Chapter 41

Parking Studies

41.1 Overview

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.

41.2 Parking system

41.2.1 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.

1. **Parallel parking**: The vehicles are parked along the length of the road. Here there is no backward movement involved while parking or unparking the vehicle. Hence, it is the most 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 figure 41:1. The length available to park N number of vehicles, L = $\frac{N}{5.9}$

2. **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.

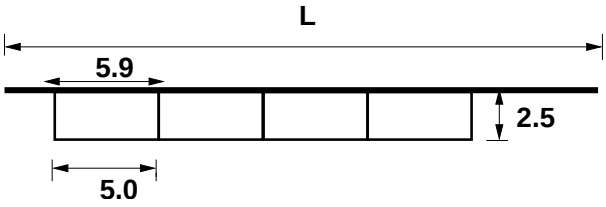

Figure 41:1: Illustration of parallel parking

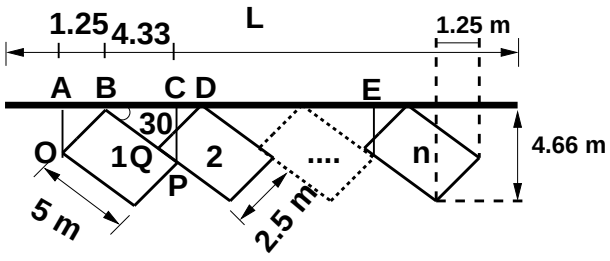

Figure 41:2: Illustration of 30° parking

Also there is better maneuverability. Delay caused to the traffic is also minimum in this type of parking. An example is shown in figure 41:2. From the figure,

$$\begin{aligned} AB &= OBsin30° = 1.25, \\ BC &= OPcos30° = 4.33, \\ BD &= DQcos60° = 5, \\ CD &= BD - BC = 5 - 4.33 = 0.67, \\ AB + BC &= 1.25 + 4.33 = 5.58 \end{aligned}$$

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

3. **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 41:3, length of parking space available for parking N number of vehicles in a given kerb is $L = 3.54$ N+1.77

4. **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 41:4, length available for parking N vehicles =2.89N+2.16.

5. **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

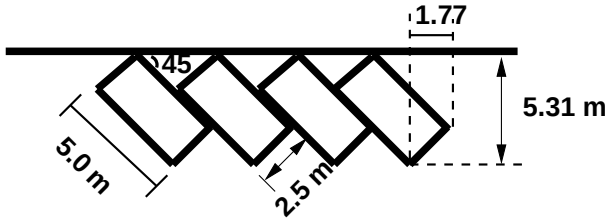

Figure 41:3: Illustration of 45° parking

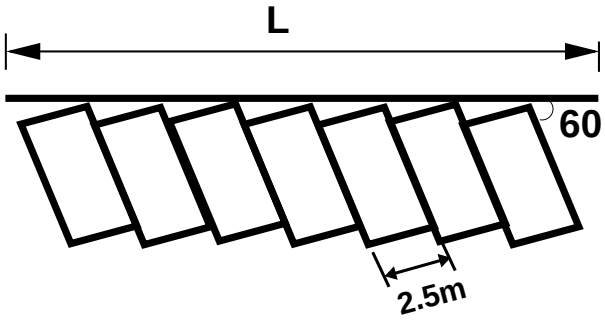

Figure 41:4: Illustration of 60° parking

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 41:5. Length available for parking N number of vehicles is $L = 2.5$N.

41.2.2 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 off-street

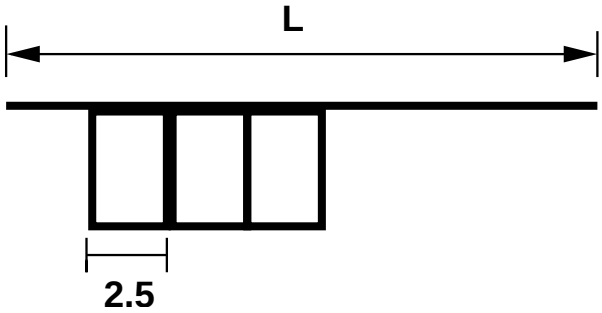

Figure 41:5: Illustration of 90° parking

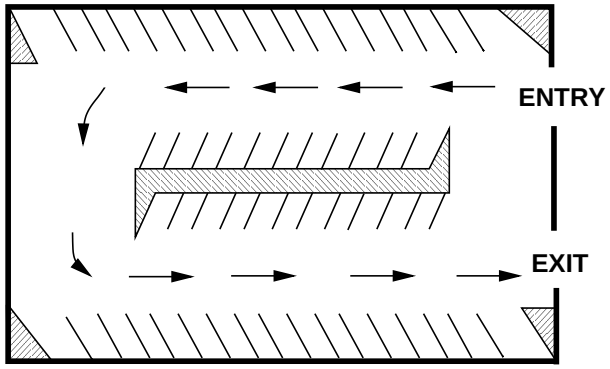

Figure 41:6: Illustration of off-street parking

parking. They may be operated by either public agencies or private firms. A typical layout of an off-street parking is shown in figure 41:6.

41.2.3 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. Offices 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.

41.2.4 Ill effects of parking

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

1. **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 cost of the vehicle increases leading to great economical loss to the community.

2. **Accidents**: Careless maneuvering of parking and unparking 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.

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

4. **Obstruction to fire fighting operations**: Parked vehicles may obstruct the movement of firefighting vehicles. Sometimes they block access to hydrants and access to buildings.

