UNIT III

Traffic Engineering & Regulation

Overview

Unlike many other disciplines of the engineering, the situations that are interesting to a traffic engineer cannot be reproduced in a laboratory. Even if road and vehicles could be set up in large laboratories, it is impossible to simulate the behavior of drivers in the laboratory. Therefore, traffic stream characteristics need to be collected only from the field. There are several methods of data collection depending on the need of the study and some important ones are described in this chapter.

Data requirements

The most important traffic characteristics to be collected from the field include sped, travel time, flow and density. Some cases, spacing and headway are directly measured. In addition, the occupancy, i.e. percentage of time a point on the road is occupied by vehicles is also of interest. The measurement procedures can be classified based on the geographical extent of the survey into five categories: (a) measurement at point on the road, (b) measurement over a short section of the road (less than 500 meters) (c) measurement over a length of the road (more than about 500 meters) (d) wide area samples obtained from number of locations, and (e) the use of an observer moving in the traffic stream. In each category, numerous data collection are there. However, important and basic methods will be discussed.

Measurements at a point

The most important point measurement is the vehicle volume count. Data can be collected manually or automatically. In manual method, the observer will stand at the point of interest and count the vehicles with the help of hand tallies. Normally, data will be collected for short interval of 5 minutes or 15 minutes etc. and for each type of vehicles like cars, two wheelers, three wheelers, LCV, HCV, multi axle trucks, non motorized traffic like bullock cart, hand cart etc. From the flow data, flow and headway can be derived.

Modern methods include the use of inductive loop detector, video camera, and many other technologies. These methods help to collect accurate information for long duration. In video cameras, data is collected from the field and is then analyzed in the lab for obtaining results. Radars and microwave detectors are used to obtain the speed of a vehicle at a point. Since no length is involved, density cannot be obtained by measuring at a point.

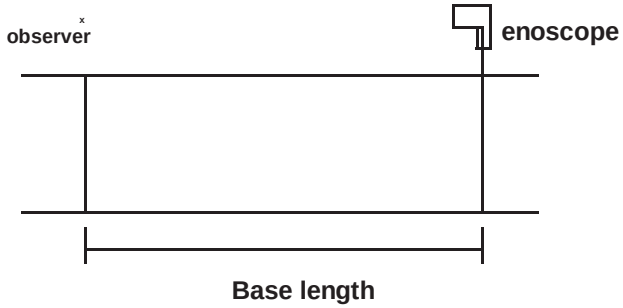


Figure 32:1: Illustration of measurement over short section using endoscope

Measurements over short section

The main objective of this study is to find the spot speed of vehicles. Manual methods include the use of enoscope. In this method a base length of about 30-90 meters is marked on the road. Enoscope is placed at one end and observer will stand at the other end. He could see the vehicle passing the farther end through enoscope and starts the stop watch. Then he stops the stop watch when the vehicle passes in front of him. The working of the enoscope is shown in figure 32:1.

An alternative method is to use pressure contact tube which gives a pressure signal when vehicle moves at either end. Another most widely used method is inductive loop detector which works on the principle of magnetic inductance. Road will be cut and a small magnetic loop is placed. When the metallic content in the vehicle passes over it, a signal will be generated and the count of the vehicle can be found automatically. The advantage of this detector is that the counts can be obtained throughout the life time of the road. However, chances of errors are possible because noise signals may be generated due to heavy vehicle passing adjacent lanes. When dual loops are used and if the spacing between them is known then speed also can be calculated in addition to the vehicle count.

Measurements over long section

This is normally used to obtain variations in speed over a stretch of road. Usually the stretch will be having a length more than 500 meters. We can also get density. Most traditional method uses aerial photography. From a single frame, density can be measured, but not speed or volumes. In time lapse photography, several frames are available. If several frames are obtained over short time intervals, speeds can be measured from the distance covered between the two frames and time interval between them.

Moving observer method for stream measurement

Determination of any of the two parameters of the traffic will provide the third one by the equation q = u:k. Moving observer method is the most commonly used method to get the relationship between the fundamental stream characteristics. In this method, the observer moves in the traffic stream unlike all other previous methods.

Consider a stream of vehicles moving in the north bound direction. Two different cases of motion can be considered. The rest case considers the traffic stream to be moving and the observer to b e stationary. If n_o is the number of vehicles overtaking the observer during a period, t, and then flow

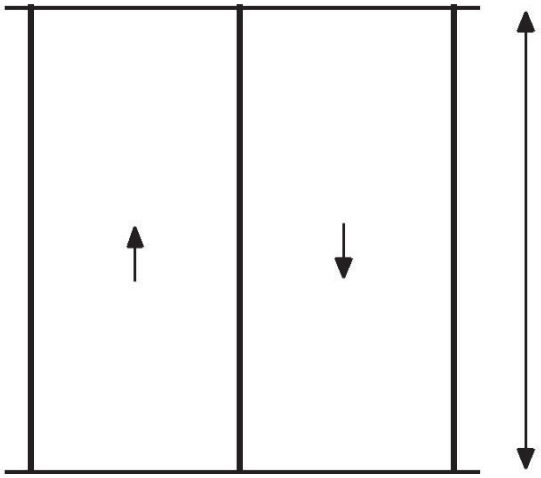


Figure 32:2: Illustration of moving observer method

$$n_0 = qt \quad (32.1)$$

The second case assumes that the stream is stationary and the observer moves with speed v_o . If n_p is the number of vehicles overtaken by observer over a length l, then by definition, density k is the density

$$n_p = kl \quad (32.2)$$

or

$$n_p = k{:}v_0{:}t \quad (32.3)$$

Where v_0 is the speed of the observer and t is the time taken for the observer to cover the road stretch. Now consider the case when the observer is moving within the stream. In that case m_o vehicles will overtake the observer and m_p vehicles will be overtaken by the observer in the test vehicle. Let the difference m is given by m_0 - m_p, then from equation 32.5 and equation 32.7,

$$m = q{:}tk{:}v_0{:}t \quad (32.4)$$

This equation is the basic equation of moving observer method, which relates q; k to the counts m, t and v_o that can be obtained from the test. However, we have two unknowns, q and k, but only one equation. For generating another equation, the test vehicle is run twice once with the traffic stream and another one against traffic stream.

Where, a; w denotes against and with traffic flow. It may be noted that the sign of equation 32.5 is negative, because test vehicle moving in the opposite direction can be considered as a case when the test vehicle is moving in the stream with negative velocity. Further, in this case, all the vehicles will be overtaking, since it is moving with negative speed. In other words, when the test vehicle moves in the opposite direction, the observer simply counts the number of vehicles in the opposite direction. Adding equation 32.5 and 32.5, we will get the first parameter of the stream, namely the flow (q)

Rewriting the above equation, we get the second parameter of the traffic flow, namely the mean speed v_s and

Thus two parameters of the stream can be determined. Knowing the two parameters the third parameter of traffic density (k) can be found out as

$$k = \frac{q}{v_s} \quad (32.7)$$

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

Traffic signs

Traffic control device is the medium used for communicating between traffic engineer and road users. Unlike other modes of transportation, there is no control on the drivers using the road. Here traffic control devices come to the help of the traffic engineer. The major types of traffic control devices used are- traffic signs, road markings, traffic signals and parking control. This chapter discusses traffic control signs. Different types of traffic signs are regulatory signs, warning signs and informatory signs.

