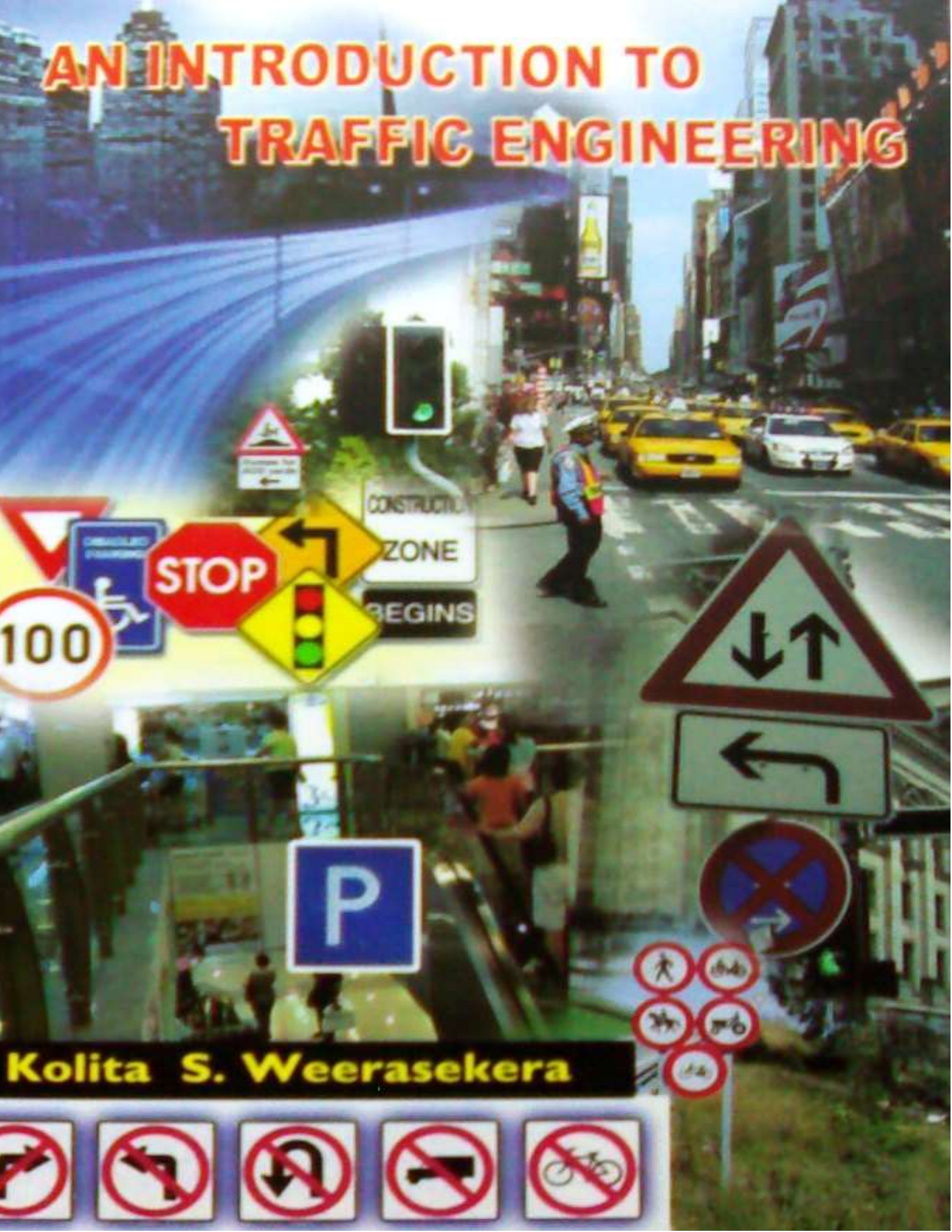
AN INTRODUCTION TO TRAFFIC ENGINEERING



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An Introduction to Traffic Engineering

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An Introduction to Traffic Engineering

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Foreword

The book authored by Dr Kolita Weerasekera on “An Introduction to Traffic Engineering” is an ideal text book for undergraduates in Engineering and Planning. It covers a wide range of topics in traffic engineering in typical traffic engineering and management courses in an engineering or planning undergraduate programme. In fact, this book will also be a help for those who pursue higher studies in traffic engineering with less exposure in this field.

Dr.Kolita Weerasekera’s wide experience in university academia and industry in Australia and Sri Lanka together with his experience in open and distance learning delivery system at the Open University of Sri Lanka has immensely helped him to write a reader friendly book. This book has been written in a simple language and easy to understand manner but has covered the depth required by engineering undergraduates.

I am very confident that this text book will be very useful to any university, where engineering or planning student pursuing courses in traffic engineering and management.

Prof. L L Ratnayake
Senior Professor
Department of Civil Engineering
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Finally I am grateful to my loving wife Darshi, son Tirath for their continuous support during the writing of the book and my dear parents who gave me all the support and strength throughout my education.

Kolita S. Weerasekera

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Chapter 1

Traffic survey and analysis

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Objectives

This chapter provides an overview of the different traffic surveys that can be conducted, how the data obtained is analysed, and the usage of this data for traffic management schemes. At the end of the chapter the reader should have an idea of the different types of data collecting methods available for different objectives and the utilisation of this data in highway development schemes.

1.1 Introduction

In any transport planning or traffic engineering project, the process begins with collection of data. To improve the traffic conditions the solutions obtained must be based on reliable data.

Field data are needed in order to ascertain actual traffic conditions, to determine trends for future work and to assess the effectiveness of solutions. To collect these data there is a need to undertake studies or surveys designed to measure specific traffic parameters.

The traffic surveys help in deciding the geometric design features and traffic control for safe and efficient movement of the traffic. The different types of traffic studies generally conducted are listed below.

- Traffic volume studies
- Speed studies
- Origin destination studies
- Traffic flow characteristics studies
- Traffic capacity studies
- Parking studies
- Accident studies

1.2 Traffic volume studies

A traffic volume study is a count of the vehicles crossing a selected section of the road per unit time at any suitable selected time duration.

Traffic volume can be used as a quantify measure of traffic flow, that is to measure, how many vehicles of what type and from which direction have passed a definite section of the road per hour and per day. In traffic volume studies the traffic volumes are usually expressed in the following terms. The definitions of these terms are as follows.

(1) **Volume** - number of vehicles passing a given point during a specified period of time.

(2) **Average Daily Traffic (ADT)** - the total volume during a given *time period* (this time period is any time duration greater than one day but less than one year) divided by the number of days in that time period.

(3) **Average Annual Daily Traffic (AADT)** - total yearly volume divided by the number of days in a year.

(4) **<u>12 Hour Volume</u>** - on a road the number of vehicles passing an observation point over a given 12 hour interval during a day.

(5) **<u>Peak Hour Volume</u>** - is the maximum traffic count observed in any 60 minute interval during a day. Usually in urban areas there are two peak hour volumes, one in the morning and the other in the evening.

(6) **<u>Average Weekday Traffic Volume (AWT)</u>** - this is the average 24 hour count over the period, Monday to Friday.

(7) **<u>Design Hour Volume (DHV)</u>** - is the traffic flow rate chosen as the design traffic load for a facility. Common practice is to choose an ‘n^{th}’ HHV as the design volume, with the 30^{th} HHV often used in a rural environment and 80^{th} HHV in an urban area (HHV denotes the highest hourly volume).

Vehicle classified counts

Vehicle classification data are important for all transport engineering applications. In these counts vehicles can be classified into separate groups such as; cars, motor cycles, buses, lorries, vans, trucks, jeeps etc. and count each category separately. Comprehensive classification data are, however, difficult to collect in urban areas, and manual methods are usually required.

Classified volume studies are useful for the structural and geometric designs of the carriageway and computing road users’ capacity.

Vehicle equivalence factors

Vehicle counts are sometimes expressed in vehicle equivalence factors, typically passenger car units (pcu). This is an attempt of expressing total impact on the traffic flow of any vehicle compared with the impact of a standard passenger car. In Sri Lanka the following passenger car units are used for different vehicle types for different terrains:

Table 1.1 – Equivalent passenger car units for two-lane, two-way roads

Vehicle Type	pcu factor		
	Flat	Rolling	Mountainous
Passenger car	1.0	1.0	1.0
Small bus	1.8	2.4	4.8
Bus	2.4	4.3	8.0
Light truck (4-wheel)	1.5	2.8	5.0
Medium truck (6-wheel)	2.0	4.0	8.0
Heavy truck (> 6-wheel)	3.8	5.6	10.0
Motor cycle	0.4	0.5	0.6
Bicycle	0.7	0.8	0.8
Animal drawn cart	2.5	6.0	14.0
Three-wheeler	0.8	1.2	2.0
Land vehicle	3.8	5.6	10.0
Truck trailer	6.0	12.0	18.0

(Source: Transportation Engineering Division, University of Moratuwa, 2006)

Table 1.2 – Equivalent passenger car units for multi lane roads

Vehicle Type	pcu factor		
	Flat	Rolling	Mountainous
Passenger car	1.0	1.0	1.0
Small bus	1.6	2.2	4.0
Bus	1.8	3.2	5.0
Light truck (4-wheel)	1.5	2.4	4.2
Medium truck (6-wheel)	1.7	3.2	5.0
Heavy truck (> 6-wheel)	2.8	3.0	5.0
Motor cycle	0.5	0.5	0.5
Bicycle	1.0	1.0	1.0
Animal drawn cart	4.0	10.0	24.0
Three-wheeler	0.8	1.0	1.4
Land vehicle	3.4	4.8	5.4
Truck trailer	4.0	6.0	8.0

(Source: Transportation Engineering Division, University of Moratuwa, 2006)

Traffic composition is required to convert traffic volumes from vehicles into pcu or vice versa, for design of lane widths or capacity calculations.

Turning movements at intersections

Information on turning movements at intersections is usually obtained from manual counts over relatively short periods (typically the peak hour or over 12 hours 7:00 am to 7:00 pm). These data are essential for design of intersections, planning of signal timings, channelisation and application of other controls such as roundabouts, give way, and stop lines etc.

Following are the main objectives of traffic volume studies.

(a) Traffic volume usually gives the idea of relative importance of roads and it helps in deciding the priority for widening and improvement of the existing roads.
(b) Traffic volume study is useful in planning the traffic control and operation of the existing roads and also for planning and designing of new roads.
(c) These studies are useful for analysing of traffic pattern trends.
(d) Pedestrian volume study is useful for planning cross walks and side walks for pedestrians.
(e) Volume distribution study is used for regulatory measures.

Traffic counting can be done by either manually (using field sheets and hand tallies) or by mechanical/electronic devices such as automatic traffic counters.

Manual traffic counts

These counts are conducted using hand counters (hand tallies) or observation sheets to facilitate traffic data recording. Manual counts are usually undertaken when:

- Detailed classification data is required (vehicle type, occupancy details etc.)
- To obtain turning movement details
- For short duration surveys
- Information such as pedestrian vehicle interaction etc.

The simplest and cheapest recording mechanism is a sheet of paper on a clip board. Specially designed forms can be used to facilitate separate recording of different types of vehicles and/or manoeuvres. If traffic flow is high, hand tallies can be used for counts.

Fig 1.1 - Manual traffic count

Automatic traffic counts

Automatic traffic counts are conducted using set of equipment consisting pneumatic rubber tube stretched across the road carriageway surface that detects the passage of axles of vehicles, plus a data logger (recorder) which records the number of vehicle axles against specified time intervals. This information recorded over a period of time later down loaded to a computer for data analysis and obtaining reports on traffic details.

Fig 1.2 - Pneumatic rubber tube which connects to data logger

Although pneumatic tubes are the most widely used traditional automatic counting method in Sri Lanka, many different methods are available for counting vehicles, such as treadle switch, piezo-electric cable, induction loop, photoelectric beam, infrared beam, microwave beam and video-imaging.

1.3 Speed studies

Vehicle speed is one of the basic changeable characters when describing the operation of individual vehicles on a highway system. Information on vehicle speeds provides awareness on level of service, travel condition, travel time, and quality of traffic flow. Speed is one of the main highway design parameters for setting design standards, and also for quantifying the effects of changes on a highway system due to any improvements or deteriorations.

Vehicle speed studies are carried out with the following objectives.

(a) For planning traffic control measures such as establishing speed zones, traffic signals, regulatory and warning signs, non-overtaking zones, danger warning zones etc.

(b) To determine the speed trends.

(c) To study the accident behaviour such as:

1. relation of accident with speed
2. to identify high accident locations
3. to check on the effectiveness of remedial measures adopted

(d) To determine the capacity of the road.

(e) For geometric designs of roads.

When conducting speed studies, one has to know the definitions of following commonly used terms.

(1) **Travel time** - is the time taken to reach between two specified locations, and this is a measure of the condition and maintenance of the road surface and an indication of the traffic congestion.

(2) **Spot speed** - is the instantaneous speed of a vehicle at a specific location. This speed may be affected by physical features of the road such as carriageway width, curve, sight distance, gradient, surface roughness, road side development, intersections, traffic condition, driver's physical and mental condition, type of vehicle etc. Spot speeds are generally measured by radar guns, endoscopes or flash boxes or may be measured by laying two pneumatic tubes at 1 metre apart across the carriageway and with the help of an automatic traffic counter.

(3) **<u>Space speed</u>** – is the speed of vehicles on a road at a given instant of time. There is a basic relationship between spot speed and space speed. This relationship is that the mean spot speed (i.e. the mean speed of all vehicles passing a roadside observer) will be slightly higher (in the order of 2 to 3 percent) than the mean space speed (the mean speed of all vehicles on a highway section at an instant of time). The average spot speed is also called time mean speed as separate from space speed.

(4) **<u>Average speed</u>** - is the average spot speed of all vehicles passing through a particular section or spot.

(5) **<u>Running speed</u>** - is the speed obtained by dividing the distance covered by the time during which the vehicle was actually in motion.

(6) **<u>Overall or travel speed</u>** - is obtained by dividing the distance between two stations by the total time taken including all delays, stoppages and travel time etc.

General locations where speed studies are conducted depend upon the purpose of the study.

- to study the general speed trends, the stations are usually established on open straight stretches of highways or at mid-block locations on urban streets away from the influence of stop or give way signs, traffic signals etc.

- when data are to be used in planning controls, the site must be within the section under study and as far removed from extraneous influence as possible.

- ‘Before and After’ studies are normally made at the same site, which is so located as to measure all possible influences.

- Problem location studies usually require approach speed data. Sites are selected so that the approach speeds are measured before vehicles are affected by the problem under study.

The period during which speeds are measured depends on the purpose of the study. It is important that trend studies and ‘before and after’ studies be made during the same hours under compatible conditions. Adverse weather and unusual volume conditions should be avoided.

1.4 Origin and destination studies

The origin and destination studies give the idea of the number of vehicular traffic, their origin and destination in each ‘zone’ of study. These studies are most essential in improving the existing road system and planning the new highway facilities to the public.

Zones

Origin destination survey data are analysed in terms of traffic ‘zones’. Therefore, prior to the commencement of the survey work, the study area is subdivided into a system of ‘internal zones’. The whole country outside the study area can be subdivided into a system of larger zones called ‘external zones’.

Cordon line surveys

The origin and destination of external-internal and through movement can be determined by cordon surveys. Road traffic movements are commonly surveyed direct interview of drivers or post card surveys. In the direct interview method, a sample of road users are stopped at the cordon survey stations by a policeman, and questioned by interviewers who enter the answers on the prepared survey form. The second method involves slowing down motorists and giving them prepared post card questionnaires. The direct interview methods require careful selection of cordon stations. A badly selected station may cause serious delay to motorists.

From the cordon line surveys the following information are collected.

- the origin and destination of the journey being made
- trip purpose and type of goods carried
- intermediate stops, if any and purpose of the stop

Other items such as type of vehicle, number of occupants, date, time, location of the survey station, direction of the vehicle can be entered by the interviewer before the interview or distribution of the survey form.

1.5 Traffic flow characteristic survey

The study of traffic flow characteristics includes the study of transverse and as well as longitudinal distribution of vehicles in the traffic stream on various routes. This study is useful in geometric design features such as traffic capacity, volume, number of lanes, width of carriageway etc. It is also useful for deciding regulatory measures such as one way traffic movement and traffic control methods etc.

Headway survey

Headway is the time interval between the passage of successive vehicles passing a given point and is generally measured from 'front to front' or 'rear to rear' of two successive vehicles.

Gap is the time interval taken between the rear and front of two successive vehicles to pass a given observation point.

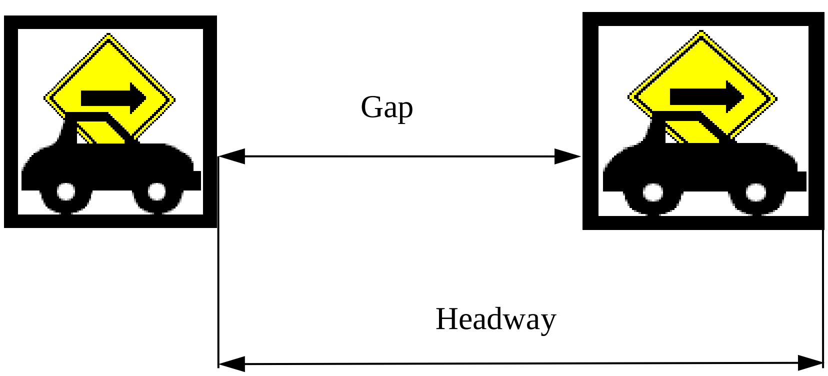


Figure 1.3 - Headway and gap

The number of headways in a given period of time is dependent on the rate of vehicular flow and is therefore a direct measure of traffic volume. Headway is inversely proportional to traffic flow.

If, h = average headway between vehicles in seconds

q = is the traffic flow in vehicles per second

$$q = \frac{1}{h}$$

However, headway alone cannot give the whole picture of the situation on the field - small headway can mean slow moving traffic but closely spaced, or fast moving traffic but more distantly spaced.

Vehicle headway surveys can be carried out to estimate traffic delays and study available gaps for vehicular and pedestrian crossings. In the analysis of many traffic engineering problems, headway data are valuable in determining the ability of pedestrians to cross a stream of traffic by selecting a safe, convenient gap; or the ability of turning vehicles to select safe convenient gaps through an opposing traffic stream.

Vehicle headway surveys are also useful the logical development of warrants for pedestrian crossings of traffic signals.

Methodology

Vehicle headways can be measured with a stop watch or by recording in a video tape. Stop watch can be used when the traffic flow is light and the latter method when the flow is moderate to heavy flows. Video recording is preferred especially when the road is multi-laned. Once recorded in a video tape by a latter viewing in the laboratory in slow motion the vehicle headways can be recorded with the help of a build in clock.

Headways should be measured at mid-block locations or at any point between two intersections where the traffic is moving on its normal speed.

Analysis

When analysing the vehicle headway data since a large amount of data has to be handled, it is necessary to group them properly. The size of each group depends on the number of data and its dispersion, the size can be 1, 2, 4, 5, or 10. Then based on the information from the summary sheets vehicle headway frequency graphs or histograms can be plotted.

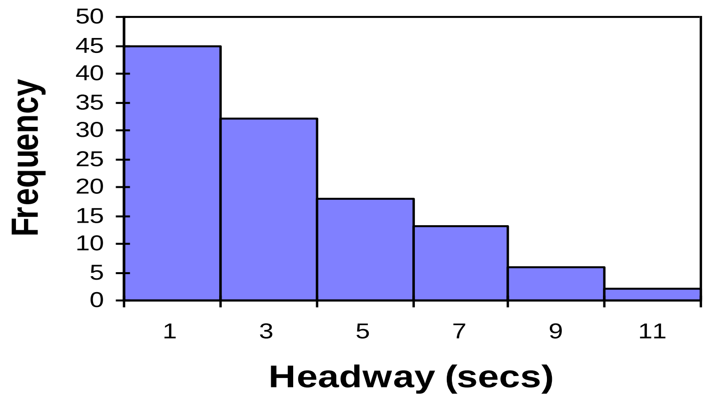


Figure 1.4 - Vehicle headway frequency histogram

1.6 Traffic capacity studies

Traffic capacity can be defined as the ability of a road to accommodate the traffic volume. It is expressed as the maximum number of vehicles on a road that pass a given point per hour.

Capacity is a basic physical characteristic of any transport facility. The interpretation of capacity is largely dependent on the type of facility (rural/urban, two-lane/multi-lane), because of the significant differences in the operating conditions. The actual numerical value of capacity is further dependent on the prevailing roadway, traffic and control conditions.

The capacity of a road is affected by the following factors:

- width of the lane
- lateral clearance
- width of shoulders
- type of vehicles
- alignment of the road
- nature of the intersections

Traffic capacity will be discussed at length in chapter 2 on *Highway capacity and level of service.*

1.7 Parking studies

The aim of parking studies is to determine the congestion in industrial, commercial and residential areas and to look for means to provide sufficient parking in these areas. Parking studies are also conducted to determine to see whether the capacity has reached in the present parking facilities and if so, to take measures to ease the situation.

The parking facility demand is increasing day by day. Thus parking studies are useful to evaluate the public demand and location of future facilities.

Parking surveys are conducted to assess the extent of the parking problem in the area under study. The objective of any parking study should be to collect data which will give an indication of the parking needs of the area. ‘Parking supply’ and ‘parking usage’ surveys are common to all types of parking studies undertaken, irrespective of the scale of the parking study. Parking studies will be discussed at length in chapter 5 on *Parking*.

1.8 Accident studies

Due to the invention of fast moving vehicles, the problem of accidents is becoming more and more complex in highway engineering. It is more acute in case of mixed traffic. Traffic accidents may involve, personal injuries, total casualties and damage to property etc. Hence it is the prime duty of the traffic engineers to carry out the systematic studies of traffic accidents to find out the main cause of the accident and suggest preventive or remedial measures. Hence the various objectives of the accident studies may be listed as follows:

(a) To study the causes of accidents and to propose remedial actions for the potential accident prone locations.

(b) To locate any accident prone locations or ‘back-spots’ and treat those locations.

(c) To check the existing designs and forward proposals for these designs to improve safety.

(d) To make estimates of financial losses and to justify the proposals for improvement in the accident problem.

The various steps involved in the traffic accident studies are as follows:

1. Collection of accident data
2. Analysis of these data
3. Identify black-spots
4. Preparation of accident reports
5. Suggestions for remedial measures

Accident studies will be further discussed in chapter 4 on *Road safety and accident studies.*

Chapter 2

Highway capacity and level of service

Contents

Objectives

The objective of this chapter is to introduce the highway capacity principle with the level of service concept. At the end of the chapter the reader should be able to decide whether a given section of highway has reached capacity or not, at a desired level of service.

2.1 Highway capacity

Capacity is defined as the maximum number of vehicles per unit of time that can be handled by a particular roadway component under the prevailing conditions. Graphically capacity can be shown in a diagram as in Figure 2.1

If on a particular section of a road, the average vehicle speeds are plotted against the vehicular volume passing through that section (i.e. number of vehicles per unit time) a plot similar to Figure 2.1 can be obtained. When the volumes are less, then the average speeds will be high. But once the volume increases the average speed will decrease and the volume of that particular section of road will reach a maximum value of Q_{max} (see Figure 2.1) which is called the capacity. At capacity the road starts to become congested and no further increase of through traffic is possible. Beyond capacity the average speeds reduce drastically and the road becomes very inefficient.

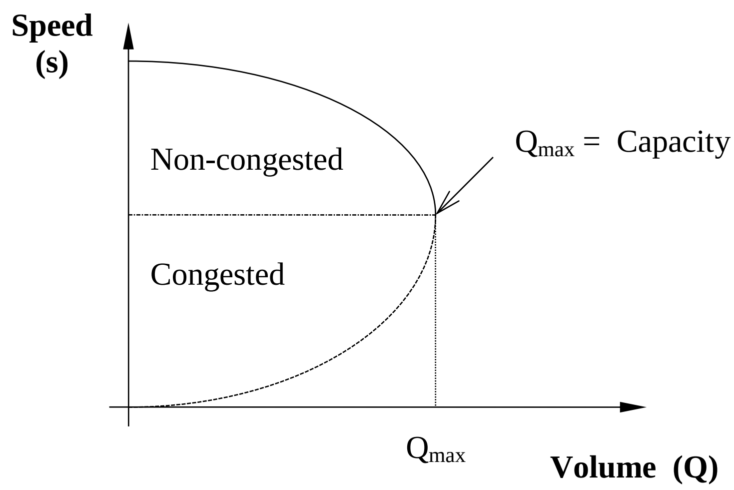


Figure 2.1 - Basic concept of highway capacity

Earlier, before the level of service concept was introduced, the highway capacity was defined in three levels.

1 **Basic capacity** - the maximum number of passenger cars that can pass a point on a lane or roadway during one hour under the most nearly ideal roadway conditions which can possibly attain.

2 **Possible capacity -** the maximum number of vehicles that can pass a given point on a lane or roadway during one hour under prevailing conditions.

3 **Practical capacity -** a lower volume is chosen without the traffic density being so great as to cause unreasonable delay, hazard or restriction to the driver's freedom to manoeuvre under prevailing roadway and traffic conditions. Practical capacity is otherwise known as design capacity.

In the 1985 edition of the *Highway Capacity Manual* of the Transport Research Board USA, the concept of practical capacity was disregarded and the concept of level of service was introduced. Since then the concept of level of service is used to describe highway capacities.

2.2 Level of service

Level of service is associated with different operating conditions that occur on a facility when it accommodates various traffic volumes. The factors which might be considered in evaluating level of service include the following.

1. Speed and travel time
2. Traffic interruptions or restrictions
3. Freedom to manoeuvre
4. Safety
5. Driving comfort and convenience
6. Vehicle operating costs (economy)

The maximum volume that can be carried at any selected level of service is referred to as the 'service volume' for that level. The concept of level of service is illustrated in Figure 2.2. Level of service is selected in six classes for application in identifying the conditions existing under various speed and volume conditions on any highway or street. Figure 2.2 shows the relationship of level of service to operating speed and volume capacity ratio.

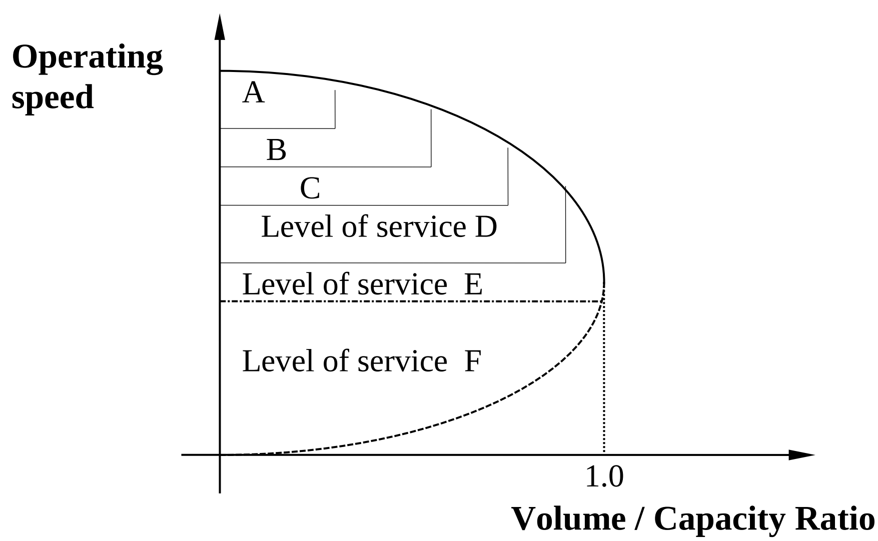


Figure 2.2 - The relationship between level of service and the operating speed, volume/capacity envelope

As per US *Highway Capacity Manual* the description of each level of service are as follows.

