Parking Studies

Introduction

Any vehicle traveling on a highway will at one time or another be parked for either a relatively short time or a much longer time, depending on the reason for parking. The provision of parking facilities is therefore an essential element of the highway mode of transportation. The need for parking spaces is usually very great in areas where land uses include business, residential, or commercial activities. The growing use of the automobile as a personal feeder service to transit systems ("park-and-ride") has also increased the demand for parking spaces at transit stations. In areas of high density, where space is very expensive, the space provided for automobiles usually has to be divided between that allocated for their movement and that allocated for parking them.

Providing adequate parking space to meet the demand for parking in the CBD may necessitate the provision of parking bays along curbs which reduces the capacity of the streets and may affect the level of service. This problem usually confronts a city traffic engineer. The solution is not simple, since the allocation of available space will depend on the goals of the community which the traffic engineer must take into consideration when trying to solve the problem. Parking studies are therefore used to determine the demand for and the supply of parking facilities in an area, the projection of the demand, and the views of various interest groups on how best to solve the problem. Before we discuss the details of parking studies, it is necessary to discuss the different types of parking facilities.

Studies must be conducted to collect the required information about the capacity and use of existing parking facilities. In addition, information about the demand for parking is needed. Parking studies may be restricted to a particular traffic producer or attractor, such as a store, or they may encompass an entire region, such as a central business district.

Before parking studies can be initiated, the study area must be defined. A cordon line is drawn to delineate the study area. It should include traffic generators and a periphery, including all points within an appropriate walking distance. The survey area should also include any area that might be impacted by the parking modifications. The boundary should be drawn to facilitate cordon counts by minimizing the number of entrance and exit points.

Once the study area has been defined, there are several different types of parking studies that may be required. These study types are listed below and discussed in detail in the remaining paragraphs.

- Inventory of Parking Facilities
- Accumulation Counts
- Duration and Turnover Surveys
- User Information Surveys
- Land Use Method of Determining Demand

Inventory of Parking Facilities

Information is collected on the current condition of parking facilities. This includes:

- The location, condition, type, and number of parking spaces.
- Parking rates if appropriate. These are often related to trip generation or other land use considerations.
- Time limits, hours of availability and any other restrictions.
- Layout of spaces: geometry and other features such as crosswalks and city services.
- Ownership of the off-street facilities.

Types of Parking Facilities

Parking facilities can be divided into two main groups: on-street and off-street.

1. on-Street Parking Facilities

These are also known as curb facilities. Parking bays are provided alongside the curb on one or both sides of the street. These bays can be unrestricted parking facilities if the duration of parking is unlimited and parking is free, or they can be restricted parking facilities if parking is limited to specific times of the day for a maximum duration.
Parking at restricted facilities may or may not be free. Restricted facilities also may be provided for specific purposes, such as to provide handicapped parking or as bus stops or loading bays.

