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This report presents guidelines for designing bus park-and-ride facilities. Specificially, guidelines are developed for: 1) locating park-and-ride lots; 2) determining the desired size of a park-and-ride lot; 3) evaluating the capacity of selected design components of the lot (access/egress, kiss-and-ride, bus loading spaces, shelter area); and 4) establishing the physical layout of the parking area. The guidelines developed should be of greatest use to those individuals already familiar with typical parking lot design who are involved in the initial design of new park-and-ride facilities.

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DESIGN GUIDELINES FOR PARK-AND-RIDE FACILITIES

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

ABSTRACT

This report presents guidelines for designing bus park-and-ride facilities. Specifically, guidelines are developed for: 1) locating park-and-ride lots; 2) determining the desired size of a park-and-ride lot; 3) evaluating the capacity of selected design components of the lot (access/egress, kiss-and-ride, bus loading spaces, shelter area); and 4) establishing the physical lay-out of the parking area. The guidelines developed should be of greatest use to those individuals already familiar with typical parking lot design who are involved in the initial design of new park-and-ride facilities.

Key Words: Park-and-Ride, Transit, Terminal Design, Mass Transportation, Bus Rapid Transit

SUMMARY

This report presents guidelines for the design of park-and-ride facilities. Guidelines are developed in the general areas of park-and-ride lot location, parking lot size, capacity of selected components (kiss-and-ride, etc.) of the parking lot, and internal parking lot layout. This report complements a previous report (Research Report 205-2) entitled "Park-and-Ride Facilities: Preliminary Planning Guidelines."

A brief summary of the major research findings is presented in the remainder of this section.

Parking Lot Location

The park-and-ride lot should be located in a highly congested travel corridor and preferably will be located upstream of the more intense traffic congestion. The lot should be located at least 3 to 4 miles (5 to 6 km), and possibly even 6 to 8 miles (10 to 13 km), from the activity center being served. The residential areas immediately upstream of the park-and-ride lot location will preferably have a high affinity to the activity center served by the park-and-ride operation. Desirably, the lot will be located in an area having both high accessibility and quick, convenient access; these features will promote operational safety and will also minimize delay time which will reduce total trip time per patron.

Park-and-ride lots can be implemented in two general manners. Service can be implemented either at an existing parking lot (shared use), or a new lot can be built to function exclusively as a park-and-ride facility. If a suitable location can be found, the shared-use approach is more compatible with the flexibility advantage that is commonly associated with park-and-ride

service; shared-use facilities provide a means of testing demand. These facilities can be implemented relatively quickly and at a relatively low cost.

Either one large facility can be provided to serve the park-and-ride demand or, alternatively, multiple smaller lots can be developed. In general, provision of one large lot appears to be the more attractive alternative. Development costs should be less, shorter bus headways can be provided, which also result in a bus being visible at the lot a greater amount of time, and provision of various amenities can be more easily justified.

Parking Lot Size

Various factors, such as walking distance, bus headways, and market-area characteristics, place constraints on the desirable size of a park-and-ride lot. As a general guideline, if exclusive, express bus service is to be provided at a lot, a demand sufficient to justify at least 200 all-day auto-parking spaces should exist. In general, for each bus-loading area at a park-and-ride lot, no more than 700 to 800 all-day parking spaces should be provided; it is feasible to provide more than one bus-loading area at a park-and-ride lot in order to serve a larger parking demand.

Design Capacities

Capacity analyses are provided for access/egress requirements, kiss-and-ride parking needs, bus-loading space needs, and bus shelter area requirements.

Access/Egress

For the size of park-and-ride lots being developed in Texas, two access/egress points (each with one lane in each direction) should provide the needed capacity.

Kiss-and-Ride

As a general rule, sufficient kiss-and-ride parking space will be available if approximately 4 percent of the total parking spaces provided are designated as kiss-and-ride spaces (refer to Figures 2 and 3).

Bus-Loading Spaces

As a general guideline, sufficient space should be provided at the lot to accommodate two to three parked buses.

Bus-Shelter Area

Sheltered waiting areas are a desirable amenity to provide at park-and-ride lots. In general, if bus service is provided at 10-minute headways, sufficient shelter area will be available if 1 square foot (0.09 sq m) of shelter area is provided for every 2 daily patrons. More detailed guidelines concerning shelter-area requirements are provided in Figures 4 and 5.

Internal Parking Lot Layout

At park-and-ride lots, the advantages of locating the bus-loading area on the periphery of the lot appear to outweigh the disadvantages of that approach. However, lots with the loading area located within the lot can also be successfully operated. In laying out the lot, the handicapped parking should be located closest to the bus-loading area, with about 2 percent of total spaces designated for handicapped parking. Kiss-and-ride parking should be given the next priority in terms of proximity to the bus-loading area.

Reasonably direct pedestrian flow patterns should be provided to the

bus-loading area. Desirably, walking distance will not exceed 400 feet (122 m); an 800 foot (244 m) walking distance can be considered as an absolute maximum.

No firm guidelines concerning the types of amenities (shelter, vending machines, landscaping, etc.) that should be provided at a park-and-ride lot in Texas have been established. A recent study prepared for UMTA does conclude that the success of a lot is dependent upon the lot being well-guarded, well-lit, having sheltered waiting areas and having telephones available. Typically, at exclusive park-and-ride lots in Texas, designated handicapped and kiss-and-ride parking areas are provided, as are lighting, designated pedestrian walkways, exclusive bus accessways, enclosed or semi-enclosed heated shelters, seating, newspaper/beverage/cigarette vending machines, and telephones. Fewer amenities are provided at shared-use lots, and many of the amenities available at those locations were already available prior to providing park-and-ride service.

IMPLEMENTATION STATEMENT

Park-and-ride is becoming a significant aspect of many transit operations in Texas. Plans exist for extensive expansion of this service.

Most of the earlier park-and-ride efforts in the state made use of existing parking areas. An emphasis was placed on quickly implementing service to test the demand response to this form of transit service.

Many of these park-and-ride efforts have been successful. In some instances, more permanent locations for existing park-and-ride operations are being sought. In other instances, constructing new facilities represents the only feasible means of providing park-and-ride service.

The result of these occurrences is that the design of new park-and-ride facilities is becoming more common. In some respects, this design differs from the design associated with a typical parking lot. This report presents guidelines that can be used by technical staff in the design of park-and-ride facilities. It complements a previous report (Research Report 205-2) entitled "Park-and-Ride Facilities: Preliminary Planning Guidelines."

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INTRODUCTION

During the past several years, significant interest in park-and-ride facilities has developed in Texas. Most of the earlier park-and-ride services made use of existing parking lots; more recently, however, local agencies are beginning to construct new parking areas specifically designed to function as park-and-ride terminals. Local agencies have considerable experience in parking lot design, and it is not the intent of this report to develop guidelines for laying out a typical parking lot. These agencies are also generally knowledgeable of bus operating characteristics.

However, since construction of exclusive park-and-ride lots is a rather new phenomenon, relatively little work has been performed to develop guidelines for the design of those park-and-ride facilities. Properly designed facilities are needed if ridership is to be maximized. Design of park-and-ride terminals differs in many respects from typical parking lot design.