Requirements of traffic control devices

5. **The control device should fulfill a need:** Each device must have a specific purpose for the safe and efficient operation of traffic flow.
6. **It should command attention from the road users**: This affects the design of signs. For commanding attention, proper visibility should be there. Also the sign should be distinctive and clear. The sign should be placed in such a way that the driver requires no extra e ort to see the sign.

7. **It should convey a clear, simple meaning**: Clarity and simplicity of message is essential for the driver to properly understand the meaning in short time. The use of color, shape and legend as codes becomes important in this regard. The legend should be kept short and simple so that even a less educated driver could understand the message in less time.

8. **Road users must respect the signs**: Respect is commanded only when the drivers are conditioned to expect that all devices carry meaningful and important messages. Over use, misuse and confusing messages of devices tends the drivers to ignore them.

9. **The control device should provide adequate time for proper response from the road users**: This is again related to the design aspect of traffic control devices. The sign boards should be placed at a distance such that the driver could see it and gets sufficient time to respond to the situation. For example, the STOP sign which is always placed at the stop line of the intersection should be visible for at least one safe stopping sight distance away from the stop line.

Communication tools

A number of mechanisms are used by the traffic engineer to communicate with the road user. These mechanisms recognize certain human limitations, particularly eyesight. Messages are conveyed through the following elements.

Color: It is the first and most easily noticed characteristics of a device. Usage of different colors for different signs is important. The most commonly used colors are red, green, yellow, black, blue, and brown. These are used to code certain devices and to reinforce specific messages. Consistent use of colors helps the drivers to identify the presence of sign board ahead.

Shape: It is the second element discerned by the driver next to the color of the device. The categories of shapes normally used are circular, triangular, rectangular, and diamond shape. Two exceptional shapes used in traffic signs are octagonal shape for STOP sign and use of inverted triangle for GIVE WAY (YIELD) sign. Diamond shape signs are not generally used in India.

Legend: This is the last element of a device that the drive comprehends. This is an important aspect in the case of traffic signs. For the easy understanding by the driver, the legend should be short, simple and specific so that it does not divert the attention of the driver. Symbols are normally used as legends so that even a person unable to read the language will be able to understand that. There is no need of it in the case of traffic signals and road markings.

Pattern: It is normally used in the application of road markings, complementing traffic signs. Generally solid, double solid and dotted lines are used. Each pattern conveys different type of meaning. The frequent and consistent use of pattern to convey information is recommended so that the drivers get accustomed to the different types of markings and can instantly recognize them.

Types of traffic signs

There is several hundreds of traffic signs available covering wide variety of traffic situations. They can be classified into three main categories.

Regulatory signs: These signs require the driver to obey the signs for the safety of other road users.

Warning signs: These signs are for the safety of oneself who is driving and advice the drivers to obey these signs.

Informative signs: These signs provide information to the driver about the facilities available ahead, and the route and distance to reach the specific destinations

In addition special type of traffic sign namely work zone signs are also available. These type of signs are used to give warning to the road users when some construction work is going on the road. They are placed only for short duration and will be removed soon after the work is over and when the road is brought back to its normal condition. The first three signs will be discussed in detail below.

Regulatory signs

These signs are also called mandatory signs because it is mandatory that the drivers must obey these signs. If the driver fails to obey them, the control agency has the right to take legal action against the driver. These signs are primarily meant for the safety of other road users. These signs have generally black legend on a white background. They are circular in shape with red borders. The regulatory signs can be further classified into :

1. **Right of way series**: These include two unique signs that assign the right of way to the selected approaches of an intersection. They are the STOP sign and GIVE WAY sign For example, when one minor road and major road meets at an intersection, preference should be given to the vehicles passing through the major road. Hence the give way sign board will be placed on the minor road to inform the driver on the minor road that he should give way for the vehicles on the major road. In case two major roads are meeting, then the traffic engineer decides based on the traffic on which approach the sign board has to be placed. Stop sign is another example of regulatory signs that comes in right of way series which requires the driver to stop the vehicle at the stop line.

2. **Speed series**: Number of speed signs may be used to limit the speed of the vehicle on the road. They include typical speed limit signs, truck speed, minimum speed signs etc. Speed

limit signs are placed to limit the speed of the vehicle to a particular speed for many reasons. Separate truck speed limits are applied on high speed roadways where heavy commercial vehicles must be limited to slower speeds than passenger cars for safety reasons. Minimum speed limits are applied on high speed roads like expressways, freeways etc. where safety is again a predominant reason. Very slow vehicles may present hazard to themselves and other vehicles also.

3. **Movement series**: They contain a number of signs that aspect specific vehicle maneuvers. These include turn signs, alignment signs, exclusion signs, one way signs etc. Turn signs include turn prohibitions and lane use control signs. Lane use signs make use of arrows to specify the movements which all vehicles in the lane must take. Turn signs are used to safely accommodate turns in un signalized intersections.

4. **Parking series**: They include parking signs which indicate not only parking prohibitions or restrictions, but also indicate places where parking is permitted, the type of vehicle to be parked, duration for parking etc.

5. **Pedestrian series**: They include both legend and symbol signs. These signs are meant for the safety of pedestrians and include signs indicating pedestrian only roads, pedestrian crossing sites etc.

6. **Miscellaneous**: Wide variety of signs that are included in this category are: a "KEEP OF MEDIAN" sign, signs indicating road closures, signs restricting vehicles carrying hazardous cargo or substances, signs indicating vehicle weight limitations etc.

Some examples of the regulatory signs are shown in gure 36:1. They include a stop sign, give way sign, signs for no entry, sign indicating prohibition for right turn, vehicle width limit sign, speed limit sign etc.