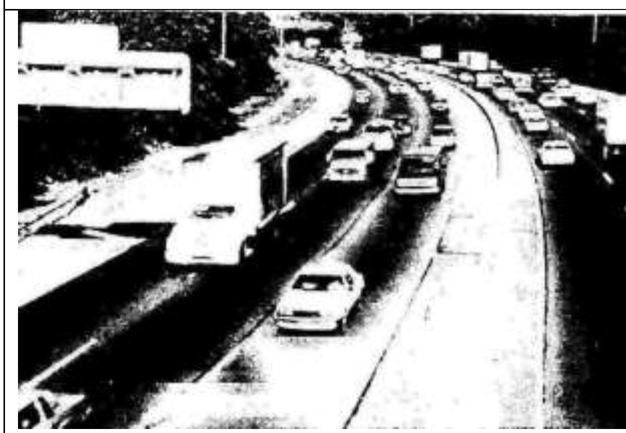
Level of Service A	Free flow, low volume and denoting high speeds. Drivers can maintain their desired speeds with little or no delay.
Level of Service B	Stable flow, operating speeds beginning to be restricted somewhat by traffic conditions. Drivers still have reasonable freedom to select their speed. Suitable for rural design standards.
Level of Service C	Stable flow, but speeds and manoeuvrability are more closely controlled by higher volumes. Suitable for urban design standards.
Level of Service D	Approaches are unstable flow, tolerable operating speeds which are, however, considerably affected by operating conditions. Drivers have little freedom to manoeuvre.
Level of Service E	Unstable flow, with yet lower operating speeds and perhaps, stoppages of momentary duration. Volumes at or near capacity.
Level of Service F	Forced flow, low volumes. Both speed and volumes can drop to zero. Stoppages may occur for short or long periods. These conditions usually result from queues of vehicles backing from a restriction downstream.

The six levels of service therefore indicate the condition of traffic in a given traffic volume. The volume to capacity (v/c) ratio and the resulting operating speed can determine what level of service is available on a particular road stretch. This is also important in traffic control to enable traffic authorities to institute measures to improve the level of service of a particular road system.

In highway design, the design capacity used is taken from the service volume appropriate for the level of service desired. The number of lanes therefore can be determined by taking into consideration the desired design capacity.

Level of Service A

Level of Service B



Level of Service C

Level of Service D

Level of Service E

Level of Service F

Figure 2.3 - Levels of Service concept : One direction of a multi-lane highway

(Source : US Highway Capacity Manual)

Maximum Service Flow *(MSF)*$_i$

Maximum Service Flow is defined as the maximum number of vehicles that can pass over a given section of lane during a specified time period while operating conditions are maintained corresponding to the selected or specified level of service. Normally the service flow is given as an hourly flow.

For a two-lane two-way rural road, Maximum Service Flow is given as follows according to the Highway Capacity Manual.

$$(MSF)_i = 2800 \times \left(\frac{v}{c}\right)_i \times f_d \times f_w \times f_{HV}$$

Where,

2800 is the capacity for the both lanes together. That is 1400 veh/hr in each direction with a directional split of 50: 50.

$\left(\frac{v}{c}\right)_i$ is the volume / capacity ratio for i^{th} level of service.

f_d, f_w and f_{hv} are the different adjustment factors introduced by the Highway Capacity Manual, and the Tables 2.1 to 2.4 given at the end of the chapter 2 can be used to compute the adjustment factors at different conditions for different levels of services.

Adjustment factors

f_w = adjustment factor for the combined effect of narrow lanes and restricted shoulders.

f_d = adjustment factor for directional distribution of traffic

(a) Adjustment factors for level grades

f_{HV} = adjustment factor for the presence of heavy vehicles

$$f_{HV} = \frac{1}{\left[1 + P_T(E_T - 1) + P_B(E_B - 1)\right]}$$

where,

P_T = percentage of trucks

P_B = percentage of buses

E_T = average passenger car equivalent for trucks

E_B = average passenger car equivalent for buses

(b) Adjustment factors for specific grades

f_{HV} = adjustment factor for the presence of heavy vehicles

$$f_{HV} = \frac{1}{\left[1 + P_{HV}\left(E_{HV} - 1\right)\right]}$$

where,

E_{HV} = $1 + \left[0.25 + P_{T/HV}\right] \times \left[E - 1\right]$

$P_{T/HV}$ = ratio of trucks / heavy vehicles

E = Passenger car equivalent for the specific grades on two-lane, two-way rural road

f_g = adjustment factor for passenger cars

$$f_g = \frac{1}{\left(1 + P_P \times I_P\right)}$$

where,

P_P = proportion of passenger cars in up grade

I_p = $0.02(E\text{-}E_0)$ = impedance factor for passenger cars

The following two exercise will explain how the Mean Service Flow is computed for difference levels of services by using the Highway Capacity Manual for a two-lane, two-way rural road for level terrains and terrains with specific grades.

<u>Exercise 1</u>

A 12 km long section of a two-lane, two-way undivided rural highway has the following characteristics.

Terrain condition	= flat terrain
Design speed	= 100 km/h
Lane width	= 3.7 m
Shoulder width	= 2.0 m
Directional split	= 70 / 30
Percentage of trucks	= 10%
Percentage of buses	= 5%

Percentage with sight distance less than 450 metres = 20%
(i.e. percent of no passing zones)

It is given that,

$$(MSF)_{ii} = 2800 \times \left(\frac{v}{c}\right)_i \times f_d \times f_w \times f_{HV}$$

By using the Tables in Highway Capacity Manual

(1) Calculate the MSF for each level of service.

(2) Determine the level of service at which the road will likely to be operating if the road has a one-way highest hourly volume of 780 veh/hr.

(3) To improve the condition of road, what measures should be taken?

<u>Solution</u>

(1) Calculation of MSF for different levels of service

Step 1

Organise the given data first

Design speed	100 km/h
Lane width	3.7 m
Shoulder width	2.0 m
Terrain	Flat
Directional split	70 : 30
% Trucks	10% = 0.1
% Buses	5% = 0.05

Percent with sight distance less than 450 metres = 20%. This is the percentage of length of the considered road stretch available for overtaking.

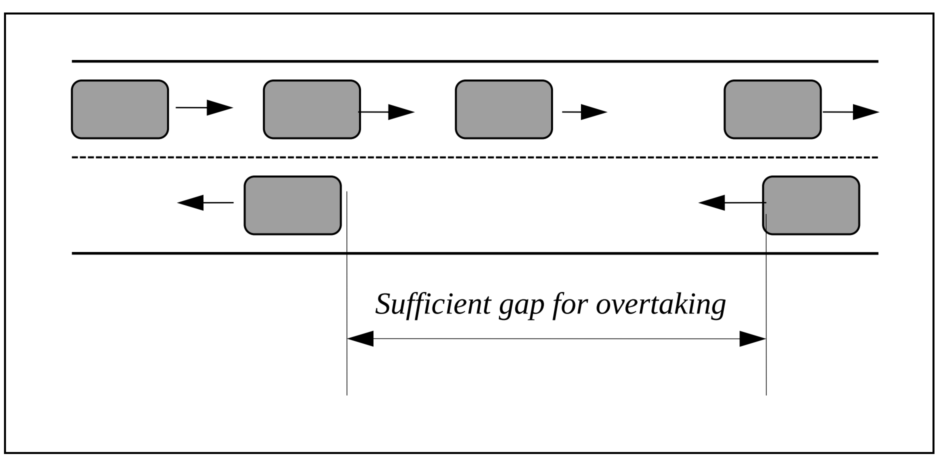


Figure 2.4 - Conditions for overtaking

Step 2

Appropriate volume / capacity ratios can be obtained from Table 2.1

Adjustment factors

f_d = use Table 2.3

f_w = use Table 2.2

f_{HV} = adjustment factor for the presence of heavy vehicles

$$f_{HV} \quad = \quad \frac{1}{\left[1 + P_T\left(E_T - 1\right) + P_B\left(E_B - 1\right)\right]}$$

P_T = percentage of trucks = 0.1

P_B = percentage of buses = 0.05

E_T = average passenger car equivalent for trucks

E_B = average passenger car equivalent for buses

From Table 2.4 obtain values for E_T and E_B for different levels of services.

Now values of f_{HV} can be computed from above equation.

LOS	P_T	P_B	E_T	E_B	f_{HV}
A	0.1	0.05	2.0	1.8	0.8772
B	0.1	0.05	2.2	2.0	0.8547
C	0.1	0.05	2.2	2.0	0.8547
D	0.1	0.05	2.0	1.6	0.8850
E	0.1	0.05	2.0	1.6	0.8850
F	0.1	0.05	-	-	-

Step 3

Compute Mean Service Flows for the different levels of services

LOS	Capacity	$(v/c)_i$	f_d	f_w	f_{HV}	*MSF* (veh/h)
A	2800	0.12	0.89	1.0	0.8772	260
B	2800	0.24	0.89	1.0	0.8547	510
C	2800	0.39	0.89	1.0	0.8547	830
D	2800	0.62	0.89	1.0	0.8850	1370
E	2800	1.00	0.89	1.0	0.8850	2210
F	2800	-	-	-	-	-

(2) Determination of level of service which the road is operating

The one-way Highest Hourly flow = 780 veh/hr

$(HHV)_{30}$ = 780 veh/hr < 830 veh/hr

Therefore the road will be operating at level of service = C at $(HHV)_{30}$

(3) Measures to be taken to improve the road condition

To improve the condition of road following measures can be taken.

1. Increase the lane width
2. Increase the shoulder width
3. Try to reduce the percentage of no overtaking sections by improving the alignment of road and lateral obstructions

Exercise 2

A 1.5 km length of a two-lane, two-way undivided rural highway with a 5% up grade has the following characteristics.

Terrain condition = level with 5% up grade
Design speed = 100 km/h
Lane width = 3.3 m
Shoulder width = 1.0 m
Directional split = 60 / 40
Percentage of trucks = 10%
Percentage of buses = 0%
Percentage with sight distance less than 450 metres = 40%
(i.e. percent of no passing zones)

By using the Highway Capacity Manual calculate MSF for different levels of service.

Solution

Step 1

Organise the given data

Design speed	100 km/h
Lane width	3.3 m
Shoulder width	1.0 m
Length	1.5 km
Grade %	5% up grade
Terrain	Level
% No overtaking	40%
Directional split	60 : 40
% Trucks	10% = 0.1
% Buses	0% = 0

Percent with sight distance less than 450 metres = 20%. This is the percentage of length of the considered road stretch available for overtaking.

Appropriate volume / capacity ratios can be obtained from Table 2.6.

Step 2

Adjustment factors

f_d = use Table 2.7

f_w = use Table 2.2

f_{HV} = adjustment factor for the presence of heavy vehicles

$$f_{HV} = \frac{1}{\left[1 + P_{HV}\left(E_{HV} - 1\right)\right]}$$

where,

$$E_{HV} = 1 + \left[0.25 + P_{T/HV}\right] \times \left[E - 1\right]$$

$P_{T/HV}$ = ratio of trucks / heavy vehicles

E = Passenger car equivalent for the specific grades on two-lane, two-way rural road

f_g = adjustment factor for passenger cars

$$f_g = \frac{1}{\left(1 + P_P \times I_P\right)}$$

where,

P_P = proportion of passenger cars in up grade

I_p = $0.02(E\text{-}E_0)$ = impedance factor for passenger cars

Now values of f_{HV} can be computed

Adjustment on specific grades

FOR HEAVY VEHICLES

$$f_{HV} = 1 \big/ \left[1 + P_{HV} \times \left(E_{HV} - 1\right)\right]$$

$$E_{HV} = 1 + \left[0.25 + P_{T/HV}\right] \times \left(E - 1\right)$$

Speed	LOS	P_{HV}	$P_{T/HV}$	E	E_{HV}	f_{HV}
88	A	0.1	1.0	12.0	14.75	0.421
80	B	0.1	1.0	5.4	6.5	0.645
72	C	0.1	1.0	3.7	4.375	0.748
64	D	0.1	1.0	3.1	3.625	0.792
56/48	E	0.1	1.0	2.7	3.125	0.825

FOR PASSENGER CARS

$$f_g = 1 \big/ \left[1 + P_p \times I_p\right]$$

$$I_p = 0.02 \times \left[E - E_0\right]$$

Speed	LOS	P_P	I_p	E	E_0	f_g
88	A	0.9	0.198	12.0	2.1	0.8487
80	B	0.9	0.076	5.4	1.6	0.936
72	C	0.9	0.046	3.7	1.4	0.960
64	D	0.9	0.036	3.1	1.3	0.969
56/48	E	0.9	0.028	2.71.3	1.3	0.975

Step 3

Compute Mean Service Flows for the different levels of services

Speed	LOS	Capacity	$(v/c)_i$	f_d	f_w	f_{HV}	f_g	*MSF* (veh/h)
88	A	2800	0.14	0.87	0.82	0.421	0.8487	100
80	B	2800	0.45	0.87	0.82	0.645	0.936	540
72	C	2800	0.79	0.87	0.82	0.748	0.960	1130
64	D	2800	0.95	0.87	0.82	0.792	0.969	1460
40-64	E	2800	1.00	0.87	0.91	0.825	0.975	1780

Table 2.1 - Level of Service Criteria for Two-Lane Two-way Rural Roads for General Terrain Classification

Level of Service	Percent Time Delayed	Average Speed [b]	Volume / Capacity Ratio [a] for Level Terrain % of length with sight distance less than 450m					
			0	20	40	60	80	100
A	< 30	> 93	0.15	0.12	0.09	0.07	0.05	0.04
B	< 45	> 88	0.27	0.24	0.21	0.19	0.17	0.16
C	< 60	> 83	0.43	0.39	0.36	0.34	0.33	0.32
D	< 75	> 80	0.64	0.62	0.60	0.59	0.58	0.57
E	> 75	>72	1.00	1.00	1.00	1.00	1.00	1.00
F	100	< 72	-	-	-	-	-	-
Level of Service	Percent Time Delayed	Average Speed [b]	Volume / Capacity Ratio [a] for Rolling Terrain % of length with sight distance less than 450m					
			0	20	40	60	80	100
A	< 30	> 91	0.15	0.10	0.07	0.05	0.04	0.03
B	< 45	> 86	0.26	0.23	0.19	0.17	0.15	0.13
C	< 60	> 82	0.42	0.39	0.35	0.32	0.30	0.28
D	< 75	> 78	0.62	0.57	0.52	0.48	0.46	0.43
E	> 75	> 64	0.97	0.94	0.92	0.91	0.90	0.90
F	100	< 64	-	-	-	-	-	-
Level of Service	Percent Time Delayed	Average Speed [b]	Volume / Capacity Ratio [a] for Mountain Terrain % of length with sight distance less than 450m					
			0	20	40	60	80	100
A	< 30	> 90	0.14	0.09	0.07	0.04	0.02	0.01
B	< 45	> 86	0.25	0.20	0.16	0.13	0.12	0.10
C	< 60	> 78	0.39	0.33	0.28	0.23	0.20	0.16
D	< 75	> 72	0.58	0.50	0.45	0.40	0.37	0.33
E	> 75	> 56	0.91	0.87	0.84	0.82	0.80	0.78
F	100	< 56	-	-	-	-	-	-

a. Ratio of the flow rate to an ideal capacity of 2,800 pc/h
b. Average speed of all vehicles in km/h for roads with a design speed equal to or greater than 100 km/h
For roads with lesser design speed, reduce the speed by 6 km/h reduction in design speed.

(Source : US Highway Capacity Manual)

Table 2.2 - Adjustment Factors for the Combined Effect of Narrow Lanes and Restricted Shoulders

Usable Shoulder Width (m)[a]	3.7m Lane		3.3m Lane		3.0m Lane		2.7m Lane	
	LOS A to D	LOS[b] E	LOS A to D	LOS[b] E	LOS A to D	LOS[b] E	LOS A to D	LOS[b] E
> 2	1.00	1.00	0.93	0.94	0.84	0.87	0.70	0.76
1	0.89	0.96	0.82	0.91	0.75	0.84	0.63	0.73
0	0.70	0.88	0.65	0.82	0.58	0.75	0.49	0.66

a. When the shoulder width is different on each side of the road, use the average shoulder width
b. This factor applies for all speeds less than 70 km/h
c. LOS is level of service

(Source : US Highway Capacity Manual)

Table 2.3 - Adjustment Factors for Directional Distribution of Traffic on General Terrain Segments

Directional Distribution	100 / 0	90 / 10	80 / 20	70 / 30	60 / 40	50 / 50
Adjustment Factor f_d	0.71	0.75	0.83	0.89	0.94	1.00

(Source : US Highway Capacity Manual)

Table 2.4 - Average Passenger Car Equivalents for Trucks and Buses on Two-Lane Highways on General Terrain Segments

Vehicle Type	Level of Service	Type of Terrain		
		Level	Rolling	Mountainous
Trucks (ET)	A	2.0	4.0	7.0
	B and C	2.2	5.0	10.0
	D and E	2.0	5.0	12.0
Buses (EB)	A	1.8	3.0	5.7
	B and C	2.0	3.4	6.0
	D and E	1.6	2.9	6.5

(Source : US Highway Capacity Manual)

Table 2.5 - Maximum AADTs for the Various Levels of Service and Types of Terrain on Two-Lane Two-Way Rural Roads

K Factor [a]	Level of Service				
	A	B	C	D	E
Level Terrain					
0.10	2,400	4,800	7,900	13,500	22,900
0.11	2,200	4,400	7,200	12,200	20,800
0.12	2,000	4,000	6,600	11,200	19,000
0.13	1,900	3,700	6,100	10,400	17,600
0.14	1,700	3,400	5,700	9,600	16,300
0.15	1,600	3,200	5,300	9,000	15,200
Rolling Terrain					
0.10	1,100	2,800	5,200	8,000	14,800
0.11	1,000	2,500	4,700	7,200	13,500
0.12	900	2,300	4,400	6,600	12,300
0.13	900	2,100	4,000	6,100	11,400
0.14	800	2,000	3,700	5,700	10,600
0.15	700	1,800	3,500	5,300	9,900
Mountainous Terrain					
0.10	500	1,300	2,400	3,700	8,100
0.11	400	1,200	2,200	3,400	7,300
0.12	400	1,100	2,000	3,100	6,700
0.13	400	1,000	1,800	2,900	6,200
0.14	300	900	1,700	2,700	5,800
0.15	300	900	1,600	2,500	5,400

a. K is the ratio of the design hour volume to the annual average daily traffic
b. All values rounded to the nearest 100 vehicles per day. Assumed conditions include 60/40 directional split, 14 percent trucks, and 4 percent buses. Percentage of length with no overtaking for level, rolling and mountainous terrain of 20, 40 and 60 have been assumed.

(Source : US Highway Capacity Manual)

Table 2.6 - Volume / capacity ratios for varying percent upgrades. Average upgrade speeds and percent length with sight distance less than 450m

Percent Upgrade	LOS	Average Upgrade Speed (km/h)	Volume/Capacity Ratios [a] Percent of Length with Sight distance less than 450m					
			0	20	40	60	80	100
3	A	88	0.27	0.23	0.19	0.17	0.14	0.12
	B	80	0.64	0.59	0.55	0.52	0.49	0.47
	C	72	1.00	0.95	0.91	0.88	0.86	0.84
	D	64	1.00	1.00	1.00	1.00	1.00	1.00
4	A	88	0.25	0.21	0.18	0.16	0.13	0.11
	B	80	0.61	0.56	0.52	0.49	0.47	0.45
	C	72	0.97	0.92	0.88	0.85	0.83	0.81
	D	64	1.00	1.00	1.00	1.00	1.00	1.00
5	A	88	0.21	0.17	0.14	0.12	0.10	0.08
	B	80	0.57	0.49	0.45	0.41	0.39	0.37
	C	72	0.93	0.84	0.79	0.75	0.72	0.70
	D	64	0.98	0.96	0.95	0.94	0.93	0.92
	E-F	56	1.00	1.00	1.00	1.00	1.00	1.00
6	A	88	0.12	0.10	0.08	0.06	0.05	0.04
	B	80	0.48	0.40	0.35	0.31	0.28	0.26
	C	72	0.85	0.76	0.68	0.63	0.59	0.55
	D	64	0.97	0.91	0.87	0.83	0.81	0.78
	E-F	56	1.00	0.96	0.95	0.93	0.91	0.90
	E-F	48	1.00	0.99	0.99	0.98	0.98	0.98
7	A	88	0.00	0.00	0.00	0.00	0.00	0.00
	B	80	0.34	0.27	0.22	0.18	0.15	0.12
	C	72	0.77	0.65	0.55	0.46	0.40	0.35
	D	64	0.93	0.82	0.75	0.69	0.64	0.59
	E-F	56	1.00	0.91	0.87	0.82	0.79	0.76
	E-F	48	1.00	0.95	0.92	0.90	0.88	0.86
a. Ratio of flow rate to ideal capacity of 2,800pc/h, assuming passenger car operation is unaffected by grades.								

(Source : US Highway Capacity Manual)

Table 2.7 - Adjustment factors for directional distribution of traffic on specific grades (f_d)

Percent of Traffic on Upgrade	Adjustment Factor
100	0.58
90	0.64
80	0.70
70	0.78
60	0.87
50	1.00
40	1.20
30	1.50

(Source : US Highway Capacity Manual)

Table 2.8 - Passenger car equivalent for specific grades on two-lane two-way rural roads

Percent Grade	Length of Grade (km)	Average Upgrade Speed km/h				
		88	80	72	64	48
0	all	2.1	1.6	1.4	1.3	1.3
		A	B	C	D	E
3	0.5	3.1	2.1	1.8	1.6	1.5
	1.0	4.2	2.6	2.1	1.9	1.8
	1.5	6.0	3.3	2.5	2.2	2.1
	2.0	8.0	4.3	3.0	2.6	2.3
	3.0	17.0	6.3	4.3	3.5	2.8
	4.0	36.0	8.8	5.9	4.6	3.3
	6.0	a	18.0	10.0	7.2	4.6
4	0.5	3.5	2.4	1.9	1.8	1.7
	1.0	5.3	3.1	2.5	2.2	2.0
	1.5	8.5	4.2	3.0	2.5	2.3
	2.0	13.0	5.9	4.0	3.2	2.8
	3.0	35.0	10.0	6.4	4.9	3.6
	4.0	a	15.0	10.0	7.1	4.7
	6.0	a	43.0	20.0	12.0	6.9
5	0.5	4.0	2.5	2.1	1.9	1.8
	1.0	6.9	3.8	2.8	2.4	2.2
	1.5	12.0	5.4	3.7	3.1	2.7
	2.0	24.0	7.8	5.1	4.1	3.3
	3.0	70.0	16.0	9.2	6.9	4.6
	4.0	a	27.0	16.0	11.0	6.3
	6.0	a	a	47.0	22.0	10.0
6	0.5	4.6	2.8	2.3	2.0	1.9
	1.0	8.7	4.5	3.3	2.8	2.5
	1.5	17.0	7.0	4.5	3.7	3.1
	2.0	36.0	12.0	6.7	5.2	4.0
	3.0	a	25.0	14.0	9.6	5.9
	4.0	a	50.0	27.0	17.0	12.0
	6.0	a	a	77.0	40.0	16.0
7	0.5	5.3	3.1	2.4	2.2	2.0
	1.0	11.0	5.2	3.7	3.1	2.7
	1.5	26.0	8.8	5.5	4.4	3.6
	2.0	60.0	16.0	8.8	6.6	4.8
	3.0	a	40.0	20.0	14.0	7.6
	4.0	a	a	44.0	27.0	12.0
	6.0	a	a	a	a	26.0
a. Speed not attainable on the grade.						

(Source : US Highway Capacity Manual)

Chapter 3

Traffic management

Contents

Objectives

This chapter provides an overview of the traffic management techniques that are available in controlling traffic over a length of road or over an area to achieve specified objectives in arterial roads and roads running through local areas. At the end of the chapter the reader should have knowledge and understanding of the different types of traffic management techniques that could be adopted for different conditions and environments. At the end of the chapter the reader should also be able to select the appropriate technique to be adopted as a management tool depending on the nature of the traffic, and expected objectives and functions at a particular location or area.

3.1 Introduction

Traffic management can be defined as the application of specific traffic control practices over a length of road or over an area to achieve specified objectives, which may be set by government (on arterial roads) or by municipalities (on local streets).

According to the above definition a range of traffic management techniques may be appropriate to meet particular objectives. Traffic management objectives and practices differ greatly between arterial roads and local streets. Hence in this chapter, arterial road traffic management and local road traffic management are described in two different sections.

3.2 Arterial road traffic management

Arterial roads can be defined as those roads that predominantly carry through traffic from one region to another region, and which form the principal avenues of communication for traffic movement.

The prime function of the arterial road system is to provide for major regional and inter-regional traffic movement in a safe and operationally efficient manner. The ability and need for particular arterial road to perform this function often depend on the competing functions which it must also undertake. For main arterial roads, commercial or industrial access requirements, or local public transport priorities may need to be given significant weight in developing suitable traffic management strategies.

In arterial roads traffic management is conducted with the objective to ensure safety, mobility and good environment. Some of the measures that could be adopted in arterial road traffic management are to introduce measures:

- to give priority to the arterial road at intersections by means of stop or give way signs, traffic signals etc.
- to control access to the arterial road by means of turn regulation, one-way sections, vehicle bans, channelisation, median island or guard rail.
- to eliminate hazardous objects or movements and increase capacity on arterial roads, by parking control, turn regulations, U-turn regulations, no lane-change, lane-use control, one-way, channelisation etc.
- to reduce the relative difference of speed in order to achieve compatibility among vehicles and reduce the severity of accidents by means of limiting the speed.
- to reduce noise, vibration or other nuisance caused by vehicular traffic by means of limiting the speeds, introducing vehicle bans or signals.

3.2.1 Different types of traffic management techniques adopted in arterial roads

The basic techniques that should be given consideration when planning for good traffic management is:

– to simplify traffic flow in order to achieve similarity among components and stabilize the traffic flow
– to segregate road uses in space and time in order to reduce conflicts and to simplify traffic flow
– to increase capacity in order to accommodate more vehicles
– to restrain traffic in order to reduce traffic volume.

The basic elements that can be used to achieve effective traffic management practice are as follows:

1 Speed Limits

Speed limits are introduced with the following objectives:
1. to simplify traffic flow by reducing difference of speed (improves safety and mobility)
2. to reduce the severity of accidents by reducing the speed (improves safety)
3. save fuel by avoiding excessive speeding (energy saving)
4. helps to have enough reaction time for drivers and pedestrians (improves safety)

Disadvantages:
* sometimes low speed limits may cause congestion and drivers may incline to disregard it.

2. Turn Regulations

Turn regulations are introduced with the objectives of
1. to increase safety by reducing conflict points
2. to increase capacity at intersections

Disadvantages:
* additional travel and increased turning movements at other locations
* delays due to additional turning movements

3. U-turn Regulations

U-turn regulations are introduced with the objectives of
1. to simplify traffic flow and increase capacity by eliminating U-turn movements in order to ensure safe and efficient flow

Disadvantages:

* additional travel
* increased turning movements at other locations
* delays due to additional turning movements

4. Parking Controls

Parking controls are enforced with the objectives

1. to increase capacity by freeing road space for the use of traffic in movement
2. to provide drivers a good vision field and to simplify traffic flow by eliminating parked vehicles
3. to increase parking revenue by having a time control on parking
4. to restrain traffic volume by prohibiting long-time parking
5. to transfer people from private cars to public transport in order to reduce traffic congestion

Disadvantages:

* increased walking distance
* circulating vehicles searching for parking spaces
* effects on environment by increasing through traffic
* traders loosing customers due to lack of on-street parking

5. No Standing

No standing situation is different from no parking situation, and could be explained as follows:

Standing is halting a vehicle temporally for a brief interval for receiving or discharging passengers. When a sign indicates no standing, a vehicle is not allowed to have even a brief stop to pickup or discharge passengers.

Parking is halting other than temporally with the engine stopped. Hence when a sign indicates no parking, a vehicle may stand for a while to pick up or discharge passengers but not allowed to stop the vehicle with the engine off. Therefore no standing is a more serious restriction to a driver than no parking.

No standing is implemented with the objectives

1. to increase capacity by freeing road space for the use of traffic mobility
2. to secure vision field for driving and avoid weaving maneuvers by eliminating standing vehicles on carriage way.

Disadvantages:

* increased walking distance
* reduced places for loading and unloading

6. Give way

The give way sign indicates to observe the right-of-way rule.

Right-of-way Rule

– when two vehicles enter an intersection from different approaches at approximately the same time, the driver of the vehicle on the left shall give way (yield) to the vehicle on right.
– the driver of a vehicle intending to turn to the left shall give way (yield) to any approaching vehicle from the right.
– the driver of a vehicle approaching a roundabout should give way (yield) to any vehicle already in the roundabout
– at marked pedestrian crossings the drivers should always give way to the pedestrians on the crossing.

The give way signs are introduced with the objectives:

1. to segregate major traffic from minor traffic and to give priority to the major flow by showing the right-of -way.
2. to indicate the drivers who has the priority at an intersection and avoid confusion.