Thus, a need exists for guidelines that specifically pertain to the design of park-and-ride facilities. This report is intended to address that need; the report discusses considerations that arise in the design of park-and-ride facilities. As such, this report complements a previous report entitled "Park-and-Ride Facilities: Preliminary Planning Guidelines" (Research Report 205-2).

This report is divided into four major sections. The first section presents guidelines for determining the location of a park-and-ride lot. The second section discusses various factors that influence the size of park-and-ride lots. The third section identifies design capacities for selected components of the park-and-ride lot. In the final section, guidelines concerning the internal arrangement of the park-and-ride lot are presented.

GUIDELINES FOR LOCATING PARK-AND-RIDE FACILITIES

During the preliminary design phase, certain flexibility may exist regarding the approach to use in implementing park-and-ride service. In this section, several factors that influence the location(s) in which the park-and-ride facility will be provided are discussed. Guidelines for identifying desirable park-and-ride locations are presented. The issue of whether to develop a new park-and-ride facility or whether to locate the park-and-ride service in an existing parking location is addressed. Finally, consideration is given to the advantages and disadvantages of developing one large park-and-ride facility as opposed to developing multiple smaller facilities.

General Factors Influencing Park-and-Ride Lot Location

In some highly developed urban areas, little choice may be available in selecting potential parking lot locations. In effect, land availability and/or cost may greatly restrict alternative lot locations.

Nevertheless, the following guidelines should be considered in locating potential park-and-ride facilities.

- Provision of park-and-ride service should be considered only in travel corridors that experience intense levels of peak-period congestion.
- The parking lot should be located in advance of the more intense traffic congestion. Potential park-and-ride patrons should have the opportunity to select the park-and-ride alternative prior to encountering the more heavily congested peak-period traffic.

- The bus portion of the average park-and-ride patron's trip should represent the major portion of that trip. Since the average work trip length in major Texas cities is approximately 8 miles (13 km) (1), park-and-ride lots should generally be located more than 3 or 4 miles (5 or 6 km) from the activity center being served by the operation.
- The lot should be located in a geographical area having a high affinity to the activity center being served by the park-and-ride operation. Since the overwhelming majority of park-and-ride patrons live within 5 miles (8 km) of the lot and since relatively few patrons backtrack to use a park-and-ride lot (2), the lot should be located so that the area immediately upstream of the park-and-ride facility generates significant travel demand to the activity center being served.

Meeting these conditions should assist in maximizing the potential park-and-ride patronage.

If flexibility exists in the selection of a park-and-ride lot site, the following factors should also be considered in determining the preferred lot location.

- The location should have a high level of accessibility, and quick, convenient access to a major thoroughfare should be available. Desirably, the lot should be visible from the major thoroughfare.
- To minimize development costs, the site should be flat and well drained. Compatibility with adjacent land uses needs to be considered.
- Space should be available for expansion of the lot. Initial demand may be underestimated, and demand should increase over time.

- Preferably, a park-and-ride lot will be located on the right side of the roadway to conveniently intercept inbound traffic. However, some successful lots have been developed that were not located in this manner.

Shared Use Versus New Park-and-Ride Facilities

Two general approaches can be used in implementing park-and-ride service. One alternative is to construct new facilities specifically designed to serve as exclusive park-and-ride terminals. The second alternative is to utilize the unused portion of an existing parking lot to serve as the parking area for the park-and-ride service. Sites commonly used in this shared-use lot arrangement include shopping centers, movie theaters, and various sporting facilities.

Both of these alternative approaches have certain advantages and disadvantages. The brief listing of advantages and disadvantages provided below may be of assistance in determining for a given set of circumstances which alternative approach to pursue.

Shared Lots, Advantages

- The parking facility is already available and, therefore, the lead time to implementation of park-and-ride service is reduced. Provision of entirely new facilities can greatly increase lead time.
- The parking area and access roadways already exist. As a result, less capital is required to implement the park-and-ride service.
- Due to the lower capital requirements, shared lots can be used as as means of testing demand. If demand proves inadequate, the service can be quickly terminated. If the demand is substantial, the

desirability of serving that demand with more capital intensive facilities can then be considered. Although the location, amenities, and transit service at a shared-use lot may not be optimal, opening a lot at that location may still generate a significant park-and-ride patronage.

- The shopping opportunities available at some shared-lot locations may encourage ridership.

Shared Lots, Disadvantages

- The park-and-ride operation must be worked into the existing lot layout. This may create difficulty in developing desirable access and circulation patterns.
- Space may not be available for expansion. Expansion area will be needed if initial demand estimates are low, or if demand increases over time. If the demand at the shared-lot location is greater than anticipated, problems may be created when the excess parking demand begins parking in areas not designated as park-and-ride lot areas.
- It may be difficult to obtain assurance that a certain number of parking spaces will be available on a daily basis. Many facilities that have unused parking area during most of the year require the use of that parking area during peak times of the year.
- Many of the amenities provided will be temporary in nature. The temporary appearance of the facility may discourage some potential ridership.
- During peak periods, especially the evening peak, congestion within the lot and at the access points may be intensified due to traffic generated by the shared use. For example, evening

shopping traffic may conflict with evening park-and-ride traffic if the park-and-ride lot is located in a shopping center.

One of the major advantages often attributed to park-and-ride operations is their great flexibility. Such services can be implemented relatively quickly and at a small capital cost. The risk associated with that type of transit improvement is relatively small as long as the services can be implemented and terminated reasonably quickly as dictated by demand. This flexibility is more closely associated with shared-use park-and-ride facilities; that approach does offer an excellent means of rapidly implementing service at low cost. If suitable sites can be found, shared-use facilities appear to offer a superior approach to initially implementing park-and-ride services.

Single Versus Multiple Lots

Given an estimated demand for park-and-ride service, a question arises as to whether that demand can better be served by providing one large lot or two or more smaller lots. Some of the advantages and disadvantages of these approaches are listed below. It appears that, as long as the maximum lot size constraints developed subsequently are not exceeded, the advantages of providing one large facility generally exceed the disadvantages of that approach.

Multiple Lots, Advantages

- Provision of multiple lots results in a larger geographical area being included in the total park-and-ride market area. The result should be some increase in total park-and-ride utilization.
- If the maximum parking lot size constraints (~800 parking spaces/

bus-loading area) developed in the following section of this report are exceeded, multiple lots provide a means of accommodating the demand.

- If either land availability and cost or available surface street capacity pose problems in providing one large lot, it may be more economical to provide multiple smaller lots rather than incur massive land and/or street improvement costs to build a single large facility.
- Smaller lots will reduce both congestion and walking distances within the lot.
- A smaller percentage of the total trip will be made by auto.