Warning signs

Warning signs or cautionary signs give information to the driver about the impending road condition. They advice the driver to obey the rules. These signs are meant for the own safety of drivers. They call for extra vigilance from the part of drivers. The color convention used for this type of signs is that the legend will be black

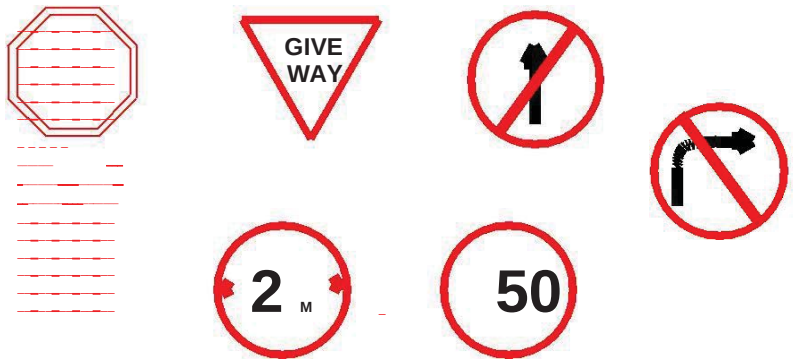


Figure 36:1: Examples of regulatory signs (stop sign, give way sign, signs for no entry, sign indicating prohibition for right turn, vehicle width limit sign, speed limit sign)

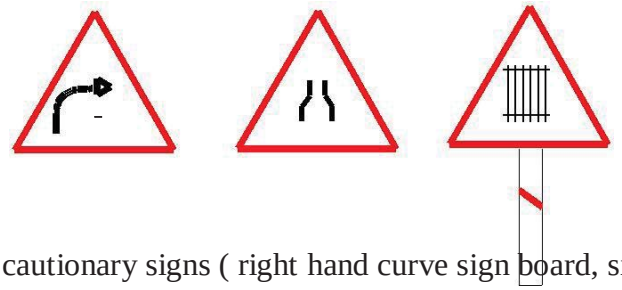


Figure 36:2: Examples of cautionary signs (right hand curve sign board, signs for narrow road, sign indicating railway track ahead)

in color with a white background. The shape used is upward triangular or diamond shape with red borders. Some of the examples for this type of signs are given in g 36:2 and includes right hand curve sign board, signs for narrow road, sign indicating railway track ahead etc.

Informative signs

Informative signs also called guide signs are provided to assist the drivers to reach their desired destinations. These are predominantly meant for the drivers who are unfamiliar to the place. The guide signs are redundant for the users who are accustomed to the location.

Some of the examples for these type of signs are route markers, destination signs, mile posts, service in-formation, recreational and cultural interest area signing etc. Route markers are used to identify numbered highways. They have designs that are distinctive and unique. They are written black letters on yellow back-ground. Destination signs are used to indicate the direction to the critical destination points, and to mark important intersections. Distance in kilometers is sometimes

marked to the right side of the destination. They are, in general, rectangular with the long dimension in the horizontal direction. They are color coded as white letters with green background.

Mile posts are provided to inform the driver about the progress along a route to reach his destination

Road markings

The essential purpose of road markings is to guide and control traffic on a highway. They supplement the function of traffic signs. The markings serve as a psychological barrier and signify the delineation of traffic path and its lateral clearance from traffic hazards for the safe movement of traffic. Hence they are very important to ensure the safe, smooth and harmonious flow of traffic. Various types of road markings like longitudinal markings, transverse markings, object markings and special markings to warn the driver about the hazardous locations in the road etc. will be discussed in detail

Transverse markings

Transverse markings are marked across the direction of traffic. They are marked at intersections etc. The site conditions play a very important role. The type of road marking for a particular intersection depends on several variables such as speed characteristics of traffic, availability of space etc. Stop line markings, markings for pedestrian crossing, direction arrows, etc. are some of the markings on approaches to intersections.

Warning lines

Warning lines warn the drivers about the obstruction approaches. They are marked on horizontal and vertical curves where the visibility is greater than prohibitory criteria specified for no overtaking zones. They are broken lines with 6 m length and 3 m gap.

Pedestrian crossings are provided at places where the conflict between vehicular and pedestrian traffic is severe. The site should be selected that there is less inconvenience to the pedestrians and also the vehicles are not interrupted too much. At intersections, the pedestrian crossings should be preceded by a stop line at a distance of 2 to 3m for un signalized intersections and at a distance of one meter for signalized intersections. Most commonly used pattern for pedestrian crossing is Zebra crossing consisting of equally spaced white strips of 500 mm wide

Classification of road markings

The road markings are defined as lines, patterns, words or other devices, except signs, set into applied or attached to the carriageway or kerbs or to objects within or adjacent to the carriageway, for controlling, warning, guiding and informing the users. The road markings are classified as longitudinal markings, transverse markings, object markings, word messages, marking for parking's, marking at hazardous locations etc.

Longitudinal markings

Longitudinal markings are placed along the direction of traffic on the roadway surface, for the purpose of indicating to the driver, his proper position on the roadway. Some of the guiding principles in longitudinal markings are also discussed below.

Longitudinal markings are provided for separating traffic flow in the same direction and the predominant color used is white. Yellow color is used to separate the traffic flow in opposite direction and also to separate the pavement edges. The lines can be either broken, solid or double solid. Broken lines are permissive in character and allow crossing with discretion, if track situation permits. Solid lines are restrictive in character and does not allow crossing except for entry or exit from a side road or premises or to avoid a stationary obstruction. Double solid lines indicate severity in restrictions and should not be crossed except in case of emergency. There can also be a combination of solid and broken lines. In such a case, a solid line may be crossed with discretion, if the broken line of the combination is nearer to the direction of travel. Vehicles from the opposite directions are not permitted to cross the line. Different types of longitudinal markings are centre line, traffic lanes, no passing zone, warning lines, border or edge lines, bus lane markings, cycle lane markings.

Centre line separates the opposing streams of traffic and facilitates their movements. Usually no centre line is provided for roads having width less than 5 m and for roads having more than four lanes. The centre line may be marked with single broken line, single solid line, double broken line, or double solid line depending upon the road and traffic requirements.

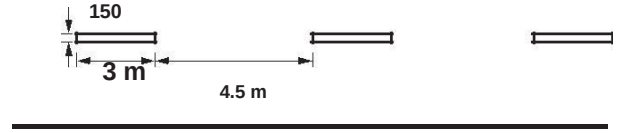


Figure 37:1: Centre line marking for a two lane road

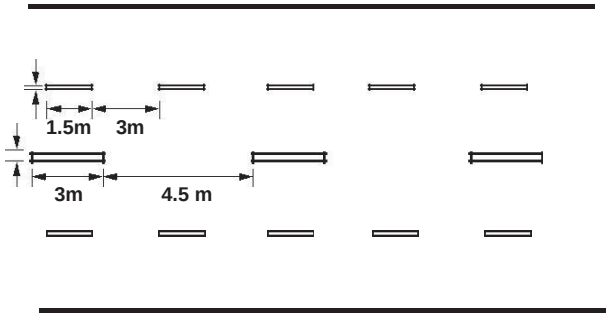


Figure 37:2: Centre line and lane marking for a four lane road

Centre line

Centre line separates the opposing streams of traffic and facilitates their movements. Usually no centre line is provided for roads having width less than 5 m and for roads having more than four lanes. The centre line may be marked with single broken line, single solid line, double broken line, or double solid line depending upon the road and traffic requirements. On urban roads with less than four lanes, the centre line may be single broken line segments of 3 m long and 150 mm wide. The broken lines are placed with 4.5 m gaps (figure 37:1). On curves and near intersections, gap shall be reduced to 3 meters. On undivided urban roads with at least two traffic lanes in each direction, the centre line marking may be a single solid line of 150 mm wide as in figure 37:2, or double solid line of 100 mm wide separated by a space of 100 mm as shown in figure 37:3. The centre barrier line marking for four lane road is shown in figure 37:4.

