stream flow.*

t_w *= average journey time when the test vehicle is running against the stream flow.*

The second parameter i.e. speed of the traffic stream is computed using the following formula:

$$\boldsymbol{v_s} = \frac{\boldsymbol{l}}{(\boldsymbol{t_w} - \frac{\boldsymbol{n_y}}{\boldsymbol{q}})}$$

where $l =$ *length over which the test vehicle is run*

Knowing the two parameters, the third parameter of traffic flow i.e. density (k) can be found out as:

$$\boldsymbol{k} = \frac{\boldsymbol{q}}{\boldsymbol{v_s}}$$

To increase the accuracy and reliability, the test is performed a number of times and the average results are to be taken.

PROCEDURE

1. A route of travel is selected and a test vehicle is driven along that route at approximately the average speed of the stream.
2. A group of observers are to be seated in test vehicle to record various observations during each run of test vehicle.
3. Some initial information is recorded in the observation sheet(s) e.g. day, date, vehicle number, route, time of start, direction etc. Alternatively, counting pads can be used by the observers.
4. In the first run, the vehicle is moved in the direction of the existing flow of traffic stream. As the vehicle moves, one of the observers records the time of start and then journey ending time.
5. Second observer records the vehicles that are overtaken by the test vehicle and also the vehicles that are overtaking the test vehicle.
6. A number of such test runs are performed over the same length of road.
7. Then the test vehicle is moved against the flow of traffic stream. Now, the observer(s) notes the number of vehicles travelling in opposite direction. In mixed traffic flow, more observers are required to count the opposing vehicles.
8. A number of test runs are made by test vehicle along the study stretch and same procedure is followed.
9. The data is tabulated and various calculations are performed using various equations. From two parameters *(i.e. flow and speed)* third parameter of traffic stream *(i.e. density)* is computed.
10. Finally, plot the three different graphs *(flow vs speed, flow vs density and speed vs density)* using the data obtained.

OBSERVATIONS

Observation Sheet 5.1

Recording of number of vehicles when test vehicle moves in the same direction as that of traffic stream

Date:		Day:		Weather:		Page:	
Name of the road:							
Name of the observer(s):							
Study length:							
Direction From:				Towards:			
Total number of vehicles observed:							
Number of vehicles observed							
Test Run No.1		Test Run No.2		Test Run No.3		Test Run No.4	
n_{11}	n_{12}	n_{21}	n_{22}	n_{31}	n_{32}	n_{41}	n_{42}
Journey time for test run No. 1=		Journey time for test run No. 2=		Journey time for test run No. 3=		Journey time for test run No. 4=	

Note: n_{ij} = number of vehicles observed for i^{th} test run.

$i = 1,2,3,4$ denotes number of test run; $j = 1$ denotes number of vehicles overtaken by test vehicle and $j = 2$ denotes number of vehicles overtaking the test vehicle

Observation Sheet 5.2

Recording of number of vehicles when test vehicle moves in the direction opposite to the traffic stream

Date:	Day:	Weather:	Page:
Name of the road:			
Name of the observer(s):			
Study length:			
Direction From:		Towards:	
Total number of vehicles observed:			
Number of vehicles observed, n_a			
Test Run No.1	Test Run No.2	Test Run No.3	Test Run No.4
Journey time for test run No. 1=	Journey time for test run No. 2=	Journey time for test run No. 3=	Journey time for test run No. 4=

CALCULATIONS

Table 5.1 Determination of fundamental/ macro characteristics of traffic stream

Test Run No.	n_a	n_1	n_2	$n_y = (n_1 - n_2)$	t_a	t_y	$q = \frac{n_a - n_y}{t_a + t_y}$	$v_s = \frac{l}{(t_w - \frac{n_y}{q})}$	$k = \frac{q}{v_s}$
1									
2									
3									
4									

ANALYSIS AND PRESENTATION

Plot the following three different graphs using the calculated data. These will give the inter-relationships between various macro parameters of the traffic stream.

- *Flow vs Speed*
- *Flow vs Density*
- *Speed vs Density*

These graphs are analysed whether they fit into some particular distribution function e.g. parabolic function, linear function or so. It is recommended to use MS Excel/ Sigma Plot software for data plotting. Some illustrations from reference example have been shown below:

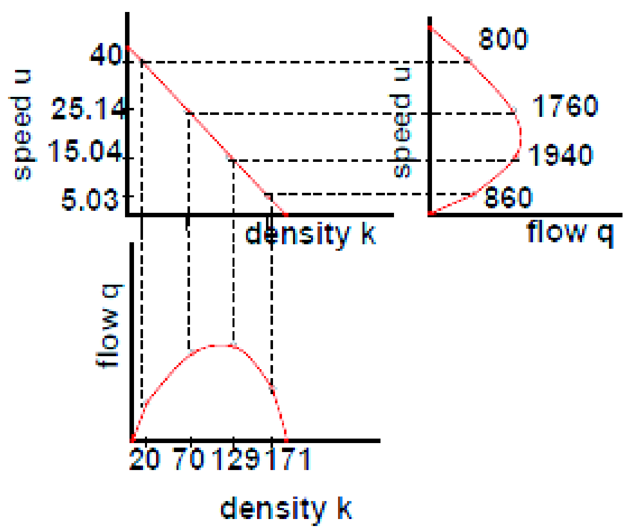


Fig. 5.2 Fundamental diagrams of traffic flow showing the inter-relationships between macro characteristics of traffic stream

INTERSECTION GEOMETRICS STUDIES 6

TE Lab 6

An intersection is defined as the general area where two or more highways join or cross, within which are included the roadway and roadside facilities for traffic movements in that area. An intersection leg is that part of any one of the roadways radiating from an intersection which is outside the area of the intersection proper.
At an intersection there are through, turning and crossing traffic movements and these traffic movements may be handled in different ways depending on the type of intersection and its design. The efficiency, safety, speed, cost of operation and capacity of the road system very much depend on the planning and design of the intersection therein.

Classification of Intersections
Intersections may be classified into two broad groups:

(i) *Intersection at-grade*: These include all roads which meet at more or less the same level. The traffic manoeuvres like merging, diverging and crossing are involved in the intersection at grade. The intersection at grade are further sub-classified into four:

a. Un-channelized
b. Channelized
c. Rotary intersection
d. Signalized intersection

(ii) *Grade separated intersection*: The intersecting roads are separated by a difference in level, thus eliminating the crossing manoeuvres. The grade separation is effected by taking one of the roads, say the major road either above the crossroad by means of an overpass or flyover or below the crossroad by means of an underpass. The turning movements between grade-separated crossroads are enabled by suitable *'interchange facilities'*.

Intersection Terminology
Intersection legs are segments of roadway connecting to the intersection. The leg used by traffic approaching the intersection is the approach leg, and that used by traffic leaving is the departure leg.

Sidewalks, crosswalks and pedestrian kerb cut ramps are considered to be within the intersection. The pavement edge corner is the curve connecting the edges of the pavement of the intersecting streets.

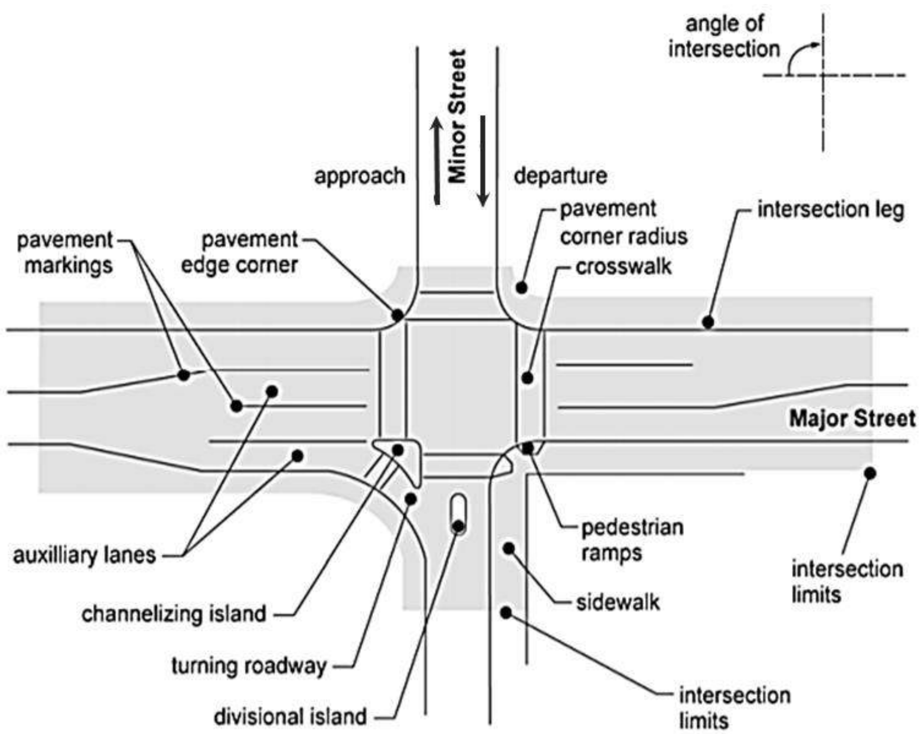


Figure 6.1 Various geometric elements of an intersection

Auxiliary lanes are lanes added at the intersection, usually to accommodate turning motor vehicles. They may also be used to add through lanes through an intersection.

Channelizing and divisional islands may be added to an intersection to help delineate the area in which vehicles can operate and separate conflicting movements. Islands can also provide for pedestrian refuge.

A turning roadway is a short segment of the roadway for a right turn, delineated by channelizing islands. Turning roadways are used where right-turn volumes are very high, or where skewed intersections would otherwise create a very large pavement area.

Traffic control devices assign right of way, to both motorized and non-motorized traffic and include traffic signals, pavement markings, STOP signs, YIELD signs, pedestrian signal heads and other devices (such as raised pavement markings, flashing beacons, and electronic blank-out signs).

All road intersections which meet at about the same level allowing traffic manoeuvres like merging, diverging, crossing and weaving are called intersections at grade.

Types of Intersection

Generally, intersections can be classified into three categories depending on the traffic conditions. These are as follows:

- *Uncontrolled Intersections at-grade*: These are the intersections between any two roads with a relatively lower volume of traffic and traffic of neither road has precedence over the other.
- *Intersection with Priority Control*: There is theoretically no delay occurring on the major road and vehicles on the minor road are controlled by "GIVE -WAY" or "STOP" sign.
- *Time separated intersection/Signalized Intersections at-Grade*: The detailed warrants for signalized intersection are laid down in IRC 93. A signalized intersection besides other warrants is justified if the major street has a traffic volume of 650 to 800 vehicles per hour (both directions) and the minor street has 200 to 250 vehicles per hour in one direction only.

The basic requirements of the intersection at grade are:

- At the intersection, the area of conflict should be as small as possible.
- The relative speed and particularly the angle of approach of vehicle should be small.
- Adequate visibility should be available for vehicles approaching the intersection.
- A sudden change of path(s) should be avoided.
- Geometric features like turning radius and width of the pavement should be adequately provided.
- Proper signs should be provided on the road approaching the intersection to warn the drivers.
- If the number of pedestrians and cyclists are large, separate provision should be made for their safe passage at intersections with a high volume of fast-moving traffic.
- Good lighting is desirable for good visibility at night.

AASHTO defines intersection capacity as *"the maximum hourly rate at which vehicles can reasonably be expected to pass through the intersection under prevailing traffic, roadway, and signalization conditions".* The Highway Capacity Manual (HCM) provides various analysis techniques for comparing different conditions at intersections. Hence, a well-designed intersection is clear to the driver with design dimensions supporting operational requirements, traffic control devices functioning as intended, and non-motorized vehicle users operating safely through the intersection.

Basic types of intersections

- Three-legged (T or Y)
- Four-legged
- Multi-legged

• Roundabout

These types may vary based on scope, shape, flaring (for auxiliary lanes), and channelization (separation/regulation of conflicting traffic).

Variables for determining the type of intersection to be used at a location include:

- Topography
- Traffic characteristics
- Number of legs
- Type of operation
- Roadway characteristics

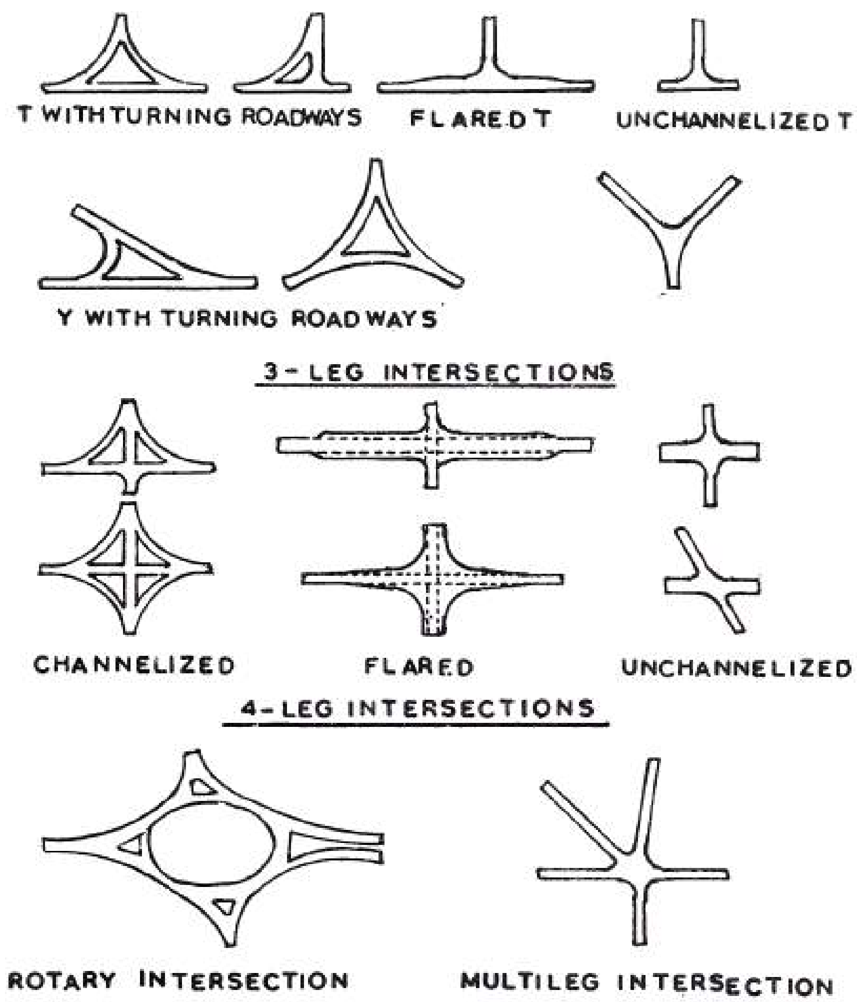


Fig.6.2 General Types of At-Grade Intersections

TE Lab 6.1

GEOMETRICS STUDY OF AT-GRADE INTERSECTION

OBJECTIVE: To study the geometrics of At-Grade intersection.

EQUIPMENT AND FACILITIES REQUIRED

1. Measuring tape(s) / Electronic Distance Measuring (EDM) Instrument
2. Observation sheet(s)
3. Traffic Monitoring Camera

NEED FOR THE STUDY

The importance of the design of the intersection stems from the fact that the efficiency of operation, safety, speed, cost of operation and capacity are directly governed by the design.

Therefore the study of geometrics of at-grade intersection helps in:

- Comparing the existing features of various geometric elements with those recommended by IRC (IRC SP:41-1994 "*Guidelines for the Design of At-Grade Intersections in Rural & Urban Areas*")
- Determining the feasibility and efficiency of an existing intersection.
- Suggesting improvements in the existing intersection in a scientific manner.

THEORY

Geometrics are the assembly of the fundamental three-dimensional features of the highway that are related to its operational quality and safety. Its basic objective is to provide a smooth-flowing, crash-free facility.
Geometric roadway design consists of three main parts:

- Cross section (lanes, shoulders, kerbs, medians, roadside slopes and ditches, sidewalks, etc.)
- Horizontal alignment (tangents and curves)
- Vertical alignment (grades and vertical curves)

Combination of these elements provides a three-dimensional layout for a roadway. Effective geometric design transmits knowledge from research and operational experience to the user. It reflects both human and vehicular characteristics and capabilities.

Guidelines and recommendations for geometric elements of At-Grade Intersections as per IRC

1. **Radius of curves at intersection**

The radii of intersection curves depend on the turning characteristics of design vehicles, their numbers and the speed at which vehicles enter or exit the intersection area.

Table 6.1 Recommended minimum radii for design speed by IRC

Design Speed, Km/hr	Minimum inner radii, m
18.5	18
15	23
20	27
30	32
40	37
50	41
75	50
100	57
125	62
150	64

2. **Radii of Curves in Urban Areas**

In urban areas, additional conditions like restriction on the right of way widths, abutting developments, pedestrian crossings, parked vehicles and high cost of land govern the minimum radii at intersections.

Generally, the minimum turning radius for a vehicle governs the design. However, to ensure efficient traffic operation on arterial streets common radii of 4.5 m to 7.3 m for passenger cars and 9 m to 15 m for trucks and buses is recommended.

3. **Intersection sight distance**

Intersection sight distance is the length of roadway along the intersecting road for the driver on the approach to perceive and react to the presence of potentially conflicting vehicles. Sight distance should also be provided to allow stopped vehicles a sufficient view of the intersecting roadway in order to enter or cross it. Intersection sight distances that exceed stopping sight distances are preferable along major roads to enhance safe and efficient traffic operations. Methods for determining intersection sight distances are based on many of the same principles as stopping sight distance. Sight triangles are areas along intersection approach legs that should be clear of obstructions that could block a driver's view.

The dimensions are based on driver behaviour, roadway design speeds, and type of traffic control. Object height (3.50 feet above the intersecting roadway surface) is based on vehicle height of 4.35 feet (representing the 15^{th} percentile of current passenger car vehicle heights). The height of the driver's eye is typically assumed to be 3.50 feet above the roadway surface.