Disadvantages:

* sometimes a queue in the minor road flow
* may not be effective when traffic on both roads are heavy

7. Channelisation of traffic

Traffic is channelised with the objectives:

1. to smoothen the traffic flow by restricting the drivers choice, reducing the conflict points and correcting the intersecting angles
2. to guide the traffic to a suitable course
3. to reduce the area of conflicts by controlling intersecting traffic streams by making they intersect at or near right angles.

4. to ensure low relative speeds between merging traffic by making the streams merge at small angles.
5. to discourage prohibited or undesirable movements
6. to protect pedestrians from turning or crossing vehicles by providing refuge.

Disadvantages:

* when drivers do not observe, it is difficult to correct them.
* continuous lane marking and regular maintenance may be costly.

8. No lane-change

No lane-change at certain sections of roads is implemented with the following main objectives:

1. to simplify traffic flow by eliminating weaving movements.
2. to make the road section safer.

Disadvantages:

* delay in certain lanes when distribution of traffic over the whole lane changes.
* unless strict lane discipline is maintained by the drivers this will be very hard to implement.

9. No overtaking

No overtaking sections of roads are implemented with the objectives:

1. to segregate opposing flows
2. to prevent accidents due to overtaking maneuvers
3. to create safe and stable flow

Disadvantages:

* delays may cause due to slow moving vehicles.

10. One-way

One-way sections are implemented with the objectives:

1. to increase capacity and travel speed by eliminating opposing vehicles performing right turns
2. traffic signals could be linked in a simple progressive pattern
3. to reduce conflict points by segregating traffic by its direction
4. may discourage undesirable through traffic in residential areas.

Disadvantages:

* diverting traffic or additional travel distance
* effects on public transport routes and increased walking distance for the passengers
* effects on traders
* hazards at transition areas between one-way and two-way operation
* confusion for strangers

11. Bus lanes

There are lanes reserved only for buses. The bus lanes may introduced with the following objectives:

1. to reduce the travel time of buses by reserving lanes for the exclusive use of buses
2. to restrain vehicle traffic by encouraging the use of buses and discouraging the use of private cars

Disadvantages:

* to be effective if strict lane discipline should be maintained
* problems at intersections because of turning movements
* reduced space available for other vehicles

12. Vehicle Ban

Certain vehicles can be banned entering particular areas if required. These vehicle bans can be introduced with the objective:

1. to eliminate particular categories of vehicles or all of them due to:
    - security reasons
    - ease congestion
    - improve traffic flow
    - discourage private vehicles

Disadvantages:

* increased flow of diverted traffic and increased travel distance
* effects on particular business
* diversion of public transport

3.2.2 Urban arterial roads

In urban arterial roads the traffic management should be conducted to ensure safety, mobility and good environment condition which is necessary for smooth functioning of urban areas. The measures that can be taken to achieve these expectations are:

(a) Re-allocate traffic over existing road network by means of re-allocation measures.

(b) Restrain vehicular traffic in order to adjust it to existing road network, by means of restraint measures.

(c) Integrate available measures in order to reinforce each other and achieve optimum pattern of traffic flow as a whole bb means of integration measures.

(a) Re-allocation measures

This is to re-allocate the demand for traffic over existing road network according to the functions of road, by taking account of the characteristics of abutting land.

- The functions of the different types of roads.

1) Arterial roads

These roads serve for carrying heavy through traffic, controlled by arterial control or special routing.

2) Collector roads.

Collector roads serve for collecting local traffic and distributing it to access streets.

3) Local streets.

Local streets serve for providing direct access to abutting land. Through traffic is being discouraged on these roads.

- Characteristics of abutting land

– residential area
– school area
– shopping area
– industrial area
– business area (commercial area)

(b) Restraint measures

This is to take measures to discourage the use of private vehicles and encourage the use of public transport. Although private vehicles are restrained the overall mobility, environment, energy conservation and safety are improved in the system. The use of private vehicles are discouraged by means of

– parking control
– providing bus lanes
– vehicle ban
– pedestrian precinct

(c) Integration measures

This is to combine elements so that they do not contradict each other and that they compensate adverse effects or reinforce mutually. It generally covers the whole area and tries to co-ordinate actions of concerned agencies and people.

3.2.3 Rural arterial roads

In rural arterial roads the traffic management should be conducted to ensure safety and good environmental condition in the rural areas.
The measures that can be taken to achieve above expectations are:

a) To divert through traffic from rural residential or shopping areas. This may be achieved through, local bypasses, turn regulations, one way sections, vehicle bans, speed limits, parking control, pedestrian precinct, special routing.
b) To restrict pedestrian crossing points and make them visible to the approaching vehicles. This may be achieved through pedestrian crossings and warning signs.
c) To bring vehicles to low speeds where crossing movements are inevitable to improve safety and reduce the severity of accidents. Speed limit will help to achieve the objectives.
d) To prevent head-on collisions due to overtaking maneuvers by means of no overtaking zones.
e) Give advance warning of hazardous conditions such as bends, crests, railway crossings, slopes, and slippery road stretches by means of warning signs or warning devices.

3.3 Local Area Traffic Management (LATM)

Although *Local Area Traffic Management (LATM)* is not much familiar in Sri Lanka, this is an area where much attention is paid in the developed countries. In this section LATM concept is attempted to introduce briefly. Before commencing this section the following definitions will be useful to have a proper understanding of the concept.

Definitions:

- Local street

  Local street may have the following typical functions

  1) Provide vehicular access to abutting properties and other properties within a local area.
  2) Provide network for the movement of pedestrians and cyclists.
  3) Provide means to enable social interaction within a neighborhood.
  4) Improve the ‘living’ environment.

- Local area

  A ‘local’ area is defined as an urban area containing local roads and bounded by arterial and sub-arterial roads or other limiting features such as rivers, railway lines or limit of urban development.

- Local precincts

  Local precincts are areas within a local area where specific local problems exist related to the speed of traffic and/or pedestrian crossing difficulties. These areas are suitable for site specific traffic measures or the installation of shared traffic zones.

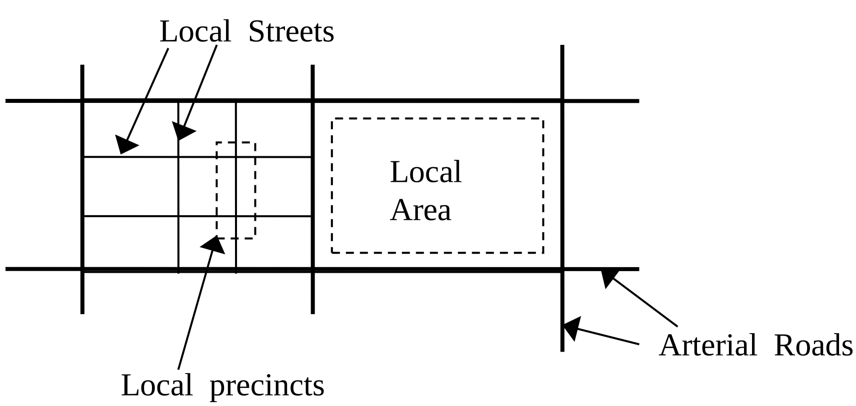


Figure 3.1 - Definition of a local area

3.3.1 Introduction to LATM

Local Area Traffic Management (LATM) is a means whereby various traffic management techniques are used in an area to modify traffic conditions without limiting access for local residents. These improvements have been achieved by the implementation of local area traffic management schemes which have incorporated various devices for reducing traffic speeds and improving pedestrian safety in predominantly residential areas.

3.3.2 Public participation

In LATM projects, before a scheme is launched it is important to have an active public involvement to assist to draw up the traffic management strategies which are broadly acceptable to the public. If these schemes are not properly discussed with the public before launching them they can create division within the community. For any scheme to be successful, it must be seen by the majority of residents as necessary. It should also be prepared in close consultation with the local residents. This type of approach is likely to ensure that the scheme is sufficiently robust to withstand opposition from disadvantaged sectors of a local community. A well designed public participation programme can greatly assist authorities in developing a workable traffic schemes which are acceptable to the maximum possible proportion of the public.

To design local traffic measures which are acceptable to the public the traffic planner must be thoroughly aware and accept the needs of various sectors within the community, and of how any changes would affect their interests and aspirations. An important objective of a public participation programme is the early determination of affected community sectors, and the needs of these sectors. These needs can then be incorporated or fitted in to the framework of the traffic objectives.

The following are some of the community groups that can be consulted before developing a LATM scheme; residents action groups, directly affected individuals, bus operators (public and private), service authorities such as police, ambulance, fire, taxi operators, local politicians, community groups and other ethnic organizations, the adjacent local councils etc.

Enlisting the active participation of such groups may assist in community acceptance of traffic scheme. It should be remembered that simply informing the public does not constitute public participation. Participation should include consultation as well as the publication of information.

Objectives of public participation

The aim of such a programme is to accommodate as many of the transport and social needs of the various community sectors as possible; while still achieving basic traffic control objectives. This in turn requires the setting of realistic traffic control objectives.

A public participation programme should be aimed at the following tasks:

- identify the perceived traffic problem
- determine the needs of residents and other affected groups (i.e. setting goals and objectives)
- obtain the active support of advantaged groups, neutral and influential parties
- to resolve conflicts with affected groups
- promote the scheme to the public

By the identification of the issues through public participation it is possible to design schemes which alleviate the problems of the majority. Striking a balance between the needs of these groups can be one of the more challenging tasks facing the traffic planner. The solutions to perceived problems from residents should be directed to residents to ascertain their comments. If support for the proposed traffic scheme is not forthcoming, then the rejection of the scheme should be seriously considered.

3.3.3 Measures taken in LATM schemes

Various traffic control measures are used in implementing a LATM scheme. These traffic regulatory measures should be implemented in a local area with the concept of majority of the residents living in the area.

LATM schemes can involve a range of devices including both regulatory control and geometric control measures. The use of *regulatory control measures* is a well developed area of traffic engineering whereas *geometric control measures* are still not in advanced stages.

(1) Regulatory controls

Regulatory controls involve the use of signs to indicate a restricted movement. There are number of regulatory controls which can be used as alternatives to the geometric devices and they include the following:

1. Give way signs
2. Stop signs
3. Turn bans
4. One-way streets
5. Heavy traffic bans
6. Speed limits

(2) Geometric controls

Geometric controls involve designing road carriage-way in such a way to manage the traffic in the desired manner. Following are some of the geometric controls applied in LATM schemes.

1. Road closure - this is where a street is fully closed off at an intersection or mid-block location, but vehicles still have access to all properties in the street. Through traffic is prevented with measure.
2. Restriction channelisation - through median islands the traffic can be channelised to reduce the speed and improve safety of both pedestrians and drivers.
3. T-Intersection treatment - T-intersections can be improved with roundabouts or intersection treatments with centre-medians.
4. Carriageway narrowing - the capacity of wide residential streets are reduced by restricting the pavement width at selected locations. Such narrow sections can be used for pedestrian crossings.
5. Speed Humps - the function of a speed hump is to vertically displace a vehicle and give the occupants some kind of uncomfortability if the expected speed limit is exceeded. Speed humps when correctly designed and placed can be very effective in reducing vehicular speeds.
6. Roundabouts - they by allocating priority uniformly to each approach, reduces delays on those approaches which may previously controlled. In addition, through the reduction of vehicle speeds and the nature of vehicle conflict points within the intersection, the number and severity of accidents are reduced.

7. Pedestrian mid-block islands - a mid-block island acts as a capacity constraint. If a series of islands is installed, this by reducing the capacity and speed improve the safety of pedestrians.
8. Slow points - although slow points are not to be seen in this country, this is an effective way of reducing the speeds in local roads and improving the road safety in the area. A slow point reduces vehicle speeds on a straight length of residential road by creating a short ‘S’ bend which must be negotiated at a slow speed. The speed at which a slow point will be negotiated can be varied according to the design adopted.

In a successful LATM scheme it is often necessary to incorporate a range of measures of regulatory controls as well as geometric controls. There are instances where techniques other than those which are mentioned above may be appropriate. Hence LATM is still an evolving process, and not yet practiced in Sri Lanka.

<u>Chapter 4</u>

Road safety and accident studies

Contents

Objectives

The objective of this section is to give the reader an understanding of the importance of road safety, and examine the methods available for traffic safety studies. This chapter also offers a description of accident data collection, analysis of accident data, and the presentation of results.

4.1 Introduction - Traffic safety studies

Traffic safety is one of the major considerations in all the traffic management schemes. The occurrence of accidents constitutes a loss to the society. These losses could be in terms of (1) direct losses, and (2) indirect losses.

(1) Direct losses are the loss of life, injuries, damage to vehicles and other property etc.
(2) Indirect losses are the loss of productivity, repair costs, insurance costs, rehabilitation costs and losses resulting from induced congestion etc.

All these losses eventually affect the economy. Therefore there is a need to reduce the number of accidents occurring annually. Traffic safety studies are detail studies made to determine the factors contributing to the occurrence of accidents and finding ways to prevent these accidents. Proper identification of contributory factors is needed to find solutions to prevent the occurrence or mitigate the effect of accidents.

4.2 Causes for accidents

Before looking into accident analysis and preventive measures of accidents, first let us generally look at the causes for accidents on roads. There are five main factors contributing to crashes and injuries on our roads. These need to be addressed carefully in improving the road safety.

- speeding
- negligence of road rules
- drunk driving
- fatigue
- poor condition of vehicle and roads

There are many other less significant factors, of course, but these five are of greatest significance.

4.2.1 Speeding

Majority of local road accidents and fatal crashes involve speed as a major factor. Speeding means not only travelling faster than the designated limit, but also travelling faster than that is suitable for the road conditions at the time. This can result in crashes. Adverse conditions such as rain, drizzle, night driving, pedestrians on road, bad road stretches or heavy traffic are just some that require drivers to decrease their speed.

4.2.2 Negligence of road rules

In Sri Lanka it is an obvious fact that almost all road rules are breached by local drivers. This happens by drivers both knowingly and unknowingly. Continuous driver education programmes through media and driving schools may be a solution to some extent. It should be encouraged programmes such as defensive driving, advance driving, and safe driving programmes for fleet operators and public. Continuous driver education programmes are necessary to improve the road rules and road manners. Safe driving is very much a matter of awareness (of hazards) and behaviour (for safe driving practices). High priority should be given on defensive driving courses with emphasis on vehicle control skills and knowledge of road rules. It is also sensible to take policy measures to restrict the imports of incompatible vehicles such as three wheelers which help largely to breach the road rules.

4.2.3 Drunk driving

There is a common misconception among some drivers that a small dosage of alcohol improves their driving ability. It is a well proven fact that alcohol affects ones driving skills. Even where people look and act as if they are not affected by alcohol, the fact is that they cannot drive as usual. Alcohol is a depressant, it slows your brain functions. It reduces your ability to respond to situations, make decisions and take actions. Police should be responsible for carrying out more frequent road-side tests and implement the law.

4.2.4 Driver fatigue

Another major contributor to fatal accidents is driver fatigue. Drivers should avoid fatigue by planning their schedules realistically, by resting before start of a long journey, by stopping for appropriate rest breaks. Avoid driving during normal sleeping hours. Most accidents caused by fatigue occur between 11pm and 7am, the body's normal sleeping time. Another high risk time is early to mid-afternoon. This does not mean that driver fatigue only happens in those periods, but it is when one is most likely to suffer the effects.

To avoid fatigue related accidents watch for the signs of tiredness, restlessness, body aches, lazy steering and sore eyes. At the first sign of these symptoms, pull over at the nearest safe place and rest until you feel completely alert.

4.2.5 Condition of vehicle and condition of roads

Condition of vehicles and the condition of the road itself are two other important factors where road safety is concerned. For minimum accident risk the condition of brakes, lamps and reflectors, tyres, wind-screen wipers, rear vision mirrors should be in good condition. It should be the responsibility of the driver and vehicle owner to get them attended to if they are defective and to have them in good condition all the time. Since no compulsory vehicle fitness tests or road worthiness tests are conducted in this country due to economic restrictions this is an area which is badly overlooked in the country. By looking at the increasing number of accidents it will be advisable for the traffic police to look in to their books to investigate what percentage of accidents are responsible due to the poor condition of vehicles and come-out with their proposals. It is also the responsibility of the highway authorities to look in to the black spots where a lot of accidents are taking place and take action to eliminate them.

4.2.6 Other factors

There are many other contributing factors to road accidents which must be closely watched. Heavy vehicles are a problem on city roads. Proper driver training is fast becoming a must for fleet operators. Every effort should be taken to transfer container movement from road to railway as much as possible to minimise heavy vehicles on national highways. Another problem is the indiscipline bus drivers. They are a main threat to the safety on our roads. Strict rules such as prohibition of a bus to overtake another bus unless due to a valid reason, maintain a minimum headway between buses etc. may be introduced.

4.3 Traffic safety study measurement methods

Traffic safety studies are conducted based on three broad measures.

(1) Measures based on reported accidents

(2) Measures based on traffic conflicts

(3) Measures based on public assessment of traffic safety

4.3.1 Measures based on reported accidents

Traffic safety studies can be conducted based on the reported accidents. In most countries the type of accidents are grouped into the following categories:

- Fatal accidents - These are accidents where at least one person is killed in the accident.
- Minor injury accidents - At least one person is seriously injured (i.e. admitted to hospital) but no one is killed.
- Major injury accidents - At least one person is injured but no one is killed or admitted to hospital.
- Property damage type accidents - No one injured but vehicle or road property damaged.

(In some countries both major and minor injury accidents are categorised under one group)

The traffic accidents can be sub-divided according to the following important factors.

- Accident type - depending on single or multiple accidents, transport modes involved in the accident, manoeuvres before the accident etc.
- Persons involved - according to age, sex and other social and physical indications.
- Location - according to road category, surface condition, whether inside or outside built-up areas, at intersections or mid-blocks, curves or straight sections etc.
- Time - by season, day of the weak, hour of the day.
- Circumstances - day light or in dark, dry or rainy.
- Traffic characteristics - hourly volume, speed distribution etc.

Information of this nature makes it possible to establish different 'indicators' of traffic safety. The absolute number of accidents is the most direct indicator of safety, and is the basic interest, for example, in 'before and after studies' ('before and after studies' will be discussed later in this chapter). A grouping of accidents with respect to seriousness gives additional information.

Level of safety

The number of accidents related to population is a good way of describing the level of safety. This measure can be used to compare the accident situations in different countries or in different cities within countries.

Accident rate

Accident rate is denoted as the number of accidents related to traffic. For road sections, the accident rate is usually expressed in terms of accidents per million vehicle-kilometres and for intersections in terms of accidents per million vehicles passing through the intersection. The accident rate is a commonly used measure of the safety level for various road sections and junctions because of the strong relationship between the number of accidents and the traffic flow. For comparisons between different transport modes, the most suitable indicators are:

(1) For passenger transport - the number of accidents (whether fatal, injury or property damage) per million passenger-kilometres.

(2) For goods transport - the number of accidents (whether fatal, injury or property damage) per million tonne-kilometres.

4.3.2 Measures based on traffic conflicts

Traffic conflicts can be classified and counted and can be used to measure traffic safety similar to reported accidents. Although several methods are available to suggest which type of conflicts should be reduced or avoided, it is hard to predict exactly the occurrence of these conflicts. Therefore the traffic conflict studies are hard to carry out and difficult to say whether conflict studies have a higher potential than reported accident studies when measuring traffic safety.

4.3.3 Measures based on the public assessment of traffic safety

In principle, it is possible to rank public assessments of traffic safety with a view to setting priorities for governmental actions. However, since analyses based on a certain amount of subjective assessment, like conflict analyses, still need much development in order to become useful tools in the quantification of traffic safety. Public assessments based almost exclusively on subjective grounds are not discussed in detail at this level.

4.4 Data collection

4.4.1 Data sources

There are several sources where road accident data can be obtained each having particular objectives which influence the extent and nature of the information collection. The most common sources are:

- Police Department accident reports
- Coronial inquest reports (where available)
- Hospitals (regarding severity of injuries)
- Road Authority reports on fatal and other road crashes
- Insurance company records (if obtainable)

In general, modest use is made of data from sources such as hospitals, coronial inquests and insurance company records.

Most road authorities collect certain information on fatal and some other road crashes particularly where litigation may arise from the circumstances relating to the crash or where a claim may be made with respect to damage to the road authorities' assets. Data from this source is also of limited use in general road crash analysis.

4.4.2 Police department road crash reports

In Sri Lanka, the police department is the sole authority for the initial investigation of any road crash. Their reports are the most common source of road crash data. This comprises data collected at the site of all 'reported' road crashes, and is collected in a database in the police department. Regarding 'property damage type' accidents, since they are mostly not getting recorded in the police; this information has to be obtained from various insurance companies which are involved.

Kumarage et al. (2003) has shown that road accidents are steadily increasing over the years on Sri Lankan roads and also has indicated that; in addition to the rapidly increasing vehicle fleet, following contributory factors have been mainly responsible for this high accident rate.

- the rapid increase in the amount of travel undertaken by the population
- shift from relatively safe form of transport such as public transport to extremely unsafe modes such as the motor cycle
- combine effect of ineffective enforcement and blatant violation of road rules
- poor road design
- lack of safety interventions and poor maintenance programmes
- high percentage of dangerous vehicles such as; recklessly driven private buses and heavy vehicles, three-wheelers and motor cycles etc.

4.4.3 Reporting and recording criteria

The criteria for reporting the data should be maintained in the following format.

NAME OF TOWN :

STREET NAME :

TIME :

* Date of Accident : (day/month/year)
* Time of Day of Accident : (hour: minute)
* Accident Report No:

LOCATION :

* Name & Type of Identifying Object :
* Distance from the Identifying Object :
* Direction from the Identifying Object :

WEATHER :

* Weather Type : (sunny, rainy, cloudy)
* Road Surface Condition : (wet, dry, ice)

VEHICLES INVOLVED :

* Type of Vehicles / Roadside Objects Involved :
* Sex and Age of Driver :
* Direction of Travel :
* Street of Travel :
* Stated Speed of Vehicle :

SEVERITY OF ACCIDENT :

* Severity of Accident : (Fatal, Major Injury, Minor Injury, Property Damage)
* Number of Persons Killed :
* Number of Persons Seriously Injured :
* Number of Persons with Minor Injuries :
* Number of Tow away Accidents :

DESCRIPTION OF THE ACCIDENT :

4.5 Accident analysis

Once the accident data is collected, the analysis can be carried-out as a long-term traffic management scheme or short-term traffic management scheme depending on the level of investigation. To conduct a comprehensive accident analysis it is suggested to collect complete accident information at-least over a period of 5 years, or more.

4.5.1 Long-term traffic management schemes

This is a detailed study to determine the factors contributing to the occurrences of accidents. In general there are two methods available in the analysis of accidents in long-term traffic management schemes.

The clinical method

This method involves studying an accident to determine how and why it happened and to draw conclusions from the particular event as to how such accidents may be avoided. This method is used when the type of accident is extremely rare and costly (e.g. air-craft crashes, major marine disasters).

Statistical method

In this method information is sought concerning circumstances or factors which are supposed to contribute to accidents. The circumstances might relate to some characteristics of the vehicle, to the condition of the road, or to the driver in terms of age, sex, personality, alcohol condition or many other factors. An attempt is made to secure precisely the same kind of information for each traffic unit involved in an accident. Then, these data are analysed statistically to determine which of the factors are present in accidents under certain circumstances. The statistical method requires large amounts of standardised data which is examined for relationships with the use of mathematical models. The difference in clinical method is that it seeks, only special relevant data in a smaller number of cases and searches for relationships by interpretation of data.

4.5.2 Short-term traffic management schemes

There are two methods of accident analysis in short-term traffic management schemes.

Before and after studies

Before and after studies are becoming more and more common for traffic safety evaluations. This method can be applied in the same way for both reported accident and traffic conflict studies. The number of accidents before launching of the traffic management scheme is compared with the number of accidents over the same period of time after the scheme is launched. This gives a fair indication of the performance of the scheme from the safety angle. Before and after studies often give rise to methodological errors which have to be taken care of. Special attention should be paid to the problem of control factors to correct for the influence of traffic growth, changes in weather conditions from the before period to the after period, and systematic alterations in the accident number due to modifications of certain factors. Considerable attention should also be given to the statistical techniques which are necessary when calculating the significance of observed changes.

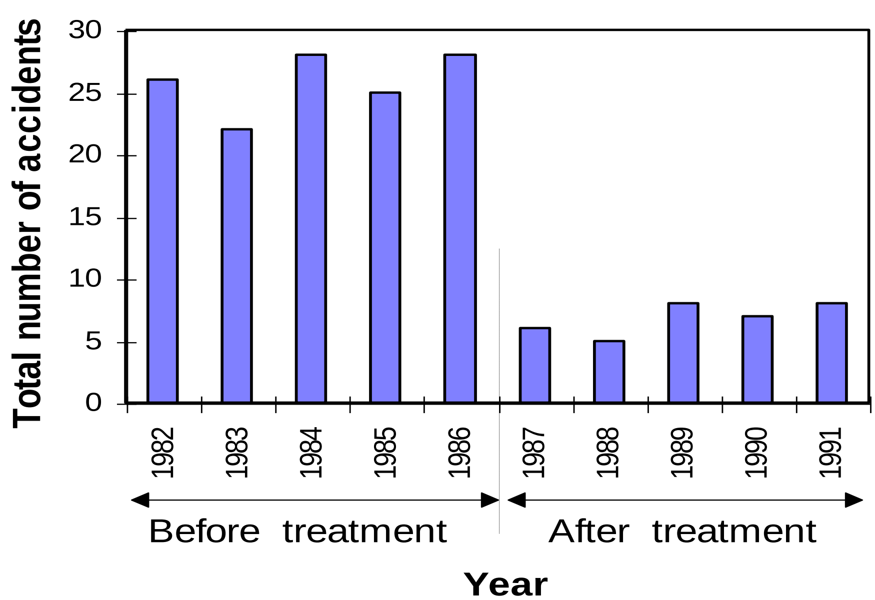


Figure 4.1 - Road accident statistics before and after the road surface treatment on High Street

Detection of hazardous road locations

Some traffic management schemes have, as a main objective, the elimination of hazardous road locations (blackspots). One important problem is the detection of these locations. This is to find out which road sections or junctions are especially dangerous by considering the method of control, traffic volumes, road type or junction type, surface texture, weather condition etc. Properly collected empirical data on accident frequencies and rates for different types of junctions or road sections are necessary to identify which areas, streets and junctions have higher accident rates than expected. Data of this kind are also essential to evaluate which remedial measures to apply as well as to estimate their effects on traffic safety.

Collision diagrams

The fundamental tool used in site-specific crash diagnosis is the collision diagram, which is a schematic representation of all crashes occurring at a given location over a specified period, typically 1-5 years (Figure 4.2). Each collision at the site is represented by a set of arrows, one for each vehicle or pedestrian involved, which indicates the type of crash and directions of travel as indicated in Figure 4.2. Arrows may be labelled with codes for date, time, day/night, weather, vehicle type, etc. Data for each crash which may be shown on the collision diagram may include crash type, severity of crashes, data and time of crashes, condition of road, light condition, geometry of the site, locational information, followed by a tabular summary of crash details (Ogden, 1994).

The collision diagram is a very valuable tool since it indicates diagrammatically the nature of accidents that have taken place at a particular location. The collision diagrams need not to be drawn to a scale, but it should clearly indicate all the details stated in the previous paragraph.

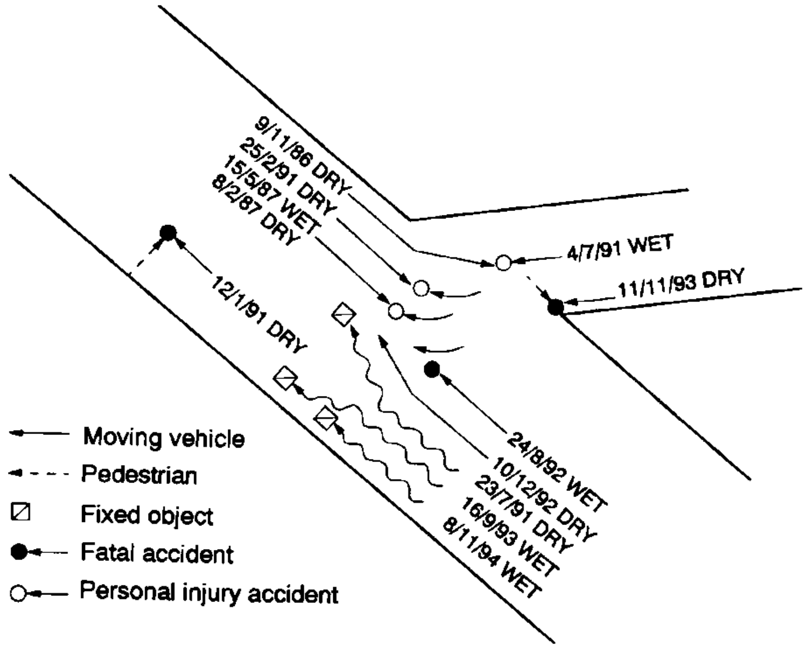


Fig 4.2 – A typical collision diagram at a three-way junction

Blackspots

The blackspots are the hazardous road locations (road sections or junctions) which are especially dangerous because of location, excessive speeds, traffic volumes, road type or junction type, surface texture, weather condition etc. However in practice road locations which are associated with high crash potential and are susceptible to remedial treatment may also is considered as hazardous locations worthy of corrective treatment.