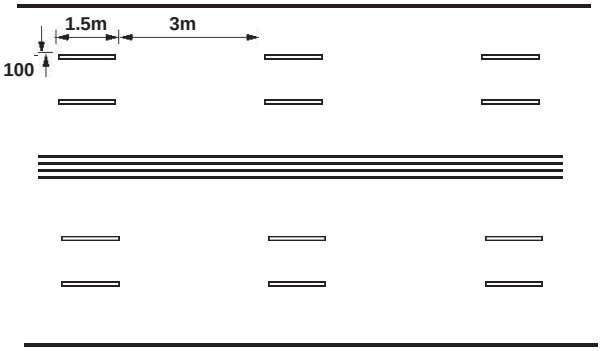


Figure 37:3: Double solid line for a two lane road

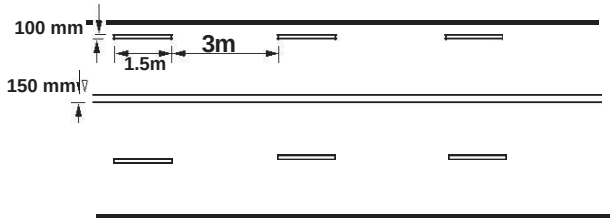


Figure 37:4: Centre barrier line marking for four lane road

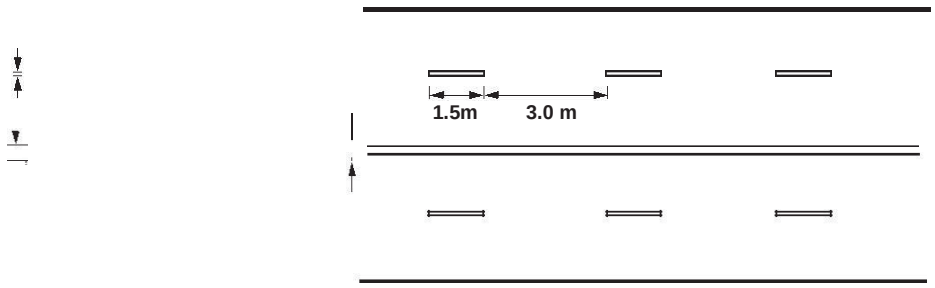


Figure 37:5: Lane marking for a four lane road with solid barrier line

Traffic lane lines

The subdivision of wide carriageways into separate lanes on either side of the carriage way helps the driver to go straight and also curbs the meandering tendency of the driver. At intersections, these traffic lane lines will eliminate confusion and facilitates turning movements. Thus traffic lane markings help in increasing the capacity of the road in addition ensuring more safety. The traffic lane lines are normally single broken lines of 100 mm width. Some examples are shown in figure 37:5 and figure 37:6.

No passing zones

No passing zones are established on summit curves, horizontal curves, and on two lane and three lane highways where overtaking maneuvers are prohibited because of low sight distance. It may be marked by a solid yellow line along the centre or a double yellow line. In the case of a double yellow line, the left hand element may be a solid barrier line, the right hand may be a either a broken line or a solid line. These solid lines are also called barrier lines. When a solid line is to the right of the broken line, the passing restriction shall apply only to the

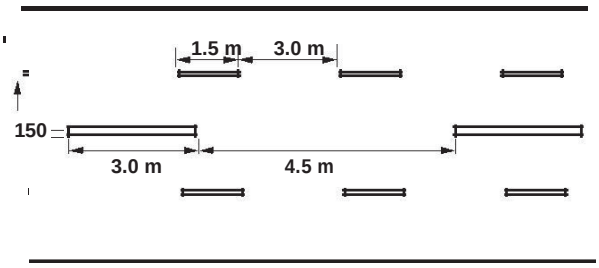
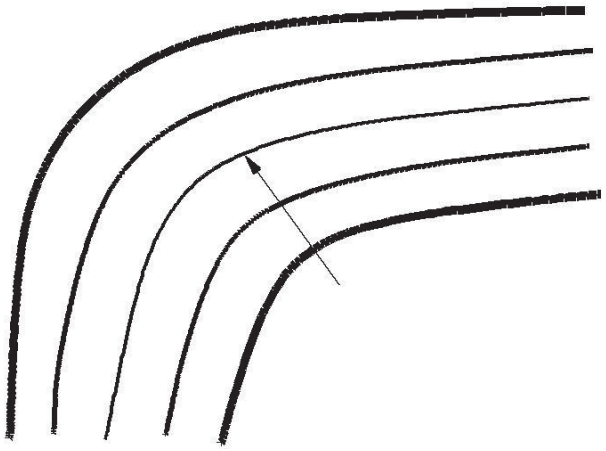


Figure 37:6: Traffic lane marking for a four lane road with broken centre line



Yellow single/double line

Figure 37:7: Barrier line marking for a four lane road

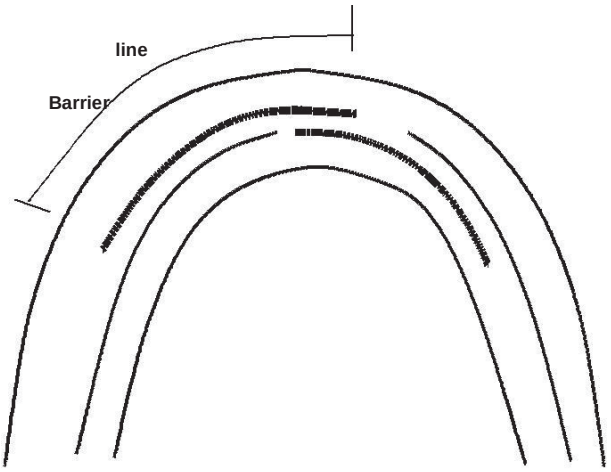


Figure 37:8: No passing zone marking at horizontal curves

Opposing traffic. Some typical examples are shown in figure 37:7 and figure 37:8. In the latter case, the no passing zone is staggered for each direction.

Warning lines

Warning lines warn the drivers about the obstruction approaches. They are marked on horizontal and vertical curves where the visibility is greater than prohibitory criteria specified for no overtaking zones. They are broken lines with 6 m length and 3 m gap. A minimum of seven line segments should be provided. A typical example is shown in figure 37:9

Edge lines

Edge lines indicate edges of rural roads which have no kerbs to delineate the limits up to which the driver can safely venture. They should be at least 150 mm from the actual edge of the pavement. They are painted in yellow or white.