Multiple Lots, Disadvantages

- The construction and maintenance of costs of one large facility will be less (assuming similar land costs and facilities) than those of multiple smaller lots. This will generally be true as long as the demand at the one large lot does not necessitate large-scale improvements to the adjacent street system.
- If express bus service is provided, longer headways will exist in the multiple-lot situation (assuming comparable bus load factors). That is, each small lot will not have the same level of bus service that would be provided at one large lot. Similarly, with shorter headways a bus will more frequently be visible at the lot; this may increase the appearance of reliable service.
- Bus breakdowns may pose a greater problem in the multiple lot situation, where the breakdown might cause headways to increase from the scheduled 15 or 20 minutes to 30 or 40 minutes. The latter

represent unacceptably long headways. Conversely, at the large lot, a bus breakdown would typically result in bus headways in the range of 10 to 15 minutes.

- Provision of certain amenities (security, information, shelters, vending machines, etc.) may be more easily justified at one large facility than at several smaller facilities.
- Although multiple lots may provide an adequate number of total spaces, a probability exists that one of the smaller lots may become filled while others have substantial unused capacity. Drivers would then be expected to travel to more than one location to find an available space.

FACTORS INFLUENCING THE DESIRED SIZE OF PARK-AND-RIDE LOTS

After establishing the desired lot location(s), certain guidelines can be followed in determining the range of potential demand that can be adequately served at a park-and-ride lot. It is not the intent of this section of the report to present methodologies for estimating park-and-ride demand, for it is assumed that planning studies have preceded the design phase; it is further assumed that these planning studies formulated both an existing and a design year demand estimate. Given a demand estimate, a relationship exists between that estimate and the size of the lot(s) that should be developed to serve that demand.

Thus, the lot design is influenced by the demand. Consideration must be given to whether daily fluctuations in demand should be expected. Also, attention needs to be focused on those factors that determine both the maximum and minimum number of parking spaces that desirably would be provided at a new park-and-ride lot. These factors are addressed in this section of the report.

Daily Demand Fluctuations

The planning process will have developed an average daily demand estimation. Due to the nature of park-and-ride services, little daily fluctuation in this demand should be expected. Persons using the park-and-ride mode are commonly doing so for the trip to work (Table 1). As would be expected, this trip is made on a regular basis (Table 2).

Thus, if a park-and-ride facility is designed to accommodate a demand approximately 10 percent greater than the estimated average demand, the probability of actual demand exceeding capacity on any given day will be small (3).

Table 1: Trip Purpose of Individuals Using Park-and-Ride Facilities

Location	Percent of Total Trips That Are Work Trips
U.S. Cities	
Suburban New York City	91
Washington, D.C.	92
Seattle	86
Richmond, Va.	99
Milwaukee	86
Lincoln Tunnel, N.J.	88
Hartford, Conn.	99
Texas Cities	
Dallas	87
San Antonio	100

Source: Reference 2

Table 2: Frequency of Use of Bus Park-and-Ride Mode (Percent)

Round Trips Per Week	Park-and-Ride Location		
	Representative U.S. Value	Dallas	San Antonio
5	74	83	77

Source: Reference 2

Constraints on Parking Lot Size

Certain design and operational features of the park-and-ride service place constraints on both the maximum and minimum desirable lot size. Some of the more pertinent factors that influence parking lot size are presented in this section.

Maximum Lot Size

The maximum desired lot size at a park-and-ride facility can be constrained by walking distance, bus headways, market-area characteristics, and other factors.

Walking Distance Constraint

In general, walking distance from the location in which the car is parked to the bus-loading area should not exceed 600 to 800 feet, or 183 to 244 m (4). Desirably, this distance should not exceed 400 feet (122 m) (3). Thus, for each bus-loading area provided at a park-and-ride facility, walking distance will place a constraint on lot size. Table 3 summarizes the impact of walking distance on total lot size, assuming that walking distance will not exceed 600 feet (183 m).

As becomes evident in the following portions of this section, other factors appear to place more stringent constraints on lot size than does the walking distance criterion.

Table 3: Constraint of Walking Distance on Maximum Park-and-Ride Lot Size Per Bus Loading Area

Type of Lot Layout	Maximum Number of Auto Parking Spaces[a]
Loading Area in the Center of a Square Lot	1600
Loading Area on the Periphery of a Square Lot	800

[a]Based on all parking spaces within 600 feet (183 m) of the bus loading area and 450 sq ft (42 sq m) per parking space.

Bus Headway or Service Constraint

The level of service, expressed as bus headways, provided at each loading location places a constraint on the amount of demand that can be accommodated at the park-and-ride facility. Based strictly on bus-loading times, bus headways of as little as 3 minutes could be attained. However, to minimize conflicts and eliminate the possible need for simultaneous loading of more than one transit vehicle, minimum headways of approximately 5 minutes appear to be realistic for preliminary design purposes.

Based on this constraint, parking lot size per bus-loading area should not exceed about 800 parking spaces.[1] If headways of less than 5 minutes are provided, this maximum lot size will, of course, increase. It is also feasible to provide more than one bus-loading area, possibly with the different loading areas serving different destination points, in a park-and-ride lot. This will also increase the parking demand that can be accommodated at the lot.

Watershed or Demand Constraint

Experience with park-and-ride services has indicated that the watershed, the primary area from which the park-and-ride lot draws its patronage, associated with a park-and-ride facility is reasonably well defined. As a consequence, the typical park-and-ride lot serves a finite, definable market area. That market area establishes the magnitude of the demand that the park-and-ride service will need to accommodate.

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[1] Twelve buses during the peak hour at 50 persons per bus yields 600 persons. Assuming this to be 55 percent of total demand (3), the total demand would be approximately 1100 persons. At 1.4 persons per vehicle (5), this results in a need for roughly 800 parking spaces.

The primary market area is typically shaped as shown in Figure 1. Census data (Table 4) are used to estimate the number of central business district (CBD) employees that might typically reside in a primary market area. Using Table 4, assuming a typical work force density of 1300 employees per square mile (502 per sq km) and that 13 percent of those employees work in the CBD, there are typically about 170 CBD employees per square mile (65 per sq km) of market area. Assuming the primary market area to contain about 25 square miles (65 sq km), 4250 CBD employees reside in the primary market area associated with the park-and-ride lot.

Analysis (5) of the primary market area of park-and-ride facilities in Dallas indicates that, of those CBD employees who reside in the primary market area, nearly 10 percent actually make use of the park-and-ride service.

