An Approach for Maximizing the Capacity of Self-Service Parking Facilities

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This paper develops a quick and effective method for determining the maximum storage capacity of a parcel of land designated for a self-service parking facility. Because of scattered and inadequate information on design guidelines, this study was authorized. The basic design unit in this analysis is the parking block, which comprises dual-stall units. The elements that constitute the block are analytically correlated. Two most widely used parking configurations are proposed for parking capacity analyses. The varying data on dimensional elements in a set of mathematical functions are entered into a developed computer program, and a series of derived graphs and application procedures that are necessary for solving a variety of parking capacity design problems is presented.

The growing use of automobiles and the decreasing availability of urban land have caused the scarcity of parking spaces. Trip generators in urban centers, which are moving toward higher and higher skyscrapers, attract more people per unit of land area than ever before, which results in higher parking needs per unit of land area. Street curb parking, which hinders traffic flow and consumes valuable driving area of street, is no longer considered feasible and desirable in areas of high traffic concentration. Hence, effective solutions—off-street facilities along with public transit—are urgently needed to accommodate the increasing parking demand in growing urban areas.

An intricate design for an off-street parking facility encompasses a complex process. To maximize the use of a facility, the design must be aimed at not only ensuring convenience and safety in and out of the facility but also keeping the cost low enough to attract users. In areas where land values are high, the problem of providing space for a parking facility becomes not only an economical one, but also one based on availability. If the parking land is obtainable, the facility should be designed to reduce the unit parking land cost. To this end, the facility designer's goal is to render the greatest efficiency of parking space use. However, specific guides to parking geometric design to maximize facility storage capacity are scattered and inadequate. Frequently conflicts arise in the design specifications when different sources are consulted. The designer, therefore, must use his or her judgment to arrive at the best solution. Obviously, this leaves room for judgment errors and thus signifies the need for standard design criteria for specific solutions in a variety of cases.

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STUDY OBJECTIVES

As indicated previously, in consideration of parking facility layout, the use of parking space and the efficiency of parking operations are equally significant. Of primary concern to this study is the development of a solution that maximizes the parking capacity of self-service parking facilities and maintains a satisfactory operational efficiency. The rectangular parking facility was chosen as a design basis because it is most commonly used. This may appear to limit the usefulness of the solution obtained. However, parking facilities of many other shapes, particularly larger ones, can be divided into rectangular units so that the solution is still applicable.

BASIC GEOMETRIC DESIGN CONSIDERATIONS

Geometric design of the parking facility is the phase that requires designer creativity in making proper selection. Design elements such as stall width and length, aisle width, parking angle, and type of parking operation leave room for trade-offs to meet particular specifications.

The parking stall normally varies in width from 2.4 to 3.05 m (8 to 10 ft). The width should be such that it provides adequate space for the occupants to get in and out of the car from either side, which makes faster operation possible. Higher values should be used where drivers are likely to be inexperienced, and lower values should be used where attendant parking is available. Also, the width of the access aisles can be reduced as the stall width is increased. The stall length should be sufficient to accommodate the average car. A length of 5.5 to 6.1 m (18 to 20 ft) is dependent on conditions such as wheel stops and walls.

The access aisle must be wide enough to allow ease of maneuvering cars in and out of stalls. Aisle widths vary according to the angle of parking. Selecting widths for access aisles is of great importance in the design. In designating the aisle width, the designer must consider the width of the stalls, the efficiency of operation desired, specifications of the design vehicles, and designated parking angle.

Initially, the general parking configuration must be chosen. The choices are a single row of cars or a double row using the herringbone or interlocking pattern. Each has its advantages and disadvantages. The goal in the manipulation of all design elements is the most economical use of land area and efficient and safe operation of the facility.