Police accident records are much useful in identifying the blackspots. The blackspot treatment programmes should be carried out gradually by giving priority for the worst locations to reduce the number of blackspots to improve the safety at those hazardous locations.

Hazardous road locations are usually identified using one or, a combination of the criteria below:

(1) Number of crashes greater than a set cut-off value

(2) Crash rate greater than a set cut-off value (where rate is defined as number of crashes per exposure or risk unit, e.g. crashes/10^8 vehicle kilometers)

There is not much agreement on which type of criterion above is more suitable for identifying hazardous locations. The first criterion focuses attention on locations where most crashes occur, and hence, the methodology has the greatest potential to reduce the number of crashes. The second criterion identifies sites where there is something truly unusual, which has caused the crashes (i.e. crash numbers are not attainable simply at high traffic volumes).

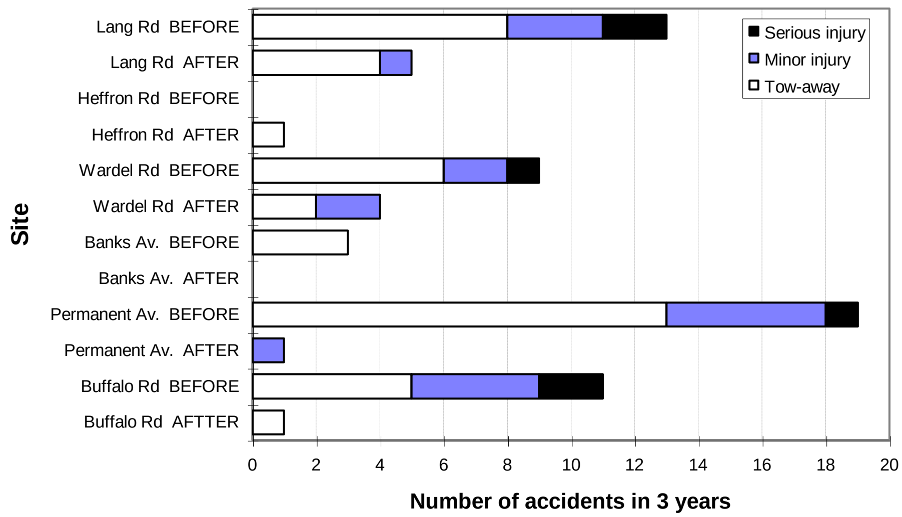


Figure 4.3 - Before and after accident results of a blackspot treatment programme

When identifying black spots regarding fatalities the most common performance indicators used for benchmarking around the world are (Ogden, 1994):

– fatalities per 100,000 persons,
– fatalities per 10,000 vehicles (registered), and
– fatalities per 100 million vehicle kilometres of travel

Each of these has its uses but none by itself will provide a comprehensive picture of road deaths. For example India has a low road death rate based on population but a very high one based on vehicles, whereas Australia India has a high road death rate based on population but a very low one based on vehicles. South Africa has population and vehicle rates just above most developed countries but an unusually high proportion of those deaths are pedestrians.

A comprehensive and concise set of definitions of hazardous road locations are given below:

- Locations of highest risk, which may be identified individually from accident history in terms of clusters of accidents occurring at:
  * blackspots - specific locations usually related to particular features of road geometry such as junctions, bends, or hills
  * blacksites - specific lengths of road with high accident frequencies
  * black areas - areas within which clusters of accidents occur; used primarily in urban areas where methods of reporting of accident locations may not be precise enough to identify, individual roads in a closely spaced network.

- Locations of intermediate risk, where accidents maybe too few to identify individual sites from accident records alone, but combination of data from groups of similar sites or observational studies additional to accident data may indicate potentially hazardous features. These may be designated greyspots, sites, or areas in similar terms to those above

- Locations where common situations or characteristics feature predominantly in accidents, that is, there may be a high frequency of accidents of a particular type not necessarily associated with clusters of accidents.

The two latter definitions above are especially important in identifying and treating hazardous roadside features that may not have an experience of accidents but have the potential for high accident frequency or severity. Roadway features may include any obstacle, device, or condition that can be measured or inventoried. These features include pavement friction, intersections, railroad grade crossings, geometric (lane width, shoulder width, grades, curvature, etc.) roadside obstacles (bridge parapets, guardrail, poles, drainage structures, etc.) and traffic control devices, and may be on or off the roadway.

To know the meanings of the following commonly used terms are useful in reading accident study reports.

Crash type - the classification used to describe a crash in terms of the vehicle movements involved, e.g. run-off road, right-turn opposing, or the type of road user involved, e.g. vehicle/pedestrian, vehicle/bicycle.

Crash rate - the number of crashes per unit of exposure.

Exposure - the measure of opportunity for a crash to occur, e.g. amount of travel in vehicle/km, length of road, number of vehicles, or vehicle/vehicle, vehicle/pedestrian, etc. conflict.

Crash severity - a measure of the consequences of a crash in terms of the most severe casualty class sustained by one of the persons involved, e.g. fatal, serious injury requiring medical treatment, injury not requiring medical treatment, no injury (i.e. property damage only).

Severity weighing - the use of factors to give additional weight to the more severe and more costly crashes.

Casualty class - a measure of the consequences of a crash in terms of the number of persons killed, injured and not injured.

Chapter 5

Parking

Contents

Objectives

The objective of chapter 5 is to give the reader a general idea about the importance of vehicle parking issue, then observe at the methods available to find out the demand for parking and how this demand can be met with. In section 5.4 different types of parking surveys are discussed at length. In sections 5.5 and 5.6 different methods of on-street parking and off-street parking techniques available in traffic management is explained. At the end of the chapter the reader should have a proper idea about the importance of parking as a traffic management tool, in what way a parking survey is designed to study a specific parking need and how the surveys are conducted, and based on the results finally how a parking layout is arranged irrespective of on-street parking or off-street parking.

5.1 Parking and environment

A large proportion of trips in day to day activities involve a driver and passenger using a private motor vehicle to reach a desired destination. Parking has an important role to play in serving this activity, and therefore to enhance the transport system. Without appropriate parking areas, drivers cannot stop and park their vehicles before participating in activities. At the most initial level, parking is needed to accommodate vehicles when they are not in use. At the other extreme, provision of parking can be used to encourage or discourage urban development.

The historic development of parking was such that, parking was initially provided on the roadway where it contained spare capacity and was used to accommodate stopped vehicles. This type of parking is referred to as *on-street* parking. In instances where a separate parking area is created solely for storing vehicles outside the carriageway of a street is referred to as *off-street* parking. Private off-street parking may range in size from a house owners garage to large industrial, commercial or residential parking structures with multi-level parking floors.

When parking is considered as an environmental issue, parked vehicles can be interfering and can detract from environmental amenity. Large expanses of parked vehicles or black bitumen off-street areas are unattractive. Concern for the visual environment and the comfort and convenience of users needs to be considered when designing a parking system. Parking can be provided either on-street or off-street in urban areas. Off-street parking provides considerable opportunities for blending the parking in with the general environment. Underground parking, where land values justify the cost, allows the construction of buildings or parks over the parking lot. Above ground parking can be blended in by using similar construction materials and architectural features as surrounding buildings. When parking areas are allocated in rural areas it has to be emphasised that the beauty of these areas should not be adversely affected by inappropriate provision of parking. Care should be taken to shield parking from sensitive views and to avoid confused and unsightly parking arrangements in local towns, particularly where the streetscape is of some historical importance or posses a scenic value.

5.2 Demand for parking

The demand for parking is generally related to the landuse or landuse served. Parking demand for various land use and development types are generally set down in different countries by various planning authorities to suit the local conditions (AUSTROADS, 1991).

Since Sri Lankan norms for vehicle trips per square kilometre per day on regional basis have not yet worked out, below indicates his information based on Australian figures, abstracted from Nicholas Clark Report (1987). The values given are to suit the local conditions in Victoria State in Australia. These values may differ from country to country depending on the national standards.

Table 5.1 - Vehicle trips per day of regions - Victoria State, Australia

Land Use	Vehicle trips per sq.: km per day
Central business district	40,000
Local business district	20,000
Inner commercial	20,000
Inner residential	15,000
Middle residential	10,000
Outer residential	5,000
Ex-urban	2,000

(Source : Nicholas Clark and Associates, 1987)

5.3 Supply of parking

Along with the demand for parking the supply for parking becomes necessary. Whether free or by charging a fee the purpose of parking is to provide a service, enhance local economic values, increase production, reduce street congestion, or attain combinations of these goals. The proper location of new general purpose parking facilities is essential if they are to provide the required services. The amount of existing parking should be taken into account when determining the need for new parking.

Factors that determine appropriate locations for parking.

- expected users
- extent of parking shortage
- the level of facility
- cost
- existing parking and street system

The location and type of major generators of vehicles must be considered if a new facility is to be of maximum service. The location of potential new generators also should be given attention.

Parking facilities are provided for many different people who may be participating in a diversity of activities. Some of these activities may be short term in nature, others may require a longer stay. Some parkers may have particular difficulties that make it difficult for them to walk a considerable distance. Therefore the characteristics of the user need have to be taken into account when determining the location of parking. Provision of parking too far away from the actual area of shortage may result in limited usage. The parking should be provided within a 'convenient walking distance' from the area of activity. But the definition of convenient walking distance may vary with number of factors such as:

- trip purpose
- activity being undertaken
- the duration of stay
- size of urban centre (or shopping area)
- luggage to be carried

Greater distances may be accepted if the actual walking distance is reduced by the use of moving footways or travellators.

5.3.1 Cost of facility

Economic conditions play a major part in the location of off-street parking. It also affects the type of parking facility needed. The main cost of supply of parking is the development of cost. Once parking is supplied if fees are charged the amount to be charged may be determined by the market demand. The other factors which influence the cost of facility, includes the construction cost and land purchase cost.

5.3.2 Location of parking areas

The location of parking areas relative to the major road system is an important consideration. Parking areas need to be close to, and have good accessibility to the main roads, in order to minimise traffic intrusion to local street areas. In general, parking areas should be surrounding the developments and have good access to the road system.

5.4 Parking surveys

Data on parking characteristics forms the basis of the design process. A brief overview of the data types and the procedures of collecting them are presented in this section.

5.4.1 Data types

Once the objectives of the parking study are defined, the data collection has to be commenced. Below gives some possible information required for a parking analysis.

- the pattern of traffic flow, its fluctuations and areas of congestion
- capacity, location and characteristics of existing facilities
- use of existing facilities, parking characteristics of motorists, violations, enforcement and peak concentrations
- location and extent of demand for space and its relationship to supply and price, the influence of large generators of demand, areas of present and future need or deficiency, site availability
- adequacy of signs and markings.

Make use of available data and try to find out the supply of parking provided by existing parking facilities and the possibilities for new development in the area of concern. Such an inventory should detail the type of parking and its location in terms of the following:

- number of parking spaces
- type of parking
- method of operation of off-street facilities
- parking restrictions
- parking fees
- occupancy and turnover rate.

The following sections discuss some procedures for collecting this data.

Use of Existing Data

Information on existing facilities can often be obtained from local councils or road authorities. This information provides a useful base upon which to work. Care must be taken, however, to ensure the accuracy of the information since records may not be up to date. This check is usually carried out by comparing the recorded information with observations of existing facilities to see if they agree.

Parking Inventory Survey

If existing inventory maps are not available or appropriate, it will be necessary to undertake field surveys. In compiling the record of the street facilities the data can be first entered, in the field, onto prepared sketch plans. These sketch plans may be based on existing local maps or each street can be sketched onto graph paper to an appropriate scale, with respect to length. The use of a suitable key enables the exact location of parking and parking restrictions to be marked on the map. The location of off-street parking could also be marked on the map but the layout of these facilities is usually detailed separately. Normally the road network is coded in relation to road lengths with each block given a number key. This coding provides a basis for recording and analyzing the data. An example of a typical inventory map is shown in Figure 5.1.

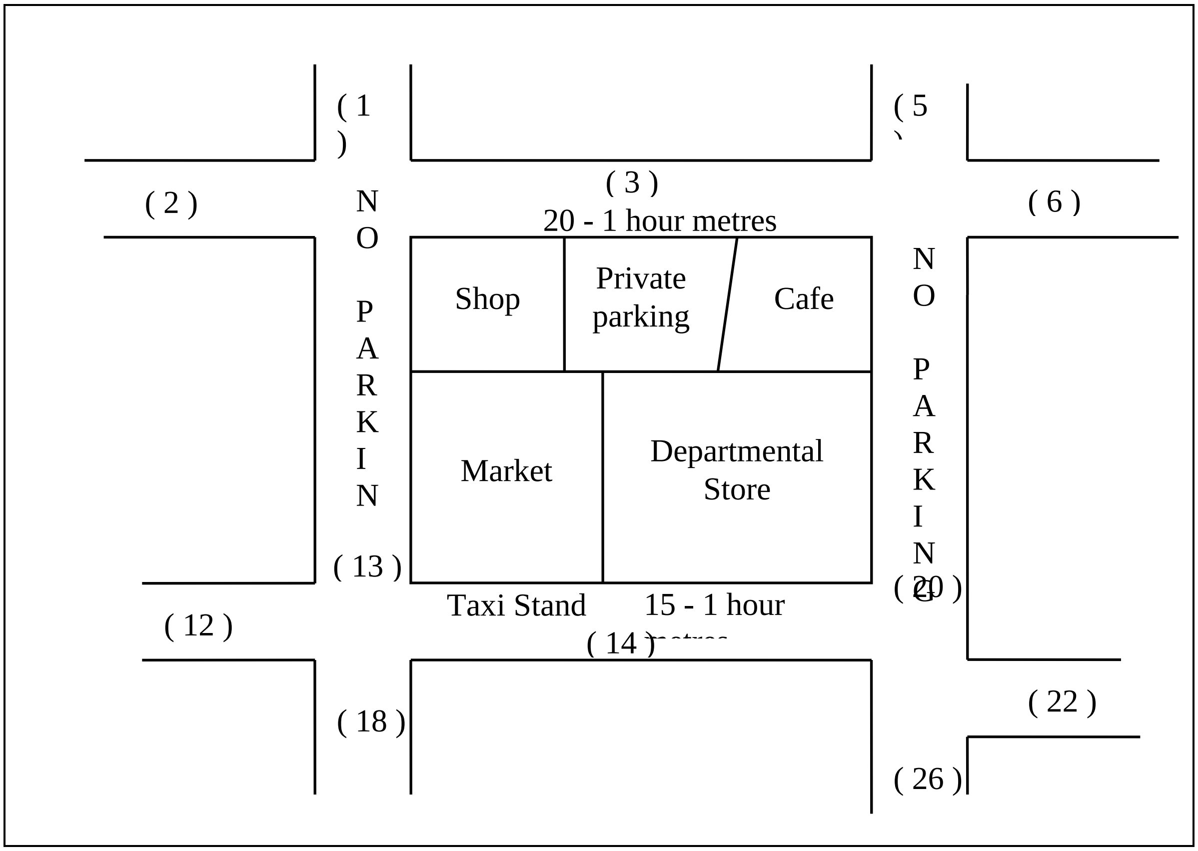


Figure 5.1 - Typical parking inventory map

Kerbside parking spaces should be inspected and particulars recorded. Typical information may include space size and parking arrangement, times, meter location (if parking metres are to be fixed) or number of parking spaces. Irregularly used informal parking spaces (e.g. grass) may be marked if required. Off-street parking can include those spaces regularly used. Principal occupants and users of commercial buildings can also be recorded. The capacity and maximum use of a parking lot should be recorded.

5.4.2 Survey of parking demand

With parking demand data it is important to distinguish between revealed demand at the present time and potential demand for parking. Revealed demand is the observed use of the facility. Potential demand is a measure of the total desired use of the facility. Potential demand will only be revealed when supply exceeds demand by a definite margin. Most parking demand data collected in the field are revealed demand data, whereas future planning data should reflect the potential demand:

The type of parking demand data needed might include:

- spatial distribution of parking demand
- spatial distribution of parking demand generators
- total number of people parking in study area over the study period
- parking duration
- trip purpose and destination
- trip origin
- utilization of existing parking.

The survey procedures discussed in this section are divided into interview surveys and observational surveys.

1 Interview surveys

If the parking demand is to cover a large geographic area, and it is expected that changes in parking supply would be likely to cause substantial change in the total number of parkers or their spatial distribution, data collected from an interview technique may be required. Four techniques commonly used :

(a) Parking person interview
(b) Reply paid questionnaire
(c) Home interview surveys
(d) Site specific interview surveys.

(a) Parking person interview

This approach involves assigning an interviewer to a predetermined number of parking spaces. The interviewer records each parking incident (parking arrival or departure) and attempts to interview people parking in this area. Questions asked in the interview may relate to:

- trip purpose (shopping, work, business, loading etc.)
- final destination of trip
- origin of trip
- places visited
- duration of parking
- alternative parking locations that were considered
- frequency of parking in the study area.

Other details that can be collected by observation at the time are:

- vehicle registration number (for identification purposes)
- vehicle classification (car, taxi, truck, etc.)
- nature of parking (kerbside, off-street, garage, etc.)
- time of arrival or departure.

The information obtained can be recorded onto an appropriate survey form and then transferred to a computer for further analysis.

The personal interview can be used to obtain data on people's attitude to various parking polices (e.g. changes in parking fees, parking restrictions, etc.). Care should be taken however, to keep the length of the interview to tolerable limits, less than a few minutes.

Interviews of on-street parkers can be carried out on parker arrival or departure. The departure interview has a number of advantages. Firstly, places visited can be reported more accurately since the parker has already visited them. Secondly, accurate duration of stay information can be obtained. Thirdly, the parker is less likely to be in a hurry and therefore more likely to complete the interview. The major disadvantage is that the interviewer may have less time to catch parkers before they leave. The personal interview technique can often be expensive since the interviewers are limited in the number of parking spaces they can handle. The number depends on the length of the interview, arrival and departure rate of parking vehicles, and the physical dimension of the area. The size of the area that can be covered by an interviewer can be determined by a preliminary pilot survey.

In the case of off-street facilities interviews can be carried out when the vehicle is entering or exiting the facility. Such facilities may have a large proportion of long term parkers and may be subject to high peaks. Greater numbers of interviewers may be required over the peak periods. Interviewing people as they leave has the advantage of avoiding the need for vehicles to queue onto the adjoining roads. If interviews are carried out upon entry provision, queuing of vehicles should be avoided.

(b) Reply paid questionnaire

When completely detailed information is not required, reply paid questionnaires may be used. These questionnaires can be inserted under the windscreen wipers of parked vehicles. Personnel costs for this method are smaller than for a personal interview since one person can cover a larger number of parked vehicles. Information on the parking location and arrival time of the vehicle can be obtained by marking or pre-coding the questionnaire. If pre-coding is used the person distributing must note the time of distribution and location. This can be recorded in a logbook or onto a portable microcomputer. The microcomputer has the advantage of quicker access and information transfer time. A disadvantage of this type of survey is the low response rate achieved in practice.

(c) Home interview survey

The above surveys [(a) parking person interview and, (b) reply paid questionnaire survey] measure parking usage, but not demand for parking. Many people wishing to visit the area may be turned away by the lack of parking facilities. Indications of potential demand could, however, be obtained by a home interview survey. The large cost associated with such an approach usually results in questions on parking being grouped with other questions on a large transport questionnaire. This approach has been shown to be a useful substitute for those mentioned previously.

(d) Site specific interview surveys

The home interview survey addresses the entire population of the urban area and is the only approach that can be used to determine potential demand in multi-use parking lots. However, some parking lots are only used by people traveling to specific locations (e.g. universities, office, parks, etc.). In such a case the total population of possible users can be defined. The population of all possible users can then be used as a basis for determining the latent demand for the particular site. This approach will not provide an indication of the demand of visitors for parking.

2 Observational surveys

Many parking studies are not concerned with information on the parkers overall trip. In this case a simplified type of survey can be warranted. These can be either cordon counts or patrol type surveys. However, the first source to be considered is existing data.

(a) Existing parking information

A technique which may be used successfully in surveying off-street parking facilities is the use of canceled parking dockets, where these are retained by the parking operator. These dockets usually show the exact time of entry and exit and hence, parking duration. The advantages of this data source are that no field survey is necessary, a complete sample is obtained (if everyone using the parking lot use a ticket), and data can be collected over an extended period of time and over a number of different parking locations. It also has the advantage that provided the attendant has kept the dockets; data on parking habits over a long period of time can be obtained. Another advantage is that information can be directly linked to a computer facilitating the data retrieval. The disadvantage of the method is that it only gives information on parking times and will not provide a complete sample if some user (e.g. parkers who hold a permanent parking place) do not use the returnable tickets for entry and exit.

(b) Cordon counts

The study area is surrounded by a closed cordon and counting stations are established on all cross roads entering and exiting the cordon. At each station, a separate count is made of vehicles entering and leaving the area hourly, or in shorter periods. The algebraic summation of entering and leaving traffic gives the accumulation of vehicles in the area. This accumulation represents the sum of vehicles parked and on the move in the study area. After removal of the moving vehicles a measure of the required parking use is obtained.

Counting can be carried out either manually or by automatic counters. Manual methods may be less expensive, and may be required in special surveys or in order to check and make corrections to the automatic counters, but provided that information is accurate. More detailed information can be obtained by recording the number plates of the vehicles entering and exiting the cordon. A typical survey form should include information on the location, number plate, direction of travel, time and type of vehicle. At the end of the study the number plates at entry and exit are matched and the duration of stay calculated.

The following information can be obtained from number plate cordon counts:

- total number of parkers;
- arrival and departure rates;
- composition of population by vehicle type;
- parking accumulation; and
- duration of parking.

5.4.3 Parking usage surveys

Parking usage surveys are conducted to determine existing parking practices, usage of available spaces, parking durations, and illegal parking etc. These surveys are also helpful to study the adequacy of existing enforcement measures. Parking usage survey is a popular type of parking observation study. This approach involves an observer walking, or being driven, along a predetermined route at fixed time intervals. The location of parked vehicles and/or their number plates are noted. Illegal parking also is recorded. Each trip around the section enables the accumulation for the parking facility to be estimated. Further, the number of times a vehicle is observed in the same parking place multiplied by the observation interval, gives an indication of the parking duration.

The total information that can be obtained using the number plate survey is:

- total number of parkers
- arrival rate
- departure rate
- parking accumulation
- parking duration
- spatial distribution of parkers within the lot.

The study area must be divided into tours sufficiently small for the surveyor to cover its length and return to the start in the time allotted for a tour. If it is possible to divide the area so that different sections complete a circuit, the time spent in returning to the start can be eliminated, and the surveyor used more efficiently. A conservative estimate of the time taken to walk between two adjoining 90^0 degree parking spaces and record the first three digits of a number plate is 5 seconds.

Patrolling by car enables longer sections to be considered in a given time interval but both a driver and a surveyor are required. When making simple counts one surveyor is required and the vehicle can be driven at the speed of the surrounding traffic. The surveyor can use a mounted tally counter or hand held computer to record the vehicle and parking types of interest. If the number plates are to be recorded it may be necessary to have two people, one calling out the registration numbers for the other to record. It may be possible a reduce personnel required for the survey by use of a tape recorder. When recording vehicle number, vehicle speeds of about 15 km/h would be appropriate for normal close right angle parking.

The observer should only record what existed when passing the parking place. It is important that the recording of the number plates is done as unnoticeably as possible. Drivers of the cars being observed may change their normal habits if they are aware they are being observed.

The most obvious disadvantage of the patrol method, however, is that many short term parkers may be missed. The number missed depends on the interval of observation and the distribution of parking duration. This effect can be minimized by selecting shorter time intervals.

5.5 On-street parking

On-street parking is when vehicles are allowed to park along the roadway itself on the spare carriageways. There are two different locations for on-street parking.

(1) Kerbside parking
(2) Centre of the road parking

Parking also can be arranged at various angles to the kerb line.

5.5.1 Kerbside parking

Kerbside parking is the most common type of on-street parking. This section will discuss the size of parking stalls, the angle to be used and the interaction with intersections.

The size of parking spaces are depending on the vehicle overall dimensions. Depending on the overall dimensions generally 3 standards are used for parking spaces.

The parking can be allowed; parallel to the kerb, 30^o degrees, 45^o degrees, 60^o degrees or 90^o degrees to the kerb. Bay widths and lengths for parallel and angle parking based on the above considerations are shown in Figure 5.2. These may be increased or decreased to meet particular conditions (Figure 5.2). Also indicates the minimum distance to be allowed from the intersection. By increasing the level of service it will result in easier entrance to and exit from the parking spaces.

- ***Choice of angle of parking***

The most common form of kerbside parking on roadways is parallel parking. It has least impact on through vehicles and requires less lane width than other parking angles. Other parking configurations can be used to suit particular situations.

Angle parking (i.e. parking at angles other than that for parallel parking) can accommodate up to twice as many vehicles along a kerb than parallel parking, for a particular length of road way. The difference is a function of the angle used; low angles (less than 30^0 degrees) give little advantage. The maximum advantage is given when 90^0 degree parking is used. Further, angle parking may be more convenient to the parker since the parking maneuver can be easier than with parallel parking. The decision of whether to use angle parking may be based on consideration of:

– width of road
– traffic volume
– type of traffic
– speed characteristics
– vehicle dimensions
– turnover expected
– nature of the neighborhood or abutting land uses
– road functional classification

Angle parking also has its disadvantages; it requires more road space for parking and unparking manoeuvres than parallel parking configurations. It is also not easily adaptable to commercial vehicle parking as the increased length of these vehicles encroaches into traffic lanes. Reversing out of 'front-in' angle parking spaces involves some of the vehicle protruding into the adjacent traffic lanes before the driver can see oncoming vehicles. This adversely affects traffic safety and also interferes with the free movement of through traffic.

