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ENTRANCE-EXIT DESIGN AND CONTROL FOR MAJOR PARKING FACILITIES

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It hasn't been too many years since a 500-space garage was thought of as a large parking facility. In recent years, garages with over 4,000 spaces have been placed in operation and larger ones are on the drawing boards. Success in the operation of these major parking facilities is dependent upon proper design of access to the facility, in addition to efficient management. Provision of adequate access design and control is a significant item which must be considered as part of the first design concept. The traffic engineer, teamed with the owner's representatives, the architect, and the future parking operator, must work together to develop a proper access and control plan. I have recently read a statement by a nationwide garage design consultant that reservoir space for entrances to garages is no longer an important consideration because of the capacity of ticket dispensers with gates. This is completely untrue as will be brought out later. Thinking of this type can lead to ineffective design which causes backup onto public streets with the accompanying potential hazards and congestion.

This paper covers three principal areas of concern: (1) determination of the number of entrance and exit lanes required based upon the parking control strategy and type of parker served; (2) data to allow comparison of the capacities of the various types of control strategies to allow selection of the one appropriate for each facility, and; (3) determination of needed reservoir space based upon the control strategy selected.

Typical capacity values for the various methods of parking control are included in this paper. A word of caution is necessary since there is much variation in capacity values due to physical conditions present as well as the familiarity of the parker with the parking facility itself. Each major facility requires detailed analysis of its needs and generalized factors are not always adequate.

Design Methodology

In order to provide adequate access design and control for major parking facilities, it is necessary to identify the probable characteristics of the future users of the facility. In this paper it is assumed that the size of the garage has been determined based upon a comprehensive parking study (general public facilities), or the amount necessary to serve a given land use (single purpose facility).

The first step is to determine directional peak hour volumes as related to the total size of the parking garage. Based upon the principal land use served, tables are included in this paper which allow the designer to prepare an estimate of peak hour volumes. In general, our research has found that it is adequate to assume for design purposes that the morning inbound peak flows are approximately equal to the evening outbound peak flows. After determining the peak volumes, a control strategy must be selected which would be appropriate for the intended operation of the garage. Selection of whether it would be best to allow parkers to enter without charge and pay as they leave or to pay a flat fee on the way in and have no control upon exiting will have a significant impact upon traffic capacity. Whether to use no fee, a flat fee, a variable fee, or a combination of fees must be determined as well as whether it is possible to receive the payment in advance, or to collect individual payment of the fee. All of these alternatives should be considered for each individual parking facility in order to determine its proper control strategy.

When the peak hour volumes and control strategy have been determined, it is then possible to determine the number of lanes which will be required to adequately serve inbound and outbound traffic to the parking facility. This requires knowledge of typical service rates of various methods of parking control. The next step is to determine the amount of reservoir space required to serve the parking control location. Following all of these steps will lead to an efficient, well-working garage which will have minimum impact upon the surrounding street system.

Determination of Peak-Hour Volumes

Comprehensive parking studies have provided much information concerning the characteristics of the users of major parking facilities. In general, it may be stated that the traffic characteristics of a garage will be principally related to the trip purpose of the user and the type of land use served by the facility. Both of these items relate to the length of time the parker is in the facility and the time of day during which major traffic flows occur.

Table 1 was prepared which compares the trip purpose of the parker with the length of time which he parks as observed in the Los Angeles Central Business District. Employees are considered long-term parkers since 80 percent parked three hours or longer; at the peak time of day, 84 percent of the daily employee parkers were present; and, their average parking duration was 5.6 hours.

A garage, which serves employees primarily, would tend to have higher peak hour volumes than would one which serves the other uses shown in the table. As an example, 85 percent of the shoppers had a parking duration of less than three hours with an average duration of 1.6 hours. More importantly, only 26 percent of the total daily parkers with a shopping trip purpose were present at the time of peak accumulation. This indicates that the peak hour inbound or outbound volume will be less for a garage serving principally shopper parkers than for a similar sized facility serving only employees.