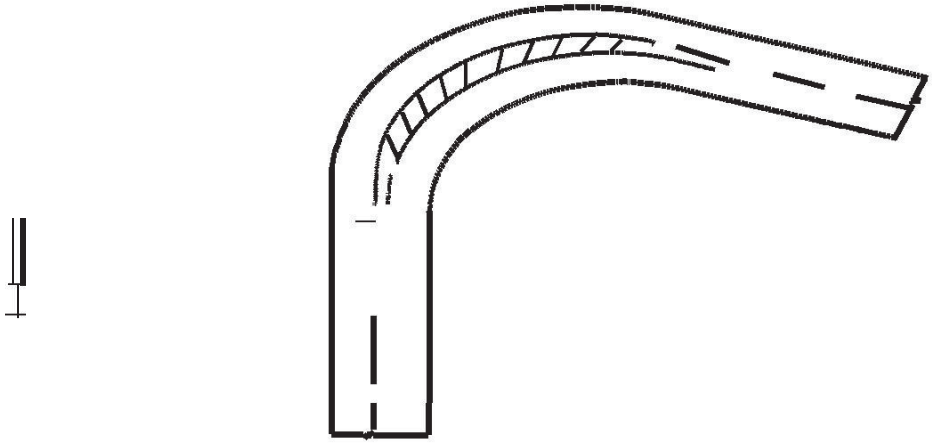


Figure 37:9: Warning line marking for a two lane road

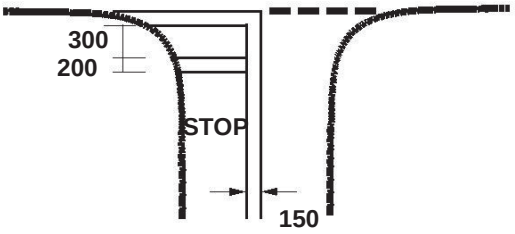


Figure 37:10: Stop line marking near an intersection

All the lines should be preferably light reflective, so that they will be visible during night also. Improved night visibility may also be obtained by the use of minute glass beads embedded in the pavement marking materials to produce a restore reflective surface.

Transverse markings

Transverse markings are marked across the direction of traffic. They are marked at intersections etc. The site conditions play a very important role. The type of road marking for a particular intersection depends on several variables such as speed characteristics of traffic, availability of space etc. Stop line markings, markings for pedestrian crossing, direction arrows, etc. are some of the markings on approaches to intersections.

Stop line

Stop line indicates the position beyond which the vehicles should not proceed when required to stop by control devices like signals or by traffic police. They should be placed either parallel to the intersecting roadway or at right angles to the direction of approaching vehicles. An example for a stop line marking is shown in figure 37:10.

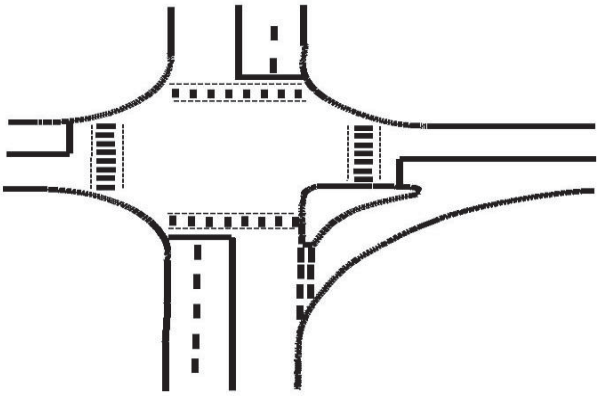


Figure 37:11: Pedestrian marking near an intersection

Pedestrian crossings

Pedestrian crossings are provided at places where the conflict between vehicular and pedestrian traffic is severe. The site should be selected that there is less inconvenience to the pedestrians and also the vehicles are not interrupted too much. At intersections, the pedestrian crossings should be preceded by a stop line at a distance of 2 to 3m for un signalized intersections and at a distance of one meter for signalized intersections. Most commonly used pattern for pedestrian crossing is Zebra crossing consisting of equally spaced white strips of 500 mm wide. A typical example of an intersection illustrating pedestrian crossings is shown in figure 37:11.

Directional arrows

In addition to the warning lines on approaching lanes, directional arrows should be used to guide the drivers in advance over the correct lane to be taken while approaching busy intersections. Because of the low angle at which the markings are viewed by the drivers, the arrows should be elongated in the direction of traffic for adequate visibility. The dimensions of these arrows are also very important. A typical example of a directional arrow is shown in figure 37:12.

Object marking

Physical obstructions in a carriageway like traffic island or obstructions near carriageway like signal posts, pier etc. cause serious hazard to the flow of traffic and should be adequately marked. They may be marked on the objects adjacent to the carriageway.

Objects within the carriageway

The obstructions within the carriageway such as traffic islands, raised medians, etc. may be marked by not less than alternate black and yellow stripes. The stripes should slope forward at an angle of 45 with respect to

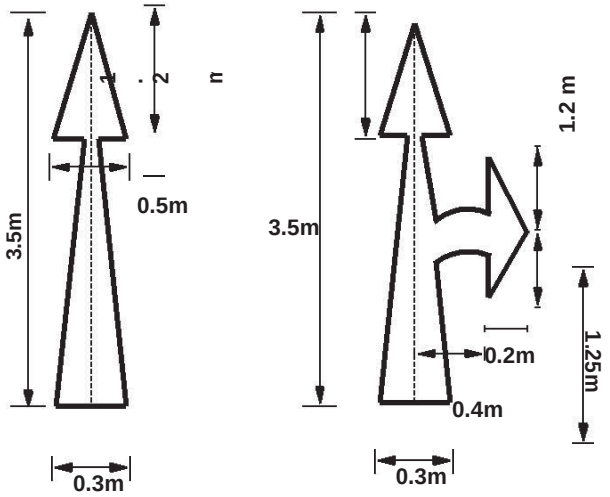


Figure 37:12: Directional arrow marking

the direction of traffic. These stripes shall be uniform and should not be less than 100 m wide so as to provide sufficient visibility.

Objects adjacent to carriageway

Sometimes objects adjacent to the carriageway may pose some obstructions to the flow of traffic. Objects such as subway piers and abutments, culvert head walls etc. are some examples for such obstructions. They should be marked with alternate black and white stripes at a forward angle of 45 with respect to the direction of traffic. Polls close to the carriageway should be painted in alternate black and white up to a height of 1.25 m above the road level. Other objects such as guard stones, drums, guard rails etc. where chances of vehicles hitting them are only when vehicle runs o the carriageway should be painted in solid white. Kerbs of all islands located in the line of traffic flow shall be painted with either alternating black and white stripes of 500 mm wide or red black and white stripes of same width. The object marking for central pier and side walls of an underpass is illustrated in figure 37:13.

Word messages

Information to guide, regulates, or warns the road user may also be conveyed by inscription of word message on road surface. Characters for word messages are usually capital letters. The legends should be as brief as possible and shall not consist of more than three words for any message. Word messages require more and important time to read and comprehend than other road markings. Therefore, only few and important ones are usually adopted. Some of the examples of word messages are STOP, SLOW, SCHOOL, RIGHT TUN ONLY etc. The character of a road message is also elongated so that driver looking at the road surface at a low angle can also read

them easily. The dimensioning of a typical alphabet is shown in figure 37:14.