Table 6.2 Recommended minimum visibility distance on rural roads by IRC

Design speed of major road, Km/hr	**Min. visibility distance along a major road, m**
100	270
80	180
65	145
50	110

Table 6.3 Recommended visibility distance along roads on Priority Junction (Urban Roads) by IRC

Design speed of Major road Km/hr	**Min. visibility distance along a major road, m**
All-purpose primary distributor	120-150
District or local distributor	90
Access road	60

Table 6.4 Recommended safe stopping sight distance of intersections by IRC

Speed, Km/hr	**Safe stopping Sight Distance, m**
20	10
25	25
30	30
40	45
50	60
60	80
65	90
80	130
100	180

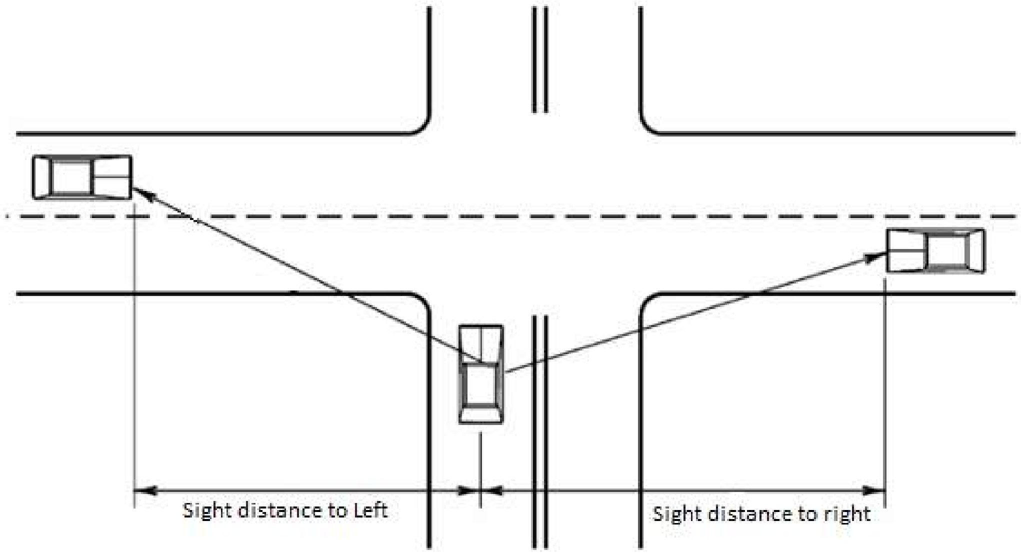


Fig.6.3 Illustration of intersection sight distance

4. **Channelization**

Channelization uses pavement markings and/or traffic islands to define definite travel paths for conflicting traffic. Appropriate channelization not only increases capacity and guides motorists but may also produce significant crash reductions and operational efficiencies.

Islands are designated areas between roadway lanes used for pedestrian sanctuary and traffic control. Channelized intersections use islands to direct entering traffic into definite travel paths. There is no single physical island type within an intersection; they may be in the form of medians and outer separations or raised curbs and pavement markings.

Table 6.5 Recommended minimum curbed corner island area by IRC

Place/ Area	**Minimum curbed corner island area, ft²**
Urban Intersection	50
Rural Intersection	75
Preferable	100

Some supplementary recommendations given by IRC are:

- The sides of corner triangular islands must be a minimum of 12 feet (preferably 15 feet).
- Elongated or divisional islands should be a minimum of 4 feet wide and 20 to 25 feet long. These island widths may be reduced to 2 feet where space is limited.

- Curbed divisional islands for high speed isolated intersections should be a minimum of 100 feet in length.

5. **Corner or directional islands**:

For an island to be clearly seen it must have the following:

- An area of at least 4.5 m^2 in urban areas and 7 m^2 in rural areas and should usually be bordered with painted raised kerbs.
- Smaller areas may be defined by pavement marking.
- Triangular islands should not be less than 3.5 m and preferably 4.5 m on a side after rounding of curves.
- It should be at an offset from the normal vehicle path by 0.3 m to 0.6 m. The layout should be tested using the track diagram for all turning movements.

6. **Centre or divisional islands**:

- Centre islands require careful location and designing. They require careful alignment and are invariably accompanied by widening of right-of-way.
- It should be preceded by a clearly marked or constructed natural area of not less than 1.5 sec travel time at approach speed.

7. **Auxiliary Lanes**

Auxiliary lanes are typically used for median openings or intersections with right/left-turning movements to increase capacity and reduce crashes. A minimum auxiliary lane width of 10 feet is desirable and should be equivalent to that for through lanes.

8. **Roadway shoulders**

Shoulders should also have the same width as adjacent shoulders (6 feet preferred – rural high-speed roads). Shoulder widths can be reduced or eliminated in many cases (urban areas, turn lanes, etc.). Paved shoulders of 2 to 4 feet may be required for auxiliary lane locations with heavy vehicle usage or off tracking.

9. **Median opening**

The minimum length of median opening for three or four-leg intersections on divided roadways should be equivalent to the crossroad width plus shoulders. The minimum opening length should equal the crossroad widths plus the median for divided roadway crossroads.

Table 6.6 Recommended minimum length of Median Opening by IRC

Median width M (m)	**Minimum length of median opening (m)**
1.2	30
1.8	23
2.5	21
3.0	19
3.6	18
4.3	16
5.0	14
6.0	13
7.2 and above	12 minimum

10. **Width of Turning Lanes at Intersection:**

Determination of widths of turning lanes at the intersection is primarily based upon the type of vehicles using it e.g. length of lanes, the volume of traffic and the necessity to pass a stalled vehicles (if kerbs are provided). Table 7.7 gives the recommended widths of turning lanes. These can be assumed to have a capacity of 1200 PCU/hr.

Table 6.7 Recommended widths of lanes at intersections by IRC

Inner radius (1)	**Design Speed km/h (2)**	**Single lane width, m (3)**	**Single lane width with space to pass stationary vehicles, m (4)***	**Two lane width for one or two-way traffic, m (5)**
10.5	18	5.5	10.53	11.5
15	23	5.5	9.5	10.5
20	27	5	9	10
30	32	4.5	8	9
40	37	4.5	7.5	9
50	41	4.5	7	8
75	50	4.5	7	8
100	57	4.5	7	8
125	62	4.5	6.5	8
150	64	4.5	6.5	8
-	-	4.5	6	7

**Note: These widths are applicable for longer slip roads (over 60m length) and should be used only if vehicles are allowed to park.*

11. **Acceleration lanes**

An acceleration lane should be designed so that vehicles turning left from the minor road may join the traffic flow on the major road at approximately the same speed as that of the nearside lane traffic in the major road. Acceleration lanes also improve capacity by enabling the use of short traffic gaps and by providing storage space for traffic waiting to merge when large traffic gaps occur. Acceleration lanes are recommended where the future traffic on the acceleration lane is accepted to be more than 1000 PCU per day.

12. **Speed Change Lanes**

Speed change lanes are more important in rural areas. In urban areas, such lanes are rarely required but the provision of short lanes to assist merging and diverging maneuvers are provided in conjunction with channelizing islands.
Speed change lanes should are uniformly tapered and have a setback of 5.4 m at the tangent point of the curve leading into or out of minor road. The turning lane should be reduced in width to 4.25 m by carriageway marking etc.

13. **Right-of-Way Flares**

To improve sight distance at intersections, right-of-way flares are obtained at all corners of the intersection where practical. The standard right-of-way flare used at rural intersections is 100 ft. × 100 ft.

14. **Turn Lanes**

On new four-lane highways, left turn lanes are usually provided at all intersecting side roads that have dedicated right-of-way. To develop left turn lanes on two-lane roadways for new construction or reconstruction projects, the pavement is widened using reverse curves and/or nearby horizontal curves on the mainline. The degree of the curve should be limited so that not more than a reverse crown super-elevation of 2.5 percent is required through the widening curves.

The minimum length required to obtain the widening is the greater of that required by the geometry and curve super-elevation, or as shown by the following formulas:

$$L = (w)(s), \text{ for design speeds of 45 mph or higher}$$

$$L = \frac{(w)(s)^2}{60}, \text{ for design speeds less than 45 mph}$$

where:
L = distance needed to develop widening (ft.)
w = width of widening (ft.)
s = design speed (mph)

15. **Position of Traffic Control devices**

To properly guide and control the traffic approaching junctions, traffic signs and signals are installed. While providing traffic signs at the intersection, due care must be taken to ensure the effectiveness of the sign posted. It should always be noted that too many signs with inadequate spacing may become totally ineffective and at times result in confusion and accidents.

The posting of traffic signs must be done with adequate care so that they perform their intended function most effectively, in as much as the sign must be posted ahead of the spot to which it refers. When more than one sign is to be posted, they should be adequately separated in space so as to be seen one at a time and convey the message with complete effect. Signs with reflective properties (preferably retro-reflective type) must be used so as to meet the requirements of night traffic.

While posting the signs, adequate care should be taken so as to avoid the chance of their causing obstruction to pedestrian and vehicular traffic. In urban areas, the lowest edge of any traffic sign should not be lower than 2.1m from the pavement when posted on footpaths/ sidewalks. In rural areas, the clear height of sign from the edge of the pavement should be 1.5 m. The nearest edge of the sign should be at least 1.2 m away from the edge of the carriageway on rural roads. When posted on raised foot-paths the same should be away by at least 30 cm from the edge of the kerb.

PROCEDURE

1. A detailed study of various geometric elements of the at-grade intersection should be done before conducting the experiment.
2. Select the suitable and feasible at-grade intersection for carrying out the experiment.
3. Analyze the layout of the intersection and traffic flow patterns.
4. Record the features of various geometric elements of the at-grade intersection like the width of lanes at the intersection, right of way flares, shoulders, auxiliary lanes, intersection sight distance, etc.
5. Compare the values obtained in Step 4 with those recommended by IRC.
6. Make sketches (manually/Auto CAD) showing various geometric features in plan and/ or sectional view. It is recommended to draw these sections to scale so that the sketches do not give a misleading picture.
7. Various recommendations can be put forward either/both in textual and/or pictorial form making sure that the recommendations and guidelines by IRC are not violated or overwritten in any case.

OBSERVATIONS

Observation Sheet 6.1

At grade road intersection geometrics recording form

Date:		Day:		Sheet No.
Location:		Weather:		
Type of Intersection:			Peak Periods:	
Name of the observer(s):				
Location/Coordinates of Intersection:				
S.No	**Geometric Elements**	**Recommended values by IRC**	**Observed Values**	**Remarks**
1.				
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ANALYSIS AND PRESENTATION

The observed geometrics are compared with IRC guidelines and are presented/ analyzed through tables and sketches. Some examples are given below. However, it should be noted that these figures are not exhaustive and should be only taken as a reference.

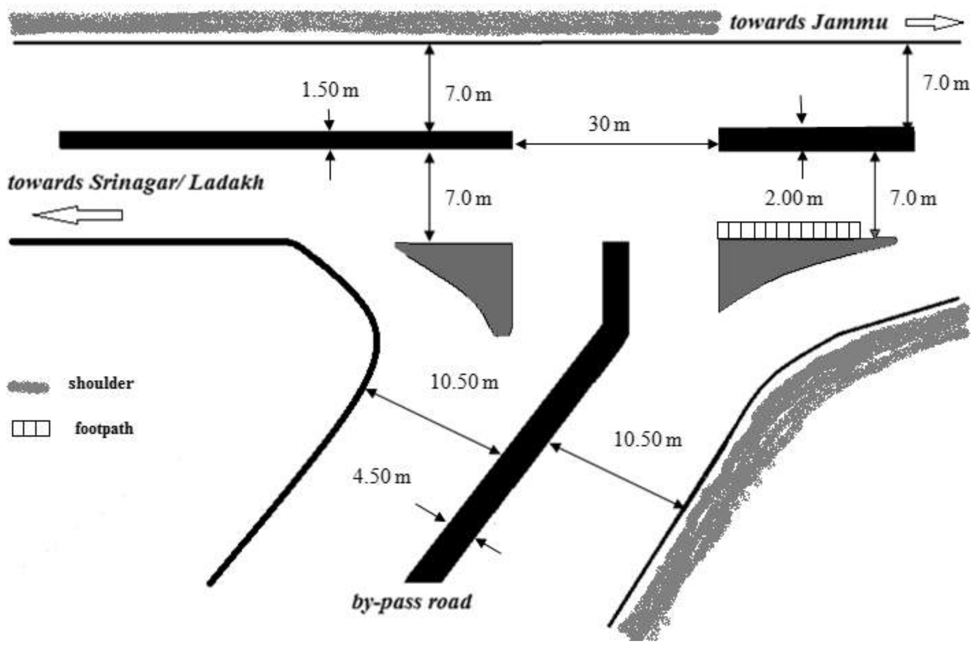


Figure 6.4 Illustration showing various dimensions of the intersection

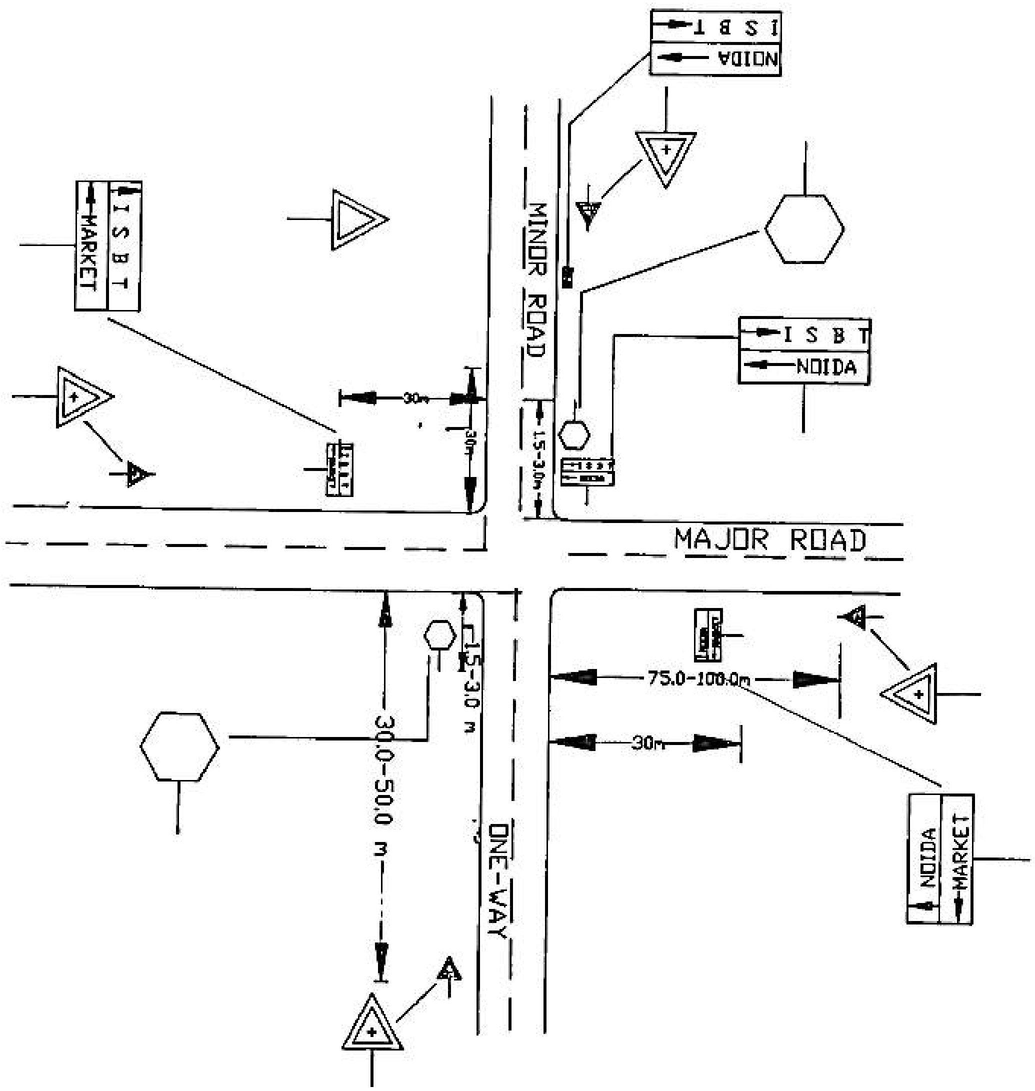


Figure 6.5 Illustration showing typical Sign Posting at an Urban Four-legged Intersection

TE Lab 6.2

GEOMETRICS OF GRADE SEPARATED INTERSECTION

OBJECTIVE: To study the geometrics of grade separated intersections.

EQUIPMENT AND FACILITIES REQUIRED

1. Measuring tape(s) / Electronic Distance Measuring (EDM) Instrument
2. Observation sheet(s)
3. Traffic Monitoring Camera
4. Theodolite/ Electronic Total Station (ETS)

THEORY

Grade Separated Intersection**:** It is a bridge that eliminates crossing conflicts at intersections by vertical separation of roadways in space. Route transfer at grade separations is accommodated by interchange facilities consisting of ramps.

Grade separation**:** It is the method of aligning a junction of two or more surface transport axes at different heights (grades) so that they will not disrupt the traffic flow on other transit routes when they cross each other. Bridges (or overpasses or flyovers), tunnels (or underpasses), or a combination of both can be built at a junction to achieve the needed grade separation.

Advantages

- Uninterrupted flow is possible for crossing traffic.
- There is increased safety for turning traffic and by interchange ramp, even right turn movement is made quite easy and safe by converting into diverging to left and merging from left.
- The capacity of the grade-separated intersection can practically approach the total capacity of the two crossroads.
- Stage construction of additional ramps is possible after the grade separation structure between main roads is constructed.

Disadvantages

- It is very costly to provide complete grade separation and interchange facilities.
- Where there is limited right of way or where the topography is not favorable, construction of grade separation is costly, difficult and undesirable.
- In flat or plain terrain, grade separation may introduce undesirable crests and sags in the vertical alignment.

Interchange

An interchange is a grade-separated intersection with connecting roadways (ramps and loops) for turning traffic between highway approaches.

Geometric configurations

The common geometric configurations of interchanges are the trumpet, diamond, cloverleaf, partial cloverleaf and rotary.

Trumpet interchange: A trumpet interchange is a 3-leg interchange. This is the simplest interchange form adaptable to "T" or "V" intersections. Of the two right turning movements, one is negotiated by a loop while the other is by a semi-direct connection. Diagonal ramps are provided for left turning movements. The ramps catering to heavy traffic volumes should preferably be provided with direct connections.