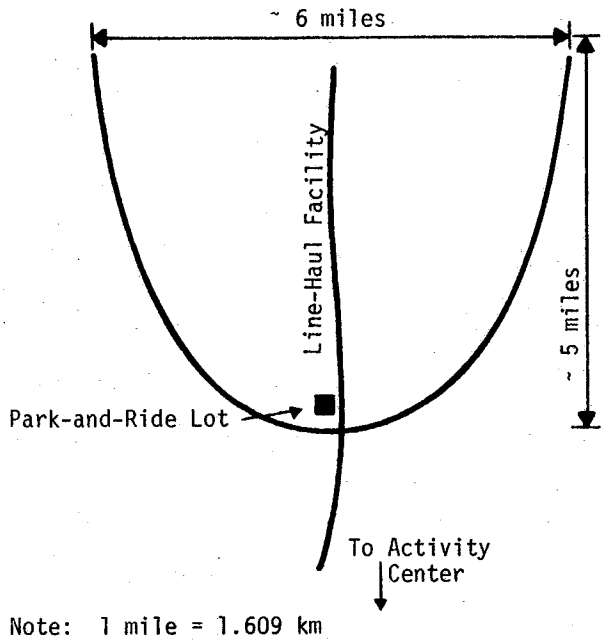

Figure 1: General Shape of the Watershed or Primary Market Area Served by a Park-and-Ride Facility

Table 4: Selected Demographic Characteristics of the Seven Largest Texas Cities

City	Land Area sq mi (sq km)	Persons in Work Force	Workers/ sq mi (sq km)	Work Force as a % of Population	CBD Workers	CBD Workers as a % of the Work Force
Austin	72.1 (187)	102,448	1,421 (549)	40.7	12,896	12.6
Corpus Christi	100.6 (261)	74,899	745 (288)	36.6	7,613	10.2
Dallas	265.6 (688)	362,458	1,365 (527)	42.9	48,927	13.5
El Paso	18.3 (306)	106,164	897 (346)	32.9	11 ,743	11.1
Fort Worth	205.0 (531)	158.755	774 (299)	40.3	14,005	8.8
Houston	433.9 (1124)	503,544	1,161 (448)	40.9	76,303	15.2
San Antonio	184.0 (477)	227,813	1,238 (478)	34.8	25,882	11.4

Source: 1970 census data for respective cities

For preliminary lot-sizing purposes, it might be assumed that an optimally located and operated park-and-ride facility could actually serve as much as 15 percent of the total primary market-area demand. If so, the daily demand generated from the primary market area would be approximately 650 (4250 x 0.15) patrons.

Experience (5) with park-and-ride service further suggests that, of the total number of patrons using the service, approximately 70 percent reside in the primary market area. Thus, if 650 patrons represent 70 percent of total demand, the typical total demand would approach 900 to 1000 patrons per day. Since about 1.4 patrons are generated per parked vehicle, parking for as many

as 700 vehicles could be required at the park-and-ride lot based on the market-area constraint.

Other Constraints

Other factors can further constrain the maximum park-and-ride lot size. Inadequate capacity on the surrounding roadways will reduce the volume of traffic that can enter or leave a lot in a given period. Without good access, substantial traffic delays may develop which will adversely affect park-and-ride patronage. Land availability and/or cost may also constrain the land area that can feasibly be obtained for park-and-ride lot development.

Minimum Lot Size

Bus headways also influence minimum lot size. A minimal level of bus service is considered essential to justify the existence of a major park-and-ride facility. Some sources (3,6) contend that peak-period headways should not exceed 10 minutes. However, certain operations in Texas have successfully generated significant demands with headways in excess of 10 minutes.

Based on the park-and-ride experiences in Texas, it appears that headways at park-and-ride lots should not exceed 15 to 20 minutes. If 20 minutes is considered to represent the longest acceptable headway, the park-and-ride facility should have at least 200 parking spaces to justify its existence.[2]

It is assumed in this minimum lot size analysis that the new lot is being provided with the intent of developing a major transit demand. Certainly smaller

[2]Three buses during the peak hour at 50 persons per bus yields 150 persons. Assuming this to be 55 percent of total demand (3), the total demand would be approximately 270 persons. At 1.4 persons per vehicle (5), this results in a need for approximately 200 parking spaces.

park-and-ride lots can function well, especially when served by non-express service. However, unless a daily demand of approximately 200 vehicles can be generated, the lot will not be of sufficient size to justify the minimal acceptable service (20-minute headways).

Summary, Park-and-Ride Lot Size Guidelines

Based on the information presented previously, it is suggested that a new park-and-ride facility should contain at least 200 all-day auto-parking spaces. If the new lot has only a single bus-loading area, as is typically characteristic of Texas lots, the size of the lot should not exceed about 700 to 800 all-day auto spaces (Table 5). Other sources (3) have established a range of 400 to 700 spaces as representing a desirable size for bus park-and-ride facilities.

Table 5: Summary of Constraints on Park-and-Ride Lot Size

Constraint	Number of All-Day Auto Parking Spaces
Constraints on Maximum Size	
Walking Distance	800-1600
Bus Headways (Service)	800
Watershed (Demand)	700
Suggested Guideline	700-800
Constraints on Minimum Size	
Bus Headways (Service)	200

DESIGN CAPACITIES FOR SELECTED COMPONENTS OF THE PARK-AND-RIDE LOT

In designing the park-and-ride lot, several features need to be evaluated that do not require evaluation in the design of a typical parking facility. In this section of the report, design considerations involving access/egress, kiss-and-ride capacity, bus-loading zone capacity, and bus-shelter capacity are discussed.

Vehicular Access and Egress

Desirably, a park-and-ride lot should have at least two access/egress points (each having at least one lane in each direction) (7). Although in terms of theoretical capacity a single access/egress point (one lane in each direction) may be sufficient, possible vehicular queueing both inside and on the periphery of the lot makes two access/egress points preferable.

To estimate access/egress design capacity, a value of approximately 300 vehicles per hour per lane appears to be appropriate (4). Using this value, which assumes that parking fees are not being collected at the entry to the lot, Table 6 provides a summary of automobile access/egress requirements at park-and-ride lots. This is in general agreement with other studies (3) that suggest that one access lane be provided for every 400 to 600 parking spaces.

The lot size constraints developed in the previous section of this report suggest that park-and-ride daily demand should not exceed approximately 800 vehicles per bus-loading area. Such lots can be adequately served by two access/egress locations, each having two lanes (one lane in each direction). The capacity of the intersections in the vicinity of the lot must also be

Table 6: Auto Access and Egress Requirements for Varying Park-and-Ride Design Demands

Design Demand[a] (Vehicles/Day)	Minimum Number of Directional Lanes	Desired Number of Access/Egress Locations
Less than 1100[b]	2	2
1100 to 1600	3	2 or more

[a]Based on 55 percent of total demand arriving during the peak hour and a capacity of 300 vehicles per hour per lane.

[b]Based on the constraints developed in the previous section, it would be unusual for a park-and-ride lot in Texas to exceed this size.

evaluated to determine the types of improvements, if any, that will be required at those locations.

Kiss-and-Ride Capacity

Kiss-and-ride patronage is represented by those persons who are dropped off by a driver at the park-and-ride lot in the morning and picked up again in the afternoon. In designing a park-and-ride lot, guidelines concerning the number of parking spaces to provide for the kiss-and-ride demand are needed. Kiss-and-ride spaces should be signed in a manner that will assure their use as short-duration parking spaces.

Initially, it is necessary to estimate the percentage of total park-and-ride patronage that makes use of the kiss-and-ride arrival mode. This percentage can vary considerably. If data are not available for the specific lot being designed, in Texas it appears that at least 20 percent of the total patronage will use the kiss-and-ride arrival mode (Table 7).