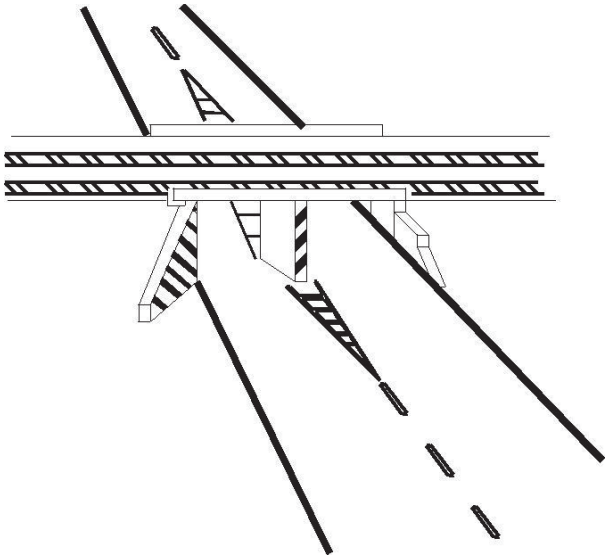


Figure 37:13: Marking for objects adjacent to the road way

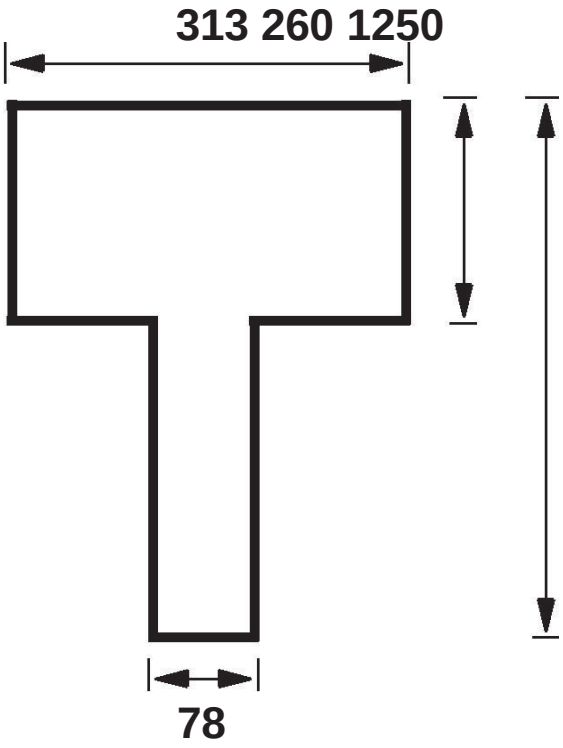


Figure 37:14: Typical dimension of the character T used in road marking

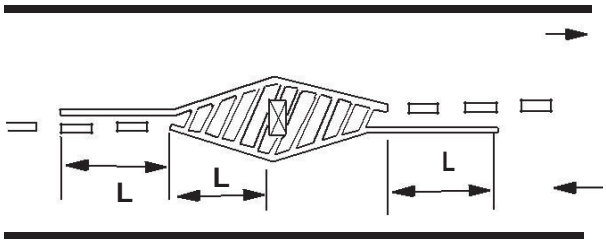


Figure 37:15: Approach marking for obstructions on the road way

Parking

The marking of the parking space limits on urban roads promotes more e cient use of the parking spaces and tends to prevent encroachment on places like bus stops, re hydrant zones etc. where parking is undesirable. Such parking space limitations should be indicated with markings that are solid white lines 100 mm wide. Words TAXI, CARS, SCOOTERS etc. may also be written if the parking area is specific for any particular type of vehicle. To indicate parking restriction, kerb or carriage way marking of continuous yellow line 100 mm wide covering the top of kerb or carriageway close to it may be used.

Hazardous location

Wherever there is a change in the width of the road, or any hazardous location in the road, the driver should be warned about this situation with the help of suitable road markings. Road markings showing the width transition in the carriageway should be of 100 mm width. Converging lines shall be 150 mm wide and shall have a taper length of not less than twenty times the offset distance. Typical carriageway markings showing transition from wider to narrower sections and vice-versa is shown in figure 37:15. In the figure, the driver is warned about the position of the pier through proper road markings.

Parking

Parking is one of the major problems that is created by the increasing road traffic. It is an impact of transport development. The availability of less space in urban areas has increased the demand for parking space especially in areas like Central business district. This affects the mode choice also. This has a great economical impact.

Parking studies

Before taking any measures for the betterment of conditions, data regarding availability of parking space, extent of its usage and parking demand is essential. It is also required to estimate the parking fares also. Parking surveys are intended to provide all these information. Since the duration of parking varies with different vehicles, several statistics are used to access the parking need.

Parking statistics

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

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

Parking load: Parking load gives the area under the accumulation curve. It can also be obtained by simply multiplying the number of vehicles occupying the parking area at each time interval with the time interval. It is expressed as vehicle hours.

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

$$\text{Parking duration} = \frac{\text{parking load}}{\text{Parking volume}}$$

Parking turnover: It is the ratio of number of vehicles parked in duration to the number of parking bays available.

$$\text{parking turnover} = \frac{\text{parking volume}}{\text{Number of bays available}}$$

This can be expressed as number of vehicles per day per time duration.

Parking volume:

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

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

$$\text{parking index} = \frac{\text{parking load}}{\text{parking capacity}} \times 100 \qquad (38.1)$$

To illustrate the various measures, consider a small example in figure 38:1, which shows the duration for which each of the bays are occupied (shaded portion). Now the accumulation graph can be plotted by simply noting the number of bays occupied at time interval of 15, 30, 45 etc. minutes is as shown in the figure.

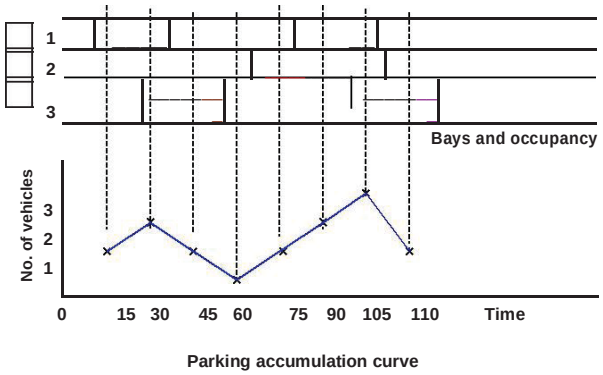


Figure 38:1: Parking bays and accumulation curve

Parking surveys

Parking surveys are conducted to collect the above said parking statistics. The most common parking surveys conducted are in-out survey, exceed period sampling and license plate method of survey.

2.2.4 In-out survey: In this survey, the occupancy count in the selected parking lot is taken at the beginning. Then the number of vehicles that enter the parking lot for a particular time interval is counted. The number of vehicles that leave the parking lot is also taken. The nil occupancy in the parking lot is also taken. Here the labor required is very less. Only one person may be enough. But we won't get any data regarding the time duration for which a particular vehicle used that parking lot. Parking duration and turnover is not obtained. Hence we cannot estimate the parking fare from this survey.