- ***Parking restrictions at intersections***

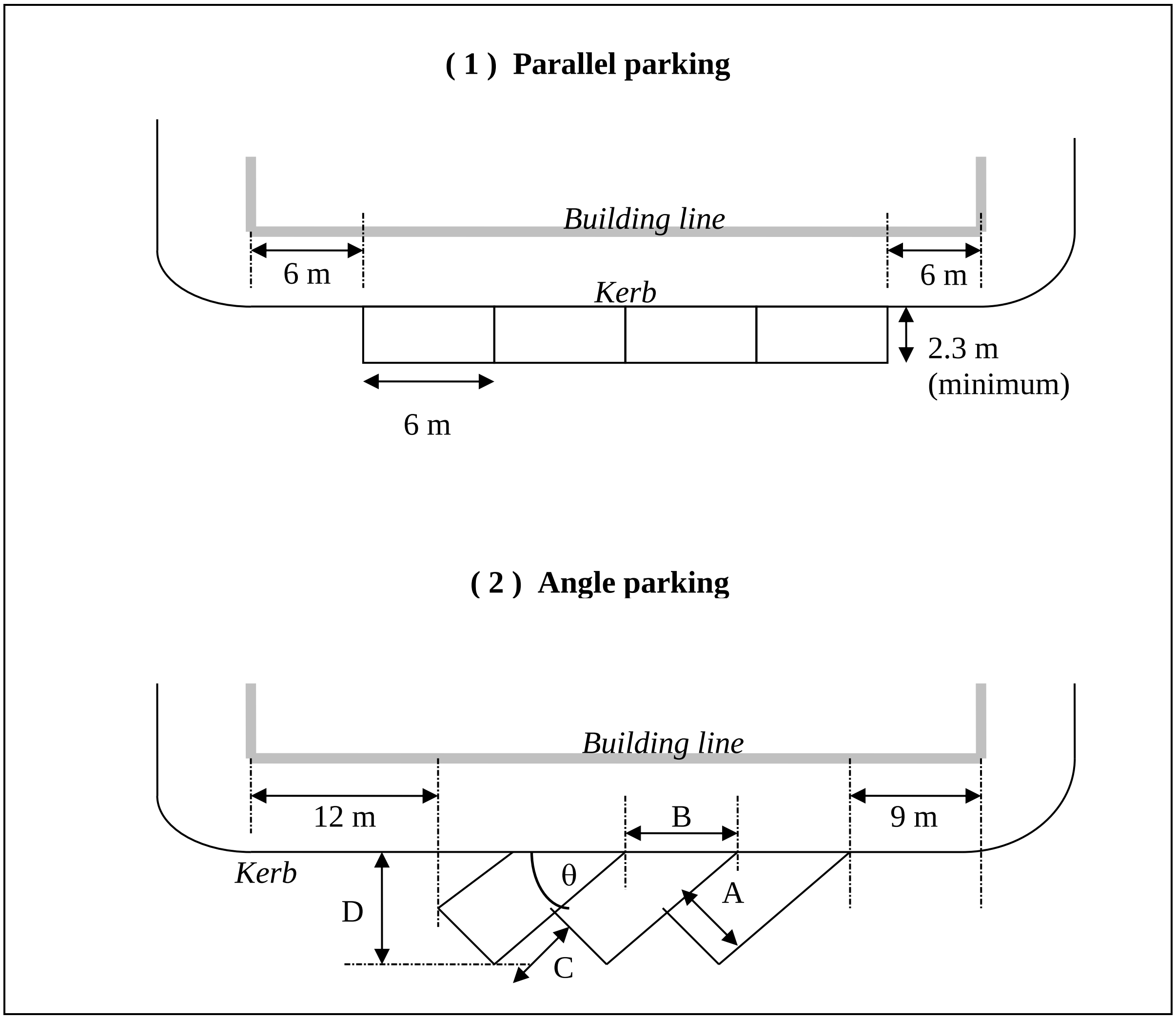
Parking should be designed so as not to interfere with sight distance or impede the flow of turning traffic at intersections.

Typical distances are:

* Parallel parking - 6 metres on both approach and exit side
* Angle parking - 12 metres on the approach side, 9 metres on the exit side

In addition to restrictions at intersections. Parking is usually prohibited for specified distances in the vicinity of:

- pedestrian crossings
- bus stops
- railway level crossings
- fire hydrants and on some road bridges unless specific provision has been made
- high security establishments



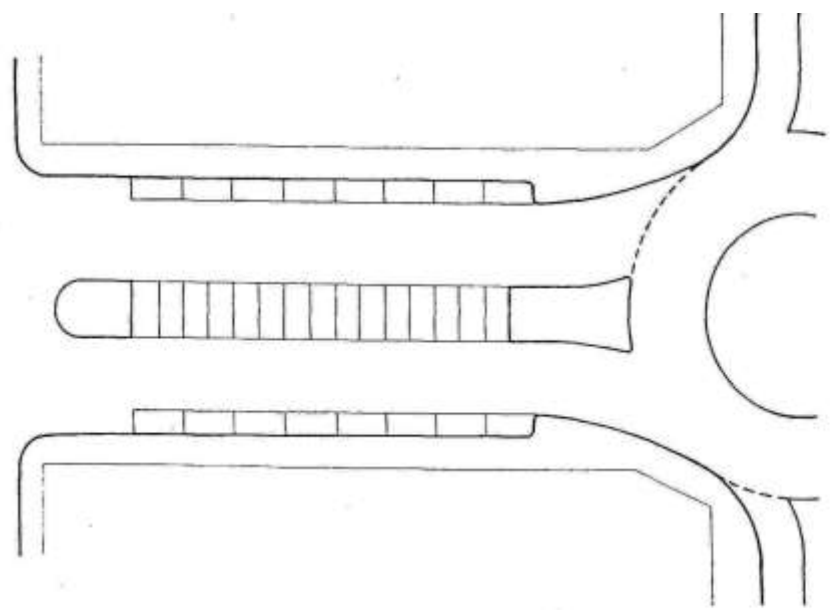
Angle of parking θ	Level of service	A (metre)	B (metre)	C (metre)	D (metre)
30°	Level of service 1	3.2	6.4	5.55	5.0
	Level of service 2	2.5	5.0	4.3	4.85
	Level of service 3	2.1	4.2	3.65	4.5
45°	Level of service 1	3.2	4.5	3.2	5.75
	Level of service 2	2.6	3.7	2.6	5.65
	Level of service 3	2.4	3.4	2.4	5.5
60°	Level of service 1	3.2	3.7	1.85	6.0
	Level of service 2	2.6	3.0	1.5	5.95
	Level of service 3	2.4	2.75	1.4	5.9
90°	Level of service 1	3.2	3.2	-	5.4
	Level of service 2	2.6	2.6	-	5.4
	Level of service 3	2.4	2.4	-	5.4

(Source: AS 1742.11)

Figure 5.2 - Kerbside parking bay sizes

5.5.2 Centre of the road parking

On roads where conditions are appropriate, parking may be provided in the centre of the road. The combination of kerbside parking and centre of the road parking provides a large number of parking places per unit length, provided that carriageway is sufficiently wide. Figure 5.3 illustrates a typical layout for centre of the road parking which is usually combined with parallel kerbside parking. It is rarely possible to combine angle kerb parking with centre of the road parking because of the large amount of road space required. Centre of the road parking is usually arranged as 90 degree parking in a single row with drive in and drive out usage. In some situations it may involve parallel parking adjacent to a median kerb. This is commonly adopted under flyover structures.



(Source: AUSTROADS, 1991)

Figure 5.3 - Typical centre of the road parking layout for low flow situations

The provision of centre of the road parking as in Figure 5.3 separates opposing traffic and provides a continuous refuge for pedestrians, but this type of parking generates additional pedestrian movements across the road. That is, pedestrians leaving and returning to their vehicle have to cross the main traffic stream to reach the footpath. Generally centre of the road parking should only be considered in streets with little through traffic and where all traffic moves slowly.

When introducing any type of centre of the road parking it is essential to preserve ample visibility at intersections. Hazardous conditions are brought about by permitting access to centre of the road parking within a median too close to intersections or pedestrian crossings.

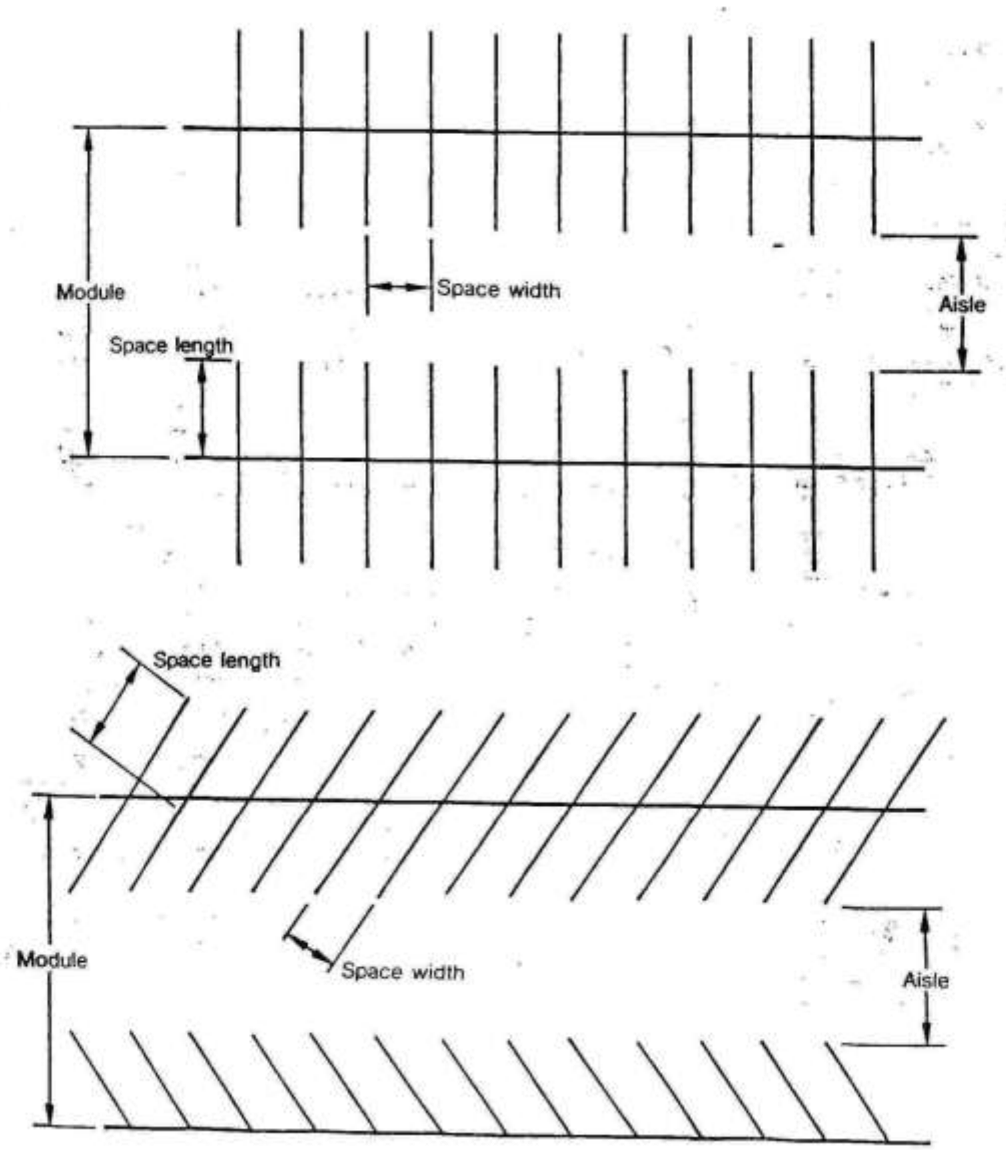
5.6 Off-street parking

Off-street parking is when a parking area is created solely for storing vehicles outside the carriageways. Off-street parking systems often form an interface between the road network and other landuses. The parking facility would be best located between the main access route and the landuse served. Location of the parking system should consider the major routes on which traffic approaches the area as well as the streets immediately adjacent to the proposed site. Major routes are often located close to the business centre and off-street parking should be placed on the business district side of the routes to minimize the need for pedestrians to cross the major route and to discourage parking on the road.

As discussed in earlier, the size of parking spaces are related to the vehicle base dimensions, the type of landuse and user characteristics. Clearances are added to the base dimensions to determine the size of a parking space as discussed previously for on-street parking. The determination of the size of off-street parking spaces is similarly based on table in Figure 5.2 to reflect the level of service catered for the users.

5.6.1 Parking lot layout and circulation

Parking lots should be rectangular with cars parked on both sides of the aisle. This is the most efficient geometric layout unless the lot size and aisle widths make it difficult. Ninety degree parking with two way aisles provides great flexibility in choice of route by the parker, and fewer aisles. The layout of a parking facility is usually made on the basis of space and aisle combinations called modules. A complete module is one access aisle servicing a row of parking on each side of the aisle (see Figure 5.4). In some cases partial modules are used where the aisle only serves a single one-sided row of parking. This arrangement is inefficient and should be avoided if possible. In general, any multiple of modules can be used, depending on the location of entrances and exits and the size and shape of the available land (see Figures 5.5 and 5.6).



(Source: AUSTROADS, 1991)

Figure 5.4 - Parking module layouts

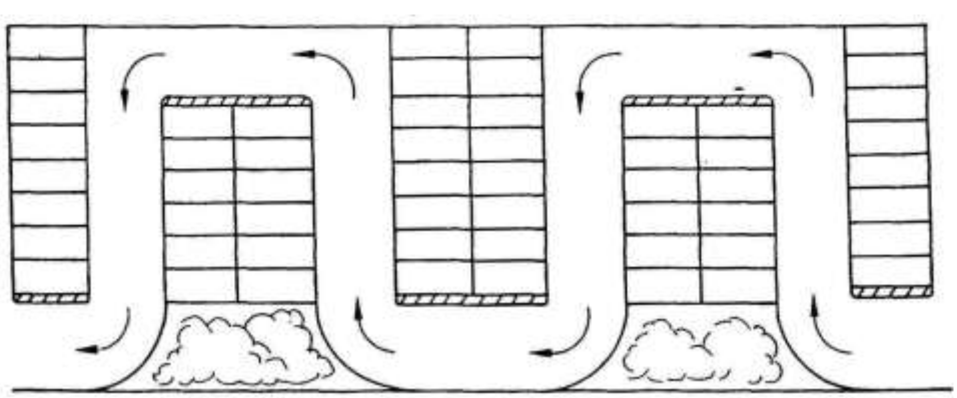
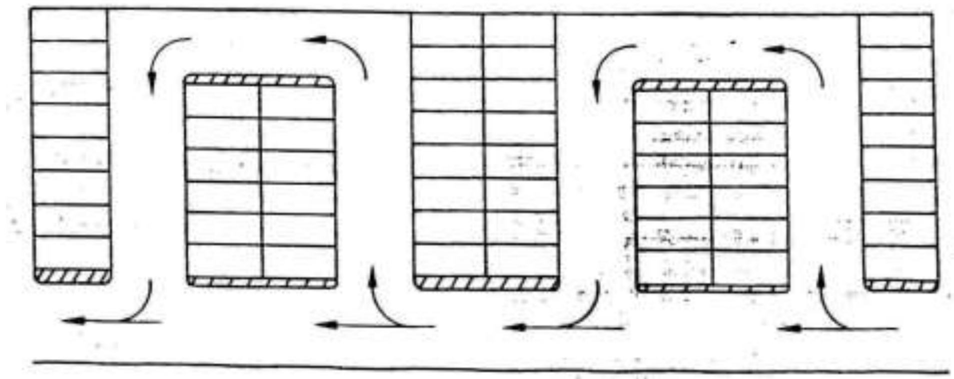


Figure 5.5 - Circulation past every parking place



(Source: AUSTROADS, 1991)

Figure 5.6 - Separation of aisles from circulation roads

5.6.2 Multi-storey car parks

Basically there are four types of layout arrangements that are adopted for multi-storey car parks:

(1) Split level layout arrangement

This layout arrangement is widely adopted. As indicated in Figure 5.7 (A) the two bins are so arranged that adjacent parking levels are separated by half storey height. The levels are connected with short interconnecting ramps running between levels.

(2) Warped slab layout

As shown in Figure 5.7 (B) in this layout arrangement, parking levels constructed with uninterrupted horizontal external edge. Steady transition of gradients provides internal connectivity between parking levels. Compared with split level layout, this arrangement needs ramps at either end of parking structure.

(3) Parking ramp layout

In this arrangement parking level is constructed in the form of a long ramp; and posses' significant effect on elevation appearance to keep to acceptable gradients, a long structure is required. If necessary, exit can be separated by adopting external helical ramp.

(4) Flat slab layout

As shown in Figure 5.7 (D) an external ramp is used to connect different parking levels.

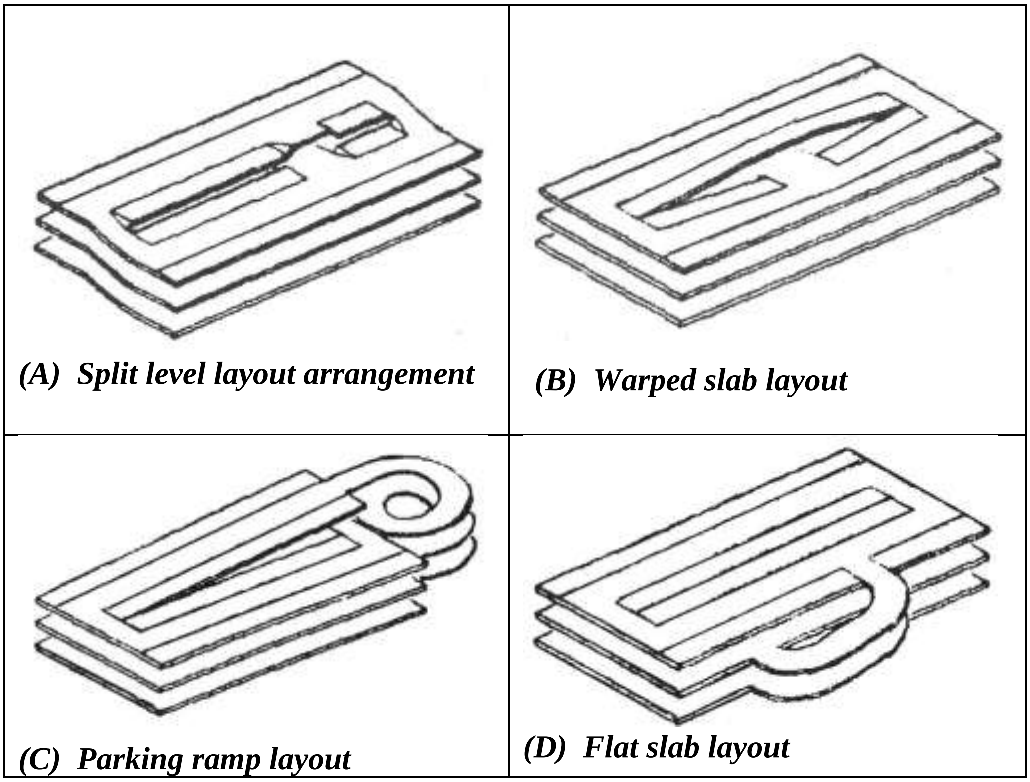


Figure 5.7 - Multi-level car park layouts

5.6.3 Entrances and exits

The following factors should be considered in setting the location of entrances and exits:

- locate entry/exits clear of intersections and other locations of complex traffic movement.
- locate entry/exits where conflicts with pedestrians and bicyclists are minimized
- locate entrances to minimize possible bank up of traffic into the street
- locate exits where adequate sight distance to street traffic is available.

Chapter 6

Planning for pedestrians

Contents

Objectives

The objective of this chapter is to study the available facilities for pedestrians, and how they should be provided to achieve safe pedestrian movement along roads. It is also discussed the measures that have to be adopted for pedestrians to cross the roads at mid-block sections and at road intersections safely. Finally the concept of environmentally adopted through roads and the road sharing principles are discussed.

6.1 Pedestrian facilities

When planning for pedestrians the main objective should be to encourage orderly and safe movement of pedestrians and vehicles without interference from each other. Pedestrians should be guided away from traffic danger spots in main roads by providing proper facilities for them, and allow them to carry-out their walking without interference from the moving traffic as much as possible. The pedestrians should be provided with sufficiently wide space with raised kerbs on the side of the carriageway for them to continue their walking safely. These sufficiently wide walking spaces should be available on all major traffic routes whether divided or undivided, for the safety of the pedestrians. However, it may not be possible to allocate this walking space in some existing roads due to restrictions in road reservations.

Footpaths

A basic requirement of the street system is to provide easily negotiable routes for all pedestrians. This is most commonly provided by footpaths along roads and streets. Footpaths should conform to minimum dimensional requirements, and obstructions to pedestrian movement should be minimized.

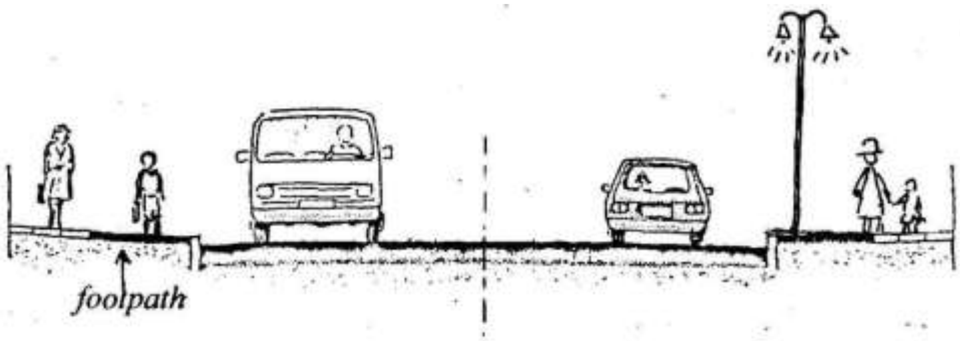


Figure 6.1 - Safe movement of pedestrians

6.1.1 Planning urban pedestrian networks

Pedestrians are particularly vulnerable road users and should have direct, easy and safe access at all times to the transport system. To achieve maximum safety, the pedestrian network itself should be separate from, but integrated with, the main road and public transport system (Figure 6.2). This will necessitate regular crossings in order to sustain the safety and continuity of the network for walking.

To achieve the optimum conditions for safety, paths must be of adequate width and well serviced with good lighting, phones, etc. Their alignment must be such that people can see far enough ahead to be able to anticipate potential danger and take evasive action.

The basic geometry of the path network should reflect the pattern of land uses and building densities, so that normally as one approaches the centre of any large town or central business district (of large cities), an intensification of the route density and pedestrian facilities should be expected.

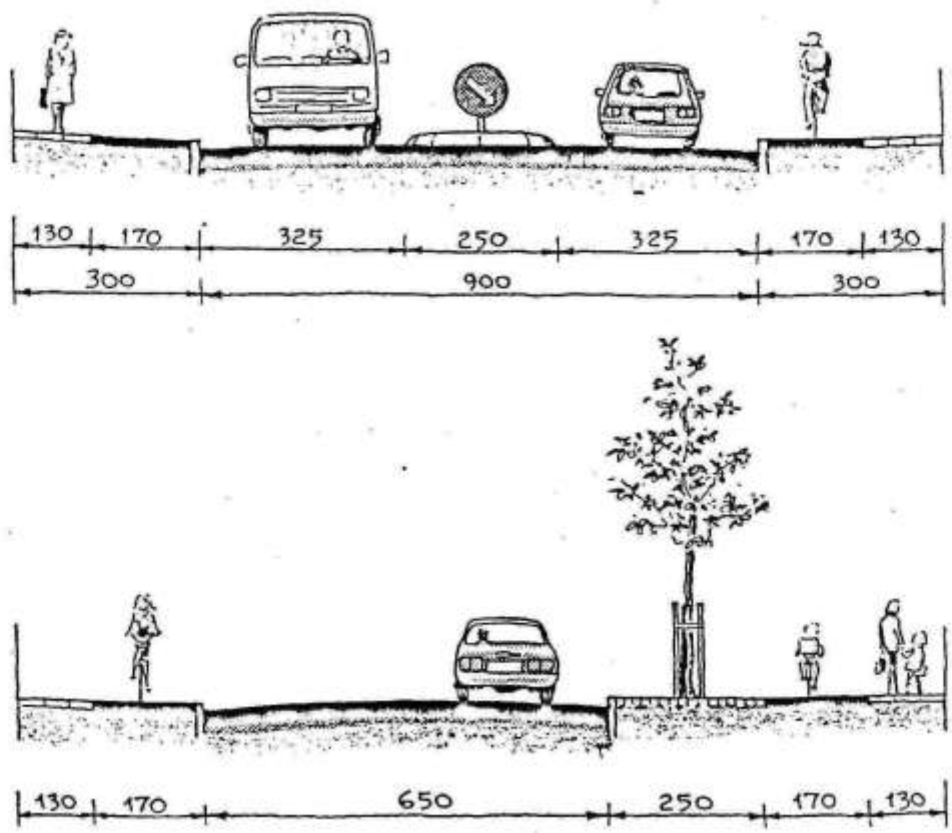


Figure 6.2 – Examples for pedestrian and bicycle movements when integrated with the main road and public transport system

When planning for pedestrians, there are number of facilities which can be used to assist the pedestrians to cross roads at intersections and mid-block (i.e. road section between intersections) locations. It is important that the facility used be suited to the needs of that location and there is a greater demand by pedestrians to cross at or near the location that is being considered.

The most important criteria that governs the provision of a pedestrian crossing are, the number of pedestrians crossing the road and the traffic volume at that location. The other minor considerations are; road hierarchy and nature of the road cross-section, operating speed of the vehicles at the location, the type of pedestrians which will be using the crossing (e.g. young children, office workers, elderly people etc.), available site distance for both pedestrians and vehicular traffic and the general environment (e.g. urban, rural or town centres). The width of the crossing is determined by the number of pedestrians using the crossing, and the minimum recommended width is 2.5 metres. It is also recommended that 0.5 m width be added for every 125 pedestrians per hour above 600 averaged over the four peak hours.

e.g.

If the average pedestrian flow over 4 peak hours is 1100, then the width of the crossing is; 2.5m + (1100 – 600)x0.5/125m = 4.5m

The pedestrian crossing techniques adopted at (i) mid-block locations, and (ii) road intersections are described in the following sections in this chapter.

6.2 Different types of pedestrian crossings at mid-blocks

Where pedestrians are to cross roads at mid-block locations the following types of pedestrian crossing techniques can be adopted.

Zebra crossing

These crossings are ideal for arterial roads and other less important roads where the interruption they cause to vehicles can be tolerated. They can generally be used where vehicular speeds are reasonably low (say less than 60 km/h). These are suited to use in town areas where high pedestrian volumes are given preferential treatment over vehicular traffic.

Pelican crossing

A pelican crossing is a pedestrian crossing at which traffic signals are used to control vehicular traffic to establish pedestrian priority on the crossing. These will indicate the period during which priority continues to be given to the pedestrians on the carriage-way. At these crossings the vehicles are stopped by a red signal to allow pedestrians to commence crossing and later a flashing amber signal warns vehicles to give way to pedestrians but proceed unimpeded. The advantage of this device over zebra crossings is that this causes less delay to traffic than the latter.

Pedestrian operated signals

Although these are not much used in Sri Lanka, they help large numbers of pedestrians to cross arterial roads, and roads going through city areas. When the roadway has an adequate median and the route is part of a signal linking system, pedestrians can be served without adversely affecting the route linking.

At these signals, if a pedestrian wants to cross the road, he/she has to press the button provided and wait for the green signal for him/her to start crossing the road. Pedestrians should never attempt to cross the road when red (or stop) signal is on. The signal for the pedestrians to cross the road offers only when someone has press the button and express his/her willingness to cross the road. Hence this does not cause any unnecessary delays on the vehicles if there are no pedestrians to cross the road.

Pedestrian overpass / underpass

These are appropriate treatments where high volumes of pedestrians are required to cross heavily trafficked arterial roads. Although pedestrians overpasses are seen in this country, not many underpasses are seen mainly due to the high costs and operational problems involved. The experience has shown that unless the delays experienced in crossing at-grade are extremely high, these grade separated crossings may not be worthwhile. Pedestrians often prefer to cross the road at-grade rather than using the overpass, unless their at-grade movement is strictly prevented. Some problems usually associated with these structures are; dropping objects into the traffic moving under; security especially at night in underpasses; vandalism; aesthetics especially for overpasses etc.

Pedestrian refuge islands

Where other pedestrian crossing facilities are not used, to help them cross the road pedestrian refuge islands can provide a substantial benefit to the pedestrians. They have the following advantages.

- this will allow the pedestrian to cross the road in two stages.
- the number of decisions which need to be made by drivers and pedestrians are reduced.
- provides a refuge and a physical protection for the pedestrian on a wide crossing. This is important at places where elderly people and children are involved in road crossings.

It is very important that these refuge islands are properly designed to be of sufficient size to cater for the needs of pedestrians. These require appropriate signing and street lighting.

School crossing

It is common to see in many European countries the flagged school crossings. These can be used on arterial and secondary roads with low traffic volumes. When vehicle volumes and/or children crossing numbers are high, this may not be a suitable method of crossing.

Locations and design of pedestrian crossings

The pedestrian crossings should be properly located and designed for the maximum safety of the pedestrians. The principles for placing of pedestrian crossings are as follows:

- fitting natural flow of pedestrians as possible.
- crossing the carriageway at right angles.
- crossing at intersections try to set near to centre of intersection as possible, to make the area of intersection narrow.
- locate the crossings at visible places where drivers can see the pedestrian easily.
- limit the length of cross walk to 15 metres - if exceeding, set a pedestrian island on halfway.
- try to keep the width of the crossing at least 2 metres.

6.3 Pedestrian crossings at intersections

(a) Crossings at signalized intersections

Where pedestrians are to cross roads at signalized intersections (i.e. within the general area bounded by the stop lines) parallel pedestrian crosswalk lines are to be marked rather than zebra type markings.

Pedestrian cross walking markings should be omitted only when there are very few pedestrians using the intersection. Always try to have these pedestrian crosswalk markings to be at 90^o degrees to the traffic stream to be crossed for safety reasons (for better driver/pedestrian visibility).