Table 7: Kiss-and-Ride Patrons As A Percentage of Total Park-and-Ride Patronage

Location	Kiss-and-Ride Patrons as a % of Total Park-and-Ride Patronage
U.S. Cities	
Washington, D.C. (2)	9
Rochester, N.Y. (2)	36
Richmond, Va. (2)	26
Seattle (2)	16
Milwaukee (5)	10
Portland, Oregon (8)	less than 5
Texas Cities	
Houston (9)	
Westloop	20
Gulf	18
Southwest	21
San Antonio (2)	23

Estimates of total daily park-and-ride vehicular demand have been developed as part of the planning process. Multiplying that value by an average vehicular occupancy of 1.4 yields daily patronage. Approximately 55 percent of that demand can be expected to occur during the peak hour (3). Thus, of total daily patronage, approximately 11 percent (20 percent of daily patronage x 55 percent of daily patronage arriving during the peak hour) is represented by peak-hour kiss-and-ride patrons. Typical kiss-and-ride occupancy is approximately 1.1 patrons per vehicle (10); peak-hour kiss-and-ride patrons divided by 1.1 yields peak-hour kiss-and-ride vehicles. Thus, the following equation can be used to estimate peak-hour kiss-and-ride vehicular demand[3].

$$q = 0.14k$$

where: q = peak-hour kiss-and-ride vehicular demand

k = total daily park-and-ride vehicular demand

[3]k x 1.4 = total daily patronage x 0.2 = daily kiss-and-ride patronage x 0.55 = peak-hour kiss-and-ride patronage ÷ 1.1 = peak-hour kiss-and-ride vehicles.

Of the two kiss-and-ride operations--dropping passengers off in the morning and picking passengers up in the evening--the evening operation determines capacity requirements since it consumes more time than the morning drop-off operation. The expected afternoon waiting time is a function of bus headways. It is interesting to note that shorter headways can result in longer waiting times. With longer headways the kiss-and-ride user can estimate the precise bus he or she will use and prearrange a specific pick-up time. With shorter headways the user is less sure of the precise bus he or she will use and, therefore, also less sure of the precise arrival time. At existing park-and-ride operations, the typical waiting time of a vehicle picking up a kiss-and-ride patron is 6 to 10 minutes (4).

Given the peak-hour demand and the average waiting time, queueing theory[4] is used to determine the number of parking spaces that need to be reserved for use by kiss-and-ride vehicles. Figures 2 and 3 summarize the results of this analysis, assuming average waiting periods per kiss-and-ride vehicle of both 5 minutes and 10 minutes. These design values are based on the peak 15 minutes within the peak hour; it is assumed that average arrival rates during the peak 15 minutes will be 15 percent greater than the average hourly arrival rate. These relationships depict the number of kiss-and-ride spaces that need to be provided to assure that, with varying levels of confidence, demand will not exceed capacity during the peak 15 minutes of the peak hour. Figure 2 might be viewed as representing a desirable design level; Figure 3 represents a minimum design level.

[4]Multiple channel queueing theory, as described in Reference 11, was utilized in this analysis.

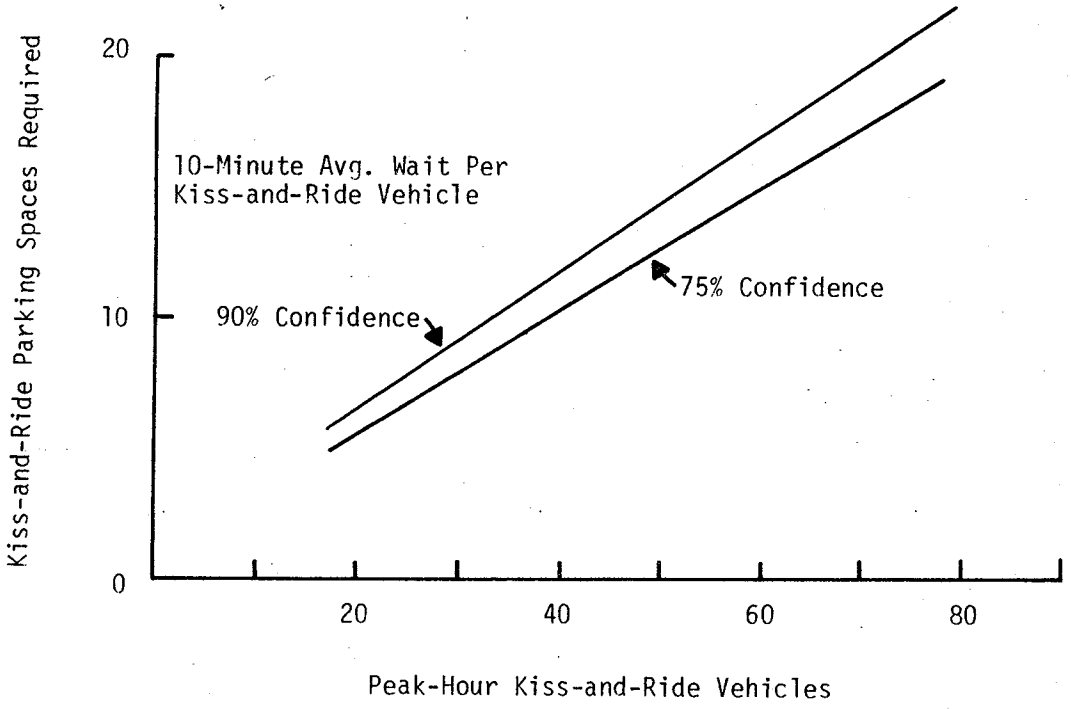

Figure 2: Peak 15-Minute Kiss-and-Ride Parking Space Requirements Assuming an Average 10-Minute Wait Per Vehicle