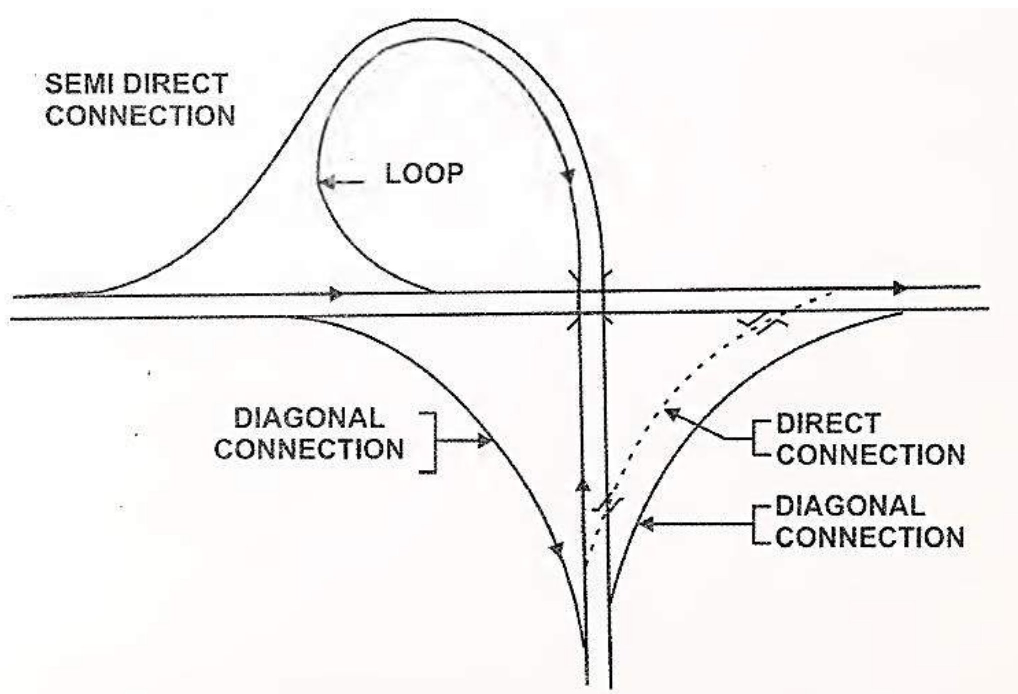
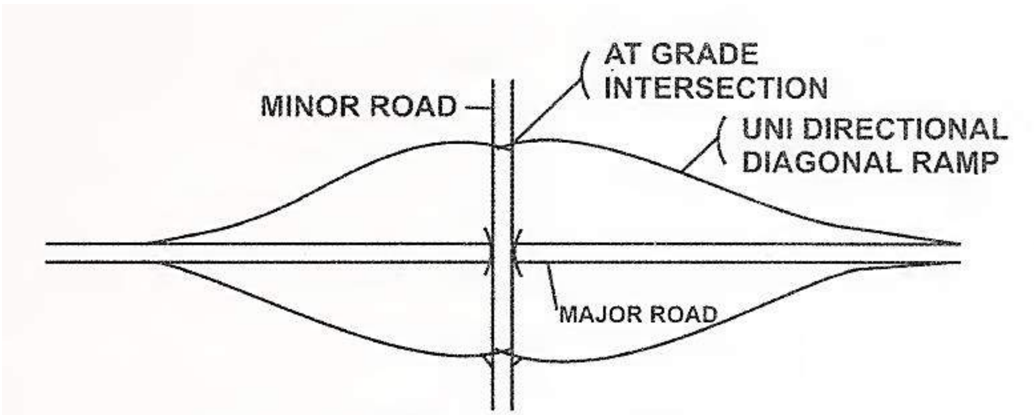


Fig.6.6 Typical geometric configurations of Trumpet interchange

Figure 6.7 A Trumpet interchange

Diamond interchange: A typical diamond interchange is the simplest of 4-leg interchange designs and is particularly adapted for major-minor highway intersections. The ramps which provide for one way movement are usually elongated along the major highway and may be curved or parallel to the major highway. The ramp terminals on the



minor road are at grade intersections providing for right and left turning movements.

Fig. 6.8 Typical geometric configurations of Diamond Interchange

Figure 6.9 A *Diamond interchange*

Cloverleaf interchange: The design of a typical cloverleaf interchange consists of one loop ramp for right turning traffic and one outer connection for left turning traffic in each quadrant. Vehicles desiring to turn right are required to turn left through about 270 degrees before attaining the desired direction.

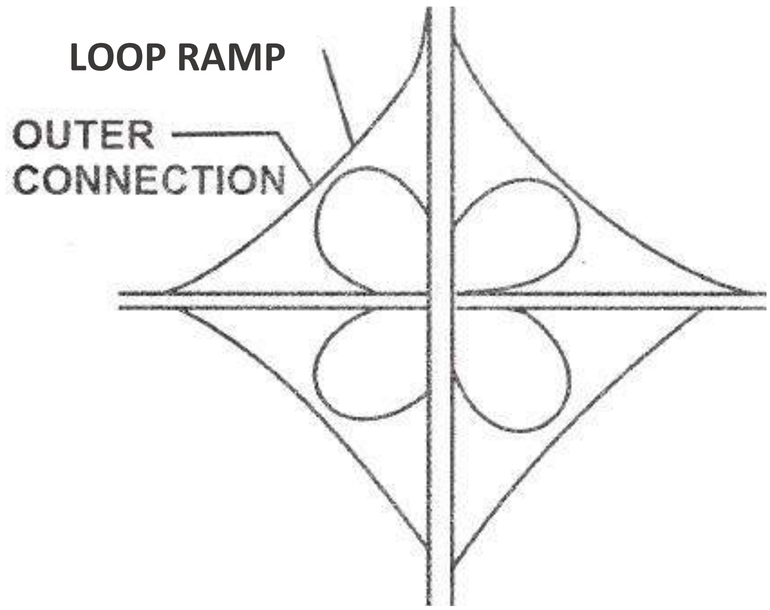


Fig.6.10 Typical geometric configurations of Full Cloverleaf

Fig.6.11 A Full Cloverleaf Interchange

Partial cloverleaf interchange: A variation of cloverleaf interchange in which there are fewer loop ramps is referred to as partial cloverleaf interchange (PARCLO).

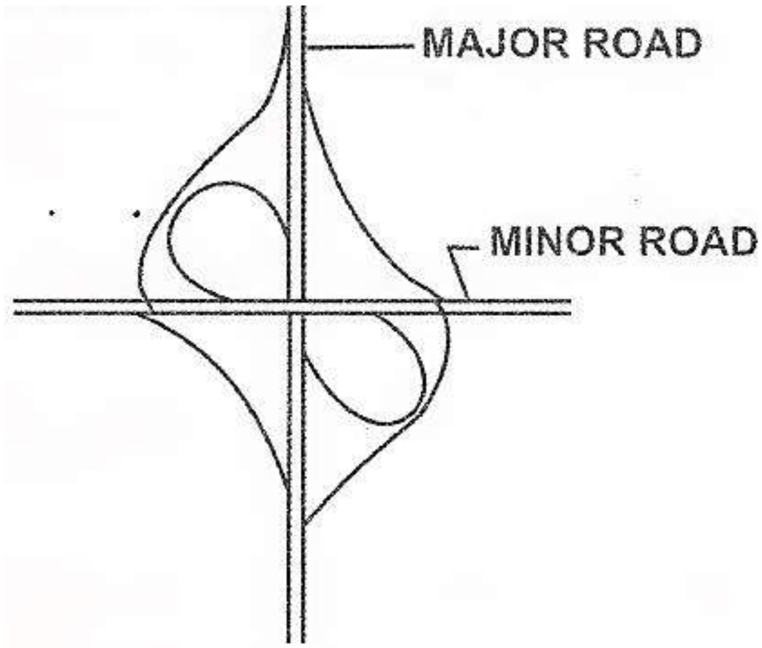


Fig.6.12 Typical geometric configurations of Partial Cloverleaf

Fig.6.13 A Partial Cloverleaf Interchange

***Rotary interchange*:** It is usually a 4-leg interchange and is particularly useful where a number of roads intersect and in locations where sufficient land is available. It requires the construction of two bridges. The main highway goes over or under the rotary intersection and turning movements are accommodated by diagonal ramps.

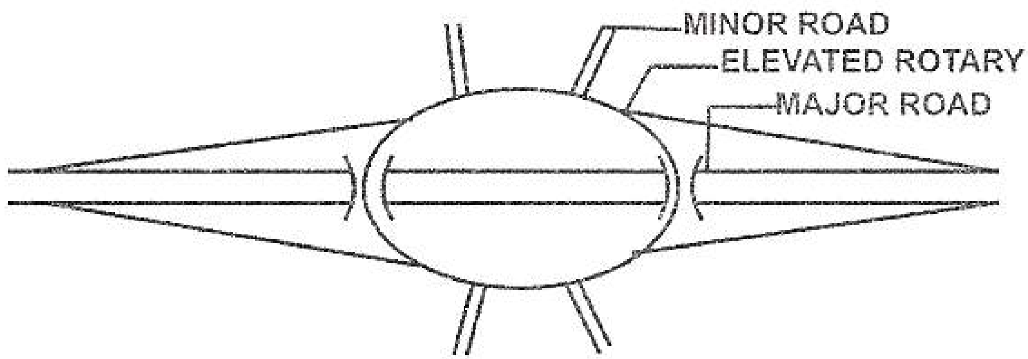


Fig.6.14 Typical geometric configurations of Rotary Interchange

Fig.6.15 A Rotary Interchange

Guidelines for choosing the type of interchange

- An interchange may be justified at the crossing of a major arterial road with another road of similar category carrying heavy traffic.
- An interchange may be justified when an at-grade intersection fails to handle the volume of traffic resulting in serious congestion and frequent choking of the intersection. This situation may arise when the total traffic of all the arms of the intersection is in excess of 10,000 PCU's per hour.

- High and disproportionate rate of fatal and major accidents at an intersection not found to respond to other traffic control or improvement measure may warrant an interchange.
- In some situations, the topography is such that interchanges are the only type that can be constructed economically.
- The requirement of interchange may also be justified from the existing constraints of the junctions other than traffic volumes like parking, market, important and religious structures and buildings with frequent crowding.

Land requirement

Table 6.8 Approximate land requirements of interchanges are as below

Category	Approximate total land (in hectares)
Trumpet interchange	4.4
Diamond interchange	2.8
Full cloverleaf	4.9
Partial cloverleaf	7.3
Flyover roundabout	18.0

NEED FOR STUDY

The ultimate objective of grade-separated intersections is to eliminate all grade crossing conflicts and to accommodate other intersecting manoeuvres by merging, diverging and weaving at low relative speed. Three primary roadway improvement objectives accomplished using grade-separated intersections are:

- Increased capacity and uninterrupted flow
- Increased safety
- Reduced vehicle-train conflict and delay

The various elements to be studied are:

1. Carriageway width
2. Kerb
3. Railings, parapet or crash barriers
4. Guardrails/Protective Measures
5. Space Standards
6. Camber
7. Super-elevation
8. Gradient
9. Horizontal curves
10. Vertical curves
11. Clearances at Elevated Structures

General Features & Geometric Standards:

General features and geometric standards shall be based on the recommendation and guidelines by IRC Codes.

Carriageway Width: The carriageway width shall be provided as per the provisions of IRC Codes for the traffic requirements as determined by traffic census and studies.

i. The carriageway width on the elevated structure shall be kept the same as on the approaching roads on either side or the widths shall not be reduced abruptly under any circumstances. The carriageway width on the connecting one-way loops or curved structures shall be not less than or equal to 2- lanes. Extra widths shall be provided on curves as per the relevant IRC Codes. Suitable merging lanes shall be provided in the highway system so that traffic coming down or taking off from the main roads on to the elevated structure do not cross the main traffic on the roads.

Kerb: The Kerb shall be provided on both sides of the carriageway as per the details are given in relevant IRC Code. The kerb should be so designed that it would be safe for vertical and horizontal loads. A safety kerb shall have the same outline as that of a roadway kerb except that the top width shall not be less than 600 mm.

Railings, Parapet or Crash Barriers: Railings or parapets shall be provided on both sides of the bridge for the protection of traffic. Crash barriers shall be provided for grade separators designed for high-speed vehicles particularly in urban areas. The crash barrier of either steel or concrete may be provided. Railings or parapets shall have a minimum height above the adjacent roadway or footway safety kerb surface of 1 .1 m less one half the horizontal width of the top rail or top of the parapet. Guardrails/Protective Measures: To protect vehicles from accidental collisions with abutments or piers, guardrails of suitable height should be provided. It is essential that guard rails are provided on both sides of the central piers or columns. Where raised footpath forms part of the cross-section on the abutment side, provision of guard rails is not considered necessary.

Space Standards: The space standards are also commonly referred to as land width or right-of-way.

Table 6.9 Recommended space standards for the various categories of urban roads

Classification	**Recommended space standards (land width), m**
Arterial	50-60
Sub-arterial	30-40
Collector street	20-30
Local street	10-20

Standards given in the above table are for ideal conditions. Where such space is not available, the minimum space standards shall be:

- For separator for 4 lanes or more: width of service road +5 m on either side of the service road.
- For separator for 2 lanes: Width of service road + 3.8 m on either side of the service road.

Camber: Camber shall be provided as per relevant IRC codes. Camber on grade separator with high type bituminous surfacing or cement concrete surfacing should be 1.7 to 2 percent.

Super-elevation: Super-elevation shall be provided on a horizontal curvature in accordance with the relevant IRC Codes. The effect of superelevation on stresses in the various members of the structure shall be taken into account in the design. Super-elevation shall be limited to 7 percent. However, on urban sections with frequent intersections, it may be limited to 4 percent.

Vertical Curves: If there is a change of gradient on the bridge deck, a suitable vertical curve shall be introduced conforming to IRC: SP: 23 for small length structures.

Horizontal Curves: In general, horizontal curves should consist of a circular portion flanked by spiral transitions at both ends. Length of transition curves is determined on the basis of the rate of change of centrifugal acceleration and super-elevation. For the design of horizontal curves, IRC: 38 may be referred to.

Clearances at Elevated Structures: Clearance is the minimum vertical or horizontal distance between boundaries at a specified position of a bridge structure/grade separator available for the passage of vehicles.

a) *Lateral Clearance*: Lateral clearance is the distance between the extreme edge of the carriageway to the face of the nearest support whether it is a solid abutment, pier or column.
b) *Vertical Clearance*: Vertical clearance stands for the height above the highest point of the travelled way, i.e., the carriageway and part of the shoulders meant for vehicular use, to the lowest point of the overhead structure.

i. The minimum horizontal clearance shall be the clear width and the minimum vertical clearance shall be the clear height available for the passage of traffic.
ii. The minimum horizontal and vertical clearances for single and multiple lane bridges with vehicular traffic shall be given as per the provisions of IRC: 5.
iii. For a bridge constructed on a horizontal curve with the super-elevated road surface, the horizontal clearance shall be increased on the side of the inner kerb by an amount equal to 5 multiplied by the super-elevation in metres. The minimum vertical clearance shall be measured in meters from the super-elevated level of the roadway.

Design considerations

Design speed for ramps & the corresponding radius: It is rarely, if ever, feasible for designing the ramps for the same speed as the through roads.

Table 6.10 Design speeds recommended for ramps as per AASHTO

Highway design speed, kmph	50	65	80	100	105	115	120	135
Ramp design speed desirable, kmph	40	55	70	80	90	100	100	105
Minimum Speed, kmph	25	30	40	50	50	50	55	65
Corresponding min. desirable radius, m	45	90	170	210	260	320	320	380
Minimum radius	15	27	45	70	70	70	90	130

For the design of loops, the speed should be about 40-45 K.P.H. For direct connections, a design speed of 60-65 K.P.H is appropriate.

Table 6.11 Standards prescribed for the ramp design elements for interchanges in urban areas in India

Particulars	**Design Value For Major Highway**				**For Loop Ramps**	
	80 K.P.H		100 K.P.H			
	Minimum	Desirable	Minimum	Desirable	Minimum	Desirable
Ramp design speed (K.P.H)	40	50	50	65	30	40
Radius of curvature (m)	60	90	90	155	30	60
Stopping sight distance (m)	45	60	60	90	25	45

Sight distance on ramps: A minimum stopping sight distance appropriate for the design speed selected for ramp design should be provided.

Gradients on ramps: AASHTO recommends ramp gradients should desirably be limited to 6% in areas subject to snow and ice and here heavy truck traffic is likely, the upward gradient should be limited to 4%. In exceptional cases, grades may be as steep as 10%, on minor ramps and low volume ramps.

Width of ramps: Ramps should preferably carry one-way traffic only. The width of pavements should be selected as appropriate for different radii.

Capacity: The practical capacity of through lanes can be taken as 1500 PCU per hour per lane for interchange design. For ramps, a capacity of 1200 PCUs per hour per lane is appropriate.

PROCEDURE

The objective of geometric design is to provide maximum efficiency in traffic operations and maximum safety at a reasonable cost. Therefore, the geometric features of a grade-separated intersection are to be studied necessarily.

1. A complete study of various geometric elements of grade separated intersection should be done before the experiment is conducted.
2. Select the suitable grade separated intersection for carrying out the experiment.
3. Analyze the layout of the intersection and traffic flow patterns.
4. Analyze and record the features of various geometric elements of the grade separated intersection. Some features can be measured directly using a tape or EDM and some other features are measured indirectly using techniques/ principles of trigonometry by means of a theodolite or ETS.
5. Compare the values obtained in Step 4 with those recommended by IRC SP-90.
6. Also, draw various sketches (e.g. plan and elevated views) in order to have a clear picture of the observations.
7. Comment on the efficiency and characteristics of the grade-separated intersection by comparing the elements with those recommended by IRC.

OBSERVATIONS

Observation Sheet 6.2

Grade-separated road intersection geometrics recording form

Date:		Day:		Sheet No.
Location:		Weather:		
Type of Grade Separator:			Peak Periods:	
Type of Interchange facility:				
Name of the observer(s):				
Location/Coordinates of Intersection:				
Number of roads connected:			Observation sheet for road:	
S.No	**Geometric Elements**	**Recommended values by IRC**	**Observed Values**	**Remarks**
1.				
2.				
3.				
4.				
5.				
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ANALYSIS AND PRESENTATION

Various sketches showing elevation and plan should be made. Recommendations should be given for improving the efficiency of the existing intersection through text and/ or pictorial form. An illustration has been shown below.

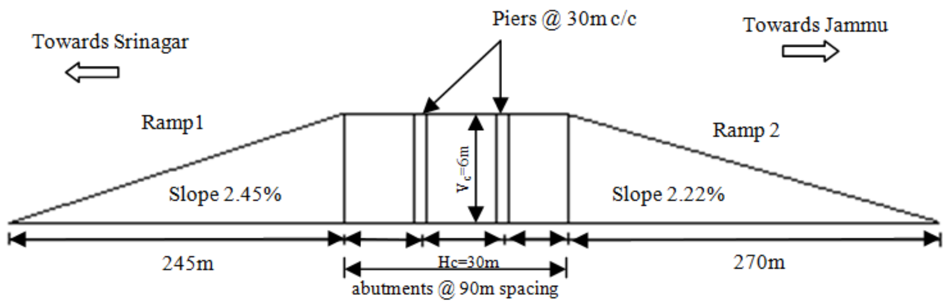

Fig.6.16 Illustration showing the sketch (elevation) of a grade separated intersection

TE Lab 6.3

GEOMETRICS OF ROTARY INTERSECTION

OBJECTIVE: To study the geometrics of a rotary intersection.