On Street Parking

2. Off-Street Parking Facilities

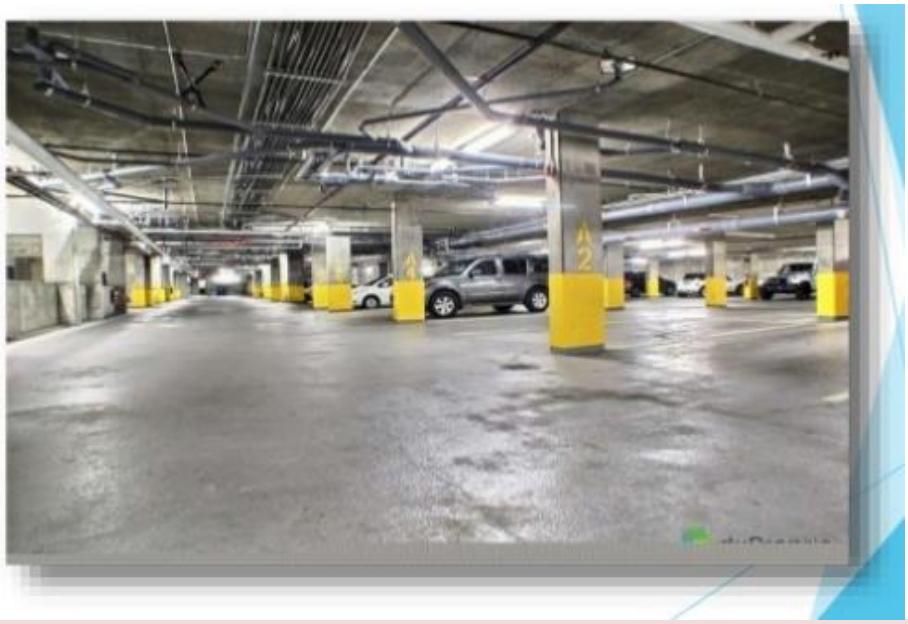
These facilities may be privately or publicly owned; they include surface lots and garages. Self-parking garages require that drivers park their own automobiles; attendant-parking garages maintain personnel to park the automobiles.

Surface Car Parking

Multi-storey Car Park.

Roof Parks.

Mechanical Parks.



Underground Parks.

Definitions of Parking Terms

1. A space-hour is a unit of parking that defines the use of a single parking space for a period of 1 hour.

2. Parking volume is the total number of vehicles that park in a study area during a specific length of time, usually a day.

3. Parking accumulation is the number of parked vehicles in a study area at any specified time. These data can be plotted as a curve of parking accumulation against time, which shows the variation of the parking accumulation during the day.

4. The parking load is the area under the accumulation curve between two specific times. It is usually given as the number of space-hours used during the specified period of time.

5. Parking duration is the length of time a vehicle is parked at a parking bay. When the parking duration is given as an average, it gives an indication of how frequently a parking space becomes available.

6. Parking turnover is the rate of use of a parking space. It is obtained by dividing the parking volume for a specified period by the number of parking spaces.

Methodology of Parking Studies

1. Inventory of Existing Parking Facilities

An inventory of existing parking facilities is a detailed listing of the location and all other relevant characteristics of each legal parking facility, private and public, in the study area. The inventory includes both on- and off-street facilities. The relevant characteristics usually listed include the following:

- Type and number of parking spaces at each parking facility
- Times of operation and limit on duration of parking, if any
- Type of ownership (private or public)
- Parking fees, if any, and method of collection
- Restrictions on use (open or closed to the public)
- Other restrictions, if any (such as loading and unloading zones, bus stops, or taxi ranks)
- Probable degree of permanency (can the facility be regarded as permanent or is it just a temporary facility?)

2. Collection of Parking Data

Accumulation: Accumulation data are obtained by checking the amount of parking during regular intervals on different days of the week. The checks are usually carried out on an hourly or 2-hour basis between 6:00 a.m. and 12 midnight. The selection of the times depends on the operation times of land-use activities that act as parking generators.
For example, if a commercial zone is included, checks should be made during the times when retail shops are open, which may include periods up to 9:30 p.m. on some days. On the other hand, at truck stops, the highest accumulation may occur around midnight which requires information to be collected at that time. The information obtained is used to determine hourly variations of parking and peak periods of parking demand. (See Figure 1.) Below:

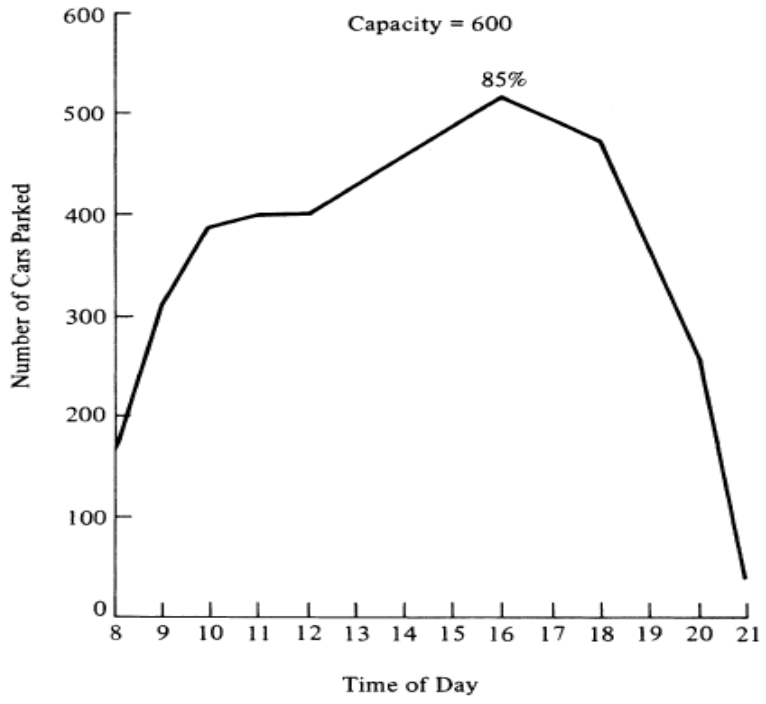
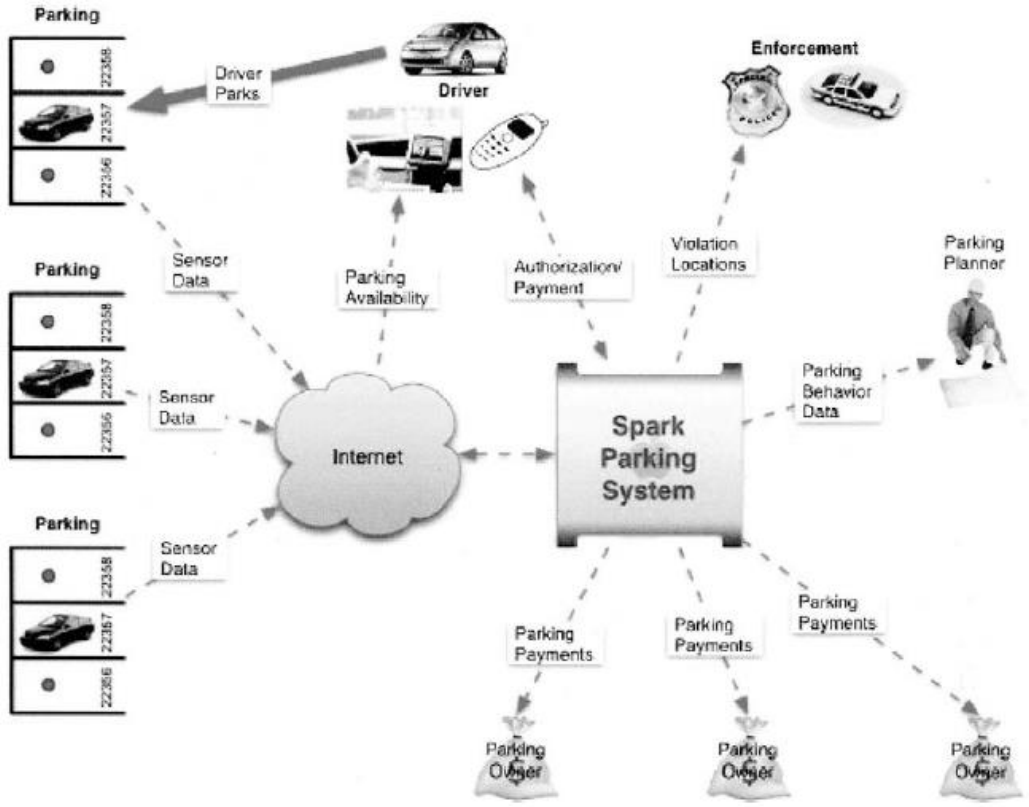


Figure 1. Parking Accumulation at a Parking Lot.