41.3 Parking statistics

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. The following parking statistics are normally important.

1. **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.

2. **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.

3. **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.

4. **Average parking duration**: It is the ratio of total vehicle hours to the number of vehicles parked.
$$\text{parking duration} = \frac{\text{parking load}}{\text{parking volume}} \tag{41.1}$$

5. **Parking turnover**: It is the ratio of number of vehicles parked in a duration to the number of parking bays available. This can be expressed as number of vehicles per bay per time duration.
$$\text{parking turnover} = \frac{\text{parking volume}}{\text{no. of bays available}} \tag{41.2}$$

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

$$\text{parking index} = \frac{\text{parking load}}{\text{parking capacity}} \times 100 \tag{41.3}$$

Numerical Example

To illustrate the various measures, consider a small example in figure 41:7, 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 shown in the figure. The various measures are calculated as shown below: Parking

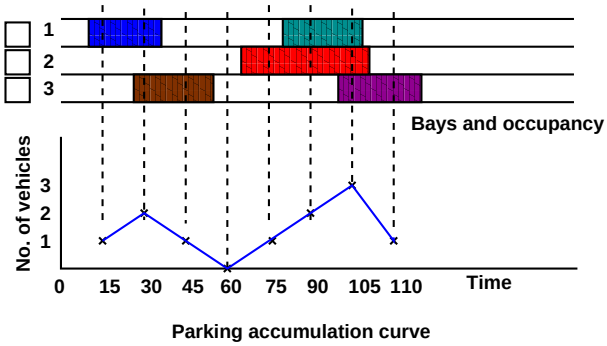

Figure 41:7: Parking bays and accumulation curve

volume is given as 5 vehicles. Parking load is given as $(1+2+1+0+1+2+3+1)\frac{15}{60}=\frac{11\times15}{60} = 2.75$ veh hour. Average parking duration is computed as $\frac{2.75 \text{ veh hours}}{5\text{veh}}= 33$ minutes. Parking turnover is obtained as $\frac{5 \text{ veh}/2 \text{ hours}}{3\text{bays}}= 0.83$ veh/hr/bay. Parking index is calculated as $\frac{2.75 \text{ veh hour}}{3\times2 \text{ veh hours}} \times 100=$ 45.83%

41.4 Parking surveys

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

41.4.1 In-out survey

In this survey, the occupancy count in the selected parking lot is taken at the beginning. Then the number of vehicles that enter the parking lot for a particular time interval is counted. The number of vehicles that leave the parking lot is also taken. The final occupancy in the parking lot is also taken. Here the labor required is very less. Only one person may be enough. But we wont get any data regarding the time duration for which a particular vehicle used that parking lot. Parking duration and turn over is not obtained. Hence we cannot estimate the parking fare from this survey. For quick survey purposes, a **fixed period sampling** can also be done. 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.

Numerical Example

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 41:1. Find the accumulation, total parking load, average occupancy and efficiency of the parking lot.

Table 41:1: 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 41:2

Table 41:2: 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

- 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, $Parking\ index = \frac{26}{40} \times 100 = 65\%$. 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 = $26 \times 5 = 130$ 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

41.4.2 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.

Numerical Example

The parking survey data collected from a parking lot by license plate method is s shown in the table 41:3 below. Find the average occupancy, average turn over, parking load, parking capacity and efficiency of the parking lot.

Table 41:3: Licence 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

Solution See the following table for solution 41:4. Columns 1 to 5 is 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.

Table 41:4: Licence plate parking survey solution

Bay	Time				Time				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	15	30	45	60	15	30	45	60	Turn over
1	1456	9813	-	5678	1	1	0	1	3
2	1945	1945	1945	1945	1	1	1	1	1
3	3473	5463	5463	5463	1	1	1	1	2
4	3741	3741	9758	4825	1	1	1	1	3
5	1884	1884	-	7594	1	1	0	1	2
6	-	7357	-	7893	0	1	0	1	2
7	-	4895	4895	4895	0	1	1	1	1
8	8932	8932	8932	-	1	1	1	0	1
9	7653	7653	8998	4821	1	1	1	1	3
10	7321	-	2789	2789	1	0	1	1	2
11	1213	1213	3212	4778	1	1	1	1	3
12	5678	6678	7778	8888	1	1	1	1	4
	Accumulation				10	11	9	11	
	Occupancy				0.83	0.92	0.75	0.92	2.25

- Turn over is computed as the number of vehicles present in that bay for that particular hour. For the first 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 turn over = $\frac{\text{Sum of turn-over}}{\text{Total number of bays}} = 2.25$
- 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 = 10
- Parking volume = Sum of the turn over 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 = $\frac{(10+11+9+11)\times 15}{27} = 22.78$ 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 = $\frac{0.83+0.92+0.75+0.92}{4} \times 100 = 85.42\%$.
- 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 = $\frac{(10+11+9+11)\times 15}{60} = 10.25$ vehicle hours
- Efficiency = $\frac{\text{Parking load}}{\text{Total number of bays}} = \frac{10.25}{12} = 85.42\%$.

41.5 Summary

Providing suitable parking spaces is a challenge for traffic engineers and planners in the scenario of ever increasing vehicle population. It is essential to conduct traffic surveys in order to design the facilities or plan the fares. Different types of parking layout, surveys and statistics were discussed in this chapter.

41.6 References

1. L. R Kadiyali. *Traffic Engineering and Transportation Planning.* Khanna Publishers, New Delhi, 1987.