2.2.5 Fixed period sampling: This is almost similar to in-out survey. All vehicles are counted at the beginning of the survey. Then after a fixed time interval that may vary between 15 minutes to i hour, the count is again taken. Here there are chances of missing the number of vehicles that were parked for a short duration.

The marking of the parking space limits on urban roads promotes more efficient use of the parking spaces and tends to prevent encroachment on places like bus stops, re hydrant zones etc. where parking is undesirable. Such parking space limitations should be indicated with markings that are solid white lines 100 mm wide. Words TAXI, CARS, SCOOTERS etc. may also be written if the parking area is specific for any particular type of vehicle. To indicate parking restriction, kerb or carriage way marking of continuous yellow line 100 mm wide covering the top of kerb or carriageway close to it may be used.

2.27 License plate method of survey: This results in the most accurate and realistic data. In this case of survey, every parking stall is monitored at a continuous interval of 15 minutes or so and the license plate number is noted down. This will give the data regarding the duration for which a particular vehicle was using the parking bay. This will help in calculating the fare because fare is estimated based on the duration for which the vehicle was parked. If the time interval is shorter, then there are less chances of missing short-term parkers. But this method is very labor intensive

5. Parking survey

- To identify parking patterns and occupancy rates
- Survey should cover
  - Study Area streets + streets within a buffer of 500 m on both sides
  - Both on-street parking + off-street public or semi-public parking
- Parking demand to be assessed and classified by vehicle type
- Parking fee structure

.

Ill effects of parking

Parking has some ill-effects like congestion, accidents, pollution, obstruction to re- lighting operations etc.

Congestion: Parking takes considerable street space leading to the lowering of the road capacity. Hence, speed will be reduced; journey time and delay will also subsequently increase. The operational count of the vehicle increases leading to great economical loss to the community.

Accidents: Careless maneuvering of parking and un parking leads to accidents which are referred to as parking accidents. Common type of parking accidents occur while driving out a car from the parking area, careless opening of the doors of parked cars, and while bringing in the vehicle to the parking lot for parking.

Environmental pollution: They also cause pollution to the environment because stopping and starting of vehicles while parking and un parking results in noise and fumes. They also affect the aesthetic beauty of the buildings because cars parked at every available space create a feeling that building rises from a plinth of cars.

Obstruction to relighting operations: Parked vehicles may obstruct the movement of relighting vehicles. Sometimes they block access to hydrants and access to buildings.

Parking requirements

There are some minimum parking requirements for different types of building. For residential plot area less than 300 sq.m require only community parking space. For residential plot area from 500 to 1000 sq.m, minimum one-fourth of the open area should be reserved for parking. Once it may require at least one space for every 70 sq.m as parking area. One parking space is enough for 10 seats in a restaurant where as theatres and cinema halls need to keep only 1 parking space for 20 seats. Thus, the parking requirements are different for different land use zones.

On street parking

On street parking means the vehicles are parked on the sides of the street itself. This will be usually controlled by government agencies itself. Common types of on-street parking are as listed below. This classification is based on the angle in which the vehicles are parked with respect to the road alignment. As per IRC the standard dimensions of a car is taken as 5 2.5 meters and that for a truck is 3.75 7.5 meters.

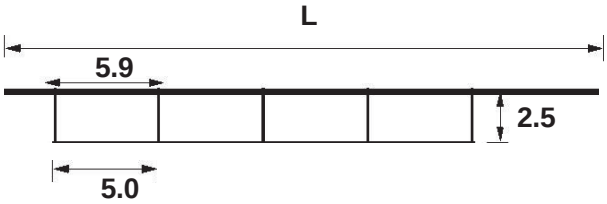


Figure 38:2: Illustration of parallel parking

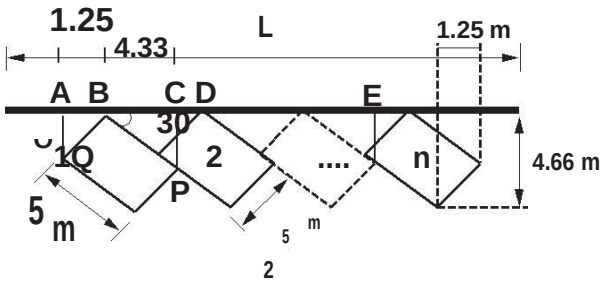


Figure 38:3: Illustration of 30 parking

Parallel parking: The vehicles are parked along the length of the road. Here there is no backward movement involved while parking or unpacking the vehicle. Hence, it is the safest parking from the accident perspective. However, it consumes the maximum curb length and therefore only a minimum number of vehicles can be parked for a given kerb length. This method of parking produces least obstruction to the on-going traffic on the road since least road width is used. Parallel parking of cars is shown in

30 parking: In thirty degree parking, the vehicles are parked at 30 with respect to the road alignment. In this case, more vehicles can be parked compared to parallel parking. Also there is better maneuver-ability. Delay caused to the traffic is also minimum in this type of parking. An example is shown in figure 38:3. From the figure,

AB = OBsinN30 = 1:25;
BC = OP cosN30 = 4:33;
BD = DQcosN60 = 5;
CD = BDBC = 5 4:33 = 0:67;
AB + BC = 1:25 + 4:33 = 5:58

For N vehicles, L = AC + (N-1)CE =5.58+(N-1)5 =0.58+5N

45 parking: As the angle of parking increases, more number of vehicles can be parked. Hence compared to parallel parking and thirty degree parking, more number of vehicles can be accommodated in this type of parking. From figure 38:4, length of parking space available for parking N number of vehicles in a given kerb is L = 3.54 N+1.77

60 parking: The vehicles are parked at 60 to the direction of road. More number of vehicles can be accommodated in this parking type. From the figure 38:5, length available for parking N vehicles =2.89N+2.16.

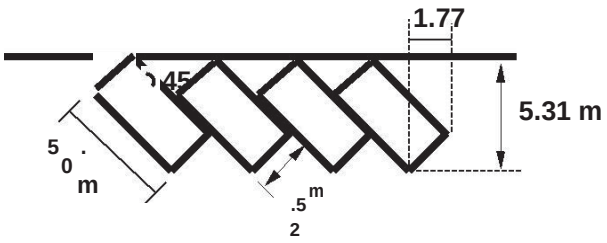


Figure 38:4: Illustration of 45 parking

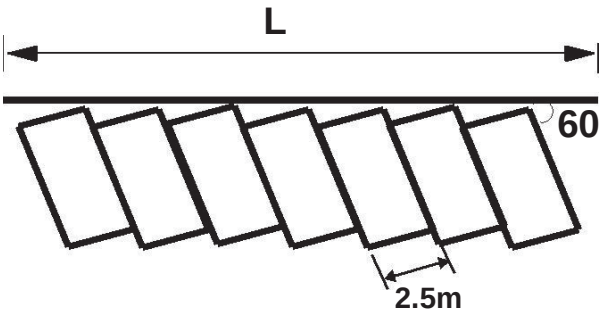


Figure 38:5: Illustration of 60 parking

Right angle parking: In right angle parking or 90 parking, the vehicles are parked perpendicular to the direction of the road. Although it consumes maximum width kerb length required is very little. In this type of parking, the vehicles need complex maneuvering and this may cause severe accidents. This arrangement causes obstruction to the road traffic particularly if the road width is less. However, it can accommodate maximum number of vehicles for a given kerb length. An example is shown in figure 38:6. Length available for parking N number of vehicles is L = 2.5N.