Table 1

TRIP PURPOSE VS. LENGTH OF TIME PARKED

TRIP PURPOSE	PERCENT OF DAILY PARKERS WITH DURATION SHOWN		RATIO OF PEAK ACCUMULATION TO TOTAL DAILY PARKERS	AVERAGE DURATION
	SHORT-TERM (less than 3 hrs.)	LONG-TERM (3 hrs. or longer)		
	(percent)	(percent)		(hours)
Work	20	80	0.84	5.6
Shopping	85	15	0.26	1.6
Commercial Business	86	14	0.25	1.5
Social-Recreational	91	9	0.24	1.2
Personal Business	94	6	0.21	1.0
Eat Meal	97	3	0.22	0.9

Source: Los Angeles CBD Parking Study, 1967

In order to relate the type of land use served with peak hour volumes, the term <u>entering-leaving ratio</u> has been used. This term represents the volume of cars entering or leaving during a peak hour divided by the maximum accumulation of cars in the parking facility (taken as the size of the facility). If the inbound morning or outbound evening peak hour is equal to half the number of spaces in the garage, the entering-leaving ratio is 0.50. Using data obtained by special counts taken by personnel of my firm, as well as information reported in various parking studies, Table 2 was prepared which shows the range of values of the entering-leaving ratio for various land uses served. It may be seen in the table that the range of values for an individual parking facility may vary considerably. This variation may be explained by the typical length of time parked as well as the variation in the times when employees must start work or are let out of work. In locations where there is some staggering of employment hours, the entering-leaving ratio tends to be lower. The characteristics of the potential users of the parking facility must be studied in detail to arrive at the proper entering ratio.

Once the entering-leaving ratio has been selected, it is possible to determine the actual peak hour design volumes to be used in determining the parking control strategy and the design of access lanes.

Table 2

LAND USE SERVED VS. ENTERING-LEAVING RATIO

PRINCIPAL LAND USE SERVED	ENTERING-LEAVING RATIO [a] (Range of Values)
Hotel-Motel	0.25-0.35
College-University	0.40-0.60
Retail Commercial	0.45-0.65
Public Office Building	0.45-0.65
Private Offices-Multiple Tenant	0.45-0.60
Private Offices-Single Tenant	0.55-0.75
Hospital	0.60-0.70
Medical Offices	0.70-0.85
Airport (public parking)	0.70-0.85
Manufacturing Plant	0.70-0.90
Restaurant (sit-down)	0.80-0.95
Branch Bank	0.90-1.20

[a] Volume of cars entering and leaving in peak hour divided by maximum accumulation of cars (capacity of facility)

Source: Special counts by RC and A; various parking studies by others

Parking Control Strategy Selection

Selection of the proper type of parking control strategy is exceedingly important in the successful operation of a major parking facility. The strategy involves the method of parking control, the charge which will be placed upon the user, and the type of payment to be collected from the user. Table 3 shows the application of various control strategies as related to the type of parking facility used as well as to the type of parking control equipment. For shopper and business parkers, it is normal to allow free entry with payment of a variable fee on an individual basis as they exit the garage. In the case of employees, it is more normal to allow them to enter freely and have a prepaid monthly charge which could be checked through the use of parking permits, coded cards, tokens, or other means as they exit. Parkers at sports events exhibit high peak volumes but have a length of time parked which can be estimated. For this type of condition, it is much more appropriate to collect a flat fee inbound and to have no control outbound. This latter type of control was the one which we recommended for use at the Los Angeles Convention Center.