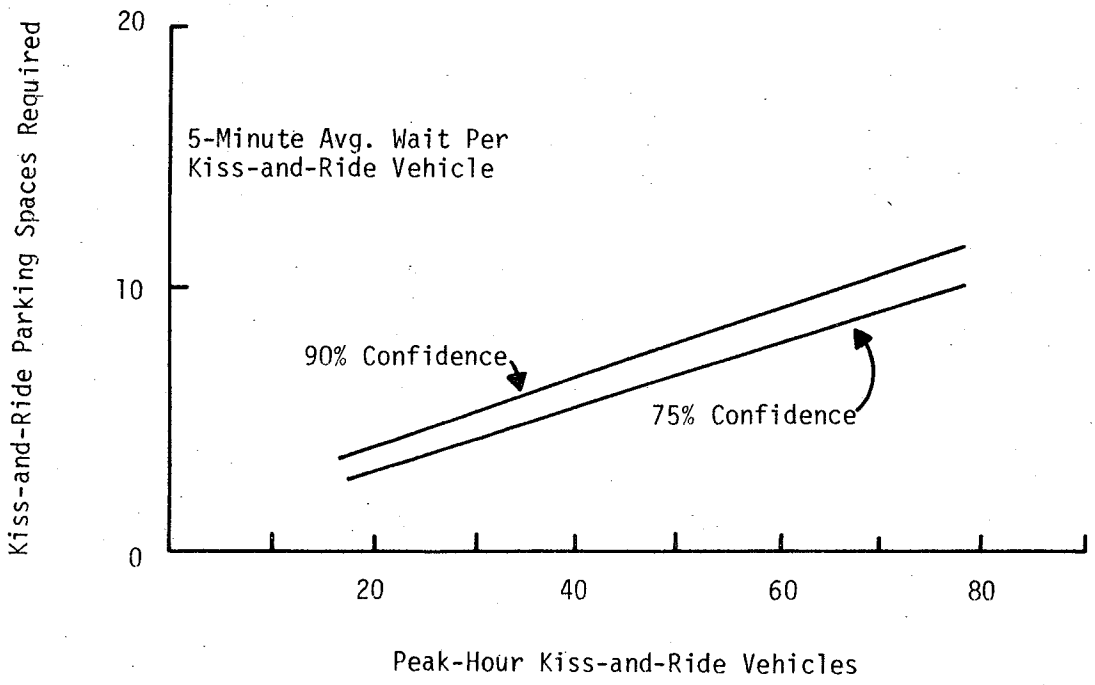

Figure 3: Peak 15-Minute Kiss-and-Ride Parking Space Requirements Assuming an Average 5-Minute Wait Per Vehicle

Example Problem

Given: Total auto parking demand requires provision of 500 all-day parking spaces.

Therefore: Peak-hour kiss-and-ride vehicular demand will be 70 vehicles (500 x 0.14)

- Assuming a 10-minute average wait per vehicle (Figure 2), it will be necessary to provide 17 kiss-and-ride spaces in order to be 75 percent certain that capacity will not be exceeded during the peak 15 minutes.

Bus-Loading Space Capacity

Space needs to be provided within or adjacent to the park-and-ride lot for buses to park while loading and unloading passengers. If both the loading and unloading of passengers occur at the same location, the morning peak will determine capacity requirements, since the loading of passengers generally requires more time than the unloading of passengers (3). This will be true unless the loading passengers have already paid their fare, in which case the loading and unloading of passengers require similar periods of time.

Queueing theory[5] was used to estimate the number of bus-loading spaces required; in order to assure that streets and circulation roadways are not blocked, it is suggested that a sufficient number of loading spaces be provided so that a 90 percent certainty exists that demand will not exceed space supply during the peak hour. It is further suggested that one additional

[5]Multiple channel queueing analyses are based on procedures documented in Reference 11.

loading space be provided for possible use by broken-down buses, service, or emergency vehicles. The resulting design guidelines are summarized in Table 8.

Table 8: Number of Bus-Loading Spaces Required[a] to Accommodate Varying Levels of Transit Service

Average Headway During Peak 15 Minutes	Service Time[b]			
	60 Seconds	120 Seconds[c]	180 Seconds	300 Seconds
5 Minutes	2	3	3	4
10 Minutes	2	2	3	3
20 Minutes	2	2	2	2

[a]Sufficient loading space is provided so that one space is available for use by a broken-down vehicle, and there is 90 percent certainty that the demand will not exceed the remaining capacity.

[b]The bus loading time or the required bus waiting time, whichever is longer.

[c]In the absence of other data, 120 seconds represents a reasonable time to load a 50-passenger bus.

In general, for the types of park-and-ride operations that will exist in Texas, 2 to 3 bus-loading spaces will be needed at each bus-loading area. It is particularly critical that sufficient bus-loading space be provided at those locations where buses load at turnouts located adjacent to streets; inadequate space at those locations will cause the waiting bus to block a moving traffic lane.

Bus-Shelter Capacity

Bus shelters are an amenity commonly provided at new park-and-ride facilities. Probability theory[6] is used to determine the required size of these facilities.

It is assumed that the shelter will be designed to accommodate the demand that occurs during the peak 15 minutes of the morning peak hour; it is further assumed that average arrivals during that 15-minute period will be 15 percent greater than the average peak-hour arrival rate.

For design purposes, at least 4 square feet (0.37 sq m) of shelter area should be provided per person (3); this should be viewed as a minimum value in that other sources suggest that as much as 8 square feet (0.74 sq m) should be provided per person (4). These space guidelines are for the waiting area only. Space devoted to vending machines, fare collection, restrooms, etc., must be in addition to the required waiting area.

Based on the probability analysis, Figures 4 and 5 provide a means of determining the shelter size needed to accommodate the peak 15-minute demand. These curves consider neither the possibility of bus breakdowns nor unusually high demands that may result during periods of inclement weather. During such instances, shelter capacity may be exceeded.

Example Problem

Given: Daily demand of 600 autos and 5-minute scheduled headways.

Therefore:

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[6]Probability relationships, as developed in Reference 12, are utilized. It is assumed that the arrival of patrons during the peak 15 minutes corresponds to a Poisson distribution. It is further assumed that buses will depart at their scheduled headway; virtually no variation in headways will exist.

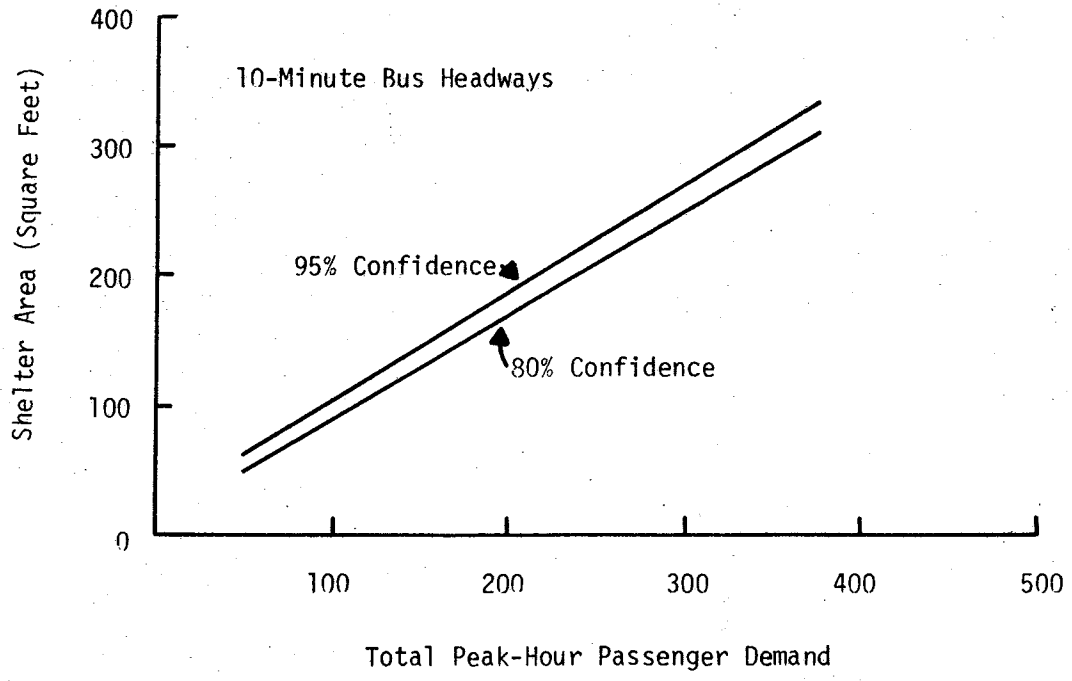


Figure 4: Shelter Waiting Area Required to Serve Peak 15-Minute Demand, 10-Minute Schedule Headways