Turnover and Duration: Information on turnover and duration is usually obtained by collecting data on a sample of parking spaces in a given block. This is done by recording the license plate of the vehicle parked on each parking space in the sample at the ends of fixed intervals during the study period. The length of the fixed intervals depends on the maximum permissible duration. For example, if the maximum permissible duration of parking at a curb face is 1 hour, a suitable interval is every 20 minutes. If the permissible duration is 2 hours, checking every 30 minutes would be appropriate. Turnover is then obtained from the equation:

$$T = \frac{\text{number of different vehicles parked}}{\text{number of parking spaces}}$$

Although the manual collection of parking data is still commonly used, it is now possible for all parking data to be collected electronically. Some of these electronic systems use wireless sensors to detect the arrival and departure of a vehicle at a parking space and the information sent to a central location through the internet. An example of this is the Spark Parking Inc. system. In addition to collecting data on parking, the Spark Parking System can be used to collect parking fees. The system provides for drivers to make calls soon after occupying a parking space from their mobile phones to record their credit cards and other personal information. The credit cards are then used for automatic payment of the parking fees. Figure 2 illustrates the general principles of the system.



The Spark Service System.

Parking Demand

Information on parking demand is obtained by interviewing drivers at the various parking facilities listed during the inventory. An effort should be made to interview all drivers using the parking facilities on a typical weekday between 8:00 a.m. and 10:00 p.m.
Information sought should include:

- trip origin,
- purpose of trip, and
- Driver's destination after parking.

The interviewer must also note the location of the parking facility, times of arrival and departure, and the vehicle type.
Parking interviews also can be carried out using the postcard technique, in which stamped postcards bearing the appropriate questions and a return address are handed to drivers or placed under windshield wipers. When this technique is used, usually only about 30 to 50 percent of the cards distributed are returned. It is therefore necessary to record the time and the number of cards distributed at each location, because this information is required to develop expansion factors, which are later used to expand the sample.

Analysis of Parking Data

Analysis of parking data includes summarizing, coding, and interpreting the data so that the relevant information required for decision making can be obtained. The relevant information includes the following:

- Number and duration for vehicles legally parked
- Number and duration for vehicles illegally parked
- Space-hours of demand for parking
- Supply of parking facilities

The analysis required to obtain information on the first two items is straightforward; it usually involves simple arithmetical and statistical calculations. Data obtained from these items are then used to determine parking space-hours.
The space-hours of demand for parking are obtained from the expression:

$$D = \sum_{i=1}^{N} (n_i t_i)$$

Where
D = space vehicle-hours demand for a specific period of time.
N= number of classes of parking duration ranges.
t_i = midparking duration of the i^{th} class.
n_i =number of vehicles parked for the i^{th} duration range.

The space-hours of supply are obtained from the expression:

$$S = f \sum_{i=1}^{N} (t_i)$$

Where
S = practical number of space-hours of supply for a specific period of time N = number of parking spaces available.
t_i =total length of time in hours when the i^{th} space can be legally parked on during the specific period.
f =efficiency factor.

The efficiency factor f is used to correct for time lost in each turnover. It is determined on the basis of the best performance a parking facility is expected to produce. Efficiency factors therefore should be determined for different types of parking facilities.
For example, surface lots, curb parking, and garages. Efficiency factors for curb parking, during highest demand, vary from 78 percent to 96 percent; for surface lots and garages, from 75 percent to 92 percent. Average values of f are 90 percent for curb parking, 80 percent for garages, and 85 percent for surface lots.