Table 3

APPLICATION OF VARIOUS CONTROL STRATEGIES

	CONTROL STRATEGY APPLICABILITY					
	CONTROL METHOD		TYPE CHARGE		TYPE PAYMENT	
ITEM	Free-In Pay-Out	Pay-In Free-Out	Flat Fee	Variable Fee	Pre-Paid	Individual Payment
<u>Preferred Method to Serve:</u>						
Employee	X	X	X		X	
Office Building Visitor	X			X		X
Sports Event		X	X			X
Shopper	X			X		X
Student	X		X		X	
Air Traveler	X			X		X
<u>Control Type:</u>						
Ticket Spitter	X			X		X
Cashier/Attendant	X	X	X	X	X	X
Time Stamp Ticket Manually	X			X		X
Coded Card	X	X	X		X	
Coin-Operated Gate	X		X			X
Token-Operated Gate	X	X	X	X	X	
Parking Meter	-	-	X	X		X

Parking Control Operating Characteristics

Table 4 indicates our findings concerning the service rates for various types of parking controls. We have taken the design service rate as being equal to 80 percent of the maximum service rate. There is considerable variation in service rates and careful study must be given to the probable characteristics of the users of the parking facility as well as the experience of the personnel operating the facility.

For the control measures normally used in entering a facility, the average headways vary from 3.6 seconds per vehicle for a clear aisle with no control to 20.4 seconds per vehicle for a coin-operated gate. In terms of design hourly capacities, the rates would be 800 per hour per lane for clear aisles and only 140 per hour per lane for coin-operated gates. The most common type of control used at major parking facilities is the ticket dispenser with a gate. Research in England identified the fact that there is a significant difference in the capacity of this equipment depending upon whether the parker has an easy direct approach or if a sharp turn is required to approach the equipment. This is obvious since a straight approach allows a parker to position himself in a reasonable location to pull the ticket to open the gate. Thus, the design of the approach to a ticket dispenser can cause the hourly capacities to vary between 305 and 520 vehicles per hour.

Internally, the circulation pattern can affect the capacity of the inbound approach. It is very important to have a minimum of interference within the parking facility so that once a driver leaves the entrance parking control, he can do so without delaying the next inbound parker immediately behind him. This can be accomplished by avoiding situations where <u>outbound</u> parkers queued up from the exit control block parkers entering the facility.

The capacity of exits from a major parking facility are dependent upon adequate space approaching the exit control location as well as adequate reservoir between that location and the driveway to the public street. Analysis must be conducted on both of these reservoir needs and sufficient lanes as well as sufficient reservoir length provided to allow proper operation. The emphasis of this paper will be upon the capacity of the exiting parking control itself. The most common type of operation involves use of a cashier collecting a variable fee from a parker based upon length of time parked. This type of control has a capacity of approximately 150 vehicles per hour. Another approach might be to have the parker pay his fee to the cashier <u>before</u> entering his car and then utilize a token operated gate as a means of exit control. This control strategy would have over twice the capacity of a cashier lane itself and could have application where there is insufficient space to provide an adequate number of cashier lanes.