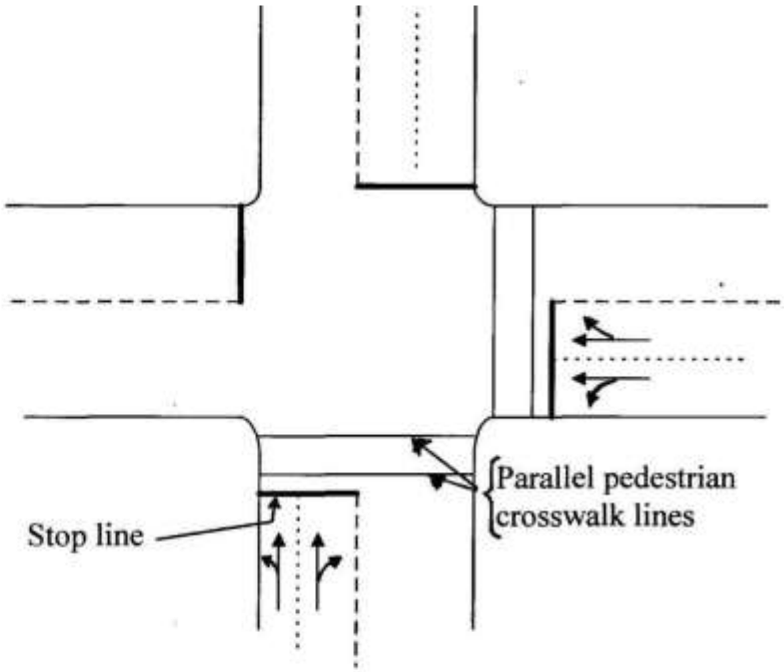


Figure 6.3 - Signalized intersection

(b) Pedestrian crossings at unsignalized intersections

Where pedestrians are to cross roads at unsignalized intersections, zebra crossings can be used after the stop or give way line.

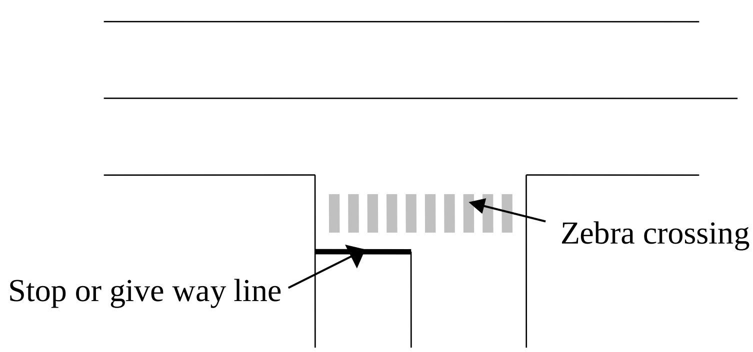


Figure 6.4 - Unsignalized intersection

(c) Pedestrian crossings at roundabouts.

Where pedestrians are to cross the road at a roundabout, zebra crossing can be used before the give way line.

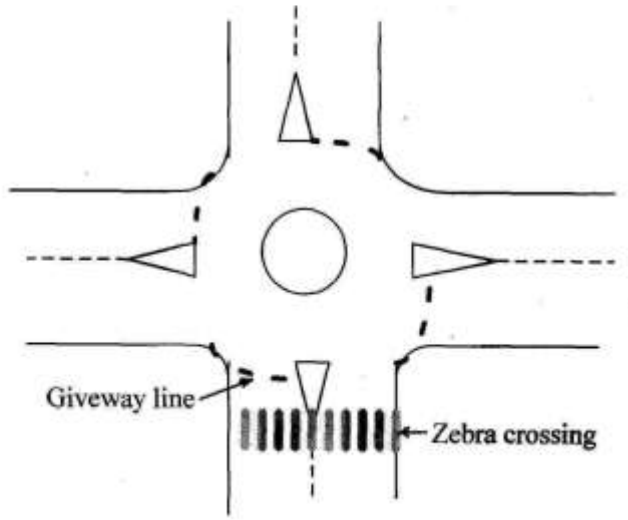


Figure 6.5 - Roundabout

6.4 Environmentally adopted through roads

The concept of *'Environmentally adopted through roads'* was initiated in rural towns in Denmark as an alternative to construct more expensive bypass roads to avoid through traffic passing through rural towns (Hass-Klau, 1990). In environmentally adopted through roads the main idea is to give greater priority to pedestrians, cyclists and the town environment over the through traffic. This can be achieved through a variety of speed reduction devices and other treatments, such as pre-warning signs, centre-median arrangements, regulatory speed signs, road staggering using lateral and central islands, parking bays, kerb extensions and roundabouts. In addition, there may be special pedestrian facilities such as kerb extensions and very wide pedestrian crossings across the road pavement and the bicycle paths. The speeds on these road stretches should be limited to around 40 km/h. In environmentally adopted through roads in school environments, should have highly visible pedestrian crossings preferable with centre refuges. These crossings sometimes are placed on raised platforms such as wide humps.

Although in these road stretches there will be an increase in travel time for through traffic drivers, the pedestrians and cyclists are able to cross the main road more comfortably and more frequently in a safer way.

A better quality road environment can be achieved by:

- widening and improving footpaths
- using quality pavement materials
- providing continuous weather protection
- designing of footpaths for a range of users
- creating attractive places for social interaction and events
- carefully selecting and locating the street furniture
- using appropriate street trees and landscaping

Advantages in environmentally adopted through roads.

* more safe for pedestrians and cyclists
* easier and safer road crossing opportunities for pedestrians and cyclists
* low rate of accidents
* improved environmental conditions
* improved amenity

Disadvantages:

* slight improvements in travel times for through traffic
* speed reductions in through traffic

Shared zones

Shared zones already exist in an informal manner in various locations of pedestrian / motor vehicle mix; such as public parking areas, on university campuses, around large shopping malls, and in areas where children use the street space for play. The basic difference in a shared zone is that *pedestrians have equal rights with motor vehicles* in the specified zone. Motor vehicles use the shared space but at greatly reduced speeds which do not present a safety hazard to pedestrians.

It should be careful not to confuse the principal of shared zones with the local area traffic management (LATM) discussed in section 3.3 of chapter3. Shared zones are applicable only to very lightly trafficked residential and shopping streets. They can be incorporated into new area subdivision design or into an area-wide LATM scheme which will reduce volumes and speeds in general area setting the scene for more restricted vehicular speeds. Finally it should be stressed that although shared zones can reinforce an LATM plan but they cannot by themselves hope to achieve an LATM objective.

Shared zones can be adopted in the following areas.

- high density residential areas
- around playgrounds and parks
- shopping streets and malls
- tourist activity areas
- near schools, temples, churches and civic centres
- parking areas, universities etc.

The success of a shared zone depends on the visual change achieved by redesigning a local street so that drivers clearly see that they are entering a special area. The general layout of the area should clearly express the fact that traffic must share the street space with pedestrians.

(Photo: Hass-Klau, 1990)

Figure 6.6 - A shared zone : pedestrians and public transport sharing the road (buses are traveling at low speed)

Chapter 7

Environmental effects of road traffic

Contents

Objectives

The objective of this chapter is to study the impacts road traffic have on the environment, see how they can be quantified, and learn about the measures that can be adopted to minimise these adverse impacts.

Road traffic will have a direct impact on the environment due to following effects:

(a) Noise pollution
(b) Air pollution
(c) Ground water pollution
(d) Vibration

7.1 Noise pollution

Highway noise is unwanted sound generated due to road traffic movement that can have a negative impact on the environment and surrounding neighbourhood. Noise has the potential for disturbing human activities such as interference of sleeping, distraction of concentration and cause uncomfortability to humans. It can also affect a person's physical health as well as cause nervous stress and annoy people. It can increase fatigue and contribute towards lower productivity and also increase the risk of heart disease. Medically it has been proven that noise is harmful to humans and many other living organisms as well.

Motor vehicles cause two sorts of noise pollution.

(1) There is a noise pollution from heavy traffic flow, where each vehicle contributes to the general roar. Because of their larger size and rugged suspension arrangements trucks and lorries create more noise than cars. Trucks and lorries contribute about half the noise from traffic, even though their numbers are less than other vehicles on the road.

(2) There is also noise pollution from individual excessively noisy vehicles which contribute more than their fair share to general traffic noise. In this country the noise generated from vehicle horns due to bad driving habits is creating a hazardous condition.

Sources of road side noise

Excessive noise can come from:

- deterioration of exhaust system from corrosion
- fitting a unsuitable muffler
- engine modifications such as raising the maximum governed speed
- bad road surfaces such as corrugations and pot-holes
- steep gradients
- road surface texture
- locations around intersections
- removing sound absorbent materials
- bad driving habits (avoid using the exhaust brake, noisy accelerations/decelerations in built up areas, excessive use of horn)
- body noise on hitting bumps in the road (empty tipper trucks can make lots of noise)

Some commonly used road noise terminology

This section will present some relevant fundamentals of acoustics and noise terminology for any road noise discussion.

Decibel (dB)

All sounds are created by a sound source; a voice speaking or a vehicle on the road. It takes energy to produce this sound. Energy is transmitted through the air in sound waves - oscillations of pressure just above and just below atmospheric pressure. Sound pressures impinge on the ear creating the sound we hear. As our ears are sensitive to a wide range of sound pressures, we compress the entire range into more meaningful range by introducing the concept of ‘sound pressure level’.

Sound pressure level (SPL) is a measure of the sound pressure of a noise source relative to a standard reference value - the quietest sound that a young person with good hearing is able to detect:

$$SPL = 10\log_{10}(p_m^2 / p_r^2)$$

where,

p_m = pressure measured; and

p_r = reference measure.

Sound pressure levels are measured in decibels (dB). As shown in above equation, decibels are logarithm quantities; the logarithm of the ratio of two pressures, where the denominator is the reference pressure.

Useful rules of thumb are:

(a) if two sound sources each produce the same SPL and are operated together add 3dB.
(b) if one source is much louder than the other (by 9dB or more) the louder source masks the quieter one.
(c) changes in SPL of less than about 3dB are readily detectable by people outside of a laboratory environment.
(d) most of us perceive a 6 to 10 dB increase in SPL as a doubling of loudness.

A - Weighted Decibel

An important characteristic of sound is its frequency, expressed in units called Hertz (Hz). When analysing the total noise of any source, the noise is divided into frequency components (or bands) to determine how much is low-frequency noise, how much is middle-frequency noise, and how much is high frequency noise.

Human ears are better equipped to hear mid and high frequencies but are quite sensitive to lower frequencies - increasingly so for frequencies lower than 1000 Hz. Thus, instrument manufacturers have designed filters which match this sensitivity of our ears. This helps us judge the relative loudness of various sounds made up of many different frequencies. The A-filter does this best for most environmental noise sources. Sound pressure levels (SPL) measures through this filter are referred to as A - weighted sound levels, measured in dBA.

Time above a threshold level, TA

One concept grasped more intuitively by the community, and more readily accepted by them as a measure of impact, is the accumulated amount of time one or more noise events (measured as A- weighted sound levels) are above a specified threshold. Despite this intuitive appeal, studies have shown that total sound energy of a road project provides a much better means of comparing noise sources and judging community response. Figure 7.1 indicates that, during time t_1 and t_2, A – weighted sound level is greater than the specified threshold TA (i.e. 70 dB)

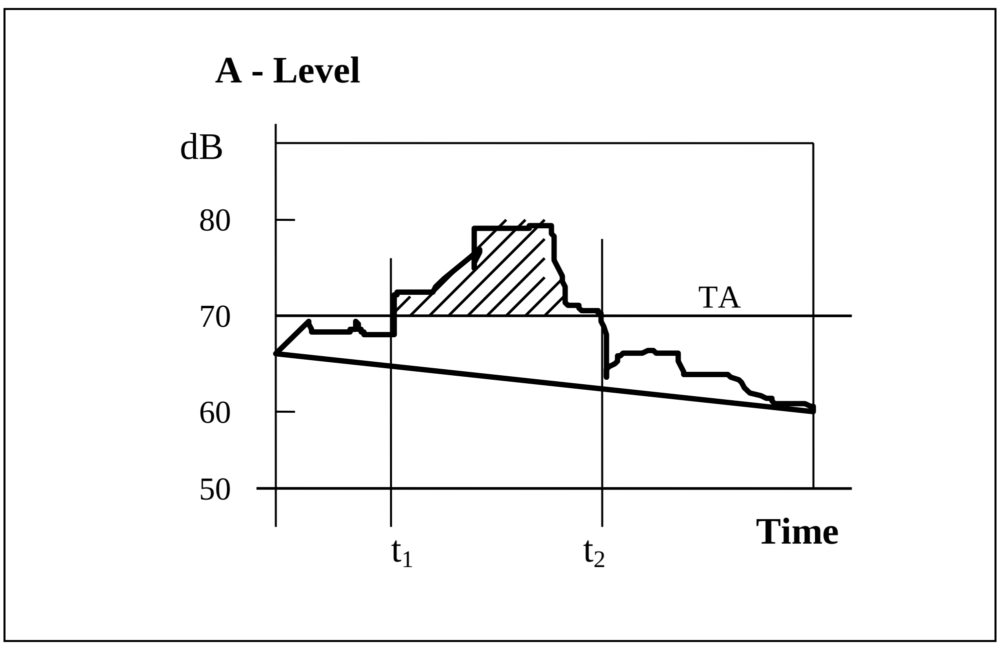


Figure 7.1 - Time above a threshold level, TA

Noise barriers

When designing road projects noise barriers can be constructed to prevent the noise emit from vehicular traffic reaching the householder's ears. Barriers can be simply formed while grading the street thus providing screening from noise and sight. These noise barriers can be properly landscaped to hide the traffic and to provide an effective noise barrier to the nearby houses and buildings.

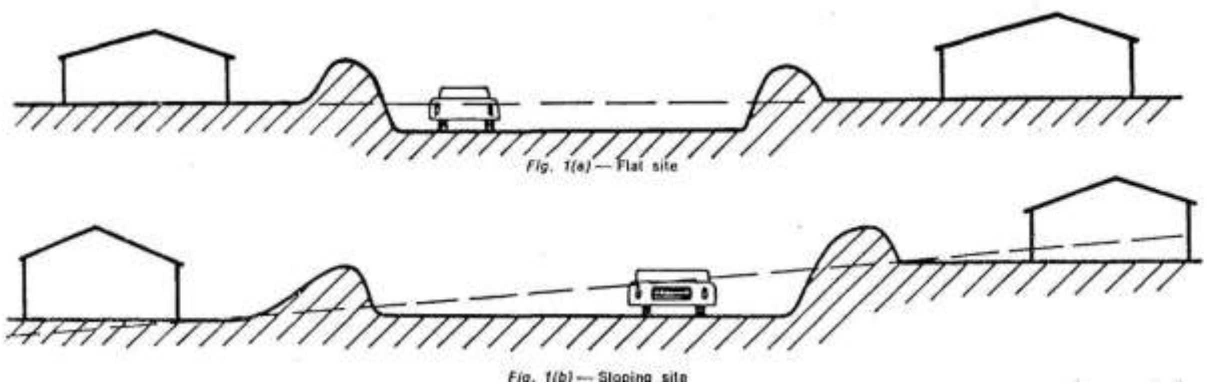


Figure 7.2 - Roads with noise barriers

Barriers can be simply formed while grading the street thus providing screening from noise and sight. Landscaping of these mounds does not significantly affect the overall reduction of noise levels. It does however; improve the street's appearance which in turn helps to reduce any feelings of annoyance about its total effect on the environment.

7.2 Air pollution

Air is a mixture of gases which surrounds the earth in a comparatively thin layer. Most of the air (95%) is in the first 20 km above the earth's sea level. The lower part of this layer, the troposphere, is about 8 km thick at the earth's poles, and about twice this at the equator. Man's activities take place, for the most part, on the earth's surface within the first 2 km of atmosphere.

The major constituents of air, nitrogen (78%), oxygen (20.94%) and argon (0.93%), do not react with one other under normal circumstances. Similarly, the trace components helium, neon, krypton, xenon, hydrogen and nitrous oxide have little or no interaction with other molecules. But reactive gases such as sulphur dioxide (SO_2), nitrogen oxides (NO and NO_2), carbon monoxide (CO), and non-methane hydrocarbons cause pollution problems.

Air pollution is the results from the emission of various gases and particles from transportation and other human activities into the atmosphere. It is fundamentally different from the noise in the sense that once emitted into the atmosphere, pollutants such as carbon monoxide, hydrocarbons and oxides of nitrogen remain there for extended periods and can be carried by air currents to other locations.

During the recent years there has been a widespread attempt to reduce air pollution from all sources. During these years there has been a marked increase in the volume of road traffic and as a result a tremendous increase in pollution from this road traffic. This increase of air pollution is more in busy areas with more human activity. It is estimated that approximately one-third of the carbon monoxide in the atmosphere is produced from vehicle exhausts.

The major sources of atmospheric pollution caused by motor vehicles can be classified as:

(1) exhaust gases
(2) evaporative losses from the fuel tanks and carburettors
(3) crank case losses
(4) dust produced by the wearing away of tyres, brake linings and clutch plates.

Considering the exhaust gases, the following compounds are normally present in the discharge from vehicle exhausts:

(a) carbon dioxide
(b) water vapour
(c) unburnt petrol
(d) organic compounds produced from petrol
(e) carbon monoxide
(f) oxides of nitrogen
(g) lead compounds
(h) carbon particles in the form of smoke

On occasions these components of the exhaust may react with each other to produce unpleasant secondary products such as ‘smog’. Smog is produced sometimes when bright sunlight and the topography of the region, is formed by the reaction of the oxides of nitrogen and some of the hydrocarbons.

Both petrol and diesel engines give rise to similar products in their exhausts but the relative proportions differ. Diesel engine exhaust gases contain significantly lower proportions of pollutants than do those produced by petrol engines. But an incorrectly operated or maintained diesel engine is liable to emit smoke and produce an offensive smell but even then, apart from carbon particles, the degree of pollution is less than that produced by petrol engines.

In addition to the gaseous products a number of polynuclear aromatic compounds are also emitted with the exhaust gas in the form of very fine particles, which can persist in the air for lengthy periods.

Prevention of exhaust pollution

Pollution from individual engines is likely to be reduced by the modification of existing engines or the development of new engine types. One source of pollution however, lead, can be eliminated by omitting it from petrol and maintaining the same octane rating by more expensive means. Alternatively engines with lower compression ratios can be used.

More general measures that can be used to reduce exhaust pollution include; the use of smaller engines and vehicles in congested urban areas; the use of electrically driven vehicles; the improvement of vehicle flow or ease traffic congestion; restrictions on the use of private vehicles in the central areas of cities.

- **Smoke pollution**

Excessive smoke from vehicles is not only illegal, unpleasant and at times dangerous, but if left unchecked can mean expensive engine repairs and times off the road.

Blue smoke normally means engine wear or damage. Black and grey smoke results from incomplete combustion and may be caused by a number of factors which can normally be fixed during routine maintenance of vehicles.

7.3 Ground water pollution

Ground water pollution results from certain types of emissions from transportation system; e.g. oil, carbon etc. Hence proper street drainage is required to remove run-off from streets that would flood the street, nearby property, stagnate in pools and eventually pollute the ground water situation causing endanger to the public health. Therefore road carriageways should be designed and maintained with suitable cross falls, superelevations at curves, gradients and proper drainage facilities for the street run-off not to spill over to the adjoining properties.

Proper drainage of rain water from road surface is important with respect to preventing the deterioration of road surfaces itself. One of the major causes of deterioration of roads is water. It has been proved that increase in moisture content in soil tends to reduce the bearing capacity of soil. Thus the stability of roads may reduce by the increase in moisture content of the soil. Hence the proper street drainage is very essential for the existence of the road as well as preserving the ground water condition in the area.

7.4 Vibration

Vibration occurs in the vicinity of major surface transportation arterials where heavy vehicles are operated in close proximity to structures containing human activities that are extremely sensitive to vibration (e.g. rail, subway lines). Constant exposure to vibration over long periods may cause stress, fatigue, headaches, and even hearing deficiencies. Vibration also causes damages to residential dwellings which are not designed to stand vibration.

<u>**Chapter 8**</u>

Street lighting

Contents

Objectives

The objective of this chapter is to study the principles involved in street lighting and the practical applicability of street lighting in order to improve the safety of both drivers and pedestrians at dark. At the end of the chapter the reader should be able to understand the principles involved in street lighting and be able to propose a lighting layout for intersections and mid-blocks in a street layout.

8.1 Introduction

Some of the main objectives of street lighting are the promotion of safety at night by providing quick, accurate, and easy seeing for drivers and pedestrians, improvement of traffic flow at night by providing light condition which aids the driver in orienting himself, observing road markings, judging opportunities for overtaking, etc. In addition street lighting also helps to reducing street crimes after dark, and enhancement of commercial properties by attracting evening shoppers.

8.2 Basic principles of lighting

Since traffic engineering involves in assisting the lighting of the road system it is necessary to have a basic knowledge of the principles involved.

Some of the common terms met with street lighting are explained below.

Definition of terms

Luminous intensity (I) -

Luminous intensity is the density of luminous flux emitted from a light source in a given condition.

Candela (cd) -

This is the unit of luminous intensity.

Candle power –

Luminous intensity expressed in candelas.

Luminous flux (F) -

Luminous flux is the time rate of flow of light radiates from a source.

Lumen (lm) -

This is the unit of luminous flux.

Illumination -

Illumination is the luminous flux incident per unit area upon a point on a surface, and is measured in lumens per square metre (lm/m^2)

Lux -

Number of lumens per square metre is expressed as a lux.

The above terms can be further explained with Figure 8.1 which shows a source of light with a luminous intensity I, radiates luminous flux F (in lumens). Then the illumination E that can be measured in lumens per square metre (lux) is received by the surface.

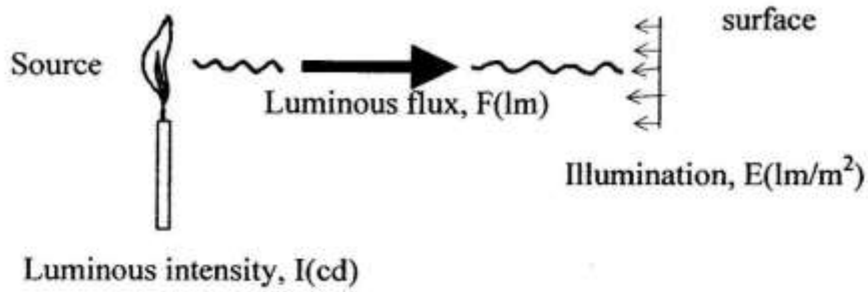


Figure 8.1 - Principles of lighting

It can be shown that the level of illumination on a plane, normal to the incident light, will be inversely proportional to the square of the distance from the source to the plane. Also the amount of light received is proportional to the cosine of the angle, θ to the normal. This can be seen from Figure 8.2.

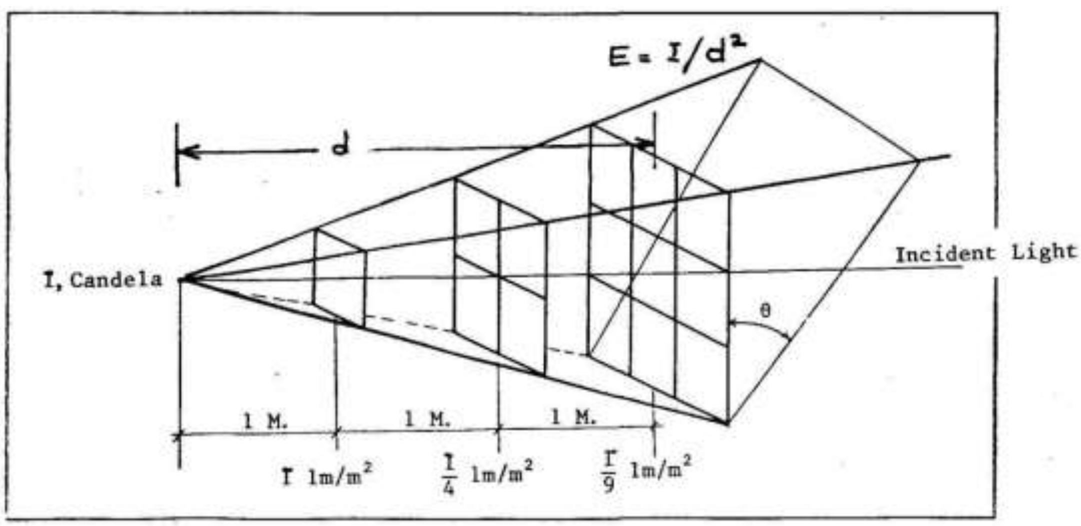


Figure 8.2 - Level of illumination on a plane

Combining this, illumination, E can be obtained as :

$E = I \cos \theta / d^2$

The most important application of this formula is the determination of the proper mounting height of lamp head for better illumination of the road surface, correct appreciation of traffic signs and other devices at night and for correction of glare (see Figure 8.3). Mounting height is the vertical distance between the centre of the lantern and the carriageway.

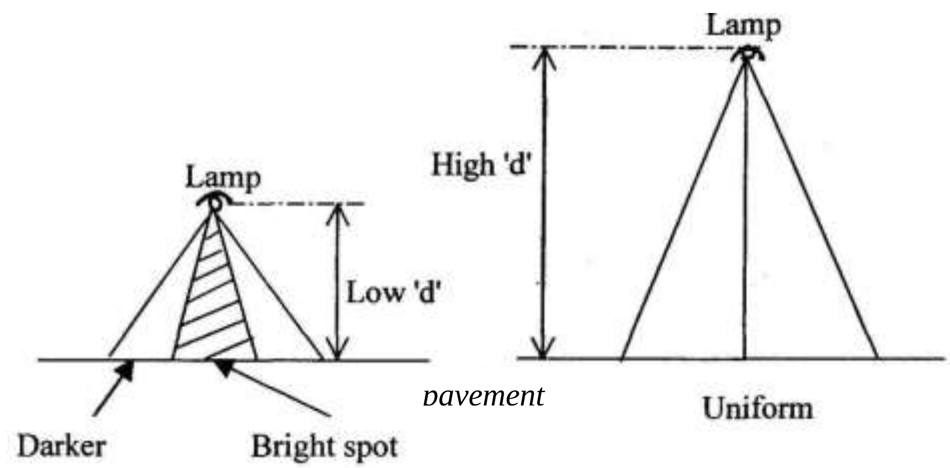
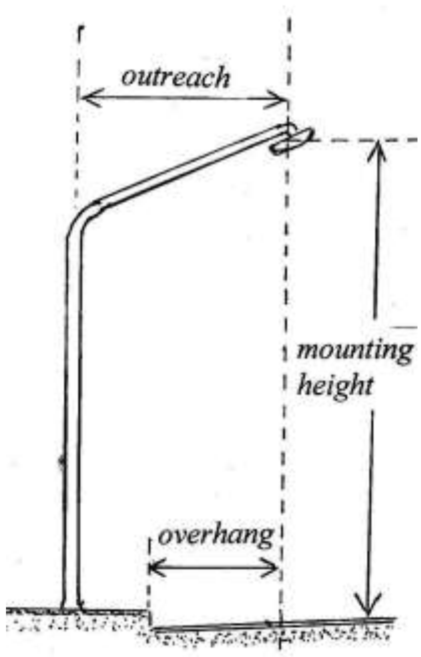


Figure 8.3 - Mounting height of lamp head

Overhang and outreach



Overhang is the horizontal distance between centre of a lantern and the adjacent edge of carriageway. Normally overhang distance is kept under 1.8 metres for better results.

Outreach is the horizontal distance between centre of the lantern and the centre of its mounting column. The amount of outreach depends on the amount of overhang and the distance of mounting column from the edge of the carriageway.

lamps

Principal means of discernment

1. Silhouette

When the obstacle to be seen has a lower brightness than its background, it is most easily recognised because of the silhouette it casts. Under most street lighting conditions, seeing by silhouette is the predominant method of recognition.

2. Reverse silhouette

When the obstacle to be seen has brightness higher than its background, but of such low level that surface detail is lost and it is recognised mainly or largely because of its general shape and size, it is said to be seen by reverse silhouette.