Example
The owner of a parking garage located in a CBD has observed that 20% of those wishing to park are turned back every day during the open hours of 8 a.m. to 6 p.m. because of lack of parking spaces. An analysis of data collected at the garage indicates that 60% of those who park are commuters, with an average parking duration of 9 hr, and the remaining are shoppers, whose average parking duration is 2 hr. If 20% of those who cannot park are commuters and the rest are shoppers, and a total of 200 vehicles currently park daily in the garage, determine the number of additional spaces required to meet the excess demand. Assume parking efficiency is 0.90.

Solution

$$D = \sum_{i=1}^{N} (n_i t_i)$$

Commuters now being served = 0.6 * 200 * 9 = 1080 space-hr

Shoppers now being served = 0.4 * 200 * 2 = 160 space-hr

Total number of vehicles turned away = (200 /0.8) -200 = 50

Commuters not being served = 0.2 * 50 * 9 = 90 space-hr

Shoppers not being served = 0.8 * 50 * 2 = 80 space-hr

Total space-hours of demand = (1080 + 160 + 90 + 80) = 1410

Total space-hours served = 1080+ 160 = 1240

Number of space-hours required = 1410 - 1240 = 170

$$S = f \sum_{i=1}^{N} (t_i)$$

S = 170
Use the length of time each space can be legally parked on (8 a.m. through 6 p.m. = 10 hr) to determine the number of additional spaces.

0.9 *10 * N = 170
N = 18.89

At least 19 additional spaces will be required, since a fraction of a space cannot be used.

Parking Stall Layout Considerations

The objective of the layout design is to maximize the number of stalls, while following the guidelines below.

- The layout of the parking facility must be flexible enough to adapt to future changes in vehicle dimensions.
- The stall and aisle dimensions must be compatible with the type of operation planned for the facility.

The critical dimensions are the width and length of stalls, the width of aisles, the angle of parking, and the radius of turns. All of these dimensions are related to the vehicle dimensions and performance characteristics. In recent years there have been a number of changes in vehicle dimensions. The popularity of minivans and sport utility vehicles has had an impact on the design of parking facilities. For the near future, a wide mix of vehicle sizes should be anticipated. There are three approaches for handling the layout:

- Design all spaces for large-size vehicles (about 6 feet wide and 17-18 ft long).
- Design some of the spaces for large vehicles and some for small vehicles (these are about 5 ft wide and 14-15 ft long).
- Provide a layout with intermediate dimensions (too small for large vehicles and too big for small vehicles).

For design, it is customary to work with stalls and aisles in combinations called "modules". A complete module is one access aisle servicing a row of parking on each side of the aisle. The width of an aisle is usually 12 to 26 feet depending on the angle at which the parking stalls are oriented.

Stall Width

For simplicity, the stall width is measured *perpendicular to the vehicle, not parallel to the aisle*. If the stall is placed at an angle of less than 90^o, then the width parallel to the aisle will increase while the width perpendicular to the vehicle will remain the same.

Stall Length

The length of the stall should be large enough to accommodate most of the vehicles. The length of the stall refers to the *longitudinal dimension* of the stall. When the stall is rotated an angle of less than 90^o, the stall depth perpendicular to the aisle increases up to 1 foot or more. It should be noted that the *effective* stall depth depends on the boundary conditions of the module, which could include walls on each side of the module, curbs with or without overhang, or drive-in versus back-in operations. For parking at angles of less than 90^o, front bumper overhangs beyond the curbing are generally reduced with decreasing angle and, for example, drop to about 2 feet at 45^o angles.