EQUIPMENT AND FACILITIES REQUIRED

1. Measuring tape(s) / Electronic Distance Measuring (EDM) Instrument
2. Observation sheet(s)
3. Traffic Monitoring Camera
4. Theodolite/ Electronic Total Station (ETS)

NEED FOR THE STUDY

Traffic rotaries reduce the complexity of crossing traffic by forcing them into weaving operations. The shape and size of the rotary are determined by the traffic volume and share of turning movements. Observing and analyzing the various geometric elements of a rotary helps to:

- Determine the feasibility and efficiency of a rotary in solving various traffic problems.
- Compare the dimensions of various geometric elements with those recommended by IRC (IRC: 65-1976 "*Guidelines for the design of traffic rotaries*")
- Suggest improvement(S) at the existing rotary intersection.
- Propose new and more efficient methods of channelizing traffic at the observed intersection like grade separators etc.

THEORY

Rotary intersections or *roundabouts* are a special form of at-grade intersections designed for the movement of traffic in one direction around a central island. The vehicles entering the rotary are gently forced to move in a clockwise direction in an orderly fashion. They then weave out of the rotary to the desired direction.

Main functions of Rotary

- Essentially all the major conflicts at an intersection namely the collision between through and right-turn movements are converted into milder conflicts namely merging and diverging.
- Crossing maneuver is converted to weaving action by providing weaving length.
- It eliminates the necessity of stopping even for crossing streams of vehicles, thus reducing the area of conflict.

IRC Guidelines for selection of Rotary

- Selection of rotary at an intersection depends on the geometric layout of the site, traffic characteristics and proportion of right turning traffic. Rotaries are not warranted for intersections carrying very light traffic. For consideration of the rotary intersection, the lowest traffic volume should be about 500 vehicles per hour.

- Rotaries are most adaptable where the traffic volumes entering different intersection legs are nearly equal.
- Traffic rotary can handle a maximum traffic volume of 3000 vehicles per hour entering from all the legs of the intersection.
- A rotary design is most appropriate when the proportion of right-turning traffic is high i.e. greater than 30%.
- A rotary is preferable when there are more than three or four approaches to the junction so near that there would be insufficient space for the formation of queues.
- A rotary is suitable when it is impossible to provide separate lanes for through and right-turning traffic.

Geometric Elements of Rotary Intersection

1. ***Shape of Central Island***: The central island is the raised area in the center of a roundabout around which traffic circulates. The shape of Central Island provided for rotary intersection should not contain any corners or sharp edges. It should be formed by curves to allow the comfortable rotations around it. The shape and layout of the rotary island depend upon the layout of the intersecting roads and the traffic flow patterns. The shapes generally provided are circular, elliptical, turbine and tangential.

Table 6.12 Shapes of central island of a rotary and their uses

Type	Remarks
Circular	Suited where roads of equal importance carrying approximately equal volumes intersect at nearly equal angles.
Square with rounded edges	Suited for predominantly straight-ahead flows.
Elliptical, elongated, oval or rectangular	Intended to favor through traffic and to provide long weaving lengths.
Turbine or tangent	To accommodate in layout four or more intersecting roads, enables reduction of speeds of vehicles entering and speeding up of vehicles going out of the rotary
Irregular	Shape is dictated by the existence of a large number of approaches.

2. ***Radius at Entry***: The entry radius is the minimum radius of curvature of the outside kerb at the entry. The radius at the entry depends on various factors like

design speed, super-elevation, and coefficient of friction. The entry to the rotary is not straight, but a small curvature is introduced. This will force the driver to reduce speed. IRC gives guidelines for the selection of radius of curve at entry shown in Table 6.13.

Table 6.13 IRC guidelines for selection of radius of curve at entry of rotaries

Area	Rotary design speed V, kmph	Radius at entry, m
Rural Areas	40	20-35
Urban Areas	30	15-25

3. ***Radius at Exit***: The exit radius is the minimum radius of curvature of the outside kerb at the exit. The exit radius should be greater than the entry radius and the radius of the rotary island so that the vehicles will discharge from the rotary at a higher rate. General practice is to keep the exit radius as 1.5 to 2 times the entry radius.
4. ***Radius of Central Island***: The radius of the central island is governed by the rotary design speed and should be equal to the radius of the entry curve. The radius of the central island, in practice, is given a slightly higher radius so that the movement of the traffic already in the rotary will have priority. The radius of the central island which is about 1.33 times that of the entry curve is adequate for all practical purposes. The *inscribed circle diameter* is the basic parameter used to define the size of a roundabout. It is measured between the outer edges of the circulatory roadway.

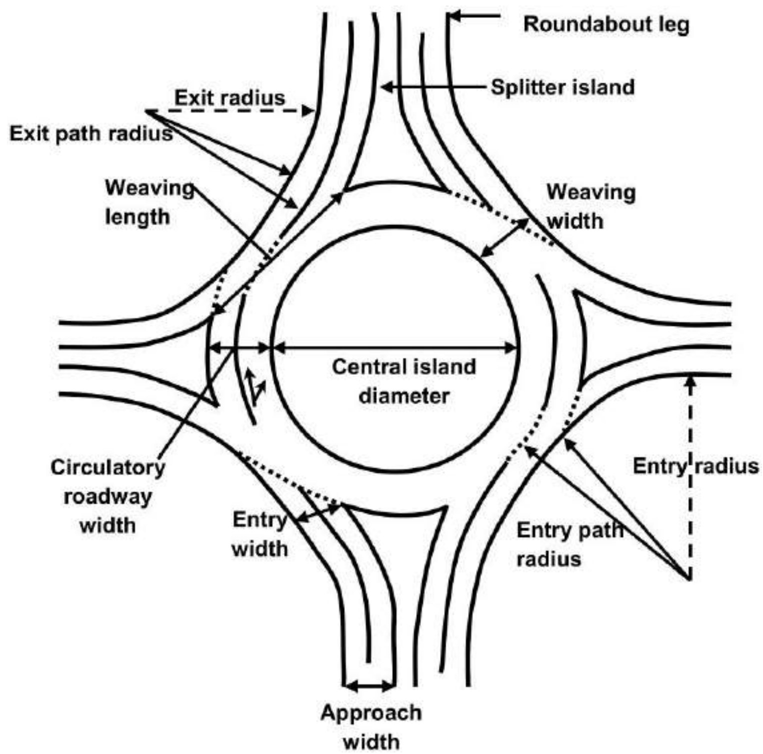

Fig.6.17 Key Rotary Dimensions

5. ***Width of carriageway at entry and exit*:** The entry width defines the width of the entry where it meets the inscribed circle. It is measured perpendicularly from the right edge of the entry to the intersection point of the left edge line and the inscribed circle. The exit width defines the width of the exit where it meets the inscribed circle. It is measured perpendicularly from the right edge of the exit to the intersection point of the left edge line and the inscribed circle. The width of the carriageway at entry and exit will be lower than the width of the carriageway at the approaches to enable reduction of speed.

Table 6.14 IRC guidelines for entry and exit widths for different carriageway widths of approach roads on urban and rural rotaries

Carriageway width of approach road, m	Radius at Entry, m	Width of carriageway at entry and exit, m
7 (2 lanes) 10.5 (3 lanes) 14 (4 lanes) 21 (6 lanes)	25-35	6.5 7.0 8.0 13.0
7 (2 lanes) 10.5 (3 lanes) 14 (4 lanes) 21 (6 lanes)	15-25	7.0 7.5 10.0 15.0

6. ***Weaving width***: Weaving width is given as

$$\boldsymbol{Weaving\ width\ (W) = \frac{e_1+e_2}{2} + 3.5\ metre}$$

where e_1 is the width of the carriageway at the entry
e_2 is the carriageway width at exit

7. ***Weaving length***: Weaving length determines how smoothly the traffic can merge and diverge. It is decided based on many factors such as weaving width, the average width of entry, the proportion of weaving traffic to the non-weaving traffic, etc.

$$\boldsymbol{Weaving\ length, L = 4 \times weaving\ width}$$

Table 6.15 Minimum values of weaving lengths suggested by IRC

Design Speed, kmph	Minimum Weaving Length, m
40	45
30	30

8. ***Entry and Exit angles***: Entry angles should be larger than exit angle and it is desirable that the entry angles should be 60˚, if possible. The exit angles should be small (30˚).
9. ***Splitter Island***: A splitter island is a raised or painted area on an approach used to separate entering from exiting traffic, deflect and slow the entering traffic and provide storage space for pedestrians crossing the road in two stages. It is a better form of channelization and it reduces the area of conflict between intersecting traffic streams. The shape of the splitter island depends on the actual conditions of each site.
10. ***Apron***: An apron is the mountable portion of the central island adjacent to the circulatory roadway which is the curved path used by vehicles to travel in a clockwise fashion around the central island. The apron is provided on smaller roundabouts to accommodate the wheel tracking of large vehicles.
11. ***External Curb Line***: External kerb line of weaving section should consist of straight or large radius curve to eliminate waste of area.
12. ***Camber and Superelevation***: The algebraic difference in the cross-slopes opposite to each other should be limited to about 0.07. The superelevation should be limited to the least amount consistent with design speed.
13. ***Give-Way line***: A give-way line is a pavement marking used to mark the point of entry from an approach into the circulatory roadway and is generally marked along the inscribed circle. Entering vehicles must yield to any circulating traffic coming from the left before crossing this line into the circulatory roadway.

14. ***Pedestrian crossing*:** Accessible pedestrian crossings should be provided at all roundabouts. The crossing location is set back from the yield line, and the splitter island is cut to allow pedestrians, wheelchairs, strollers, and bicycles to pass through.

PROCEDURE

1. A complete study of various geometric elements featuring in a rotary should be made before moving to the site.
2. Select a suitable site involving a rotary intersection where the study is to be conducted.
3. Analyze the layout of the intersecting roads and the traffic flow pattern.
4. Observe and record the shape and radius of Central Island and Splitter Island using theodolite or ETS.
5. Analyze and record the dimensions of various geometric elements of a rotary like entry radius, exit radius, weaving length, the width of carriageway, entry and exit angles, etc.
6. Compare the values obtained in step 5 with those recommended by IRC.
7. By the comparison, comment on the efficiency of rotary.
8. Suggest/propose ways through texts and sketches for improvement(s) in the overall efficiency of the rotary.

OBSERVATIONS

Observation Sheet 6.3

Rotary intersection geometrics recording form

Date:		Day:		Sheet No.
Location:		Weather:		
Type of Intersection:			Peak Periods:	
Name of the observer(s):				
Location/Coordinates of Intersection:				
Number of roads connected:			Observation sheet for road:	
S.No.	**Geometric Elements of Rotary**	**Recommended values by IRC**	**Observed values**	**Remarks**
1.	Shape of central island			
2.	Radius at entry			
3.	Radius at exit			
4.	Radius of central island			
5.	Inscribed circle diameter			
6.	Entry width			
7.	Exit width			
8.	Weaving width			
9.	Weaving length			
10.	Entry angle			
11.	Exit angle			
12.	Shape of splitter island			
13.	Apron			
14.	External curb line			
15.	Camber			
16.	Super Elevation			
17.	Give-Way line			
18.	Pedestrian crossing			

ANALYSIS AND PRESENTATION

Various sketches showing details rotary intersection geometrics should be made. Recommendations should be given for improving the efficiency of the existing rotary intersection through text and/ or pictorial form.

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DELAY STUDIES 7

TE Lab 7

Delay is the measure of excess time consumed in traversing the intersection. Delay is usually measured in terms of minutes or seconds per vehicle but when the delay is multiplied by the total volume of traffic on a section of road or at an intersection, it will be in hours.

THEORY

Signalized intersections are the important points or nodes within a system of highways and streets. To describe some measure of effectiveness to evaluate a signalized intersection or to describe the quality of operations is a difficult task. There are a number of measures that have been used in capacity analysis and simulation, all of which quantify some aspect of the experience of a driver traversing a signalized intersection. Delay is the most frequently used measure of effectiveness for signalized intersections for it is directly perceived by a driver. The estimation of delay is complex due to the random arrival of vehicles, lost time due to the stopping of vehicles, oversaturated flow conditions, etc.

Types of delay

- *Stopped time delay*: Stopped-time delay is defined as the time a vehicle is stopped in the queue while waiting to pass through the intersection. It begins when the vehicle is fully stopped and ends when the vehicle begins to accelerate. Average stopped-time delay is the average for all vehicles during a specified time period.
- *Approach delay*: Approach delay includes stopped-time delay but adds the time loss due to deceleration from the approach speed to a stop and the time loss due to re-acceleration back to the desired speed. It is found by extending the velocity slope of the approaching vehicle as if no signal existed. Approach delay is the horizontal (time) difference between the hypothetical extension of the approaching velocity slope and the departure slope after full acceleration is achieved. Average approach delay is the average for all vehicles during a specified time period.
- *Travel time delay*: It is the difference between the driver's expected travel time through the intersection (or any roadway segment) and the actual time taken. To find the desired travel time to traverse an intersection is very difficult. So this delay concept is rarely used except in some planning studies.

- *Time in queue delay*: Time-in-queue delay is the total time from a vehicle joining an intersection queue to its discharge across the STOP line on departure. Average time-in-queue delay is the average for all vehicles during a specified time period. Time-in-queue delay cannot be effectively shown using one vehicle, as it involves joining and departing a queue of several vehicles.

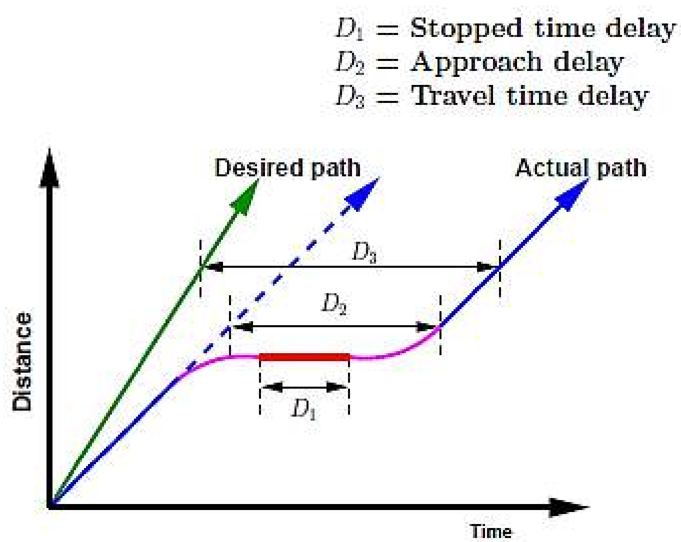


Fig.7.1 Illustration of delay measures

- *Control delay:* Control delay is the delay caused by a control device, either a traffic signal or a STOP-sign. It is approximately equal to time-in-queue delay plus the acceleration-deceleration delay component.

Delay measures can be stated for a single vehicle, as an average for all vehicles over a specified time period, or as an aggregate total value for all vehicles over a specified time period. Aggregate delay is measured in total vehicle-seconds, vehicle-minutes, or vehicle-hours for all vehicles in the specified time interval. Average individual delay is generally represented in terms of seconds per vehicle for a specified time interval.

TE Lab 7.1

INTERSECTION DELAY STUDY

OBJECTIVE: The main objective of this lab is to determine the intersection delay values at a signalized intersection during peak period.

EQUIPMENT AND FACILITIES REQUIRED

1. Survey sheet(s)/ counting pads
2. Stopwatches
3. A team of 3 to 4 members

NEED FOR THE STUDY

Delay studies are conducted to evaluate the performance of the system. Also, these studies are conducted to evaluate certain elements within the system, such as traffic control devices (signals), stop signs, and any recent changes in the roadway links.

Similarly, the intersection delay study is conducted to evaluate the stopped-time delay for vehicles and pedestrians using the intersection. The determination of the total delay for all vehicles aids in mitigating the intersection to operate efficiently for both vehicles and pedestrians. The mitigation measures may include evaluation of existing traffic controls, checking the existing signal timing, and phasing.

THEORY

The intersection delays will be higher during peak periods and low during off-peak periods. Therefore, intersection delay studies are usually conducted during peak periods. At any intersection, the vehicle could be either moving or stopped due to the existing traffic control device, delays at an intersection are defined and measured based on the state of the vehicle (moving or stopped). The following components are studied in conducting intersection delay studies at an intersection.

- *Total Delay*: The total delay caused for all vehicles stopped at an approach. An approach or leg of an intersection is defined as the direction from which vehicles are arriving at the intersection from various directions.
- *Average Delay per Vehicle*: It is defined as the ratio of total delay for the approach (leg) divided by the total number of stopped vehicles.
- *Average Delay per Approach:* It is defined as the ratio of total delay for the approach (leg) divided by the total number of vehicles in the approach, including both stopped and not-stopped vehicles.
- *Percentage of Vehicles Stopped*: The number of vehicles stopped in the approach, divided by the total number of vehicles in the approach. The same could be determined for all approaches at an intersection.

PROCEDURE

1. Select the intersection where the study needs to be conducted.
2. Specify the directions to the traffic. If the volumes at the intersections are large (over 1,500 vehicles per hour), two or more persons will be used to record the traffic flow at the intersection.

1. Record the vehicles stopped and not stopped in an approach during a specific time interval. (The time interval used ranges between 15 to 25 seconds usually depending on the cycle length of the signal at the intersection).
2. The number of vehicles stopped at the approach during each observed interval is recorded.
3. If vehicles are stopped during more than one interval of recording, the vehicle is counted in all the interval periods during which the vehicle(s) remains in the study approach.
4. It is important to record separately the total volume passing the approach during the survey period. That is record the total number of vehicles actually stopping and those not-stopping.
5. The recommended sample size is between 250 and 300 vehicles or when significant volume change is observed during the survey period.

OBSERVATIONS

Observation Sheet 7.1

Measurement of Intersection Delay

Date :				Day :		
Weather :				Page :		
Name of the observer(s) :						
Start Time :				End Time:		
Intersection Details :				Peak Periods :		
N/S Street :						
E/W Street :						
Movement Observed :						
Starting Time	**Time Interval Used In Recording Data**				**Total Vehicles**	
	Sec	Sec	Sec	Sec	Stopped	Not Stopped
Total						

Total vehicles stopped during survey period ....