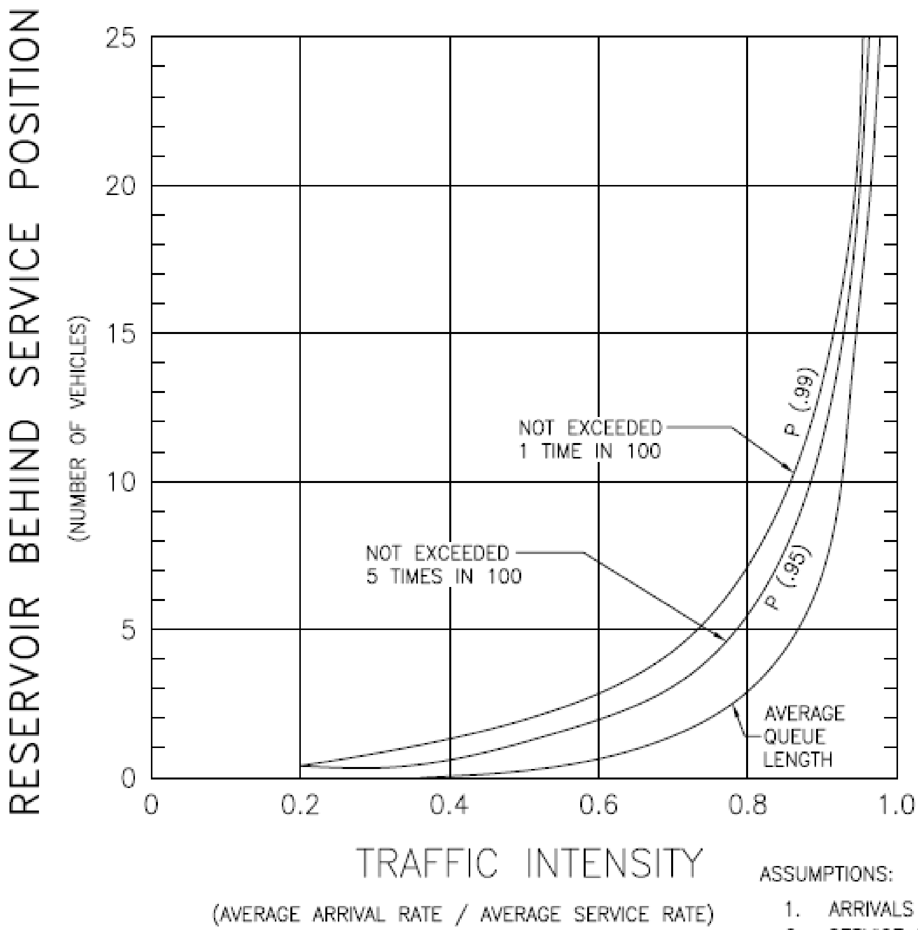
Table 4

PARKING CONTROL SERVICE RATE

TYPE OF CONTROL	TYPICAL SERVICES RATES PER LANE [a] AVERAGE HEADWAY (Sec/Veh)	HOURLY CAPACITY Design [b] (Veh/Hr)	HOURLY CAPACITY Maximum (Veh/Hr)
<u>Entering:</u>			
Clear Aisle, no control	3.6	800	1,000
Ticket dispenser, no gate	5.0	575	720
Time Stamp and hand to driver	8.5	340	425
Coded-card operated gate	8.9	340	425
Cashier, flat fee, no gate			
No information given	9.2	310	390
Direction-info needed	14.8	195	250
Ticket Dispenser w/gate			
Sharp turn at approach	9.5	305	380
Easy direct approach	5.5	520	650
Coin operated gate	20.4	140	175
<u>Internal</u>:			
Clear aisle or ramp, no parking	2.0	1,200	1,800
Straight ramp w/bend at end	2.2	1,000	1,610
Circular ramp, 30' R at C/L	2.2	840	1,650
Aisle with adjacent 9 x 18' stalls			
Inbound	3.5	830	1,040
Outbound	8.6	335	420
<u>Exiting</u>:			
Light street congestion	7.2	400	500
Moderate street congestion	9.0	320	400
Coded-card/token-operated gate	9.0	320	400
Cashier, flat fee w/gate	13.4	215	270
Casher, variable fee w/gate	19.5	150	185
Coin operated gate	20.4	140	175

[a] Assumes no significant interference by pedestrians, other traffic, etc.
[b] Taken as 80% of maximum rate; require 6 car lengths reservoir in advance of control points.

RESERVOIR NEEDS VS TRAFFIC INTENSITY



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ASSUMPTIONS:

1. ARRIVALS FOLLOW A POISSON DISTRIBUTION
2. SERVICE RATE CAN BE REPRESENTED BY AN EXPONENTIAL PROBABILITY FUNCTION.
3. FLOW IS EQUALLY DIVIDED BETWEEN EACH LANE IF MORE THAN ONE IS AVAILABLE.