Angular Parking

Perpendicular Parking

Parallel Parking

Dimensions for Standard Parking Spaces

Parking Angle	Space Width	Space Length
90	9'	18'
60	9'	21'
45	9'	19'10"
30	9'	16'10"
parallel	8'	24'

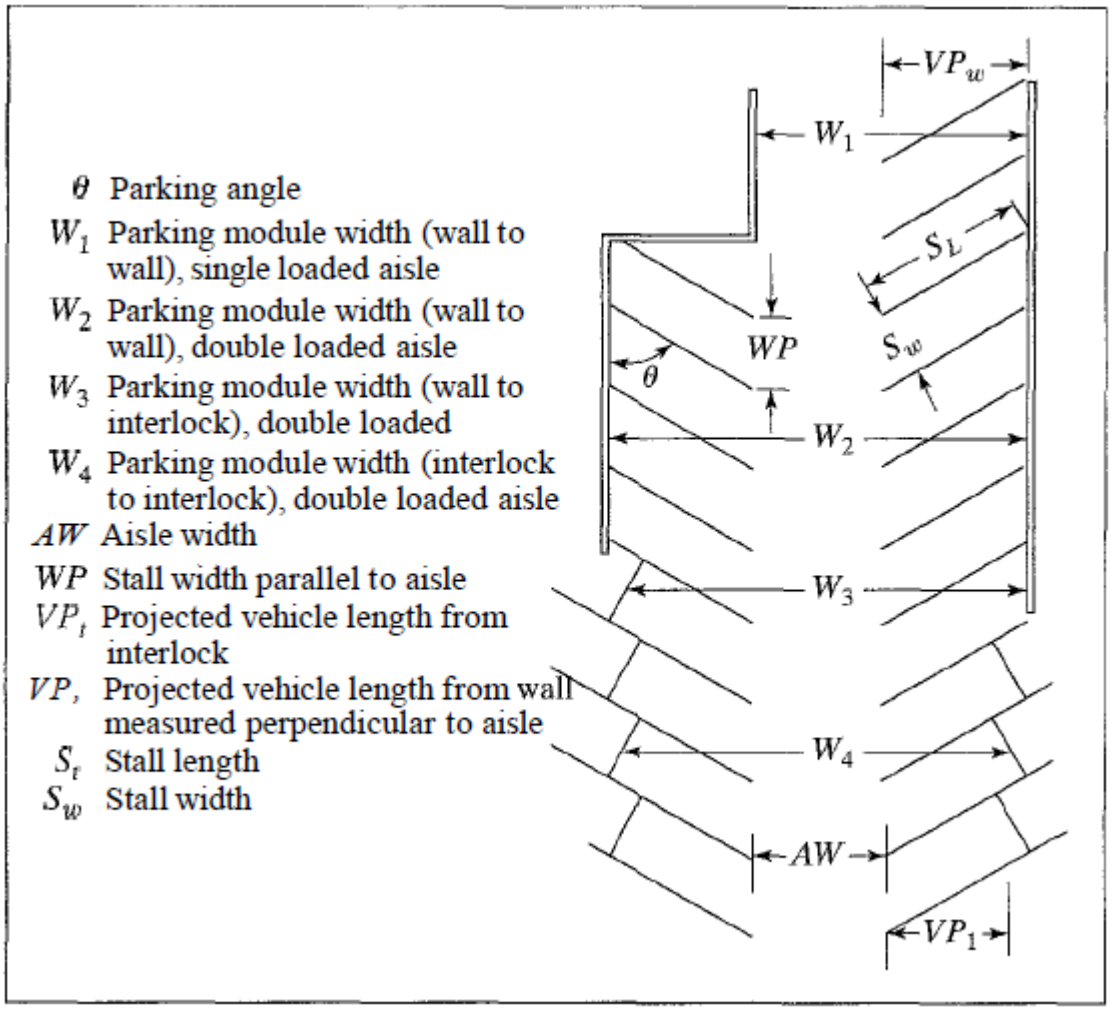


Figure 2 Dimensional Elements of Parking Modules.

Table Stall Width Design Criteria for Various Parking Classifications.

Parking Class	Stall Width (ft)	Typical Turnover			Typical Uses
		Low	Medium	High	
A	9.00			X	Retail customers, banks, fast foods, other very high turnover facilities
B	8.75		X	X	Retail customers, visitors
C	8.50	X	X		Visitors, office employees, residential, airport, hospitals
D	8.25	X			Industrial, commuter, universities

Table Parking Module Layout Dimension Guidelines.