NOTATION

The following notation is used in the analysis presented in this paper:

- A = total area of lot,
- a = area of block,
- B = area per stall,
- F_1 = number of stalls along one side of lot length,
- F_2 = number of stalls along one side of lot width,
- K = number of dual-stall units per block,
- L = lot length,
- n = total number of stalls per block,
- S = number of blocks in lot,
- t_1 = see Figures 1 and 2,
- t_2 = see Figures 1 and 2,
- U = see Figure 1,
- W = lot width,
- w = block width,
- W/L = ratio of lot width to lot length,
- x = stall length,
- y = stall width,
- z = aisle width,
- α = parking angle, and
- ℓ = block length.

Figure 1. Parking block geometrics.

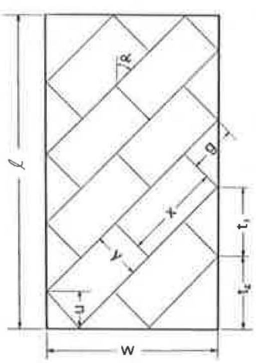


Figure 2. Parking configuration 1.

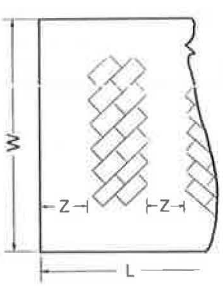
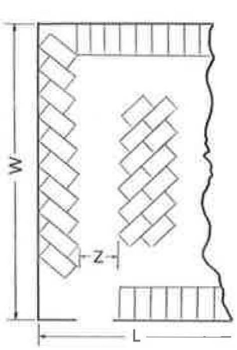


Figure 3. Parking configuration 2.

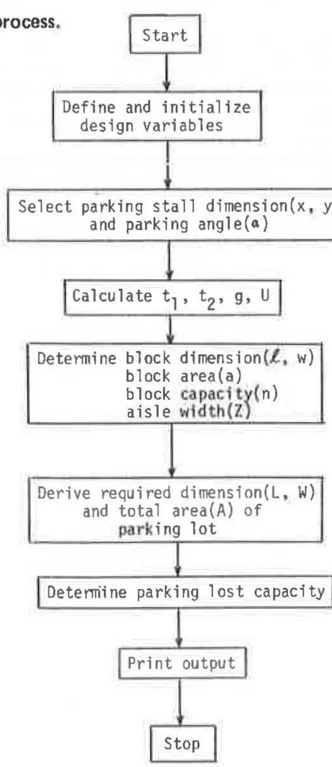


METHOD OF ANALYSIS

In this analysis, the parking block comprised of dual-stall units (Figure 1) is selected as the basic unit for capacity estimation. The geometric elements that constitute the block are analytically correlated. A two-part analysis of the relationship between parking angle and aisle width is made: one applied to a parking angle of 75 deg or less and the other for a 90-deg parking angle. The reason for separate analysis is that only one-way traffic is allowed for parking angles less than 75 deg, whereas a 90-deg parking angle can serve two-way traffic flow in the aisle. The mathematical relationships of the variables involved in the parking block are shown in Figure 1. To expand the equations for the total facility area requires that aisle width be taken into consideration. The computation can be made by using any, say, 15-deg increment of parking angles from 30 to 90 deg. The variation in angle parking and the corresponding changes in the aisle width are suggested in many published sources.

Two typical types of parking configurations (Figures 2 and 3) are proposed for this analysis. These configurations consist of parking rows in a herringbone parking

Figure 4. Computer process.



pattern. This specific parking pattern was selected because it is not only adaptable to changes in the angle of parking but also flexible in providing alternate traffic flow patterns in the parking facility. For the purpose of capacity analysis, various design parameters are correlated into a series of mathematical equations for the configurations shown in Figures 2 and 3. Based on those equations, a computer program has been developed to facilitate the calculations for specified data sets. A flow chart of the computer process is shown in Figure 4.

As shown in Figures 5 through 10, the graphical relationship between the total facility area and the required area per car is derived from changing the values of the block patterns and aisle widths for the selected herringbone configurations. The graphs shown in those figures can be used to obtain the maximum numbers of cars that can be stored in a given size of facility. The ratio of the facility width to its length should be known before

Figure 5. Parking configuration 1 for S = 2 blocks.