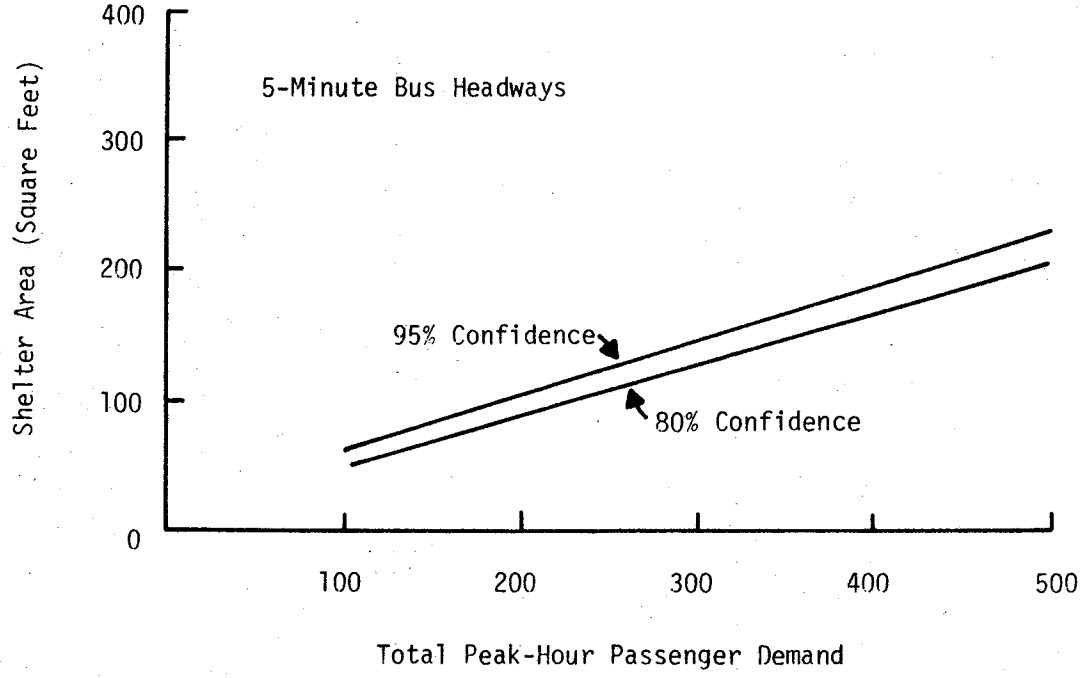


Figure 5: Shelter Waiting Area Required to Serve Peak 15-Minute Demand, 5-Minute Scheduled Headways

- 600 autos (1.4 persons/auto) = 840 persons
- 840 x 0.55 = 462 peak-hour persons
- From Figure 5, a shelter waiting area of 210 square feet (20 sq m) is required to be 95 percent confident that demand will not exceed capacity during the peak 15 minutes.

INTERNAL LOT DESIGN GUIDELINES

In many respects, the layout of a park-and-ride lot is similar to the layout of a regular parking lot. Guidelines (13,14) concerning regular parking lot design are readily available. In this section of the report, certain features that are unique to park-and-ride facilities are discussed. Considerations involving the location of the bus-loading area are reviewed. A brief overview of the different types of parking that need to be provided in the lot is presented. Pedestrian flow patterns are briefly addressed. A discussion of some of the amenities commonly provided at park-and-ride locations is included in the final part of this section. In providing these park-and-ride components, the need to develop safe, convenient circulation patterns should be recognized.

Location of the Bus-Loading Area

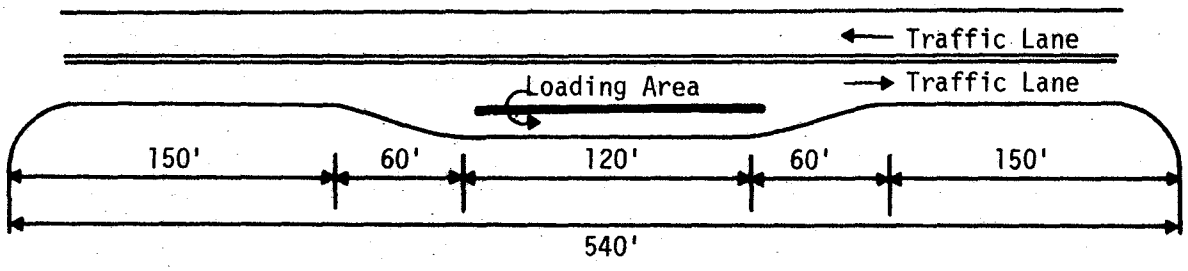
The bus-loading/unloading area represents the focal point of the park-and-ride facility. All parking areas are oriented toward this location and, as a consequence, an initial step in the design process involves establishing the location of the loading area. Two general alternatives exist; the loading area can either be located on the periphery of the lot or within the lot.

For the reasons listed below, the loading location adjacent to the parking area may be preferred. However, well designed park-and-ride lots can also function satisfactorily with bus-loading area located within the lot.

- The land requirements for the loading/unloading area are minimized.
- The conflict between autos and buses exiting and entering the lot may be eliminated.

- The time required for a loaded bus to enter the line-haul thoroughfare is generally reduced.

Locating the loading area adjacent to the lot does pose certain problems. The average walking distance from the parking spaces to the loading area is increased. Pedestrian flows along the sidewalk adjacent to the lot may be interrupted. Also, sufficient curb length must be available; nearly 550 feet (168 m) of curb space is needed to provide a bus-loading area with space for 2 parked buses (3). Figure 6 illustrates a configuration that could be used in developing a bus-loading area adjacent to the park-and-ride parking lot.



Note: 1 foot = 0.305 m

Note: The 150 foot (45.7 m) dimension is intended to avoid interference with driveways or intersections.

Figure 6: Typical Geometrics Associated with a Bus-Loading Area Adjacent to the Parking Lot

If the bus-loading area is located within the lot, several factors should be recognized. The closer the loading area is located to the center of the lot, the shorter the average walking distance will become. Bus circulation within the lot should be minimized both to conserve space and reduce bus travel time to the line-haul facility. At least one source (13) suggests that, after park-and-ride demand exceeds 500 all-day spaces, it is desirable to provide separate bus access roads to the loading/unloading area.

Location of Different Parking Functions

Several different types of parking--handicapped, kiss-and-ride and park-and-ride--will typically be included in the parking area. Desirably, the design should minimize the transfer time from these parking areas to the bus shelter. In terms of proximity to the bus shelter, handicapped parking should be immediately adjacent to the shelter; kiss-and-ride parking should be given the next priority in terms of proximity to the shelter; the park-and-ride all-day parking area will generally be the farthest removed from the bus-loading area.