Reservoir Needs

If you have ever watched cars approaching any type of parking control, you know that they do not come at an even rate. Even though there may be nearby traffic signals which may cause the approaching parkers to arrive in groups or platoons, random arrival is the normal approach characteristic assumed. Research has shown that random arrivals or events in a traffic stream tend to follow the Poisson mathematical distribution. This distribution provides a means that, if the average rate is known, the probability of exceeding a given volume in a unit of time may be calculated. Thus, if you know the average volume, you may calculate the surges in volume to allow design of reservoir space. As an example, if the average number of cars in a five-minute interval is 10, use of Poisson statistical techniques will yield the fact that no more than 18 cars will arrive in the five-minute interval within a probability that this amount will be exceeded only one time in 100 five-minute intervals. Use of these calculation techniques allow the determination of the amount of reservoir required to serve a given type of parking control.

The relationship between the arrival of vehicles and the ability of the parking control equipment or strategy to handle these vehicles are the most important items in determining reservoir space. If the average number of arrivals per unit of time is called "v" and "s" is the average rate of service (discharge) per unit of time, the ratio of v/s is used to determine the amount of reservoir space. This ratio is called traffic intensity ("i"). The average length of the queue ($\bar{q}$) behind the vehicle being serviced is equal to $\bar{q} = \frac{i^2}{(1-i)}$. This formula assumes that the arrival of vehicles at the service point follows a random distribution, the servicing time for vehicles can be represented by an exponential probability function, and that the flow is equally divided among service facilities if there is more than one lane serving a given area of the garage.

Knowing the average queue length and selecting a probability value which represents the frequency that the design length will be exceeded, will allow the designer to determine the amount of reservoir required behind the service position. These formulas and probabilities were utilized to prepare Figure 1 which compares traffic intensity with required reservoir for common probabilities used in design. The mathematics are such that, as the average volume approaches the average service rate, the amount of backup will be infinite. In addition, the probability that the amount of reservoir space for a given volume will never be exceeded also is infinite. In actuality, these conditions do not occur but the general relationships hold true based on our field observations.

As may be noted in the figure, an insignificant amount of reservoir is required when the average arrival rate is 50 percent or less of the average service rate of the parking control device. At this level, only a two-car reservoir would be required. As the ratio of traffic intensity increases above 0.7, the amount of reservoir space increases rapidly. We have selected a traffic intensity of 0.8 as appropriate for design and a probability that the determined reservoir would be exceeded only five times in 100. Thus, if the average service rate for a given type of parking control is known and sufficient lanes are provided so that the average arrival rate during the peak hour is 0.8 times the average service rate, a reservoir of six car lengths behind each service position would be adequate to meet the needs of the facility. If this is physically impossible, a traffic intensity of 0.6 should be used to determine the number of lanes requiring only a two-car reservoir.