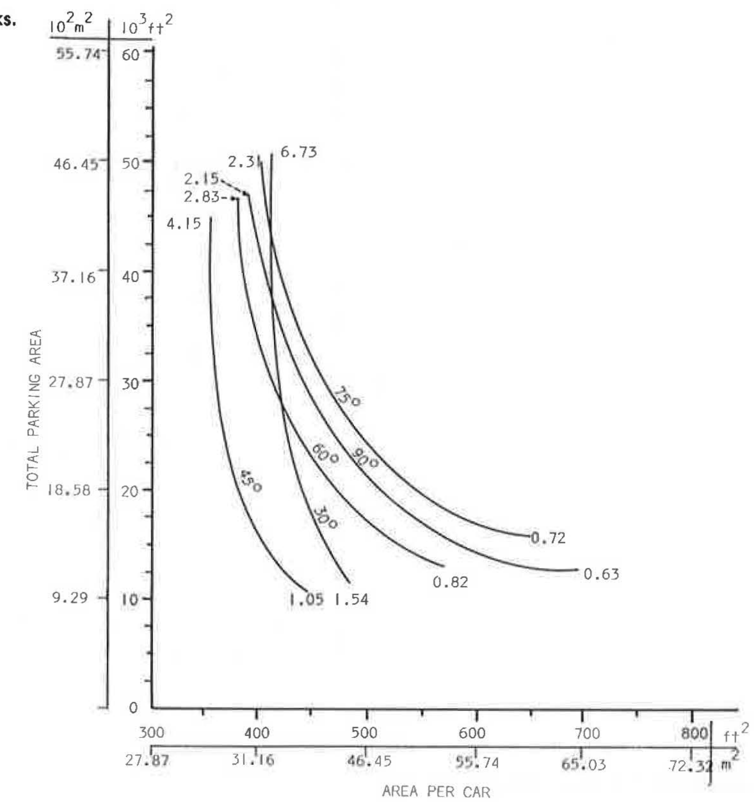
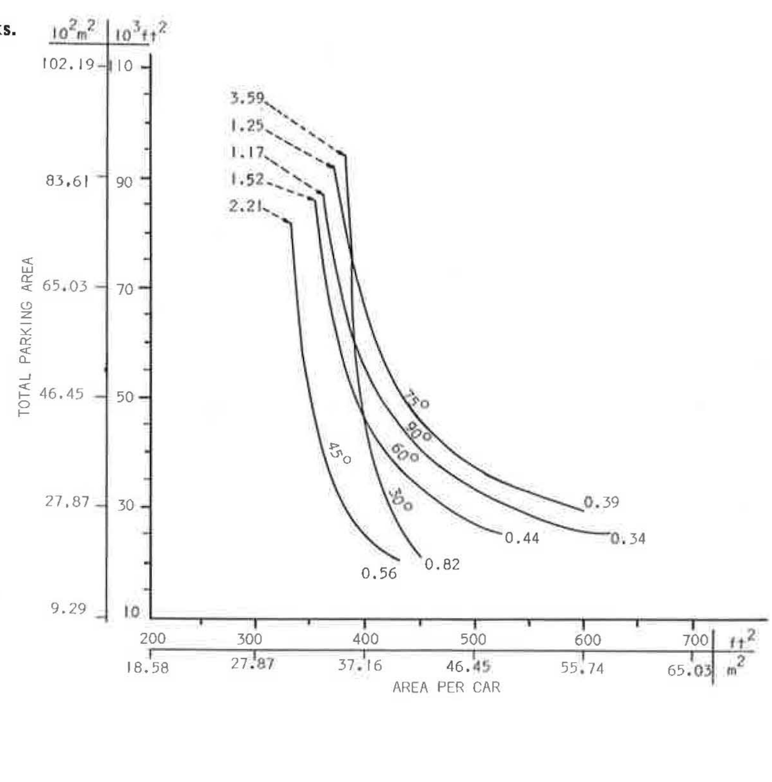


Figure 6. Parking configuration 1 for S = 4 blocks.



the optimum space use is obtained. The ratios of widths to lengths are labeled at the end points of the curves. To obtain the ratio for any point on the curve, a linear interpolation is used between the indicated ratios at the end points of each curve.