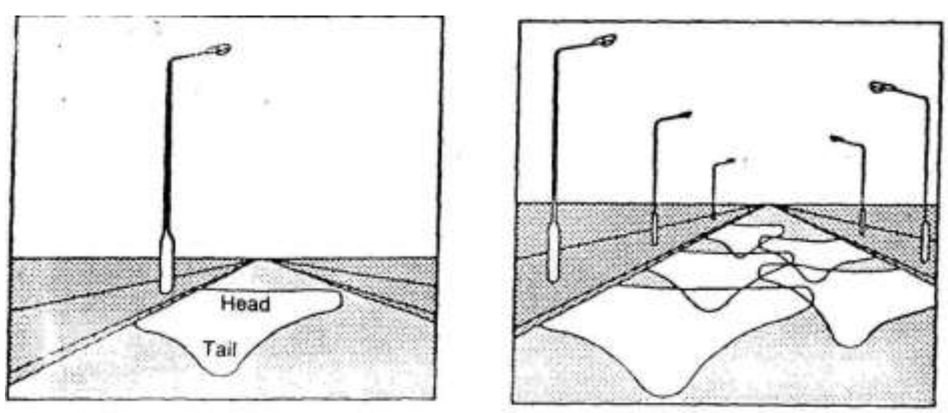
3. Surface detail

When the brightness of the object is such that much of the surface detail is visible, it becomes most easily recognised because of this detail and it is said to be seen by surface detail.

8.3 Pavement brightness

When a road is referred to as being 'evenly lit', this means that, when viewed from a car, the road surface appears to be 'evenly bright'.

If a lamp is hung some 10 metres above a road surface, a patch of light is reflected from the road. The shape of this patch depends on the road surface. On surfaces of very fine texture which take a noticeable polish, such as asphalt, the patch is long, extending even to the feet of the observer. On the more usual rough roads, the patch extends across the road rather than down it. Hardly any bright area will be seen on the far side of the post supporting the lamp (see Figure 8.5A). The patches are not as well defined as shown in the sketch, but can nevertheless be observed quite distinctly.



(A) Luminance patch from a single lamp **(B)** Luminance patches merging to give even lighting

(Course Notes on Transportation and Traffic Technology, 1983)

Figure 8.5 - Luminous patches

If a succession of lanterns along the length of the road is so arranged that the bright patches merge to cover the road area, objects on the road will be seen as dark silhouettes against the bright surface. This is the principle upon which most street lighting is based, since it proves more economic to produce silhouettes than it would be to make objects light and the road surface dark.

Because of the importance of discernment by silhouette, it is clear that apparently uniform pavement brightness of adequate level is desired. This is dependent on:

1. Reflection characteristics of the pavement, and
2. The spacing, mounting height, design of the complete lighting device.

8.4 Pavement reflection

The amount of light reflected to the observer from the pavement is dependant on angle of incidence, position of observer relating to the incident rays, and reflection factor and characteristics of pavement surface.

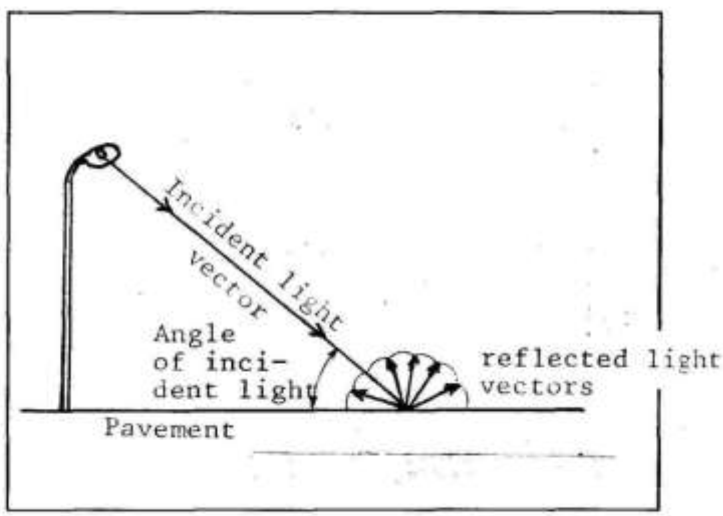


Figure 8.6 - Pavement reflection

In practice, the angle of incidence varies from 0 to 75^{o} from the vertical. Reflection factor and the characteristics of reflection are dependent on the pavement surface and its conditions. Reflection factor is defined as the ratio of light reflected to the light incident.

Generally speaking, the reflection factor of pavements are very low, usually ranging from about 20% for clean concrete to 3 to 10% for asphalt, and may be diffuse or spread over a wide area. As shown in Figure 8.5, the forward motion of the vehicle results in a continuous change of the angles of incidence and reflection.

8.5 Glare

Glare is defined as intense disagreeable brightness. The level of brightness for a given traffic condition is modified by the amount of glare. Glare not only causes discomfort but also reduces visibility.

The glare from luminaries may be controlled by:

- mounting height
- shielding the light source
- reducing the brightness contrast of the light source with that of the general level of illumination

The shielding of the light source is dependent on design and manufacture of luminaries.

The brightness contrast is related to lamp size and the design of reflectors and refractors, for a given level of illumination. Mounting height remains then, as the principal corrective of glare in a given application.

8.6 Types of lamps

Generally the main source of power for lighting of street lamps is electricity, although gas was used in some countries sometime back now it is not much used. There are many types of electric lamps available for street lighting installations.

Main types of street lamps that are commonly used:

(1) *Tungsten filament* – Tungsten filament bulb type is the most common and simplest lighting type. This is suitable for lighting of residential streets and pedestrian walk-ways. Although the light producing efficiency is low, sometimes this type is preferred because of its low installation cost.

(2) *Tubular fluorescent* – Tubular fluorescent lamps consist of a long narrow tube with its interior coated with a fluorescent powder layer. When an electric current is passed through the tube, an electric discharge takes place at low pressure within the tube causing an excitation of the fluorescent powder. As a result of this process, a bright white light is emitted from the tube. This type of lamps are used for busy towns where lot of pedestrian activities are taking place around the street such as; around shopping areas, and areas where lot of night time out door activities occur.

(3) *Sodium vapour discharge* – These lamps operate with an electrical discharge in a Sodium vapour surrounding. There are two possible variations (a) low pressure discharge lamp, and (b) high pressure discharge lamp.

The low pressure discharge lamp gives a characteristic mono-chromatic yellow light. The disadvantage of this type is that colours cannot be distinguished in this lighting environment. This type is used for night security at factories, warehouses, stores etc.

The high pressure discharge lamp gives a white colour, and helps to distinguish other colours, which is suitable for pedestrian activity areas. Because of its high efficiency, long life and pleasing light makes sodium vapour high pressure type lamps ideal for street lighting. This type of lamps is commonly seen in street lighting layouts all over the world.

(4) *High pressure mercury fluorescent* – These lamps operate by an electric discharge emitted between two electrodes inside Mercury surrounding causing the Mercury to evaporate. The discharge is of a brilliant greenish white. These types of lamps are very efficient, and also very costly.

8.7 Lighting layouts

Figure 8.7 shows some typical street lighting layouts of (a) T-junctions, (b) cross roads, (c) mini-roundabouts, (d) roundabouts, (e) mid-block straight sections, and (f) pedestrian crossings. The recommended layout at a T-junction is shown in Figure 8.7(a). Lantern A serves to show up the break in the kerb-line to drivers on the main road and approaching from the right. Lantern B is directly ahead of a driver in the side road as he approaches the junction and serves to indicate that it is a T-junction as well as revealing pedestrians crossing the mouth of the side road. Figures 8.7(b), 8.7(c) and 8.7(d) shows how the street lighting to be carried out at an intersections and roundabouts. Figure 8.7(e) shows different street lighting layouts for mid-block sections, where S is the space between adjoining street lights and W_K is the carriageway width. Overhang is indicated as (A).

After installing a well designed street lighting layout, it is equally important to properly maintain the lighting installation to ensure user safety. Cleaning of lamps and replacement of faulty lamps should be conducted at regular basis.

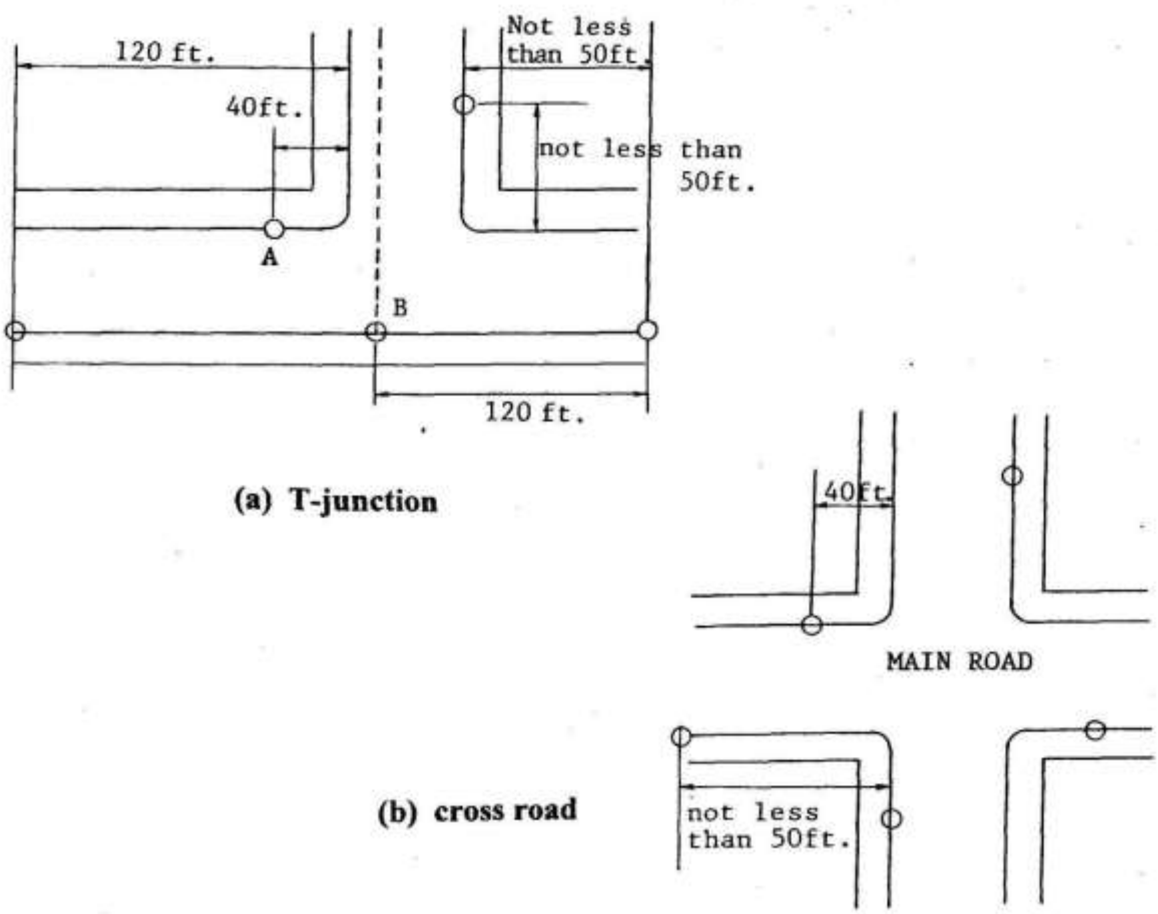
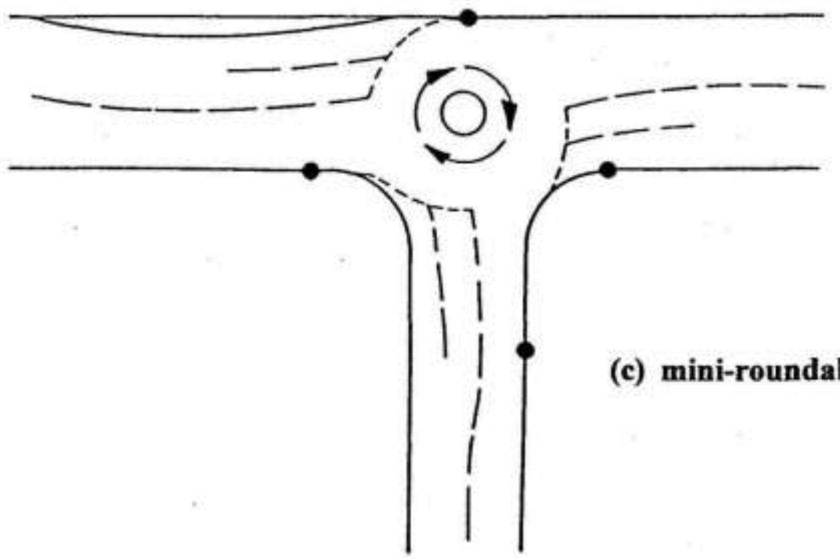
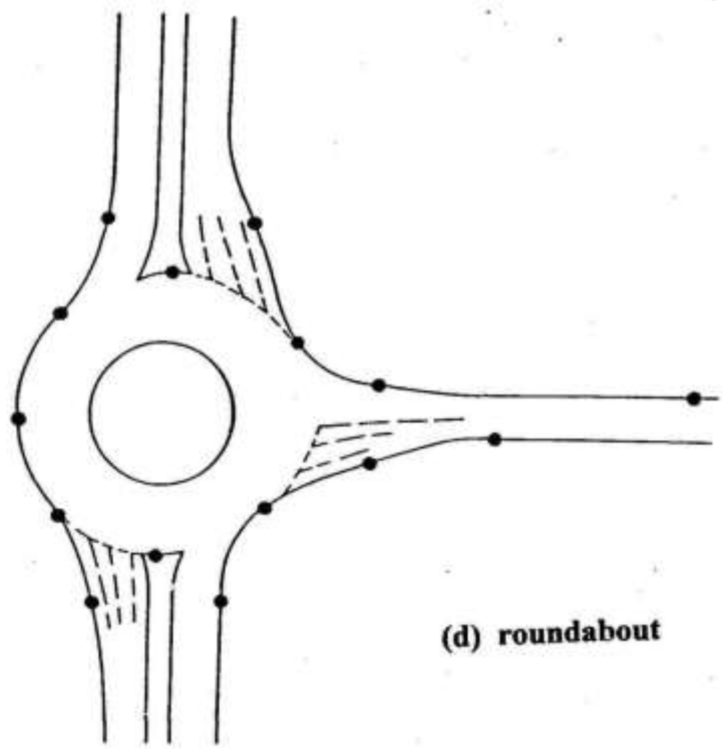


Figure 8.7 - Typical lighting layouts

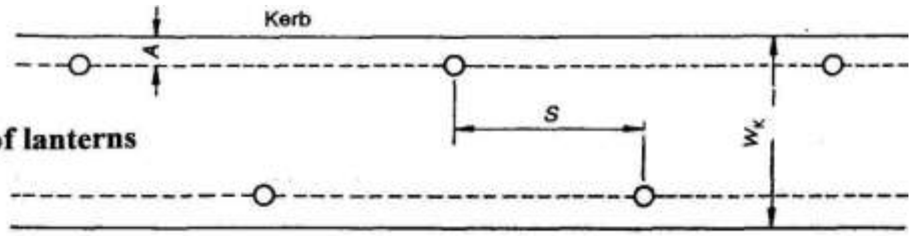


(c) mini-roundabout

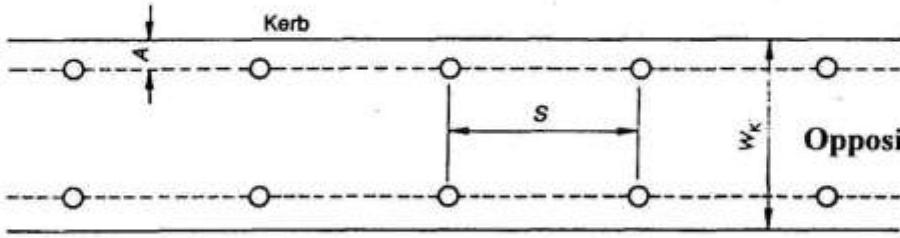


(d) roundabout

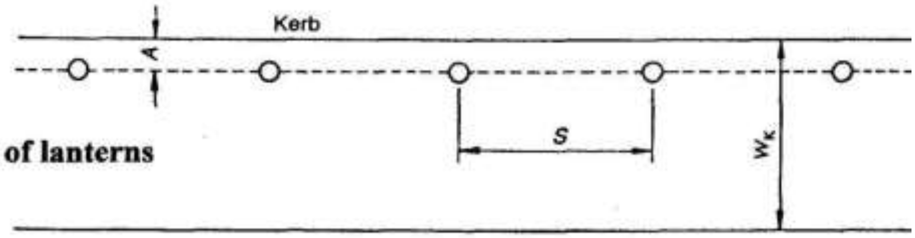
Figure 8.7 - Typical lighting layouts (Contd.)



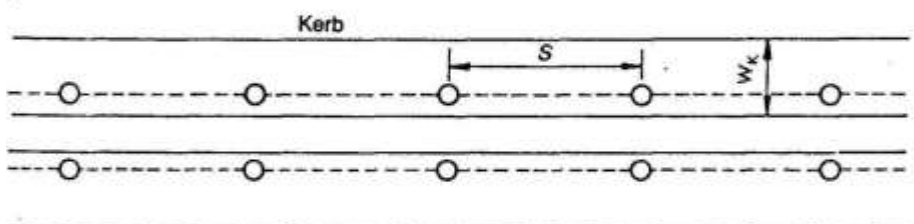
Staggered arrangement of lanterns



Opposite arrangement of lanteri

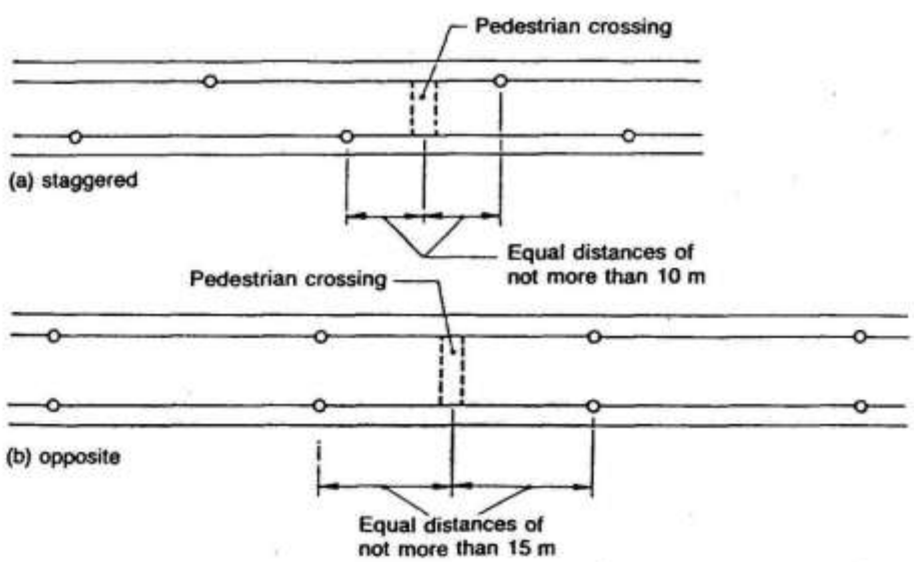


Single side arrangement of lanterns



Twin central on duel carriageway arrangement of lanterns

(e) mid-block straight sections



(f) pedestrian crossings

Figure 8.7 - Typical lighting layouts (Contd.)

Chapter 9

Computer applications in traffic and transportation engineering

Contents

Objectives

There are many ways in which digital computers have helped in solving transportation problems. The objective of this section is to give the reader a glimpse of a few such applications. The brief description given in this section is not an extensive coverage of each subject, but only selected as illustrations of some of the more feasible and interesting applications that are used in traffic and transportation industry.

9.1 Basic functions of computer applications

Every successful computer application must satisfy one or more of the following functions:

1. It should provide economy – Economy is gained when less man power is required to solve the problem, when the same program can be used over and over again, or when speed and accuracy of computation have an economic value.

2. It should provide insight – Insight is gained when the computer can be used to simulate situations in order to analyse the impact of various alternatives.

3. It should provide feasibility – Feasibility is gained when the problem could not be solved without using the computer because the results must be available in a very short time after the input data are available or when millions of pieces of data must be manipulated with precision and reliability.

9.2 Computational applications

Computer applications that are computational in nature are differentiated from data processing applications in the context of computations and the amount of data involved. Computational applications are those uses which usually have small amounts of data but require much calculation. They are primarily used in design and structural analyses. Below are some specific traffic engineering applications that are classed as computational programs:

1. Designing guide signs

The task of determining the legend positioning on highway guide signs is a difficult and tedious job because each guide sign is unique and there are numerous detailed rules and spacing criteria to be followed. Computers have been used to aid the traffic engineers in designing highway guide signs.

Computer programs have been developed which not only determined the layout of all sign legend in accordance with commonly used spacing rules and criteria, but also causes a computer driven plotter to draft the signs. The plots are made to any scale specified and the legend can be shown in its true shape and proper position.

One of the major benefits of these plots is the opportunity it affords the traffic engineer to visually check the balance and the positioning of the sign copy before the sign is constructed. These sign plots can be used in preparing the plans for signing contracts. Their use helps the sign fabricators by showing them exactly what the fabricated sign finally should look like.

2. Traffic signals

Trial and error, and graphical methods for determining progressive timing of traffic signals can become involved under the following conditions.

(a). Signals are not uniformly spaced.
(b). Phase splits are not the same at all signals.
(c). Traffic speed patterns vary from one section of the system to another section.
(d). Traffic speeds differ by direction of travel.
(e). Travel distances between stop lines differ by direction of travel.
(f). Progression is unbalanced or proportional to directional traffic volumes.

Computer programs have been designed to handle all these variable elements in optimising the widths of the progressive bands or other figures of merit. Output from these programs consists of printed table and an intermediate file containing all the parameters necessary for a supplemental computer program to prepare a time space diagram of the optimum solution.

Following are examples of few well used traffic control systems which are used in some countries where a large amount of traffic is handled through the computers.

(1) SCOOT - of UK

SCOOT (Split Cycle Offset Optimising Technique) is an adaptive traffic control system for reducing delay to traffic in an urban traffic-signal controlled network. Until the development of SCOOT, traffic control was achieved by fixed time systems which used historical information to calculate fixed time plans at certain times of the day (e.g. morning peak plan, holiday plan etc.). SCOOT was developed by the UK Transport and Road Research Laboratory. In SCOOT, with computer programs the capacity at the roads and intersections has been maximised. In this system the computers fully handle the traffic movements at the intersections so that the role the humans have to play is very minute.

(2) TRANSYT programme

TRANSYT (Traffic Network Study Tool) is an off-line programme for calculating optimum co-coordinated signal timings in a network of traffic signals. This is the most widely used computer application programme in traffic network signals in the world.

This model can analyse the traffic behaviour in a highway network where most intersections are controlled by traffic signals. The model works based on a ‘performance index value’ for the network links for a given fixed-time plan and an average set of flows on each link. The performance index measures the overall cost of traffic congestion which is a combination of total delays and number of stops by vehicles. By using the TRANSYT model, for varying traffic flows on different lanes, an optimisation process is conducted to adjust the signal timings. Through a successive iteration process optimising is carried out to obtain the most efficient signal timings.

(3) SCATS - of Australia

SCATS (Sydney Coordinated Adaptive Traffic System) is a computer based area traffic signal control system. It is a complete system of hardware, software and control philosophy. It operates in real-time, adjusting traffic signal timings throughout the system in response to variations in traffic demand and system capacity. The purpose of SCATS, as with any area traffic control system, is to control traffic on an area basis rather than an individual uncoordinated intersection basis.

In SCATS through computers the coordinated traffic signals provide a 'green-wave' progression whereby a motorist travelling along a road receives successive green signals. The computers help to minimise the overall stops and delay. When traffic demand at an intersection is heavy by allowing maximising the throughput at the intersection by giving priority for heavier movements. Without computers this type of accurate traffic handling is unthinkable.

3. Capacity computation

The task of using the charts and tables available for making highway capacity calculations has been considered cumbersome and involved by the users. One proposed solution to this problem has been the development of a series of computer programs to calculate the capacity at the critical locations such as:

- (a). intersections
- (b). exclusive turning lanes
- (c). freeways and highways
- (d). ramps
- (e). weaving sections

Computer programs are developed to enable to print summaries of all input data modification statements, if any, and the results.

Data processing applications serve primarily to reduce large amounts of raw data to more convenient form. They are used in summarising field observations in preparing summary statistics, and in making graphs and plots of data. Below are several specific applications that are classed as data processing programs:

Output from speed check programs usually includes identifying conditions at the study site and the following statistics.

(a). 85th (or 90th) percentile speed (maximum speed limit indication)

(b). 15th (or 10th) percentile speed (minimum speed limit indication)

(c). average speed

(d). median speed

(e). standard deviation of speeds

(f). maximum speed

(g). percentages travelling faster than specified speeds

(h). sample size

4. Intersection directional volume counts

Manual observation using a clip-board is the most efficient method yet devised to obtain a turning movement count at an intersection. Efficient computer methods, however, are being used in processing the count once it has been observed and recorded.

In order to eliminate the chances for errors in reading, transcribing, or keypunching the observed volumes, a method of recording the count in the field that can be read directly by data processing equipment would be desirable. One of several possible approaches is the use of CAMDAS computer program developed by the Australian Road Research Board. CAMDAS is a new video vehicle detector, providing information about vehicle movements from VCR pictures and transferring this information in to the computer. Once the vehicle movement is recorded in a VCR tape, the information in this tape can be analysed with CAMDAS video analysis program, and the data abstracted can be straight away send in to a computer for subsequent analyses.

5. Interpretation of results

In preparing tabulations and tables for this and other applications, some thought should be given to sizing the resulting print-outs. Eventually the print-outs will be filled. If the tabulations have been formatted to fit on an $8^1/_2 \times 11$ inch (or A4 size) sheet, they will not only fit in standard size files or loose-leaf binders, but they can also be reproduced on almost any copy machine and can be included full size in report.

For quick, visual interpretation of intersection, directional volume counts, an intersection flow chart is helpful. The computer has been used not only to tabulate the count, but also to prepare flow charts. Other programs compare the summarise volumes with the warrants for traffic signals and prepare traffic signal warrant graphs and traffic volume histograms.

6. Accident summaries

Because of the great number of accident reports to be processed, states and large cities have sought the aid of the computer in performing some of their accident recording and processing functions. Information pertaining to each accident is coded and recorded in a database where this database can be sorted and interrogated to produce the desired accident summaries.

Two engineering uses of this accident data generally fall into the following six categories.

(a). Statistical accident summaries. A state-wide, country-wide, or city-wide statistical breakdown of the number of accidents occurring by time of day, day of week, month of year, severity, kind of collision, kind of vehicles, weather condition, surface condition, light condition, casual factors, vehicular movements, driver sex and other factors.

(b). Route summaries. A brief single-line summary of each route showing route length, average daily traffic, type and number of accidents, and accident rate. The listing may be arranged by consecutive route numbers or descending accident rates.

(c). Sequential listing of individual accidents. A brief single-line capsule summary of each accident. These listings are most helpful if the accident condition codes are interpreted. With such a decoded format high accident locations and accident patterns are more readily identified.

(d). Listing of high accident locations. A brief single-line summary of each intersection or roadway section having a cluster of ‘n’ or more accidents during a given time period. The listing may be arranged by sequential locations by descending accident frequency or by descending accident rate.

(e). Preparation of accident collision diagrams. Several attempts have been made to let the computer prepare accident collision diagrams for high-accident locations. This plot indicates the following accident characteristics:

1. direction of travel
2. vehicle manoeuvres
3. kind of accident
4. light condition
5. road surface condition
6. weather condition
7. time of accident (date and time of day)
8. accident severity

(f). Special reports. Special tabulations to summarise all accidents involving only railroad crossings, construction zones, bicycles, pedestrians, or other special situations as desired.

(g). Computers are also widely used in highway design and improvement of highway safety aspects of these new designs. A computer package such as MOSS is widely used in the world for safe highway designs.

9.3 Computer simulation applications

Simulation applications attempt to model physical systems that are too complex for direct analytical evaluation. These applications permit a wide range of conditions to be analysed at less cost and in less time than would be possible under actual conditions.

Following are specific simulation applications:

1. Traffic assignment

   One of the important tasks in transportation planning is to determine future traffic loads on the street and highway network. The method used in accomplishing this task is a computer simulation of future traffic flow. This simulation process involves the following basic steps:

   (a). Establish computer files representing the street network.
   (b). Establish computer files indicating future trips between origins and destinations.
   (c). Simulate the driver's decision processes in selecting routes between origins and destinations. Factors that might be considered in selecting routes include travel times, travel distances, travel speeds and volume-capacity relationships.
   (d). Assign the trips to the selected routes and count the number of trips passing over each link of the network
   (e). Prepare maps and tabulations for use in evaluating the network.