Percent Stopping Data Per Approach			
Direction	Vehicles Stopped	Vehicles Not Stopped	Percent Of Vehicles Stopped
Eastbound			
Southbound			
Westbound			
Northbound			

ANALYSIS AND PRESENTATION

Data collected should be analyzed and suggestions for reducing the intersection delay should be worked out. Also, the cost incurred by the users and environmental impact can be worked out.

TE Lab 7.2

TRAVEL TIME DELAY STUDY

OBJECTIVE: To determine the fixed delay, variable delay and total travel time delay for a road using floating car method.

EQUIPMENT AND FACILITIES REQUIRED

1. Survey sheet(s)/ counting pads
2. test vehicle
3. Stopwatches
4. A team of 3 to 4 members

NEED FOR THE STUDY

1. To determine running speed, overall speed, fluctuation in speed and to find out delay time between two stations of road spaces apart.
2. To gather information such as amount, location, duration frequency and the causes of the delay in the traffic stream.
3. To determine the spots of congestion and causes and in arriving at suitable remedial measures.
4. To find the travel time, average journey time, and benefit-cost analysis.
5. To rate the efficiency of a road.

THEORY

Due to congested roads at peak hours, public face speeding problems, this may also lead because of traffic jams, accidents, bad traffic management, etc. Travel time plays a key role in the city's life and it indicates the level of service of roadway network performance. From the mobility point of view travel time reflects the degree of convenience from one point to the other point.
Various definitions used in travel time delays are as follows:

- ***Journey speed***: It is the effective speed of the vehicle on a journey between two points and is the distance between the two points divided by the total time taken for the vehicle to complete the journey including any stopped time (if any).
- ***Running speed***: It is the average speed maintained over a particular course while the vehicle is moving and is found by dividing the length of the course by the time duration the vehicle was in motion.
- ***Delay time***: The additional travel time experienced by a driver, passenger or pedestrian due to circumstances that impede the desirable movement of traffic. It is measured as the time difference between actual travel time and free-flow travel time.

There are various methods of carrying out speed and delay study, namely:

1. Floating car or riding check method

2. License plate or vehicle number method
3. Interview technique
4. Elevated observations, and
5. Photographic technique

Some merits of floating car or riding check method have been enlisted below:

- The method gives an unbiased estimate of the flow. Random errors can, however, occur due to observers' errors and random fluctuations in flow, but these are not serious under normal conditions.
- As compared to the stationary observer method, the moving observer method is equivalent to a stationary count over twice the single journey time. Hence, it is economical in manpower.
- It enables data on speed and flow to be collected at the same time. This is particularly advantageous when analyzing the relations between the two.
- It gives mean values of flow and speed over a reaction, rather than at a point. Thus, it gives directly space mean speed; whereas spot speed studies give the time mean speed.
- It gives additional information on stops at intersections, delays, parked vehicles, etc.

PROCEDURE

1. A route of travel is selected and a test vehicle is driven along that route at approximately the average speed of the stream.
2. First, the day, vehicle number, route, time of start, direction, etc. are recorded in the journey log.
3. As the vehicle moves, one observer is seated in the test car with two stopwatches, one for recording the continuous time at different points along the route and the other for measuring the duration of individual stopped time delays.
4. The second observer records the time, location and cause of these delays during each test run.
5. The number of vehicles overtaking the test vehicle and number overtaken by the test vehicle are noted in each test run by the third observer.
6. The fourth observer notes the number of vehicles travelling in the opposite direction in each test run. In mixed traffic flow, more observers are required to count the opposing vehicles.
7. A number of test runs are made by test vehicle along the study stretch and the same procedure is followed. Repeat the procedure in another direction also.
8. Find the average of respective values in journey log for the number of test runs made. First, convert the vehicles moving in opposing direction in PCU and then find their average.

9. Calculate the volume (PCU/hr.), mean journey speed (kmph) and average journey time (hr. or min) in both directions. Also, find the running speed and mean run time for both directions.

OBSERVATIONS

Observation Sheet 7.2

Travel time delay recording form

Name Of The Road:	Day & Date:
Section From: To:	Hour:
Vehicle No.:	Weather:
Direction Towards:	
Name of The Observer(S):	

Test Run No.	Journey Time	Stopped Time	Cause of Delay	Running Time	Vehicles Met In The Opposing Direction					Vehicles Met In The Same Direction	
					Car	2-Wheeler	3-Wheeler	Bus	Truck	Overtaking	Overtaken
1											
2											
3											
4											
5											
6											
Total											
					Total PCU =						
Average											

CALCULATIONS

$$\boldsymbol{Journey\ speed = \frac{distance}{total\ time}\ m/s}$$

$$Journey\ speed = \_\_\_\_\_\ m/s$$

$$\boldsymbol{Running\ speed = \frac{distance}{run\ time} m/s}$$

$$Running\ speed = \_\_\_\_\_\_\ m/s$$

$$\boldsymbol{Flow\ of\ vehicles = q_{n-s} = \frac{n_a - n_y}{t_a + t_y}}$$

$$q_{n-s} = \_\_\_\_\_\ veh/hr$$

where q_{n-s} *= flow of vehicles in one direction of the stream.*

n_a *= average no. of vehicles counted in the direction of the stream when the test vehicles travel in the opposite direction.*

n_y *= average no. of vehicles overtaking the test vehicle minus the no. of vehicles overtaken in the direction of q.*

$$T = (t_w - \frac{n_y}{q})s$$

$$T = \_\_\_\_\_\_\_\_\ s$$

where T *= Average Journey Time.*

t_a *= average journey time, in a minute when the test vehicle is travelling with the stream q.*

t_w *= average journey time, in a minute when the test vehicle is running against the stream q.*

ANALYSIS AND PRESENTATION

Data collected should be analyzed and suggestions for reducing the travel time delay should be worked out. Also, the cost incurred by the users and the environmental impact can be worked out.

INTERSECTION VOLUME STUDY 8

TE Lab 8

OBJECTIVE: To record and analyze turning movement counts at an intersection during peak and off-peak hours.

EQUIPMENT AND FACILITIES REQUIRED

1. Magnetic compass
2. Observation sheet(s)/ Electronic count boards/ Pneumatic tubes
3. Stopwatch(es)
4. A team of observers (number of members depend on the type of method used and type of intersection)

NEED FOR THE STUDY

Existing traffic data at an intersection or on a road section forms the foundation for analysis in the transportation engineering field. The existing traffic count data is important for both planning and operational studies. Turning Movement Counts (TMC's) are the directional volume counts of traffic passing through an intersection. The purpose of the TMC's is to summarize the counts of vehicle movements through an intersection during certain time periods. This type of volume summary is used in making important decisions regarding the geometric design of the roadway, sign and signal installation, signal timing, pavement marking, traffic circulation patterns, capacity analysis, parking zones, and vehicle classification. This data is used in making decisions at a planning-level (e.g., traffic impact analyses), as well as operational analyses-level (e.g., signal installation and timing).

TMC's are usually taken during peak periods. However, sometimes traffic flow during the off-peak period is also recorded. The volume of traffic passing through an intersection is usually recorded as vehicles per hour (veh/hr). TMC's at an intersection relates to the left, right, and through traffic leaving the intersection from each approach.

THEORY

Types of counts

- *Vehicle Counts:* Counts may be conducted manually or using video technology. For manual counts, the required number of observers is dependent on the volume levels and the geometric design of the intersection. Most likely, several observers will be necessary to perform Turning Movement Counts (TMC) at signalized intersections since the majority of these studies are performed during peak flow periods. Un-signalized intersections will typically require fewer observers. For video counts, the number of cameras and their placement will depend on the geometry and size of the intersection.

For signalized intersections, it is recommended that at least five signal cycles be captured within a specific count interval. A count interval is defined as the fraction of an hour that is used to aggregate data. The maximum cycle length should be used if the signal is actuated. Potential challenges in counting signalized intersections during actuated phasing are permissive turning movements since they do not move consistently during their green phase and right turns/right-turn-on-red movements may be easily miscounted.

- *Path-Based Counts:* Several modern intersection configurations combine multiple movements into shared lanes, and the traffic count is dependent on the origin and destination which is commonly defined as the vehicle path. Some of these intersections include modern roundabouts, super streets (through and left-turns replaced by a right-turn U-turn combination) and Michigan U-Turn (left-turns replaced by a right-turn U-turn combination) intersections. At these types of intersections, it is not possible to observe individual turning movements in isolation.
- *Unconventional Intersection Counts:* Some unconventional intersection designs include continuous flow intersections, single-point urban interchanges, and diverging diamond interchanges. These unconventional designs generally do not require path-based counts and each movement can be observed in isolation. Therefore, a volume study at these unconventional intersections is done in a similar manner to a standard intersection. The observer should be familiar with the flow patterns before conducting the study. Automated data collection methods can be used where no shared lanes with other movements are present.

Types of counts

- *Manual Observation Counts:* During this procedure, the observer manually records each vehicle as it proceeds through the point of interest. Manual counts minimize equipment cost and set-up time; however, they can become inefficient the longer the observer stays in the field. Most counts focus on peak-hour conditions; therefore, the set-up time and removal of automated equipment may not be justified.
- *Automatic Counts:* Equipment for automatic counts typically provides volume counts on the legs of the intersection (such as in-road count technologies) and may not always provide turning movement counts directly, with some exceptions (such as video imaging processing). Reliability of the equipment is

considered the traditional disadvantage and analysts must prepare contingency plans in case of equipment failure and understand technology limitations.

PROCEDURE

Note: There are a number of methods to record the counts i.e. manual counting method (using tally marks on recording forms), semi-automatic method (using electronic counting boards) and automatic method (using pneumatic tubes). These have been explained in detail. Kindly, refer to Lab 2 of this manual.

1. The intersection to be studied is visited at least 15 minutes before the scheduled period for collecting the data. It is also helpful to get familiarized with the study area and the traffic flow pattern at the intersection.
2. Note the north direction with the help of a magnetic compass.
3. The team leader assigns member(s) on different sections of the legs of the intersection. (The number of members depends on the type of intersection and type of method used as illustrated below).

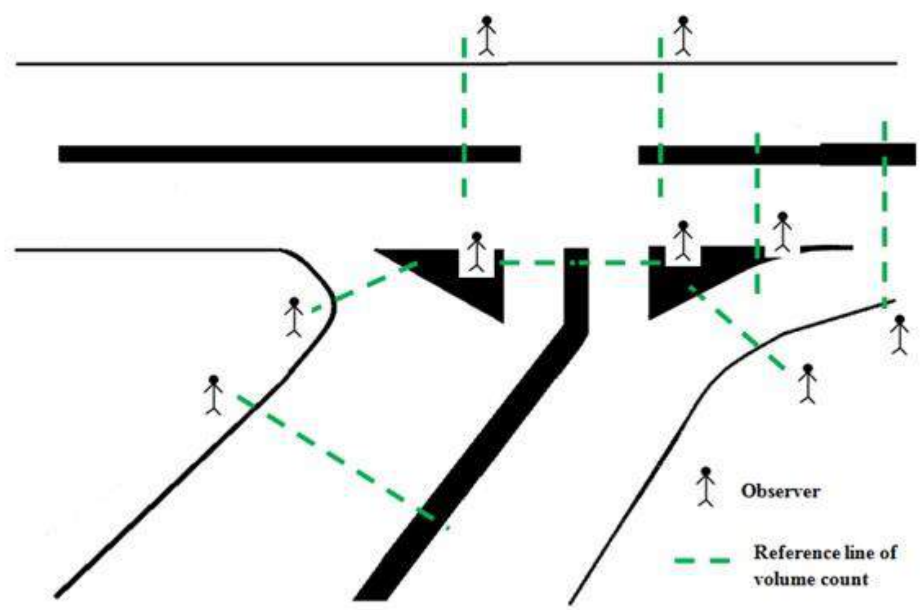


Fig.8.1 Illustration showing placement of different observers on a three- legged two-way intersection

4. Observer(s) fill all the necessary details of the intersection in the prescribed form. Additional information about the intersection can also be recorded using supplementary sheets.
5. The observers collect the TMC's either using Manual Sheets or Electronic Count Boards.
6. Stopwatch(es) are used to record the desired count interval, and a new form shall be used at the beginning of a new interval. Time intervals must be maintained and coordinated accurately when two or more observers are

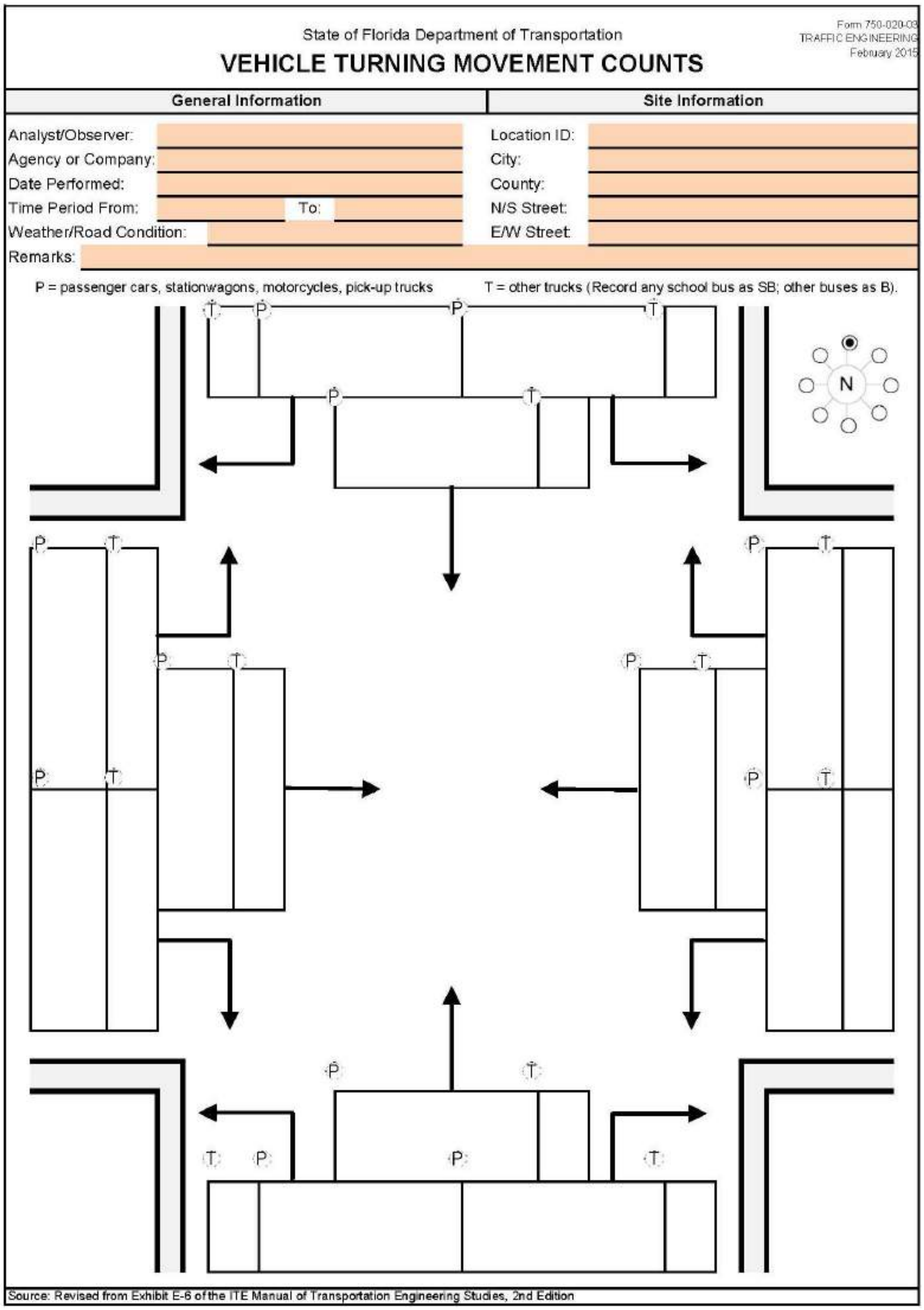
performing the counts. Any temporary traffic event such as collisions or maintenance activities should be recorded since they may lead to unusual traffic counts.

7. The manual count is done by recording each vehicle with a tick mark on a prepared field form as shown in the observation sheet below. Pedestrian and bicycle volumes may be recorded in the same form. However, if the volumes are high they may require separate sheets.
8. TMC's are collected for two hours duration at a study intersection to conduct intersection level of service (LOS) analysis.
9. Finally, all the data is summarized and presented in the form of tables and sketches.

OBSERVATIONS

Observation Sheet 8.1

Vehicle Turning Movement Counts



State of Florida Department of Transportation

Form 750-020-03
TRAFFIC ENGINEERING
February 2015

VEHICLE TURNING MOVEMENT COUNTS

General Information		Site Information	
Analyst/Observer:		Location ID:	
Agency or Company:		City:	
Date Performed:		County:	
Time Period From:	To:	N/S Street:	
Weather/Road Condition:		E/W Street:	
Remarks:			

P = passenger cars, stationwagons, motorcycles, pick-up trucks T = other trucks (Record any school bus as SB; other buses as B).

Source: Revised from Exhibit E-6 of the ITE Manual of Transportation Engineering Studies, 2nd Edition

Observation Sheet 8.2

Summary of Turning Movement Counts

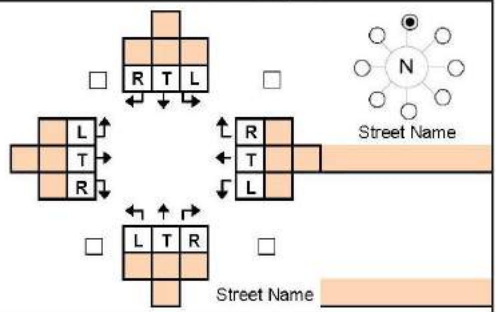
State of Florida Department of Transportation

SUMMARY OF TURNING MOVEMENT COUNTS

General Information

Analyst/Observer:
Agency or Company:
Date Performed:
Analysis Time Period:

Intersection Diagram



Site Information

City:
County:
Weather:
Remarks:

VEHICLE MOVEMENTS

Time Begins	Northbound L	Northbound T	Northbound R	Northbound Total	Southbound L	Southbound T	Southbound R	Southbound Total	Eastbound L	Eastbound T	Eastbound R	Eastbound Total	Westbound L	Westbound T	Westbound R	Westbound Total	Total All
TOTAL																	0
TOTAL																	0
TOTAL																	0
TOTAL																	0
TOTAL																	0

Source: Revised from Exhibit E-7 of the ITE Manual of Transportation Engineering Studies, 2nd Edition

NOTE: These observation sheets have been adopted from ITE Manual of Transportation Engineering Studies. An electronic version of these forms is also available in the Department's Forms Library.