APPLICATION PROCEDURES

The graphs shown in Figures 5 through 10 can be used to quickly solve the geometric design problem of maximizing parking capacity of rectangular facilities. The following is a typical design example. Find the parking

Figure 7. Parking configuration 1 for S = 6 blocks.

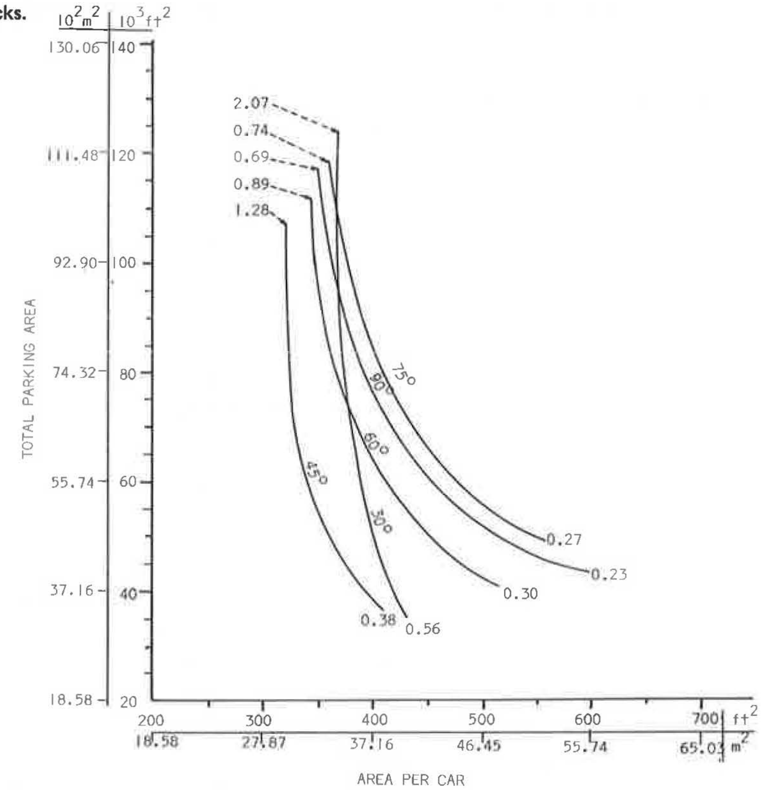


Figure 8. Parking configuration 2 for S = 2 blocks.