2. Intersection flow simulation

   Numerous attempts have been made to predict traffic stops, delays, queue build-ups, signal operation with bus presumption traffic conflicts, and accident potential at intersections by simulating the flow of vehicles in the computer. By using these simulation models, the traffic engineer is able to evaluate the effect of various traffic stream conditions, geometric configurations and traffic control techniques without the time expense and dangers involved in undertaking similar field studies.

3. Model validation

   An important step in using the computer for traffic simulation is model validation. The results of studies at field sites having characteristics similar to the intersection being simulated should compare favourably with the results of studies using the simulation model. A range of conditions should be compared in order to establish the validity of the model under the range of conditions to be simulated.

9.4 Real time control applications

In real time control applications the computer is an integral part of the system. Input data are fed to the computer from the system; the computer evaluates the data and returns output signals to control the system. Following are traffic engineering examples of real-time control applications:

1. Merging control system. It is sometimes difficult for motorists entering a freeway to merge safely with freeway traffic. Various merging control systems have been designed to aid the driver in smoothly and safely joining the traffic stream. These systems detect the position and velocity of vehicles on both the entrance ramp and the freeway, determine when an acceptable gap for a ramp vehicle to merge into the freeway traffic stream will occur, and guide the ramp vehicle into the acceptable gap by the use of ramp side driver displays.

2. Traffic surveillance and control. The efficient operation of an urban freeway and expressway system depends in part on the early detection of undesirable traffic conditions so that corrective measures can be initiated without unnecessary delay. Traffic volumes, speeds, or occupancies are continuously monitored and compared. When traffic speeds of densities reach specified values, or when the occupancy at a downstream detector falls of as the occupancy at an upstream detector builds up, signals are generated by the computer calling for corrective action. These signals may activate variable message diversion signs, ramp metering devices, or lights on a map board of the freeway system pinpointing the location of the trouble. These surveillance and control systems can also provide a wealth of information on traffic volumes, speeds and occupancies throughout the roadway network.

3. Traffic signal control. A number of cities are now using digital computers for traffic signal control. The movement of vehicles throughout the street network under computer control is sensed by using hundreds of detectors, evaluated by computer, and controlled by the computer driven traffic signals. These systems are not only traffic responsive, but they also provide great flexibility in control strategies without requiring hardware changes in the field. They can have an unlimited number of timing plans and can be expanded to include other locations for a minimum incremental cost.

9.5 Other applications relevant to traffic and transportation engineering

The following specific applications are not unique to this profession alone, for they have wide spread application in many fields. Below are ways in which the traffic engineering profession is benefiting by these specific applications:

1. Data storage and retrieval systems

Situations occur in which it is desirable to store large amounts of information, or data thereby making it available for people to retrieve the information when they need it. Libraries are some example of such an information storage and retrieval system. The basic elements of the system include.

(a). acquisition and selection of information to be stored.
(b). assignment of a storage location.
(c). establishment of indexes for providing later access to the materials stored.
(d). retrieval of specific information when needed.

Computer-based data banks can be established to accomplish this same objective; they have the same four basic elements. The advantages of using the computer for this kind of application include:

(a). the computer can organise, store, and examine vast amounts of information at high speeds.
(b). it can retrieve information and print it out very quickly.
(c). information in storage is always available; it is not ‘checked out’, but is duplicated for each user.
(d). the computer can disseminate information to remote locations.
(e). it can undertake tasks too large to consider doing manually.

The most widely known data bank application in the fields of traffic or transportation engineering is the Highway Research Information Service (HRIS) developed by the Transportation Research Board of USA. The main objectives of this specific application are:

(a). to select and store input information from current and past highway research that will be of value to users of highway information.
(b). to disseminate current information to users.
(c). to retrieve relevant information on request.

2. Document writer

The administrator in traffic or transportation engineering may encounter situations in which typewritten documents must be reprinted from time to time with only minor changes. Each revision generally requires retyping on new paper, much or all of the material, incorporating the modifications. The addition of a short paragraph, for example, may require retyping all pages from that point until the end of that unit.

Since the computer output is usually printed by a high speed printer, the administrator could take advantage of the computer's speed and accuracy characteristics. By typing the initial draft on a key board or a typewriter a data file can be prepared containing the information to be printed. Changes could easily be made by inserting, deleting, or replacing records in the file. The file could then be read by the computer and printed on the high speed printer. Subsequent revisions and reprints would only involve making the necessary changes in the file and proceeding it as before.

At least three specific applications of this nature are presently in-use within the traffic engineering profession:

1. Speed zone descriptions. A description of all current speed zones is needed by those involved in the establishment, posting, maintenance and enforcement of speed regulations.
2. Specifications for contracts. Installing traffic signals, highway lighting, or other items by contract requires the preparation of special provisions. In most cases the bulk of the special provisions may be unchanged from contract to contract.

3. Manuscripts. There are two ways in which a computer application of this nature has facilitated preparing reports and other manuscripts:
    (a). reprinting the same report material with only minor changes as in the above applications
    (b). speeding up the editorial review, and other preparation processes by reducing the time required to retype the interim and final drafts. Almost all manuscripts undergo a number of editorial changes and review between the first typewritten draft and the final copy.

3. Inventories

The purpose of an inventory is to account for the possessions of an organisation. The condition and worth of the items inventoried are usually included in this accounting. One appropriate inventory application deals with traffic signs.

Traffic sign inventories are necessary in order to:

(a). satisfy legal requirements to maintain records of traffic control devices
(b). provide a basis for proper maintenance of traffic signs
(c). provide a basis for periodic inspection, especially of regulatory and warning signs
(d). provide a basis for traffic sign upgrading and replacement programs

Information about each sign is stored in a database. Information included on the card usually includes sign location, kind of sign, sign legend, mounting method, and installation data. Information on mounting height, sign size, sign materials, physical reflective conditions of sign, and other sign characteristics may also be included on the database.

The inventory cards could be processed by computers. The following listings can be readily obtained when the data is stored in the computer:

(a). sequence of signs along specified streets.
(b). signs of a specified kind.
(c). signs mounted on a particular kind of pole.
(d). age of sign.
(e). various combinations of various categories, for example listing of all school crossing signs over five years of age.

There are many ways in which digital computers have helped in solving transportation problems world wide. By reading through this chapter the reader is directed to have a glimpse of few such applications. The description given in this chapter is not an extensive coverage of each subject that were discussed, and the world wide computer applications in traffic and transportation industry is much more.

<u>**Chapter 10**</u>

Traffic Impact Assessment (TIA) Studies

Contents

Objectives

The objective of this chapter is to make the reader aware of what Traffic Impact Assessment (TIA) studies are, and explain the requirements and main components of these studies, and finally teach the reader how to conduct such a study. In the initial sections a detail overall of; background, purpose of these studies, components to address and guidelines are explained. Section 10.7 provides a comprehensive checklist of issues to be addressed in a TIA and explained how they should be addressed. By the end of chapter 10 the reader should be able to conduct a traffic impact assessment study successfully.

10.1 Purpose of traffic impact assessment studies

When a potential builder submits a ‘development application’ to the relevant local authority (e.g. municipal council or urban council) for approval, the local authority should have accurate advance knowledge about the after effects of the development for the application to be considered for granting approval. Hence a fact finding traffic study has to be conducted to gain knowledge about the surrounding traffic environment of the locality.

When ‘development applications’ are processed, and approvals are granted for new developments, paying advance thought to the generation of future traffic due to these developments is an important issue. Guidelines outlining all aspects of traffic generation considerations relating to developments are a useful tool to carryout the prediction of traffic due to the development. These guidelines should provide information regarding traffic issues for those submitting 'development applications', and for those involved in the assessment of these applications. The overall objective is that both parties (i.e. developer and approval granting authority) have access to common information relevant to the development approval process. The information provided gives background into the likely impacts of traffic from various types of developments, thereby to take appropriate measures to accommodate the proposed development if approval is to be given.

All developments, irrespective of small or large, generate traffic. The amount of traffic generated depends on the type of development, its functions, location and size, and the number of persons using it. The traffic generated due to the development affects surrounding developments and the adjacent transport network. This effect should be consistent with the current classification and functions of the adjoining network. The impact of the development should not cause the adjacent roads to be forced into performing a function of higher road classification.

10.2 Background

With the coming up of new developments the generation of vehicular traffic due to the said developments is an issue that has been overlooked in this country over the past few decades. When studying the procedures adopted by local councils in the past for granting approval for various development activities, it was seen that no advance thought has been given to traffic generation due to the development and its expected functional activities. This has resulted inappropriate developments at wrong places, congested roads, reduction in amenity in the neighbourhoods, excessive accidents both vehicular and pedestrian, and finally a burden on the traffic police. Although UDA recent publication *Guide to Colombo Development Plan* suggests the implementation of Traffic impact assessment (TIA) as a new regulatory instrument, no guidance is given how a TIA is conducted and to what extent it should be adopted.

A primary objective of the TIA is to provide relevant supporting information for a development application, so that the highway authority can be satisfied as to the acceptability of the traffic impact of the proposed development. The findings of the TIA study are usually presented in a report; this can be a convenient form in which to provide the traffic/highway information required supporting a development application.

10.3 TIA as a management tool

TIA is a useful tool to study the impacts on the surrounding road network due to the new development. With the help of a TIA it is expected to conduct a thorough investigation of how the new development is going to affect the road network and the neighbourhood and also to see what precautionary measures should be taken to prevent any adverse effects. Therefore, conducting a TIA is an important requirement and a mandatory function of the local authorities before approving large-scale new developments in the city areas. If an accurate TIA is not conducted and preparation for the additional traffic generated/attracted in future due to the proposed development is not considered before granting approval for large-scale new developments in congested areas, the future traffic flow in that area is going to be adversely affected. It should be noted that all developments do not always cause an increase in generated traffic. However, more significant sites require a thorough evaluation and application of appropriate management measures. Hence sufficient care should be taken when deciding the necessity of a TIA depending on the scale and nature of the development. There are no statutory rules as to when a development is adequately large so that it requires a TIA. However some literature suggests some threshold based on scale of development and traffic flows is used in European countries.

It's seen that some authorities tend to see TIA as the impact of traffic on the environment, and propose it to be a part of the Environmental Impact Assessment (EIA). However most developments will not require a formal EIA, but there may be a great need for the assessment of environmental effects caused by traffic.

The traffic generated and attracted by a development depends on the location, the type of land use and the size of the development. One possible result of an increase in vehicular traffic can be an increase in the number of accidents. Therefore, access to the development and the road system must be designed to minimise conflicts between vehicles and pedestrians. Safety should be a primary consideration in planning for developments. If a development is located in an area with a high accident level, then provision must be made to reduce the potential for accidents. Also, where a development generates a lot of pedestrian movement, appropriate remedial measures must be taken to maintain safety standards.

Changes in the traffic environment in an area (due to new developments) can have the following impacts on the surroundings.

- impact on traffic efficiency – due to large scale developments a considerable amount of traffic ‘going into’ and ‘coming out of’ the development can cause detrimental effects on the through traffic if adequate traffic management measures are not taken. This may directly affect the efficiency of the road.
- impact due to lack of parking – if the proposed development is unable to provide the parking requirement of the development (as commonly seen in local townships), roadside parking is automatically going to take place, which finally reduce the road capacity.
- impact on amenity – the neighbourhood privacy and amenity can be affected if inappropriate development takes place in the area.
- impact on safety – if appropriate safety measures are not taken the newly increased traffic can be a safety threat on all road users.
- impact on road pavement life – the increased traffic (especially if the increase is in terms of heavy vehicles) may adversely affect the pavement life.

10.4 Things to look through a TIA

With the help of a TIA, improvements should be worked out in the areas such as future traffic management strategies, improvements to intersections by way of traffic signals, roundabouts or other measures, site access and smooth circulation of traffic, improvement to pedestrian facilities and their safety, recommendations on public transport facilities, reconsideration of shifting or providing new bus stops etc., and finally funding of proposed improvement (Weerasekera, 2000).

When a 'developer' or in other words the 'promoter' submits an application for a certain development project (small scale or large scale) to the local authority for approval, the local authority should decide whether or not to request a TIA report from the developer. This decision should be made depending on the impact the development is going to cause on the neighbourhood road network. At this stage the local authority should have a clear policy regarding the necessity of a TIA. This decision should be based on the proposed activity, number of users including visitors, floor area, cost of the project, function of the development, extent of the development and land use of the particular area etc. Local threshold values should be developed based on national policies and standards.

If the local authority requests a TIA report on a particular development project, the TIA report submitted by the 'developer' should clearly address the issues given in section 10.7. The TIA is a complete assessment of how the 'in-coming' and 'out-going' vehicles due to the proposed development might affect the road network in the vicinity of the development and on public transport facility. The TIA should be an impartial description of the impact and should outline both positive and negative aspects of the proposed development.

10.5 Elements of a TIA

Traffic impact assessment is the tool which is used to ensure that all relevant considerations are part of the decision making process. The relationship of the proposed activity to land use and transport planning issues, future traffic management issues and the consideration of feasible options is addressed in the traffic impact assessment process.

Following are the issues to be addressed in a TIA.

1. Purpose and need of the development – The need of the development should be justified under this section.
2. Description of the actions (including do-nothing and other alternatives) – This section should give a clear description of the proposed development, identifying the potential traffic impact. It should also include a discussion on other alternatives and ‘do-nothing’ option.
3. Description of existing traffic environment – Give a proper picture of the existing traffic environment around the proposed development.
4. Description of expected traffic increase due to the proposed development – The expected traffic generation due to the proposed development should be quantified under this section.
5. Information on the evaluation method of item 4. The calculations carried out during the evaluation of item 4 should be submitted under this section.
6. Information on ‘fitting’ to the present policies – How the generated traffic can be incorporated to the present situation and any proposed traffic management policies.
7. Information on important uncertainties – All the important uncertainties should be genuinely stated under this section.

10.6 Guideline on traffic impact studies

Any guideline on Traffic Impact Studies should have the following components:

1. Policies and issues

   This section should discus the policies and issues concerning all kinds of traffic generating developments. It also sets out some general principles for design relating to developments.

2. Traffic impact studies

   This section should look at traffic impact studies and the key issues of their use. It should outline methods of conducting traffic impact studies and compiling traffic impact statements. It also should include a checklist style table of information required to conduct such studies, and indicate the source of relevant information.

3. Land use traffic generation

   The traffic generation rates for a number of land uses based on previous experiences should be tabulated. A summary table of generation rates should be included, and can be used in conjunction with the additional information supplied with each land use.

4. Existing traffic in the area

   This section should be a comprehensive study of the existing traffic and pedestrian movement in the area. A summary of the traffic studies conducted with their findings should be given in this section.

5. Interpretation of traffic impacts

   Once the generation rate for a particular land use has been established, either using data from section 3 above or by a survey results, this section can be used to determine the impact of the proposed development on the surrounding road network. The type of impact then determines the requirements, which make the development acceptable.

6. Parking requirements for specific land uses

   Based on surveys conducted previously on a variety of land uses, parking requirements and driveway types should be recommended in this section. Definitions for each land use may be included, combined with a summary table of relevant land uses.

7. Access and parking area design

   This section should deal with geometric design aspects of access to developments, as well as internal roads and parking areas within developments.

8. Residential subdivisions – traffic and safety

   The design of residential subdivisions should be discussed in this section. The general principles of traffic and safety matters of design should be presented.

9. Cost impacts of traffic generated by developments

   This section should investigate possibilities of recovery of cost due to development. Also outline the various means of assessing costs associated with the impact of a development on the surrounding road network.

10. Reference material

   This section should contain reference material used in the study (a bibliography and a glossary), which enhances the main body of information in the guide.

10.7 Issues to be addressed (a checklist)

A traffic impact study should follow a standard format, which covers the key issues to be addressed in determining the impact on traffic of a proposed development. Use of this format and the checklist will ensure those involved in the preparation and/or assessment of development applications that the most significant matters are considered without missing any.

Key issues in preparing traffic impact studies

1. Introduction
2. General data collection / Existing conditions
3. Proposed development
4. Recommended works

10.7.1 ***Introduction***

The introduction should include the following.

(a) Brief description of the development
(b) Application and study process
(c) Introduction
(d) Background
(e) Scope of report
(f) The key issues and objectives of a traffic impact study

10.7.2 General Data Collection / Existing Conditions

The necessary data should be collected and presented regarding the following.

(a) Site location
(b) The existing traffic conditions
(c) Traffic flows
(d) Traffic safety
(e) Parking supply and demand
(f) Modal split
(g) Public transport
(h) Pedestrian network
(i) Proposed developments in the vicinity

(a) Site location

The exact location of the proposed development should be clearly indicated here. Current land use characteristics (zoning) of the proposed site and land use in the vicinity should be highlighted. Site access should be studied *in detail.*

(b) The existing traffic conditions

The following listed traffic data should be collected presented in this section.

- the existing traffic conditions
- road hierarchy; including the identification of the classified road network (major and minor roads) which may be affected by the development proposal
- inventory of road widths, road conditions, traffic management and parking control
- current and proposed roadworks, traffic management works and bikeways
- pedestrian movement pattern

(c) Traffic flows

The traffic flows which occur in the 'no development' scenario must be established for the existing situation and estimated for the proposed development year of opening and, if appropriate, for a 'future design year'. This applies to the time periods of greatest traffic impact of the development.

Key parameters to be considered:

- selection of key streets - possibly divided into the major and the minor road network; selection of key assessment periods, chosen to cover the times at which the development would be expected to have its major impacts
- AADT on key streets
- traffic trends in no development scenario
- daily traffic flow hourly distribution, particularly in or near residential areas
- estimate of the speed of traffic on the road to which vehicular access is proposed
- current traffic generation of site
- daily and peak period heavy vehicle flows and percentages
- the adaptation of appropriate computer models or techniques for assessing levels of traffic congestion and queuing conditions

(d) Traffic safety

The accident history of road network in the area to be presented. Any specific accident prone locations and black-spots should be indicated.

Pedestrians

The provision of pedestrian safety, both in and on the approaches to the development site, may require explicit description. General matters relating to pedestrian needs and provision of facilities should be taken for consideration.

Cyclists

The effect of cyclists due to the proposed development should be studied. Any detrimental effects should be taken care of.

(e) Parking supply and demand

The following aspects should be studied

- on-street parking provision
- off-street parking provision
- current parking demand, including utilisation by time of day and turnover rates
- short term pick up and set down areas

The following types of parking surveys are available to collect information on above.

Parking surveys

Parking surveys are carried out to assess the extent of the parking problem in the area being studied. The objective of any parking study should be to collect data, which will give an indication of the parking needs of the area. 'Parking supply' and 'Parking usage' surveys are common to all types of parking studies undertaken, irrespective of the scale of the parking study (Course Notes, Highway Engineering, 2002).

(1) *Parking supply survey*

Parking supply surveys are aimed at collecting detailed information regarding the available on-street and off-street parking facilities, how they are controlled, and the features, which influence the provision of parking space. A typical parking supply survey would require an inventory of all on-street parking facilities, surface car parks and multi-storey car parks located within the study area. Whether the survey is intended for the central area of a large town or a shopping area of a small town or a hospital complex, the study area should include the fringe area where persons visiting the study area and park their vehicles.

A parking supply survey can be considered to be made up of three main parts, namely,

1. on-street road space inventory.
2. a road regulation inventory
3. an off-street space inventory

Data is collected under these three main parts by simple inspection of the survey area and the important data that is normally collected under each of these survey phases is given in Table 10.1.

It is useful to mark the data obtained from a parking supply survey on a suitable scale (say 1:2500) using figures to indicate the number of parking spaces available at different locations. The information obtained from a parking supply survey is very useful in the formulation of a parking plan. For questions such as; number of on-street and off-street parking spaces available in a particular area, the answers are readily available from parking supply survey data if the survey is conducted properly.

Table 10.1 - Components of a parking supply survey

Road space inventory	Road regulation inventory	Off - street space inventory
1. Access to premises 2. Road reservations 3. Bus stops 4. Taxi/Three-wheeler stands 5. Loading/Unloading bays 6. Pedestrian Crossings 7. One –way streets 8. Private roads 9. Vacant land suitable for temporary or permanent parking spaces 10. Already available parking areas 11. Carriageway widths 12. Pedestrian walkway widths 13. Road-side activities 14. Other local factors	1. Controlled parking. (a) by regulation (b) by meters 2. Parking prohibited areas (a) always (b) during peak hours 3. Controlled loading and unloading 4. Uncontrolled parking 5.Clearway zones	1. Type (a) At ground level only (b) Multi -storey or upper level only. (c) Underground only (d) At all levels 2. Ownership and use (a) Publicly owned, for public use. (b) Publicly owned, for both public & private use. (c) Privately owned for public use. (d) Privately owned, for private use. (e) Privately owned, for both private & public use. 3. Commercial vehicles only. 4. Hiring vehicles only. 5. Parking fees. (a) fee charging (sub divided according to rates) (b) fee charging (a common rate) (c) free of charge. 6. Time limit or unlimited parking. 7. Size of parking area and no of spaces provided 8. No. of entrances and exits. 9. Internal circulating arrangements.

(2) ***Parking usage survey***

The development of a parking plan for a central area depends to a great extent on the number of spaces that is available in the central area (parking supply) and the desire to park based mainly on the destinations of the motorists (demand). However, unlike in the case of normal supply and demand, there is a third variable, which is the parking usage.

Parking usage is dependent on the desire to park close to the destination, the availability of parking space, and the desire to park within a certain cost, which varies for each individual motorist. Certain motorists are prepared to pay more than the others do in order to park close to the destination. If the parking supply is greater than the parking demand, the true parking demand can be assessed by making observations of the vehicles parked at regular intervals. If the parking supply is less than the demand, then a certain number of vehicles are suppressed from parking within the central area. In this situation, the true parking demand can be properly estimated only from a comprehensive land-use transportation survey.

(3) ***Parking concentration survey***

The aim of a parking concentration survey is determine the actual number of vehicles parked different locations (on-street and off-street) at an area can be covered by an observer travelling on for at a pre-determined time interval. The selection of suitable time-interval depends on the accuracy of the survey, the amount of money and manpower, avai1able for the survey. Normally, the time-interval select is 1/2 hour or 1-hour for on-street and off-street parking concentration surveys. If the time-interval select is 1-hour, then the observers wa1k around the area designated to them at 1-hour intervals and note do the number of vehicles parked in that area. The concentration survey for off-street faci1ities is also be carried out as for on-street parking, that is counting the number of vehicles parked in an off-street facility at regular intervals.

The selection of the time and season for concentration survey is mainly dependant on characteristics of the town and on the extent variation in parking usage likely to be experienced throughout the week. It is seen in Sri Lanka that months of April and December experience abnormal parking demand, hence it desirable to avoid these two months. Days precede or following holidays are not considered suitable carry out these surveys. The duration of the sun could generally be from 7.00 a.m. to 7.00 p.m.

(4) *Parking duration survey*

As the name of the survey implies, the purpose of survey is to determine the lengths of time vehicles are parked within the survey area. It is the normal practice to combine the duration survey with the concentration survey. The information for ‘duration survey’ could be obtained by slightly modifying the ‘concentration survey’. Instead of observer noting the number of vehicles parked during the survey time interval, he/she will be required to note registration numbers of all the vehicles parked. If it is difficult to note the full registration number of the vehicles parked, it is suggested to note the first three or four digits. Suppose the time interval is 1/2 hour then it is assumed that all vehicles parked in excess of 1/2 hour and less than 1 hour will be entered twice and the vehicles parked for more than l hour and less than 1 1/2 hours are entered thrice, and so on.

(f) Modal split

Modal split is when trips are made by different methods or modes of travel and the selection of the choice of travel mode is defined as modal split. Hence modal split and any possible changes of modal split should be given thought of in advance.

(g) Public transport

This section should consider the aspects of public transport provision relevant to the development. This may most commonly apply to buses and rail in the local context.

Key parameters to be considered:

- rail station locations.
- bus routes and bus stop locations
- pedestrian access to bus stops, constraints and conflicts.
- rail and bus service frequencies, both peak and off-peak times.
- commuter parking provision.

(h) Pedestrian network

This section should study the following.

- identify major pedestrian routes.
- pedestrian flows and potential conflicts with vehicles, particularly where such conflicts cause capacity constraint on either vehicular or pedestrian movement.
- pedestrian infrastructure, such as pedestrian crossings, walkways, refuge islands, over passes and under passes etc.

(i) Proposed developments in the vicinity

Any other proposed developments should also be considered in the study.

10.7.3 ***Proposed development***

The following should be studied with the new development

(a) The development
(b) Access
(c) Circulation
(d) Parking
(e) Impact of proposed development
(f) Traffic distribution and assignments
(g) Impact on traffic safety
(h) Impact of generated traffic
(i) Public transport

(a) The development

Factors to be considered

- study of site plans and proposed layout plans
- study the nature of development
- details such as gross areas of different components of the development
- study the number of persons involved with the development (number of employees, users, residents etc.)
- hours and days of operations
- staging and timing of development
- study the types of vehicles that will be attracted to the development

(b) Access

The proposed site access arrangements are usually best explained with the assisstance of a plans and diagrams. The nature of proposed function controls should be clearly identified.

Key parameters to be considered:

- driveway location, including review of alternative locations.
- sight distance of driveways and comparisions with stopping and desirable minimum sight distances.
- service vehicle access.
- analysis of projected queuing at entrances.
- current access to site comparison with proposed access.
- provision for access to, and by, public transport.

(c) Circulation

Factors to be considered

- proposed pattern of traffic circulation
- internal road widths
- provision of bus movements
- service area layout

(d) Parking

Factors to be considered

- proposed supply of parking
- alignment with the local parking regulations
- parking layouts
- projected peak demand, based where appropriate on similar research reports and reports on similar developments

(e) Impact of proposed development

- traffic generation during design periods
- traffic distribution and assignments
- impact on traffic safety
- impact of generated traffic
- public transport
- recommended works

(f) Traffic distribution and assignments

- hourly distribution of trips
- assignments of these trips to the road system based where possible on development feasibility studies or on origin/ destination surveys undertaken at similar developments in the areas

(g) Impact on traffic safety

- assessment of road safety impact

(h) Impact of generated traffic

- daily traffic flows and composition on key streets and their expected effect on the environment particularly in residential areas.
- peak period volumes at key intersections and effect of generated traffic on congestion levels
- impact of construction traffic during construction stages
- other proposed developments in the vicinity their timing and likely impact, if known
- assessment of pedestrian movements
- assessment of traffic noise

(j) Public transport

- options for extensions and changes to bus routes and bus stops, following discussions with the transport authorities
- provision for pedestrian access to bus stops

10.7.4 ***Recommended Works***

Information on following aspects should be dealt with under this section.

- proposed improvements to site access and traffic circulation
- proposed improvements to roads, signals, roundabouts and other traffic management measures
- proposed improvements to pedestrian facilities
- effect due to recommend works on the operation of adjacent developments
- effect due to recommended works on public transport services and any proposed suggestions (including bus routes, bus stops, access etc.)
- funding of proposed improvement projects

10.8 Difficulties associated with producing TIA reports in Sri Lanka

Some of the problems that can confront at this stage when requesting the developers to produce TIA reports are as follows:

- Lack of local norms indicating the traffic generation factors for deferent types of developments. The local authorities should try to develop norms for traffic factors for different types of developments such as, residential, hotels, commercial, office, hospitals, schools and other educational institutions, entertainment, service stations, drive-in take away food outlets, etc. on daily traffic basis and peak hour traffic basis (morning and evening).
- Difficulty of obtaining information on existing traffic conditions in the area. Difficulties regarding obtaining existing data such as traffic data, road inventory data, accident statistics etc.
- Shortage of local expertise to carry out comprehensive TIA studies.
- Influences from political elements and financial forces.

In conclusion it should be mentioned that a TIA could be used as a guide to examine ways in which a road system may best accommodate the increased demands for movement and parking of traffic while safeguarding the interests of the community at large. These include the provision of parking facilities, the improvement of existing roads and traffic management facilities, the consideration of future changes in land use, provision of public transport, increasing the traffic efficiency, minimising the impacts on amenity, safety and road pavement life etc. Decision making for large-scale developments is not possible until technical, economic and environmental assessments are available (Environmental Impact Assessment - RTA, 1998). Traffic impact assessment should be an integral part of the project appraisal. TIA becomes a significant part in the process of decision-making especially when large-scale developments are considered in the city limits.

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