Basic Layout	Parking Class	S_w Stall Width (ft)	WP Stall Width (ft)	VP_w Stall Depth to Wall (ft)	VP_i Stall Depth to Interlock (ft)	AW Aisle Width (ft)	Modules W_2 Wall to Wall (ft)	Modules W_4 Interlock to Interlock (ft)
Large Cars								
2-Way Aisle–90°	A	9.00	9.00	17.5	17.5	26.0	61.0	61.0
	B	8.75	8.75	17.5	17.5	26.0	61.0	61.0
	C	8.50	8.50	17.5	17.5	26.0	61.0	61.0
	D	8.25	8.25	17.5	17.5	26.0	61.0	61.0
2-Way Aisle–60°	A	9.00	10.4	18.0	16.5	26.0	62.0	59.0
	B	8.75	10.1	18.0	16.5	26.0	62.0	59.0
	C	8.50	9.8	18.0	16.5	26.0	62.0	59.0
	D	8.25	9.5	18.0	16.5	26.0	62.0	59.0
1-Way Aisle–75°	A	9.00	9.3	18.5	17.5	22.0	59.0	57.0
	B	8.75	9.0	18.5	17.5	22.0	59.0	57.0
	C	8.50	8.8	18.5	17.5	22.0	59.0	57.0
	D	8.25	8.5	18.5	17.5	22.0	59.0	57.0
1-Way Aisle–60°	A	9.00	10.4	18.0	16.5	18.0	54.0	51.0
	B	8.75	10.1	18.0	16.5	18.0	54.0	51.0
	C	8.50	9.8	18.0	16.5	18.0	54.0	51.0
	D	8.25	9.5	18.0	16.5	18.0	54.0	51.0
1-Way Aisle–45°	A	9.00	12.7	16.5	14.5	15.0	48.0	44.0
	B	8.75	12.4	16.5	14.5	15.0	48.0	44.0
	C	8.50	12.0	16.5	14.5	15.0	48.0	44.0
	D	8.25	11.7	16.5	14.5	15.0	48.0	44.0
Small Cars*								
2-Way Aisle–90°	A/B	8.0	8.0	15.0	15.0	21.0	51.0	51.0
	C/D	7.5	7.5	15.0	15.0	21.0	51.0	51.0
2-Way Aisle–60°	A/B	8.0	9.3	15.4	14.0	21.0	52.0	50.0
	C/D	7.5	8.7	15.4	14.0	21.0	52.0	50.0
1-Way Aisle–75°	A/B	8.0	8.3	16.0	15.1	17.0	49.0	47.0
	C/D	7.5	7.8	16.0	15.1	17.0	49.0	47.0
1-Way Aisle–60°	A/B	8.0	9.3	15.4	14.0	15.0	46.0	43.0
	C/D	7.5	8.7	15.4	14.0	15.0	46.0	43.0
1-Way Aisle–45°	A/B	8.0	11.3	14.2	12.3	13.0	42.0	38.0
	B/C	7.5	10.6	14.2	12.3	13.0	42.0	38.0

Accumulation Counts

These are conducted to obtain data on the number of vehicles parked in a study area during a specific period of time. First, the number of vehicles already in that area are counted or estimated. Then the number of vehicles entering and exiting during that specified period are noted, and added or subtracted from the accumulated number of vehicles. Accumulation data are normally summarized by time period for the entire study area. The occupancy can be calculated by taking accumulation/total spaces. Peaking characteristics can be determined by graphing the accumulation data by time of day. The accumulation graph usually includes cumulative arrival and cumulative departure graphs as well.