ANALYSIS AND PRESENTATION

Draw a sketch showing the intersection geometrics and describe the intersection characteristics based on recorded TMC's. Various pie charts can be drawn to show the composition of traffic at the intersection. Comparative analysis can be done between the off-peak hour and peak hour TMC's

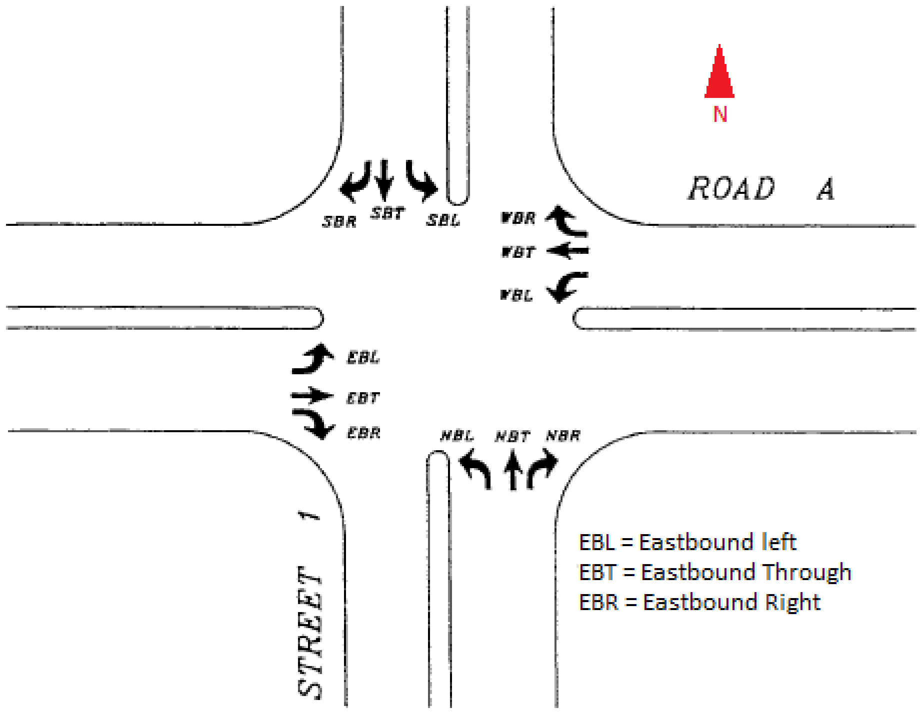


Fig.8.2Illustrations showing representation of directional movements

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SATURATION FLOW STUDY 9

TE Lab 9

OBJECTIVE: To field measure the saturation flow rates and loss time at a signalized intersection during peak period.

EQUIPMENT AND FACILITIES REQUIRED

1. Recording form(s)
2. Stopwatches
3. Lime/ tape/ stop bar for demarcation
4. At least two observers

NEED FOR THE STUDY

In calculating the Level of Service (LOS) of a signalized intersection, the saturation flow rate plays a key role in determining the capacity. As per the Highway Capacity Manual (HCM), the capacity of a signalized intersection is based on saturation flow rate. The LOS, in general, indicates the operational qualities of an intersection and it is usually represented alphabetically from A to F. LOS A represents a delay of fewer than 5 seconds and LOS F represents a delay of more than 60 seconds at the intersection for all vehicles. Saturation flow rate and loss time are two critical items in any signal timing analysis. Loss time is the time lost in the very beginning of the green time when vehicles are starting to depart from the approach lane(s). These two important elements form the basis of delay methodology adopted by HCM.

THEORY

Saturation flow rate is the maximum rate of flow (vehicles) that can pass through an intersection approach or lane group under existing roadway and traffic conditions, assuming that the approach or lane group has 100 percent real-time available as effective green time. Thus, the saturation flow rate is expressed in units of vehicles per hour of green time (vehicles/hour of green, vphg). In general, where saturation flow rate data is not available, an ideal value of 1900 vphg is used for through lanes, 1700 vphg for left, and 1600 vphg right turn lanes. The lost time used is usually two seconds in most cases.

The value of the saturation flow rate is affected by the following factors at an intersection:

1) Location of parking

2) Number of lane(s) in each group
3) Composition of heavy vehicles
4) Approach grade
5) Blocking effect of local transit
6) Area type (Central Business District)
7) Lane group (through, left or right)
8) Driver and road characteristics (type of vehicle, lane width, and pocket length)

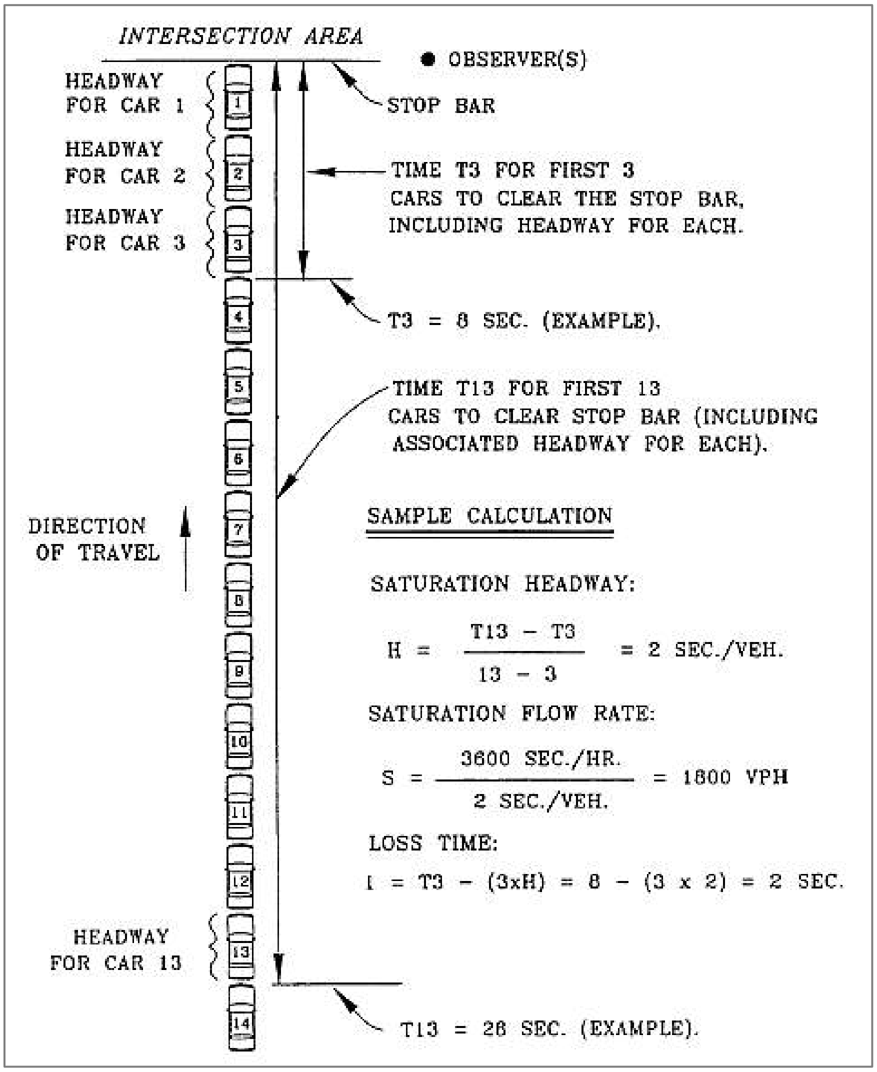


Fig.9.1 Measurement of saturation flow rate

Saturation flow rate is used in determining the capacity of a given lane group or approach at a signalized intersection. It is calculated by the following equation:

$$Q = S_i \left(\frac{g}{c}\right)_i$$

where *c = Capacity of lane group or approach i (veh / hr)*

S_i = Saturation flow rate for lane group or approach i (veh/hr of green)

$\left(\frac{g}{c}\right)_i$ = *Green ratio for lane group or approach*

PROCEDURE

Saturation flow rate measurement at a signalized intersection will require at least two observers to record the data. Fig. 9.1 shows how to calculate loss time and saturation flow rate using the field data. In Fig.9.1, headway is defined as the time between two successive vehicles in a traffic lane as they pass a point (stop bar) on the roadway, measured from front bumper to front bumper, in seconds.

The following steps are to be observed in collecting the field data for saturation flow:

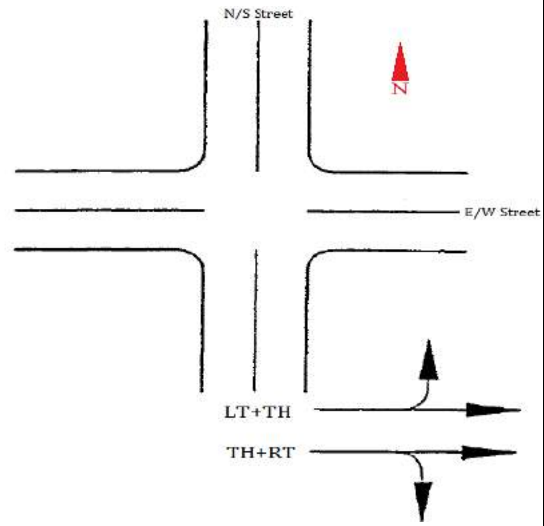
1. Complete intersection data worksheet and visit site 15 minutes before data recording.
2. Record phasing sequence and cycle time of the signal.
3. Select a suitable observation point depending on the approach selected (stop bar in Fig.9.1).
4. Use the road markings as a reference point or mark appropriate reference point on the road using lime/tape. The reference point will form the basis for all data readings.
5. A minimum of ten cars (in the queue) is required for any data recording. Record the required data in the properly designed worksheet.
6. It is essential that the time recording observer coordinate the work well with data recording observer in the field.
7. If loss time is to be determined, record the time of the first three cars as indicated in Fig.9.1.

OBSERVATIONS

Observation Sheet 9.1

Intersection data for Saturation Flow Rate

Date:		Day:	
Weather:			
Location:			
Type of Intersection:			
Name of the observer(s):			
Time of start:			
Time of finish:			
Number of Lanes	Left	Through	Right
NB			
SB			
EB			
WB			



S = shared lane

Record lanes with more than one movement, e.g.: Through with Right Turn.

	Major Street	**Minor Street**	**Comments**
Posted Speed			
Classification			
Grade % (±)			
Pedestrian Movement			
Controls (S/Un/OT)			
% Of Trucks / Buses			
Cycle Length (S)			
Parking On Street			
Type Of Intersection			
Area Type (CBD)			
Phasing Sequence			

S = Signalized UN = Un-signalized OT = Other

Observation Sheet 9.2

Saturation Flow Rate recording form

Date:	Day:	Weather:	Page:
Name of the observer(s):			
Movement observed:			
Type of Intersection:			
Peak period(s):			

Vehicles in queue	Cycle 1			Cycle 2			Cycle 3			Cycle 4			Cycle 5			Cycle 6		
	Time	HV	T	Time	HV	T	Time	HV	T	Time	HV	T	Time	HV	T	Time	HV	T

HV = Heavy Vehicles T = Turning Vehicles (Left / Right)

CALCULATIONS

$$Saturation\ Headway, H = \frac{T_n - T_i}{n - i}$$

$H =$ ___________ sec/veh

where T_n =Time for "n" number of cars to clear stop bar including associated headway for all the preceding cars

T_i = Time for first "i" number of cars to clear stop bar including headway for all the preceding cars

$$Saturation\ Flow\ Rate, S = \frac{3600\ sec/hr}{H\ sec/veh}$$

$S =$ ___________ veh/hr

$$Time\ Lost, t = T_i - i(H)$$

$t =$ ___________sec

ANALYSIS AND PRESENTATION

Intersection geometric sketches should be drawn. Factors influencing the saturation flow rates should be worked out. Also, it should be checked whether the saturation flow rates for any movement(s) can be increased. Suggestions for increased mobility and safety should be given at the end and same should (if possible) be shown via sketches.

TRAFFIC SIGNAL DESIGN 10

TE Lab 10

OBJECTIVE: Design a signalized intersection by IRC method.

EQUIPMENT AND FACILITIES REQUIRED

1. Traffic volume counts (directional counts) data
2. Road geometrics data

Note: The details of the collection, analysis, and presentation of the above data have already been explained in previous labs. So that has been excluded in this lab to avoid repetition.

NEED FOR THE STUDY

A traffic signal is an aid to control traffic at intersections where other control measures fail. The signals operate by providing a right of way to a certain set of movements in a cyclic order. It is, therefore, necessary that a traffic engineer is able to design the timings of a signal in an optimum way so that the efficiency of an intersection can be improved.

THEORY

The conflicts arising from movements of traffic in different directions are solved by time-sharing principle. The advantages of traffic signal include an orderly movement of traffic; an increased capacity of the intersection and requires only simple geometric design. The average delay and the overall delay to the vehicles at signalized intersection vary with the signal cycle length. The average delay per vehicle is high when the cycle length is very less, as a sizeable proportion of vehicles may not get cleared during the first cycle and may spill over to subsequent cycles. As the signal cycle time is increased the average delay per vehicle decreases up to a certain minimum value and thereafter the delay starts increasing, indicating that there is an optimum signal cycle time corresponding to the least overall delay.

Definitions used in the Design of a Signal:

A number of definitions need to be understood in signal design. They are discussed below:

- **Cycle**: A signal cycle is one complete rotation through all of the indications provided.

- **Cycle length**: Cycle length is the time in seconds that a signal takes to complete one full cycle of indications. It indicates the time interval between the starting of green for one approach until the time next green starts.
- **Interval**: It indicates the change from one stage to another. There are two types of intervals - change interval and clearance interval. *Change interval* is also called the yellow time. It indicates the interval between the green and red signal indications for an approach. *Clearance interval* is also called *all-red* time. It is included after each yellow interval indicating a period during which all signal faces show red and is used for clearing off the vehicles in the intersection.
- **Green interval**: It is the green indication for a particular movement or set of movements. This is the actual duration the green light of a traffic signal is turned on.
- **Red interval**: It is the red indication for a particular movement or set of movements. This is the actual duration the red light of a traffic signal is turned on.
- **Phase**: A phase is a green interval plus the change and clearance intervals that follow it. Thus, during the green interval, non-conflicting movements are assigned to each phase. It allows a set of movements to flow and safely halt the flow before the phase of another set of movements start.
- **Lost time**: It indicates the time during which the intersection is not effectively utilized for any movement. For example, when the signal for an approach turns from red to green, the driver of the vehicle which is in the front of the queue will take some time to perceive the signal (usually called as reaction time) and some time will be lost here before he moves.

IRC-93 Guidelines

- The pedestrian green time required for the major and minor roads is calculated based on walking speeds of 1.2 m per second and initial walk time of 7.0 seconds. These are the minimum green time required for the vehicle traffic on the minor and major roads respectively
- The green time required for the vehicle traffic on the major road is increased in proportion to the traffic on the two approach roads.
- The cycle time is calculated after allowing ember time of 2 seconds each.
- The minimum green time required for clearing vehicles arriving during a cycle is determined for each lane of the approach Road assuming that the first vehicle will take 6 seconds and the subsequent vehicles or the PC you of that you will be cleared at the rate of 2 seconds the minimum green time required for the vehicle traffic on any of the approaches is limited to 16 seconds
- The optimum signal cycle time is calculated using Webster's formula. The saturation flow values are given by IRC.

- For widths above 5.5 m, the saturation floor may be assumed as 525 PCU per hour per metre width. The Lost time is calculated from the Amber time inter-green time and the initial delay of 4 seconds for the first vehicle on each leg.
- The signal cycle time in the faces maybe revised keeping in view the green time required for clearing the vehicles and the optimum cycle length determined in about steps.

Table 10.1 Saturation flow values recommended by IRC

PCU/hr	Road Width, m
1850	3.0
1890	3.5
1950	4.0
2250	4.5
2550	5.0
2990	5.5

PROCEDURE

1. The normal flow values q_1 and q_2 on roads 1 and 2 are determined from field studies conducted during the design hour or the traffic during the peak hour period.
2. Calculate the pedestrian crossing time.
$$\text{Pedestrian crossing time} = \frac{\text{width of road}}{1.2} + 7\ sec$$
3. Pedestrian crossing time is the minimum green time for traffic on the respective approaches having parallel movement with that of pedestrian movement.
4. The green time required for the vehicular traffic on the major road is increased in proportion to the traffic on the two approach roads. Thus, calculate the revised green time.
5. Add 2 sec each towards clearance amber and 2-sec inter-green period for each phase. The cycle time calculated may be conveniently set in multiples of 5 seconds. The extra time if any for cycle may be apportioned to the green times of both roads.
6. Check for clearing the vehicles arrived during the green phase.
7. Check for the optimum signal cycle by Webster's equation.

OBSERVATIONS

In this Lab, the observations are retrieved from the previous labs. TMC's are used as input for the design of signals.

CALCULATIONS

The saturation flow of vehicles is determined from careful field studies by noting the number of vehicles in the stream of compact flow during the green phases and corresponding time intervals precisely.
The standard values for saturation flow are given as in Table 10.1.
Based on selected values of normal flow and the saturation flow, the ratios are determined on approach roads 1 and 2.

$$Y_1 = \frac{q_1}{S_1} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

$$Y_2 = \frac{q_2}{S_2} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

The optimum signal cycle is given by the relation

$$C_0 = \frac{1.5\mathrm{L}+5}{1-\mathrm{Y}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

where L = total lost time per cycle in seconds given by

$$L = 2n + R = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

n = number of phases,
R = all-red time.

Green time for each phase is determined as

$$G_1 = \frac{y_1}{\mathrm{y}} \times (C_0 - \mathrm{L})$$

$$= \_\_\_\_\_\_\_\_\_\_\_\_$$

$$G_2 = \frac{y_2}{\mathrm{y}} \times (C_0 - \mathrm{L})$$

$$= \_\_\_\_\_\_\_\_\_\_\_\_$$

where Y = $\boldsymbol{y}$1+$\boldsymbol{y}$2

ANALYSIS AND PRESENTATION

The optimum cycle timing is distributed into "n" number of phases and is represented by means of phase timing diagrams and/ or phase plan arrow diagram. An illustration of the phase timing diagram is shown below:

Fig.10.1 Illustration showing 3-phase signal timing diagram

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DRIVER CHARACTERISTICS STUDY 11

TE Lab 11

OBJECTIVE: To conduct a vision screening test with the use of driver vision screening instrument in the lab.

EQUIPMENT AND FACILITIES REQUIRED

1. Driver vision screening instrument
2. Power supply
3. Recording form
4. Examiner and subject

NEED FOR THE STUDY

While driving, it is important to have a clear and comfortable vision. One needs to be able to judge distances, read road signs and traffic lights and respond to the sudden changes in surroundings in time. According to the Association of Optometrists (AOP), drivers with poor vision cause estimated 2900 road casualties every year. So, it is important to conduct driver vision screening test for the safety of road users.