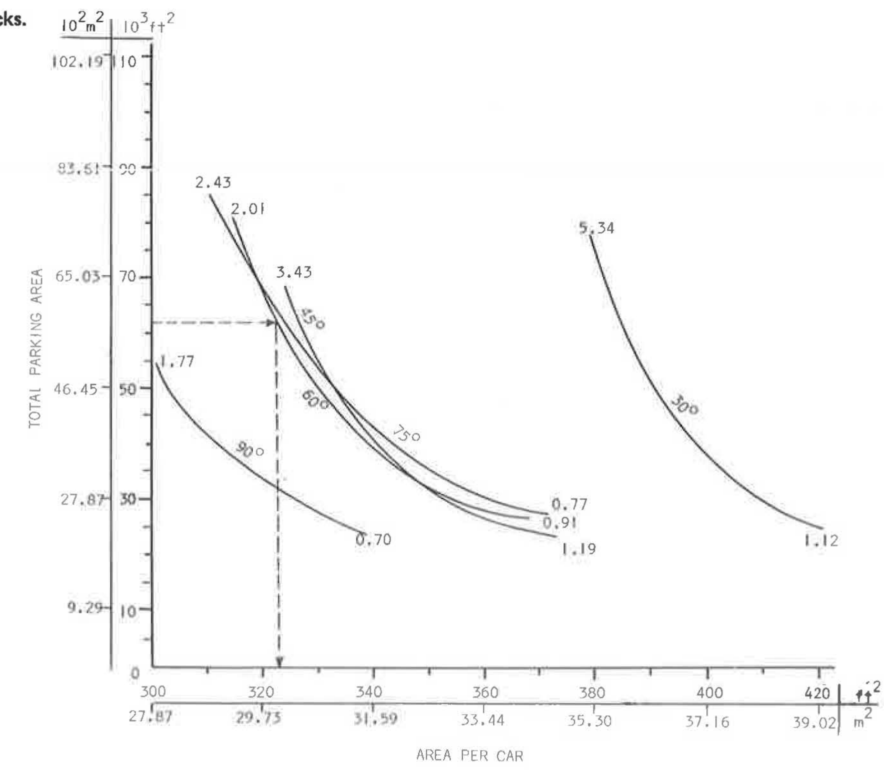


Figure 9. Parking configuration 2 for S = 4 blocks.

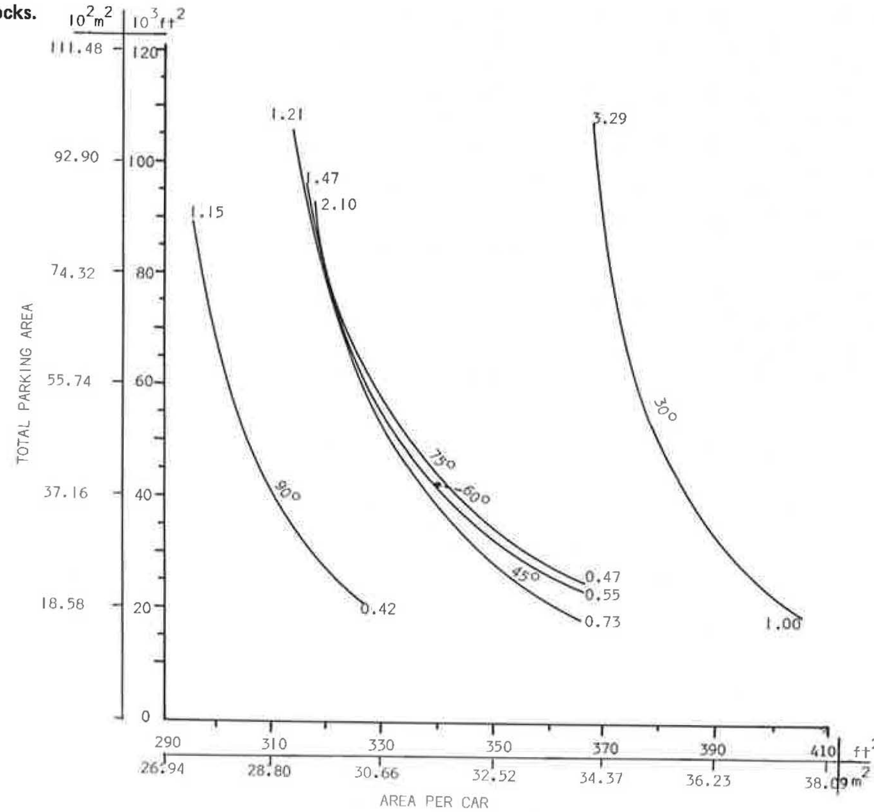
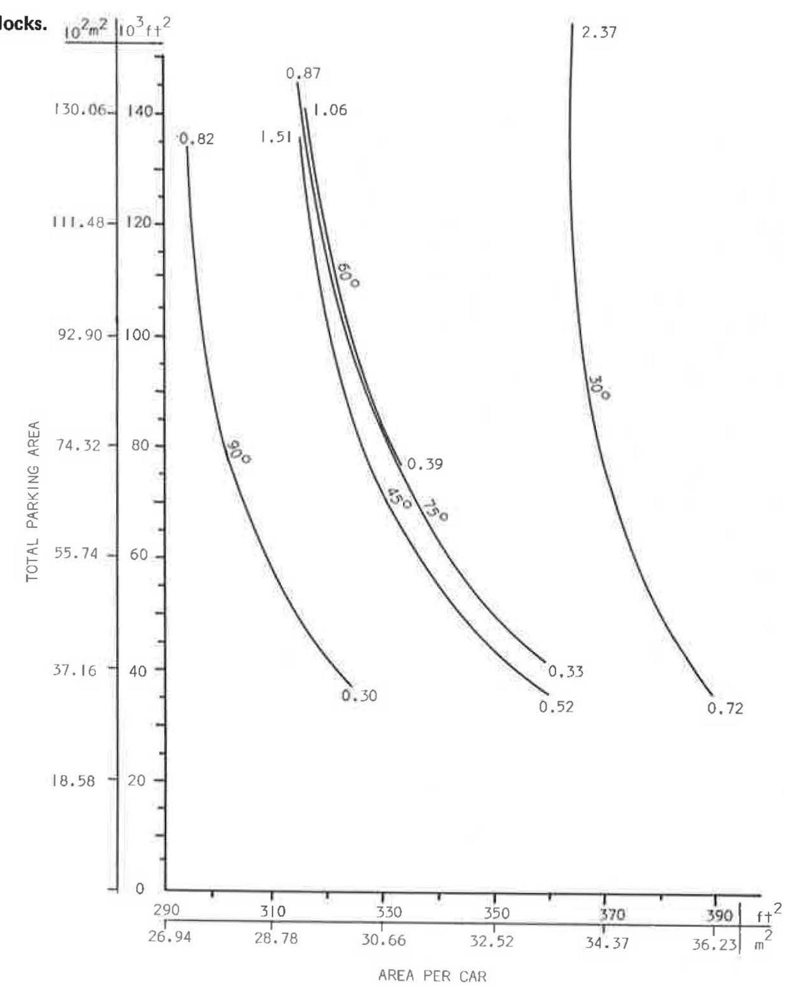