Off-street parking

In many urban centers, some areas are exclusively allotted for parking which will be at some distance away from the main stream of traffic. Such a parking is referred to as o -street parking. They may be operated by either public agencies or private rms. A typical layout of an off-street parking is shown in figure 38:7.

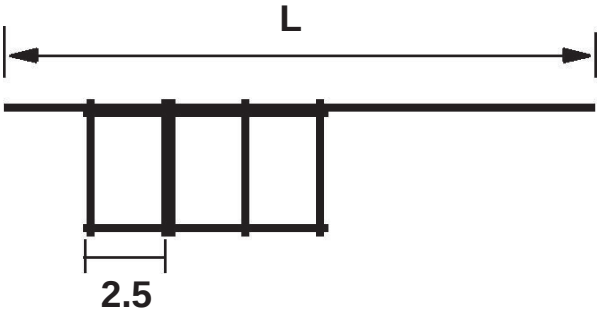


Figure 38:6: Illustration of 90 parking

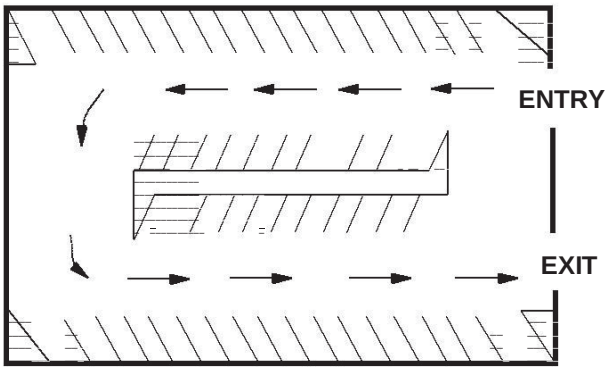


Figure 38:7: Illustration off-street parking

Example 1

From an in-out survey conducted for a parking area consisting of 40 bays, the initial count was found to be 25. Table gives the result of the survey. The number of vehicles coming in and out of the parking lot for a time interval of 5 minutes is as shown in the table 38:1. Find the accumulation, total parking load, average occupancy and efficiency of the parking lot.

Table 38:1: In-out survey data

Time	In	Out
5	3	2
10	2	4
15	4	2
20	5	4
25	7	3
30	8	2
35	2	7
40	4	2
45	6	4
50	4	1
55	3	3
60	2	5

Solution The solution is shown in table 38:2

Accumulation can be found out as initial count plus number of vehicles that entered the parking lot till that time minus the number of vehicles that just exited for that particular time interval. For the first time interval of 5 minutes, accumulation can be found out as 25+3-2 = 26. It is being tabulated in column 4.

Occupancy or parking index is given by equation For the First time interval of Five minutes, parking index =

Table 38:2: In-out parking survey solution

Time (1)	In (2)	Out (3)	Accumulation (4)	Occupancy (5)	Parking load (6)
5	3	2	26	65	130
10	2	4	24	60	120
15	4	2	26	65	130
20	5	4	27	67.5	135
25	7	3	31	77.5	155
30	8	2	37	92.5	185
35	2	7	32	80	160
40	4	2	34	85	170
45	6	4	36	90	180
50	4	1	39	97.5	195
55	3	3	39	97.5	195
60	2	5	36	90	180
Total					1735

(26/40) *100 = 65%. The occupancy for the remaining time slot is similarly calculated and is tabulated in column 5.

Average occupancy is the average of the occupancy values for each time interval. Thus it is the average of all values given in column 5 and the value is 80.63%.

Parking load is tabulated in column 6. It is obtained by multiplying accumulation with the time interval. For the first time interval, parking load = 26 5 = 130 vehicle minutes.

Total parking load is the summation of all the values in column 5 which is equal to 1935 vehicle minutes or 32.25 vehicle hours

Example 2

The parking survey data collected from a parking lot by license plate method is s shown in the table 38:3 below. Find the average occupancy, average turnover, parking load, parking capacity and efficiency of the parking lot.

Solution See the following table for solution 38:4. Columns 1 to 5 are the input data. The parking status in every bay is coded first. If a vehicle occupies that bay for that time interval, then it has a code 1. This is shown in columns 6, 7, 8 and 9 of the table corresponding to the time intervals 15, 30, 45 and 60 seconds.

Turnover is computed as the number of vehicles present in that bay for that particular hour. For the rst bay, it is counted as 3. Similarly, for the second bay, one vehicle is present throughout that hour and hence turnout is 1 itself. This is being tabulated in column 10 of the table. Average turnover = $\frac{\text{Sum of turn over}}{\text{Total number of bays}}$ = 2.25

Table 38:3: License plate parking survey data

Bay	Time			
	0-15	15-30	30-45	45-60
1	1456	9813	-	5678
2	1945	1945	1945	1945
3	3473	5463	5463	5463
4	3741	3741	9758	4825
5	1884	1884	-	7594
6	-	7357	-	7893
7	-	4895	4895	4895
8	8932	8932	8932	-
9	7653	7653	8998	4821
10	7321	-	2789	2789
11	1213	1213	3212	4778
12	5678	6678	7778	8888

Accumulation for a time interval is the total of number of vehicles in the bays 1 to 12 for that time interval. Accumulation for First time interval of 15 minutes = 1+1+1+1+1+0+0+1+1+1+1+1 = 10

Parking volume = Sum of the turnover in all the bays = 27 vehicles

Average duration is the average time for which the parking lot was used by the vehicles. It can be calculated as sum of the accumulation for each time interval time interval divided by the parking Volume = $\frac{(10+11+9+11)\ 15}{27}$ = 22.78 minutes/vehicle.

Occupancy for that time interval is accumulation in that particular interval divided by total number of bays. For first time interval of 15 minutes, occupancy = (10 100)/12 = 83% Average occupancy is found out as the average of total number of vehicles occupying the bay for each time interval. It is expressed in Percentage. Average occupancy = $\frac{0:83+0:92+0:75+0:92}{4}$ 100 = 85.42%.

Parking capacity = number of bays number of hours = 12 *1 = 12 vehicle hours

Parking load = total number of vehicles accumulated at the end of each time interval time = $\frac{}{60}$ 10.25 vehicle hours

Efficiency = $\frac{\text{Parking load}}{\text{Total number of bays}}$ = $\frac{10:25}{}$ = 85.42%.