A driver sight test is important to check or screen the following abilities of the drivers:

- Glare recovery
- Night vision
- Horizontal and vertical peripheral
- Depth perception
- Traffic sign recognition
- Acuity
- Colour perception
- Balance and coordination of eye muscles

THEORY

The road user is subjected to a series of stimuli both expected and unexpected. The time taken to perform an action according to the stimulus involves a series of stages like:

- **Perception**: Perception is the process of perceiving the sensations received through the sense organs, nerves, and brain. It is actually the recognition that a stimulus on which a reaction is to happen exists.

- **Intellection**: Intellection involves the identification and understanding of stimuli.
- **Emotion**: This stage involves the judgment of the appropriate response to be made on the stimuli like to stop, pass, move laterally, etc.
- **Volition**: Volition is the execution of the decision which is the result of the physical actions of the driver.

Visual acuity and driving

The perception-reaction time depends greatly on the effectiveness of the driver's vision in perceiving the objects and traffic control measures. The PIEV time will be decreased if the vision is clear and accurate. Visual acuity relates to the field of clearest vision. The most acute vision is within a cone of 3 to 5 degrees, fairly clear vision within 10 to 12 degrees and the peripheral vision will be within 120 to 180 degrees. This is important when traffic signs and signals are placed, but other factors like dynamic visual acuity, depth perception, etc. should also be considered for accurate design. Glare vision and color vision are also equally important. Glare vision is greatly affected by age. Glare recovery time is the time required to recover from the effect of glare after the light source is passed, and will be higher for elderly persons. Color vision is important as it can come into the picture in case of sign and signal recognition.

A reference value above which visual acuity is considered normal is called 6/6 vision, the USC equivalent of which is 20/20 vision: At 6 meters or 20 feet, a human eye with that performance is able to separate contours that are approximately 1.75 mm apart. The vision of 6/12 corresponds to lower, the vision of 6/3 to better performance. Normal individuals have acuity of 6/4 or better (depending on age and other factors).

Table 11.1 Snellen Equivalents

20/20	20/25	20/30	20/40	20/50	20/60	20/70	20/100	20/200
6/6	6\7.5	6\9	6\12	6\15	6\18	6\21	6\30	6\60

Phoria

A phoria is a misalignment of the eyes that only appears when binocular viewing is broken and the two eyes are no longer looking at the same object. The misalignment of the eyes starts to appear when a person is tired. Therefore, it is not present all of the time. A phoria can be diagnosed by conducting the cover/cover test.

Parts of the instrument

The instrument is designed for both standardized and completely confidential testing. Targets are enclosed in the unit, so subjects cannot see or study them in advance. Internal target illumination ensures consistency of operating conditions, and the unit pivots through a 63° arc to adjust to the eye level of any subject.

Fig.11.1 Driver testing Equipment

1 Lists active target (test slide) number. A lamp next to each test label indicates the target being presented.

85° Illuminates horizontal peripheral vision target lamps. A signal lamp indicates the eye and angle being tested.

Illuminates vertical peripheral vision target lamps. A signal lamp indicates the eye being tested.

Occludes (darkens) left eye.

Occludes (darkens) right eye.

Activates glare lighting.

(De)activates reduced illumination/night vision conditions.

Head sensor override button (off/on) allows operation of the machine without sensor activation by examinee's head. Eliminated on some models.

Resets drum, lights and lenses to original setting.

Reverse to previous stereo target.

Advance to next stereo target.

Fig.11.2 Hand Control Unit

The various parts are:

1. ***Headrest***: It accommodates a wide variety of eyeglass frames. During testing, the subject's forehead should rest lightly against this specially-designed strip.
2. ***Peripheral Vision Test***: Horizontal peripheral vision fields are measured using light-emitting diode target lamps, positioned between the lenses and recessed in the temple areas of the viewing head so that eyeglass frames will not interfere with testing. Vertical peripheral vision is measured by illuminating LEDs above and below the nasal area.
3. ***Elliptic Hand Control Unit***: By pressing appropriate buttons, the examiner can advance or reverse the test targets, occlude either of the subject's eyes and control target illumination. It is designed for hand-held or desktop operation.
4. ***Power Switch***: The on-off power control is located on the rear of the instrument.
5. ***Power Supply***: To eliminate electrical and heat hazards, power is converted to 12Volts DC. To ensure safe operation of the equipment, the instrument must only be used with the transformer supplied by the manufacturer.

Features of tests of Vision Screening Instrument

Test 1: Quick Acuity

There are nine separate blocks containing three 20/40 acuity letters each. The first column tests both eyes, the second tests right eye acuity, and the third tests left eye acuity. All three lines should be read, and only two digits in each column can be misread without failure.

Test 2: Colour Vision

This is a test for gross, red/green colour deficiency. If at least 3 of the 4 numbers presented are not identified by the subject, further examination by a vision professional should be recommended. The correct numbers are to be read back by the examinee.

Horizontal and Vertical Peripheral Vision/Field Testing

Miniature lamp (LED) targets between the lenses and recessed in the temple (side) areas of the viewing head show how far to the side a subject's visual field extends when s/he looks straight ahead. Persons with "tunnel vision", a grossly-restricted peripheral field, are quickly identified. The horizontal targets are selectively lit by individual buttons on the control panel to show a 45° nasal field and to check temporal fields at angles of 85°, 70°, and 55°. A total field of from 100° to 130° can be measured for each eye. The eyes may be tested separately or together. The vertical targets measure a total field of 70° with four settings. There are two nasal settings and angles of 35° above and 35° below.

This test is particularly significant in the case of vehicle operators. A person with normal lateral vision will be able to see a moving object with it is 90° (or at a right angle) to his/her eye on the outside. Keystone strongly recommends a lateral reading for both eyes of 70° should be considered the minimum standard for safety as is required by the

U.S. Interstate Commerce Commission. It is suggested that when a test subject who holds a motor vehicle

Operator's license demonstrates a severely restricted field, even though his/her other visual skills are normal, s/he be referred to a vision specialist for examination and professional opinion regarding driving.

Test 3: Depth Perception and Sign Recognition

Subjects are asked to identify six road signs (at least five correctly to pass) *and* determine, both the closest and the farthest sign.

Tests 4, 5, and 6: Acuity

To test acuity (fineness of visual discrimination), blocks of digits are presented for identification by the subject for:

- Right eye (Test 4)
- Left eye (Test 5)
- Both eyes together (binocular – Test 6).

Test 4 checks the acuity of the right eye while the left eye is open and seeing. It tests at Far Point and results are calibrated at values from 20/200 to 20/20 (6/60 to 6/6). Test 5 similarly tests the acuity of the left eye while the right eye is open and seeing. It tests at Far Point and the results are calibrated at values from 20/200 to 20/20 (6/60 to 6/6). Test 6 screens binocular vision at Far Point as well as night vision. It presents the same number groups to both eyes simultaneously and provides seven ratings ranging from 20/200 to 20/20 (6/60 to 6/6).

Test 7: Binocular Coordination (Phoria)

This simple test determines if the subject's eye muscles are properly balanced and coordinated. A passing response to the question,

"Is the dot inside or outside the box?" will be, "Inside the box." It is completely normal for the subject to see the dot move around a bit.

However, its movement should slow down to a limited range after a few moments.

Test 8: Glare Recovery

In this, the driver's ability is tested to adapt to decreased illumination and to recover rapidly from exposure to glare such as one would be exposed to driving at night. Subjects are presented 3 rows of 7 numbers shown under decreased (night) illumination, glare and then a return to night illumination to gauge visual recovery from glare. If at least 6 of the 7 numbers in a row are not correctly identified, further examination by a vision professional is recommended.

PROCEDURE

Each vision test takes only a few minutes, however careful handling of the instrument should be ensured throughout. The examiner needs to follow these steps:

1. Place the driver vision screening instrument on a plain and level surface e.g. table.
2. The subject whose vision is to be tested looks into the screen-reader vision testing instrument.

3. The examiner with a record form has to note the observations for each test.
4. After looking into the instrument, the observer reads aloud (or writing or using sign language) a series of letters or numbers that appear on the screen.
5. The examiner has to indicate when a flashing light appears and on which side (left or right) the light appears.
6. The examiner after listening to the letters and/or numbers check the number of correctly identified entries by the subject and notes the data for each test in the respective columns in the record form.
7. Various tests are to be performed in a similar manner and observations are recorded in record form.

OBSERVATIONS

The observations are recorded in a record form provided below.

Observation Sheet 11.1

Driver vision screening test recording form

Name ______________________________ ______________

Occupation ______________________________ ______________

Does the examinee wear Glasses ☐ or Contacts ☐ (If yes, how often?) Always ☐ Somtimes ☐

What kind of Vision Correction? Distance Only ☐ Reading ☐ Multifocals ☐

TEST DESCRIPTION AND KEY (Corresponds to Remote Control Key)	UNACCEPTABLE	RETEST	ACCEPTABLE	NIGHT VISION PASS	NIGHT VISION FAIL
QUICK ACUITY TEST BOTH RIGHT LEFT 1. 958 479 823 2. 347 563 268 3. 426 728 534	ROW ONE: ☐ Six or Less Correct 1. 958 2. 479 3. 823	☐ Seven Correct	☐ Eight or More correct		
	ROW TWO: ☐ Six or Less Correct 1. 347 2. 563 3. 268	☐ Seven Correct	☐ Eight or More correct		
	ROW THREE: ☐ Six or Less Correct 1. 426 2. 728 3. 534	☐ Seven Correct	☐ Eight or More correct		
COLOR 4163	Two or Less Correct 4163	Three Correct 4163	All Correct 4163		
HORIZONTAL FIELD TEST	LEFT SIDE ☐ 85 ☐ 70 ☐ 55 ☐ NASAL		RIGHT SIDE ☐ NASAL ☐ 55° ☐ 70° ☐ 85°		
VERTICAL FIELD TEST	UPPER ☐ 35° ☐ NASAL		LOWER ☐ NASAL ☐ 35°		
SIGNS/DEPTH 1. STOP NEAR 4. ROAD CLOSED 2. MERGE 5. HANDICAPPED FAR 3. NO LEFT TURN 6. SIGNAL AHEAD	No Depth Awareness	Either NEAR FAR	Both NEAR FAR		
RIGHT EYE: ACUITY A B C 1. 20 = 547638 25 = 428576 30 = 943852 2. 40 = 795823 50 = 357248 60 = 7236 3. 70 = 9574 100 = 92 200 = 5	20/70 = 9574 20/200 = 5 20/60 = 7236 20/100 = 92 20/50 = 357248	(One Miss 20/40 = 795823	Allowed Per Line) 20/30 = 943852 20/25 = 428576 20/20 = 547638		
LEFT EYE: ACUITY A B C 1. 20 = 745932 25 = 578236 30 = 346752 2. 40 = 534268 50 = 752386 60 = 6254 3. 70 = 8453 100 = 85 200 = 3	20/70 = 8453 20/200 = 3 20/60 = 6254 20/100 = 85 20/50 = 752386	(One Miss 20/40 = 534268	Allowed Per Line) 20/30 = 346752 20/25 = 578236 20/20 = 745932		
BOTH EYES ACUITY A B C 1. 20 = 857432 25 = 674235 30 = 382457 2. 40 = 563472 50 = 859423 60 = 8927 3. 70 = 2978 100 = 43 200 = 9	20/70 = 2978 20/200 = 9 20/60 = 8927 20/100 = 43 20/50 = 859423	(One Miss 20/40 = 563472	Allowed Per Line) 20/30 = 382457 20/25 = 674235 20/20 = 857432		
PHORIA DOT INSIDE BOX	Dot out of Box	Dot on Line	Dot in Box		
GLARE RECOVERY	☐ Four or less Correct	☐ Five Correct	☐ Six or more Correct		
ROW 1. 2651439	2651439	2651439	2651439		
ROW 2. 8294635	8294635	8294635	8294635		
ROW 3. 6395274	6395274	6395274	6395274		

ANALYSIS AND PRESENTATION

Finally, on the basis of observations, it is decided whether the subject's vision is fit for driving or not.

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ORIGIN-DESTINATION STUDY 12

TE Lab 12

OBJECTIVE: To conduct Origin & Destination study in order to obtain travel information for determining future traffic patterns.

EQUIPMENT AND FACILITIES REQUIRED

1. Map of the study area
2. Designed questionnaire/ observation sheets

NEED FOR THE STUDY

The objectives of the origin and destination (O-D) studies are as follows:

1. To determine the amount of by-passable traffic that enters a town, and thus establishes the need for a bypass.
2. To develop trip generation and trip distribution models in transport planning process.
3. To determine the extent to which the present highway system is adequate and to plan for new facilities.
4. To assess the adequacy of parking facilities and to plan for future.
5. O-D studies on vehicular traffic are essential for comprehensive planning of new road network and for improvements in the existing road network.

THEORY

In transportation study, it is often necessary to know the exact origin and destination of the trips. It is not only necessary to know how many trips are made, but also group these trips with reference to the zones of their origin and destination. Other information yielded by O-D survey includes land-use (commercial, residential, etc.) of the zones of origin and destination, trip purpose and mode of travel.

Study area: The boundary of the study area is defined by what is called as ***external cordon*** or simply the ***cordon line***. A sample of the zoning of a study area is shown in Figure 12.1 and 12.2. Interactions with the area outside the cordon are defined via external stations which effectively serve as doorways to trips, into, out of, and through the study area. The study area should be defined such that the majority of trips have their origin and destination in that area and should be bigger than the area-of-interest covering the transportation project.

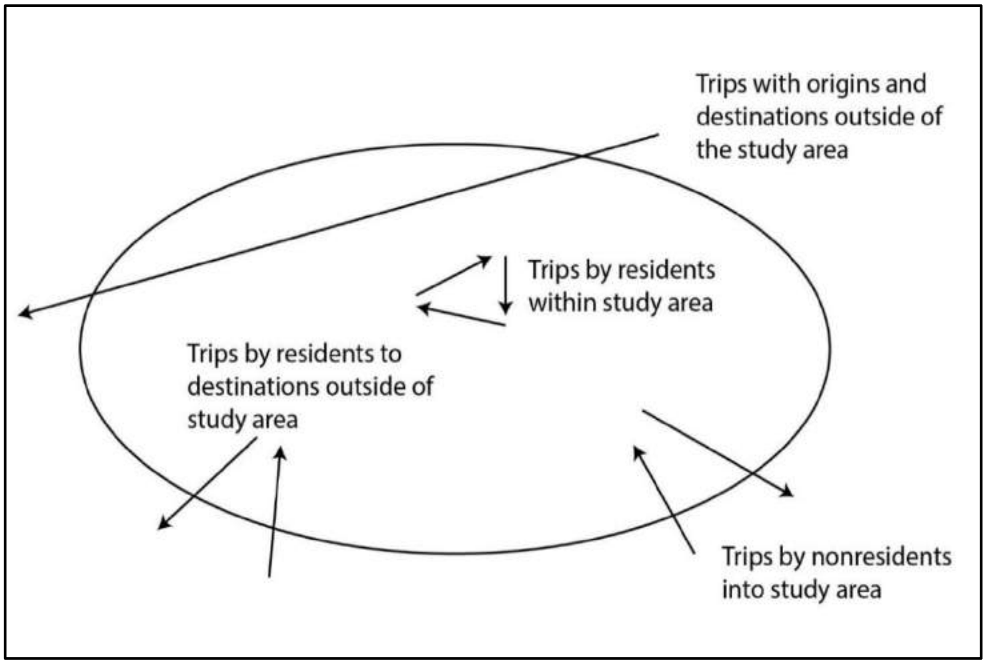

Fig. 12.1 Representation of study area

Zoning: Once the study area is defined, it is then divided into a number of small units called traffic analysis zones ***(TAZ)***. The zone within the study area is called internal zones. Zones are modeled as if all their attributes and properties were concentrated in a single point called the zone centroid. The centroids are connected to the nearest road junction or rail station by centroid connectors. The intersection from outside world is normally represented through external zones. The external zones are defined by the catchment area of the major transport links feeding to the study area. These provide useful information about trips from and to external zones.

In addition to external cordon lines, there may be a number of ***internal cordon lines***

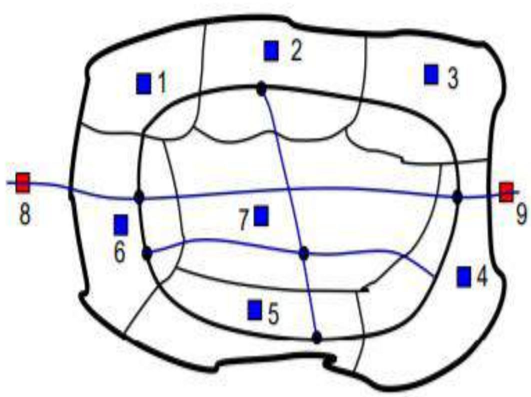

Fig.12.2 Zoning of the study area
(1, 2… 7 represent different zone centroids)

arranged as concentric rings to check the accuracy of survey data. ***Screen lines*** divide the study area into large natural zones, like either sides of a river, with few crossing points between them.

Guidelines for selection of zones:

1. Zones should match administrative divisions, particularly census zones.
2. Zones should have homogeneous characteristics, especially in land use, population, etc.
3. Zone boundaries should match cordon and screen lines, but should not match major roads.
4. Zones should be as smaller in size as possible so that the error in aggregation caused by the assumption that all activities are concentrated at the zone centroids is minimized.