Figure 10. Parking configuration 2 for S = 6 blocks.



angle that requires the minimum area per car (or maximum parking capacity) for a facility with given total area and dimensions (facility width and length). Compute the value of width/length (W/L). Locate on the graphs (Figures 5 through 10) the respective facility area, and proceed to the right and find the lines intersected at a point where the value of W/L is approximately that computed. Several curves will probably contain the specified W/L value. It is possible to find more than one of these points. If more than one is close, choose the one that gives the least area per car value. When the minimum area per car is found, the intersected line will give the angle of parking for the maximum parking capacity for a given size and shape of land. This procedure for a specific design problem can be completed in a very short time period.

Determine the maximum parking capacity of a parcel of land having the dimensions of 53.3 by 106.7 m (175 by 350 ft).

First, determine the size of the area and parking lot width-length ratio; that is, $A = 53.3 \times 106.7 = 5687.11\ m^2$ ($61\ 250\ ft^2$) and W/L ratio = 106.7/53.3 = 2.00. The following data are obtained by using graphs:

Figure	Area per Car (m^2)	Parking Angle (deg)
6	37.16	30
8	29.91	60
9	30.35	45

The minimum area per car is $29.91\ m^2$ ($322\ ft^2$) for a parking angle of 60 deg, as given by Figure 8. The maximum number of cars N that can be parked is N = 5687.11/29.91 = 190 cars.

CONCLUSIONS

The ever-increasing number of automobiles has been creating a parking space shortage, particularly in high-density urban areas. Therefore, maximizing parking space use is a very important consideration in parking facility design. Although the geometric design problem is not new, the development of a better method for practical design purposes is still an urgent need for present and future parking facilities. The basic approach used to maximize storage capacity for any parking facility simply decides which type of configuration will prove most satisfactory for a specific parcel of land. However, because the design problem differs in each type of parking facility, the solution becomes very difficult to generalize. The approach undertaken in this study has developed a simple and practical tool for maximizing storage capacity of parking facilities, specifically for larger parking lots.

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