Summary

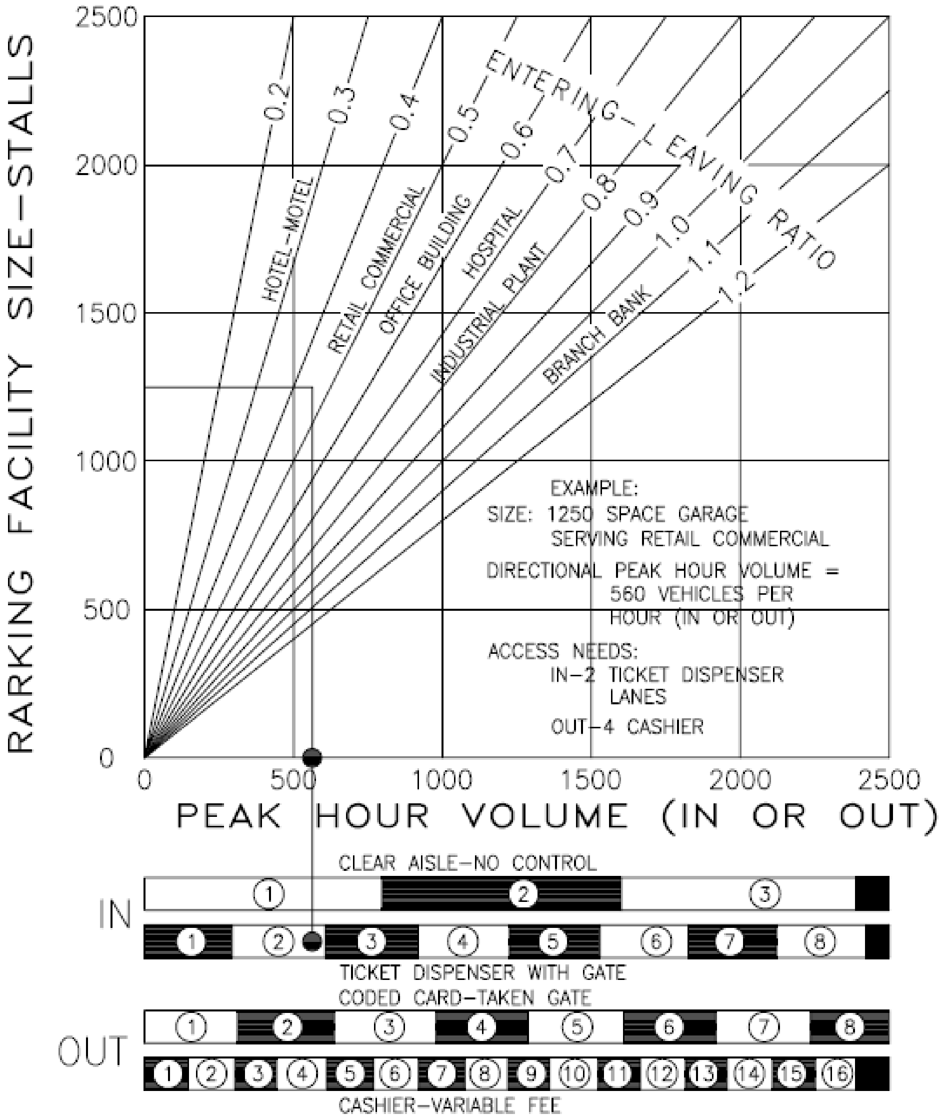
Having determined the peak hour volumes, the parking control strategy, the number of lanes, and the reservoir length to adequately serve the peak-hour volumes, the physical design of the facilities then may be made. As noted previously, having an inadequate capacity to serve the traffic volumes approaching the control means can have a very drastic effect upon the backup which will occur. This backup creates adverse operating characteristics in and around the facility and also causes the length of time that a parker is involved in entering or leaving a garage to grow significantly. Thus, the design features of the facility can have an impact on the attitudes of the users and indirectly affect the success or failure of the parking facility in attracting customers or users.

To provide a means of easily determining the number of lanes necessary for various types of parking garages, Figure 2 was prepared which allows the designer to directly translate the size of the garage and the type of land use served into the number of necessary access lanes for the parking control strategy assumed. The example shows that a 1,250-space garage serving a retail commercial facility will normally have a directional peak hour volume of 560 vehicles per hour. If inbound ticket dispensers with gates are used, two lanes will be adequate to serve this garage. If cashiers collect variable fees, a total of four exit cashier lanes will be required. Normally these four lanes will not be provided all in the same location and, of course, it could be necessary to operate all four only during peak hours.

In the case of an office building rather than a retail facility, it would be possible to use coded card exit gates for monthly parkers. This would significantly reduce the required number of exit lanes since transient visitors are a much lower percentage of the peak hour volumes for an office building than they are in a garage serving a retail facility. The reduction in construction and operating cost would be significant.

A warning is necessary concerning the use of Figure 2 since it was based upon very generalized information. Each individual major parking facility must be considered on its own and its access needs determined in light of the characteristics of the probable users of the facility itself. In order to have satisfied customers and users of a major parking facility, thorough investigation and determination of access needs must be accomplished.

PARKING FACILITY SIZE VS ACCESS NEEDS



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