Survey methods: O-D survey methods for data collection include the following:

1. Roadside Interview
2. License plate mail-out surveys
3. Telephone surveys
4. Postcard mail-back type surveys
5. GPS Receiver
6. Online surveys
7. Home interview method
8. Questionnaire method

a) Roadside Interview: This interview includes directing vehicles into a designated area and asking a series of short questions. This involves asking questions to a sample of drivers and passengers of vehicles crossing a particular location. Unlike household survey, the respondent will be asked with few questions like origin, destination, and trip purpose. This technique is widely used and has a very high response rate but sometimes implementation is difficult due to disruption of traffic. In this method investment cost is low but requires high labour and personnel requirements. This method has a broad geographical coverage as it includes vehicles from outside the study area also, but implementation can be for limited locations and hence sampling may be biased.

b) License plate mail-out surveys: The license plate mail-out survey involves recording license plate numbers of vehicles on a selected roadway, tracing vehicle ownership, and mailing a survey to owners. There are different methods for tracing the license plate number: taking a photo/video or manually recording the tag on vehicles. Photo/video is often used for high volume highways. Labour requirements are more for tracing the ownership of vehicles but no disruption of traffic occurs.

c) Telephone survey: In this type of survey, appropriate vehicle owners are contacted on phone and are interviewed through a series of short questions. No disruption of traffic occurs but has high personnel requirements as compared to mail surveys. Some other advantages are low investments. This method has many disadvantages also, such as, appropriate sampling is difficult and low responses may create biased data.

d) Postcard mail-back type surveys:
In this type of survey, postcards are distributed to passing motorists to be completed and returned by postage-paid, business reply mail. The mail-back card includes basic questions such as the origin and destination address, activity at the origin and destination, the trip purpose, vehicle occupancy, etc. There is not much disruption of traffic and also low investments are required. But response rates are low which may create a biased data.

e) GPS Receiver: Cell phone tracking provides data on phone (owner's) movements as cell phone transitions from one cell tower to another. But widespread utilization of GPS receivers for O-D data collection is currently cost prohibitive, especially for large rural and urban areas. Though there is no disruption of traffic, it requires very high equipment cost. This method is limited to samples only in the study area and also information regarding trip purpose is limited.

f) Online survey: Web-based surveys as compared to other surveys provide more valuable information less expensively. Response rate of these surveys can be very high if proper incentives are provided, as the money saved for data input and validation can be used to boost up the response. Out of all origin and destination survey methods, these surveys provide ideal solution for information gathering because of their fast turnaround and can cover very large sample size. Sampling is difficult in this method though the response rate is very high and no disruption of traffic occurs.

g) Home interview method: The home interview method is preferred when the comprehensive traffic and transportation requirements are to be planned for a city. A random 5-10 percent of the population is selected depending on the number of residencies. The residencies are visited by the trained personnel and they collect the travel data from each member of the household. Detailed information regarding the trios made by the members is obtained on the spot.

h) Questionnaire method: In this method, questionnaires are designed for collection of data required for the study. A good design will ensure better response from the respondent and will significantly improve the quality of data. Design of questionnaire is more of an art than a science. The questionnaire should be simple, direct, should take minimum time, and should cause minimum burden to the respondent.
It mostly consists of the following questions.

a. How do you normally travel to and from your place of duty?
b. How many people are in the car (include self)?
c. Where does your trip originate?
d. What is your place of duty?

e. Where do you park your car during duty hours?
   Give parking lot number, nearby building, or nearest intersection.
f. If in car pool, what is on-post destination of other members of car pool?

Table 12.1 Comparison of four O-D methods

Item	Roadside interview method	License plate method	Home interview method	Questionnaire method
Applicability	When through trips are significant but not the internal trips.	Determining proportions and patterns of through traffic.	Preferred when the comprehensive traffic and transportation requirements are to be planned for a city.	On most installation, when work trips dominate traffic.
Method & place of interview	Interviews on roadways at or near entrance gates.	Mark cars and/or check license plates at or near entrance gates.	Sample interviews in selected dwelling units.	Distribute questionnaire at place of work or duty.
Cost involved	Substantial	Minimum	Maximum	Minimum
Advantages	Control of sample. Accuracy of trip distribution.	Low cost. Provides simple answer to a specific problem.	Accuracy. Completeness.	Minimum cost. Large sample. No interference to traffic.
Disadvantages	Interference with traffic in peak hours. Doesn’t fully reflect internal trips.	Limited to specific problems only.	Greater cost, time and complexity.	Does not detect through trips.

PROCEDURE:

1. Define a cordon line by studying the map of the area very carefully.
2. Choose the points on the road network at which the data is to be collected.
   Note: (The survey should normally be conducted for three consecutive days and must encompass the weekly market day and one working day).
3. Record the number as well as the type of all the vehicles passing the station.
4. Stop the drivers at random and interview for origin, destination, commodity carried, etc.
5. Then, represent the data as O-D matrix, in which the origin zones and destination zones are represented.
6. Develop a desire line diagram of the area within the cordon line.

OBSERVATIONS

Observation sheet 12.1

Sample questionnaire for O-D study

1. How do you normally travel to and from your place of duty?

   A) Drive car B) Passenger in car

   C) Public transit D) Walk

2. If you drive a car, please answer the following:

   a. How many people are in the car (include self)?

      A) One B) Two C) Three

      D) Four E) Five F) Six

   b. Where does your trip originate?

   Street Address: ____

   City: ____

   c. Through which gate do you enter the post?

      A) Gate 1

      B) Gate 2

      C) Gate 3

      D) Gate 4

d. What is your place of duty?

e. Where do you park your car during duty hours?

Give parking lot number, nearby building number, or nearest intersection.

f. If in car pool, what is on-post destination of other members of car pool?

Note: Students are advised to design a customized questionnaire as per the requirement.

PRESENTATION OF O-D DATA:

1. O-D surveys yield a vast amount of data. The most convenient form of representing the data is ***O-D matrix***, in which the origin zones and destination zones are represented.
2. The most popular pictorial representation is by means of a ***desire line chart***. Desire lines are straight lines connecting the origin points with destinations, summarized into different area groups. The width of desire lines is scaled proportional to the number of trips in both directions. In this chart, the trips between any pair of zones are represented by a straight line connecting the centroids of the two zones. These desire lines may be compared with an existing flow pattern along the existing routes by superimposing over the other with the help of tracing sheets.
3. The relative magnitude of the generated traffic and geometrical relationships of the zones involved may be represented by pie-charts, diameter of circles being proportional to the number of trips.
4. Contour lines may be plotted similar to topographic contours. The shape of the contours would indicate the general traffic need of the area.

O-D Matrix

<table>
<tr><td></td><td colspan="7">Destinations</td><td rowspan="2">Total Trip Production</td></tr>
<tr><td rowspan="7">Origins</td><td></td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr>
<tr><td>A</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>B</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>C</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>D</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>E</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>F</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Total Trip Attracted</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

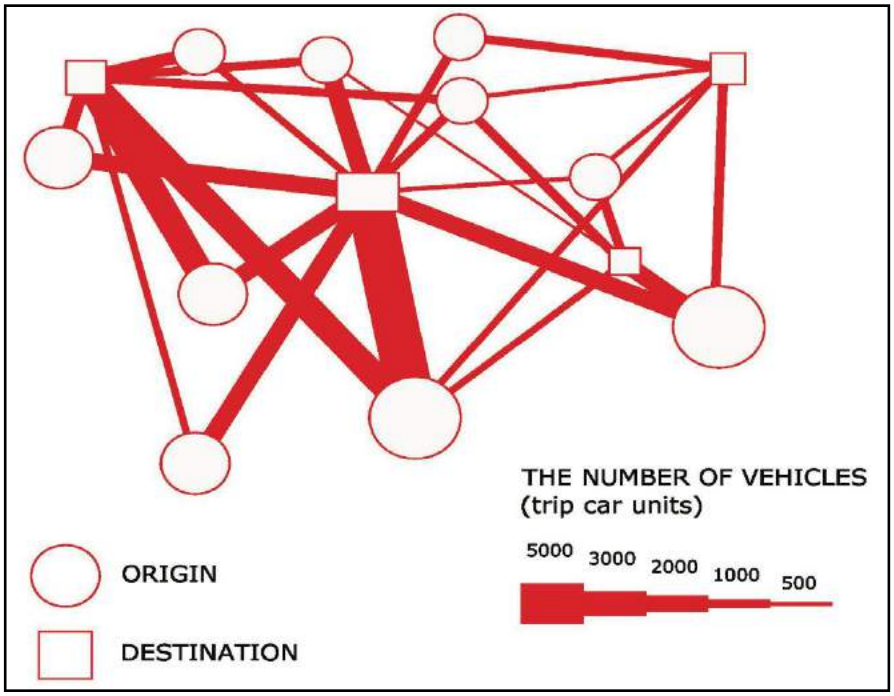

Fig. 12.3 Desire line diagram

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INTRODUCTION TO SOFTWARES 13

TE Lab 13

OBJECTIVE: The main objective of this lab is to provide an introduction to various softwares (such as TRANSYT-15, PICADY, SPSS and Sigma Plot) and their application in transportation planning and traffic operations.

EQUIPMENT AND FACILITIES REQUIRED

1. Traffic data analysis machines (Computer System with up-to-date hardware and software)
2. Application software (such as TRANSY-15, PICADY, SPSS and SigmaPlot)

NEED FOR THE STUDY

Use of computers is assisting transportation and traffic professionals to be efficient and complete projects on time. There are many mathematical formulas and calculations that need to be done and some needs to be repeated, the role of microcomputers becomes very apparent in those situations. Now, with computers available to most professionals and with the advent of online information regarding transportation is available at any time. The computers and hand held mini computers have assisted in developing software that helps in data gathering and transferring as required. As advances in microcomputers are growing, existing applications are being expanded. Thus, it is very important for transportation professionals to get familiar with these application softwares.

THEORY

1. **TRANSYT-15**

TRANSYT is a macroscopic off-line computer program for studying everything from isolated road junctions to large signal-coordinated networks. Traditionally TRANSYT's primary role has been the study and determination of optimum fixed time, co-ordinated, traffic signal timings in any network of roads for which the average traffic flows are known. However, TRANSYT 15 is also designed specifically to be used for the assessment of isolated signal controlled junctions, signalised roundabouts, partially signalised roundabouts and for any network of non-signalled and signal controlled junctions which influence the behaviour of each other's traffic. A traffic model of the network calculates a Performance Index (P.I.) in monetary terms, which, in its simplest form, is a weighted sum of all vehicle delay and stops. A number of available optimising routines systematically alter signal offsets and/or allocation of green times to search for the timings which reduce the P.I. to a minimum value. TRANSYT is the most widely used program of its type throughout the world.

2. PICADY

Priority Intersection Capacity and Delay is based on three decades of research and development by TRL and is used for predicting capacities, queues, delays (both queueing and geometric) and accident risk at priority intersections. Three and four-arm unsignalised give-way intersections are modelled using well established TRL/Kimber capacity relationships (the Picady Model), which takes into account key geometries such as road width, visibility, the space available for traffic making an offside turn, and so on. This empirical framework intrisically links priority junction geometry to driver behaviour and in turn to predicted capacities, queues and delays.

What does PICADY Module model?

- Any three or four arm priority junction, including T-junctions, crossroads and staggered crossroads
- Major roads with both single and dual carriageways may be modelled, including ghost islands and bollards
- Minor roads with single, flared and two lane approaches
- One way or two way roads
- Signalised and unsignalised pedestrian crossings can be included
- Accident prediction is available for both rural and urban junction layouts
- Both drive-on-the-left and drive-on-the-right situations

Features in the PICADY Module

1. Average arriving vehicle delay
2. Partial blocking effect by major road turning traffic
3. Auto-updating summary results
4. Multiple geometric layouts, time periods and design years in one file
5. Point-to-point journey times

How the PICADY Module works?

- The program uses the geometric parameters of the junction with the traffic flows to predict queue, delay and capacity.
- Additional results such as geometric delay and accident prediction are also available.
- The geometric parameters and the controlling flows, split into smaller time periods, are used to calculate the capacity of each non-priority traffic stream. The queues and delays are then calculated for each time period, using time dependent queueing theory.
- The PICADY model is an empirically derived one, based on extensive data sets collected at existing junctions.

3. SPSS

SPSS is a widely used program for statistical analysis. It is also used by market researchers, health researchers, survey companies, government, education researchers, marketing organizations, data miners and others.

Statistics included in the base software:

- Descriptive statistics: Cross tabulation, Frequencies, Descriptives, Explore, Descriptive Ratio Statistics
- Bivariate statistics: Means, t-test, ANOVA, Correlation (bivariate, partial, distances), Nonparametric tests, Bayesian
- Prediction for numerical outcomes: Linear regression
- Prediction for identifying groups: Factor analysis, cluster analysis (two-step, K-means, hierarchical), Discriminant
- Geo spatial analysis, simulation
- R extension (GUI), Python

SPSS Statistics places constraints on internal file structure, data types, data processing, and matching files, which together considerably simplify programming. SPSS datasets have a two-dimensional table structure, where the rows typically represent cases (such as individuals or households) and the columns represent measurements (such as age, sex, or household income). Only two data types are defined: numeric and text (or "string"). All data processing occurs sequentially case-by-case through the file (dataset). Files can be matched one-to-one and one-to-many, but not many-to-many. In addition to that cases-by-variables structure and processing, there is a separate Matrix session where one can process data as matrices using matrix and linear algebra operations. The graphical user interface has two views which can be toggled by clicking on one of the two tabs in the bottom left of the SPSS Statistics window. The 'Data View' shows a spreadsheet view of the cases (rows) and variables (columns). Unlike spreadsheets, the data cells can only contain numbers or text, and formulas cannot be stored in these cells. The 'Variable View' displays the metadata dictionary where each row represents a variable and shows the variable name, variable label, value label(s), print width, measurement type, and a variety of other characteristics. Cells in both views can be manually edited, defining the file structure and allowing data entry without using command syntax. This may be sufficient for small datasets. Larger datasets such as statistical surveys are more often created in data entry software, or entered during computer-assisted personal interviewing, by scanning and using optical character recognition and optical mark recognition software, or by direct capture from online questionnaires. These datasets are then read into SPSS.

4. Sigma Plot

Systat Software has released Sigma Plot 13, the latest version of their most advanced scientific data analysis and graphing software package. SigmaPlot 13 provides researchers an enriched user interface, increased ease of use and new features to quickly analyze data and create exact, publication-quality graphs that best present research results for presentation, publication or the web. SigmaPlot is a proprietary software package for scientific graphing and data analysis. It runs on Microsoft Windows. The software can read multiple formats, such as Microsoft Excel spreadsheets, and can also perform mathematical transforms and statistical analyses. SigmaPlot provides more than 100 different 2-D and 3-D graph types. From simple 2-D scatter plots to compelling contour plots, SigmaPlot gives you the exact technical graph type you need for your demanding research. With so many options, you can always find the best visual representation of your data. SigmaPlot 13 provides researchers with an enriched user interface, increased ease of use and new features to quickly analyze data and create exact, publication-quality graphs that best present research results for presentation, publication or the web.

This latest version contains many workflow efficiency improvements, new enhancements to SigmaPlot's curve fitting features and a wider range of graphing options including Forest Plot, Kernel Density Plot, Principal Component Analysis (PCA) and ANCOVA.

New Graph Features

- Forest Plot
- Kernel Density Plot
- Dot Density Graph with mean and standard error bars
- 10 New Color Schemes
- Legend Improvements
    - Horizontal, Vertical and Rectangular Legend Shapes
    - Variable number of legend item columns
    - Reorder and reverse legend items
    - Direct Labeling

New User Interface Features

- Rearrange Notebook items in a section by dragging
- Line widths from a worksheet column
- New SigmaPlot tutorial PDF file

As before SigmaPlot has

- A huge data worksheet
- A wide range of flexibly customizable 2D and 3D graphs
- Numerous technical graph options
- A wide range of data analysis and statistics features

References

[1] Dr. Khanna, S.K. and Dr. Justo, C.E.G. "*Highway Engineering*", Nem Chand & Bros., Roorkee, 2010.

[2] *ITE Manual of Transportation Engineering Studies*, 2nd edition

[3] IRC: 67-2012 "C*ode of Practice for Road Signs (Third Revision)*" Indian Roads Congress, New Delhi, India, 2012

[4] IRC: SP:19-2001 "*Manual for Survey, Investigation and Preparation of Road Projects (Second Revision)* ", Indian Roads Congress, New Delhi, India, 2001

[5] IRC:SP:12-2015 "*Guidelines for Parking Facilities in Urban Roads* (First Revision)", Indian Roads Congress, New Delhi, India, 2015

[6] IRC SP:041-1994 *"Guidelines for the Design of At-Grade Intersections in Rural & Urban Areas"*, Indian Roads Congress, New Delhi, India, 1994

[7] IRC:93-1985 *"Guidelines for Design and Installation of Road Traffic Signals",* Indian Roads Congress, New Delhi, India, 1985

[8] IRC:SP:90-2010 *"Manual for Grade Separators and Elevated Structures",* Indian Roads Congress, New Delhi, India, 2010

[9] IRC :65-1976 *"Guidelines for the design of traffic rotaries",* Indian Roads Congress, New Delhi, India, 1976

[10] Kadiyali, L. R. *"Traffic Engineering and Transportation Planning",* Khanna Publishers, New Delhi, 1987

[11] nptel.ac.in

[12] Papacostas, C.S. and Prevedouros, P.D. *"Transportation Engineering & Plannig (third edition)",* PHI Learning Private Limited, Delhi, 2014

[13] Papacostas, C.S. "*Fundamentals of Transportation Engineering*", Prentice-Hall, New Delhi, 1987

[14] Roess, R. P., Prassas, E. S. and McShane, W.R, *"Traffic Engineering (fourth edition)",* Dorling Kindersley india Pvt. Ltd, 2015

This manual titled "Traffic Engineering Laboratory Manual" is mainly designed to meet the requirements of Under Graduate (UG) and Post Graduate (PG) Engineering Students of National Institute of Technology Srinagar, Hazratbal, Jammu & Kashmir. It is intended to be used for performing various traffic engineering studies efficiently. An attempt has been made to make this manual student friendly as much as possible.

Traffic engineering is a practical area of study and many of its aspects are difficult to understand, analyze and simulate in classroom. This manual has been formulated to help in proper planning and organization of various traffic studies. It provides the guidelines to perform traffic studies efficiently and also gives detailed procedures to perform the whole experiment/ traffic study in a systematic manner. During the process of formulation of this manual, number of feedbacks from students and teachers were taken on a regular basis which were analyzed and incorporated with utmost care. Immense efforts were put in to answer the three basics questions often asked by the students:

"Why do we need to perform a particular traffic study?"

"Where do we need to perform it?"

"How do we perform it?"

The framework of this manual has been designed in such a manner that it becomes student friendly. Every experiment/ traffic study starts by defining its objectives followed by various equipments/facility required. The preliminary work required to be conducted in the laboratory, before a traffic survey is initiated, has also been included. Prior knowledge of theory is extremely important to perform any traffic survey. Keeping this in view, brief theoretical concepts have been included for each experiment/ study. Experimental procedures and observation sheets are designed such that these are concise and simple to use. Brief description on how the data can be analyzed and presented (both manually as well as using software[s]) is also included. Effort has been made to keep the textual content of the manual of the highest quality.

A chapter introducing the various softwares, routinely used for data analysis, traffic simulation and/or modeling, has also been included towards the end, in this manual. This has been done to make students familiar with the application of these softwares.

We (authors) hope that students of both UG and PG level will find this manual extremely useful. Moreover, we invite comments and/or criticisms that will help us to improve it further.