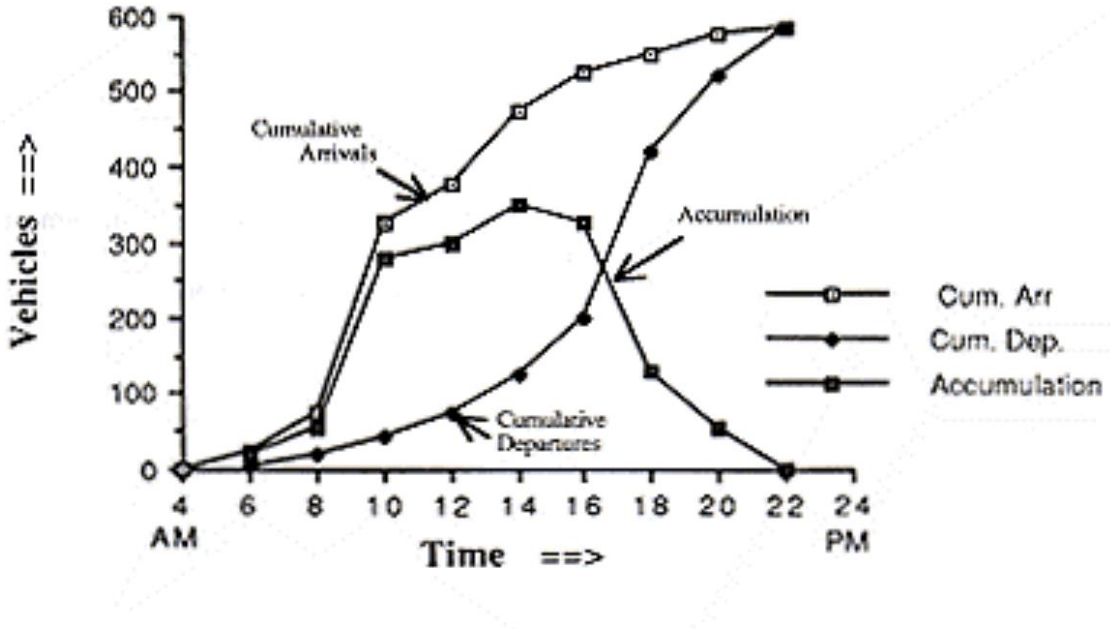


Figure Accumulation Parking Diagram

In planning a license plate survey, assume that each patrolling observer can check about four spaces per minute. The first observer will be slower, because all the license plate numbers will have to be recorded, but subsequent observers will be able to work much faster. The form shown below can be used for a license plate survey.

Parking turnover is the rate of use of a facility. It is determined by dividing the number of available parking spaces into the number of vehicles parked in those spaces in a stated time period.

Table. Typical License Plate Survey Field Form for Curbside Survey

Street_____Side ____Study Date_____
Data Collector_____From_____
To _____ Direction of Travel _____

Space No	Space Desc.	Time at beginning of Patrol							
		8:00	8:30	9:00	9:30	10:00	10:30	11:00	11:30

User Information Surveys

Individual users can provide valuable information that is not attainable with license plate surveys. The two major methods for collecting these data are parking interviews and postcard studies. For the parking interviews, drivers are interviewed right in the parking lot. The interviews can gather information about origin and destination, trip purpose, and trip frequency. The postage paid postcard surveys requests the same information as in the parking interview. Return rates average about 35%, and may include bias. The bias can take two forms. Drivers will sometimes overestimate their parking needs in order to encourage the surveyors to recommend additional parking. Or, they may file false reports that they feel are more socially acceptable.

Land Use Method of Determining Demand:

Parking generation rates can be used to estimate the demand for parking.

- Tabulate the type and intensity of land uses throughout the study area.

- Based on reported parking generation rates, estimate the number of parking spaces needed for each unit of land use.
- Determine the demand for parking from questionnaires. A rule of thumb is to overestimate the demand for parking by about 10 %. If the analysis suggests that the parking demand for a particular facility will be 500 spaces, then the design should be for 550 spaces.