Preferably, it should not be necessary for handicapped patrons to cross any internal-circulation roadways in traveling from their parking location to the bus-loading area. Ramped curbs should be provided in that walkway area. Recent research (15) in Texas suggests that approximately 2 percent of total parking spaces should be devoted to handicapped parking needs.

The bus-loading area should be highly visible from the kiss-and-ride parking locations. Desirably, the kiss-and-ride operation should be separated from the longer term park-and-ride area. Kiss-and-ride parking areas need to be signed, marked, and enforced to assure their use as short-duration parking areas only.

Park-and-ride all-day parking is generally designed to be right-angle parking; this provides a simple, orderly configuration and also requires less land area per space. The parking aisles are typically aligned normal to the bus shelter to facilitate convenient pedestrian movement. Parking spaces will typically be 9 feet (3 m) wide, have a depth of 19 feet (6 m), and an aisle width (width between spaces) of 26 feet (8 m). For park-and-ride lots, dividing the total area on which the lot is located by the total number of parking

spaces provided will typically yield an average area per parking space of between 400 and 450 square feet (37 to 42 sq m).

A representative example layout of a park-and-ride facility is shown in Figure 7.

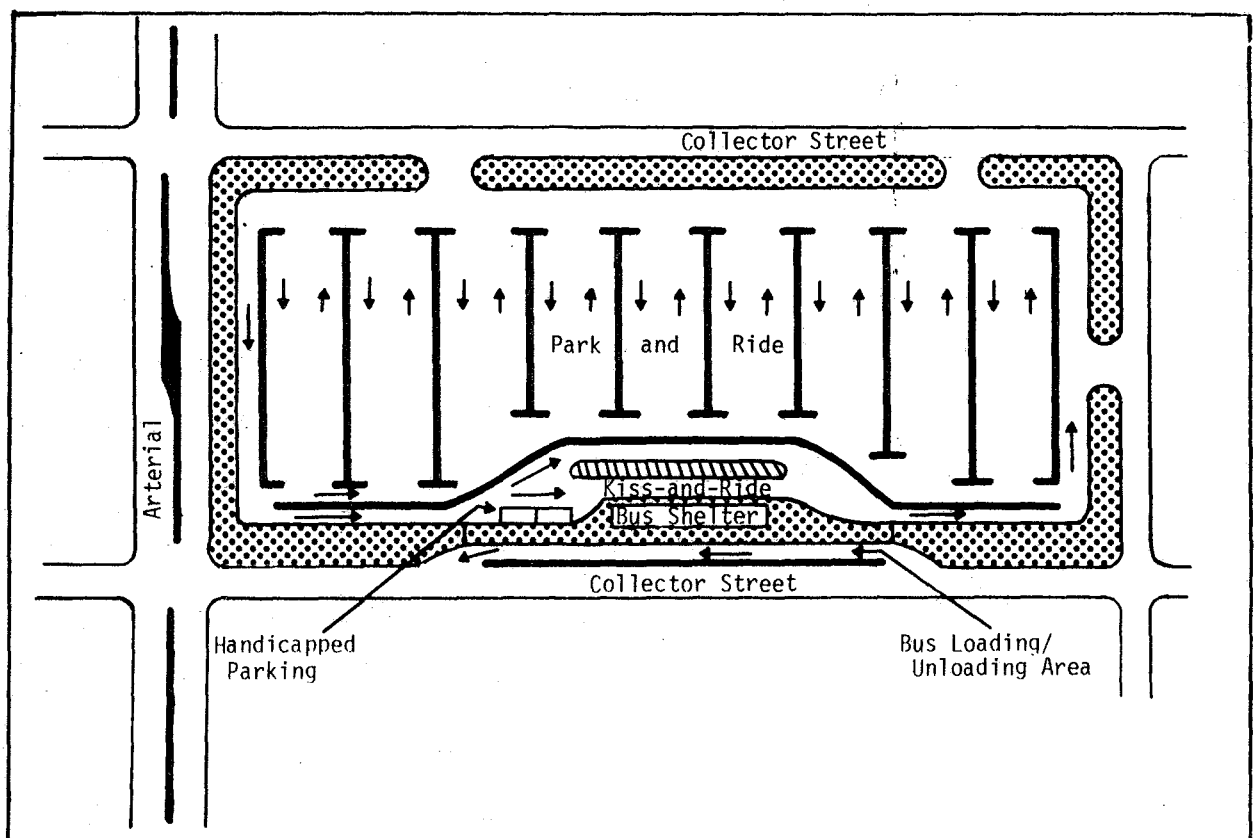


Figure 7: A Representative Layout for a Park-and-Ride Facility

Pedestrian Flow Patterns

As noted previously, the distance a patron has to walk from his car to the bus-loading area should, desirably, not exceed 400 feet (122 m). A walking distance of 800 feet (244 m) should be viewed as an absolute maximum.

The parking area should be laid out to facilitate pedestrian movement to and from the bus-loading area. Pedestrians will tend to follow the most direct route from the vehicle to the loading area.

To assist in laying out a park-and-ride lot, various sources (3,4) have developed what is referred to as a coefficient of directness. This coefficient is determined from the following formula.

$$C = \text{coefficient of directness} = \frac{\text{designated walking path distance}}{\text{straight-line distance}}$$

It is suggested that pedestrian flow patterns be designed so that this coefficient of directness does not exceed a value of 1.2; 1.4 should be considered a maximum value.

Amenities

In the design phase of a park-and-ride facility, there are a number of minor considerations that need to be evaluated although they do not necessarily directly influence the lot layout. These considerations, termed park-and-ride "amenities," are supplemental facilities or services which are provided either to improve the overall operation or to attract and sustain transit patronage. These considerations are, therefore, not essential elements of the park-and-ride design. Nevertheless, certain amenities may be important to various localities planning park-and-ride facilities. Amenities include features such as lighting, landscaping, and bus shelters. Particular facilities or services that benefit specific ridership subgroups, such as bicycle racks for bicyclists, restroom provisions, and ramps at curbs for the handicapped, may also be termed amenities.

It does not appear realistic to develop specific guidelines concerning which amenities should be provided at a park-and-ride lot. Indeed, differences of opinion exist on this topic. One contention (16) is that the level of service provided should be relatively constant throughout the park-and-ride operation; in effect, the attractiveness of using express, air-conditioned bus service

is greatly negated if the patron has to be exposed to inclement weather in waiting for the bus. Another opinion (17), based on a ridership survey, concluded that "convenience items such as bus shelters, minimal walking distances, security, and the availability of late evening bus services are not perceived as very important features." A third study (18) recently prepared for the Urban Mass Transportation Administration concluded that the success of the lot is highly dependent upon the lot being well-lit, guarded, having sheltered waiting areas, and having telephones.

For purposes of presentation, the amenities discussed in this section have been arbitrarily divided into two categories. The first category includes those amenities that generally relate to the parking area. The second category relates to those amenities associated with the bus-boarding area.

Since it does not appear realistic to establish guidelines concerning which amenities should be provided at all park-and-ride facilities, a survey of those amenities currently available at certain park-and-ride operations in Texas was undertaken. That survey information may be of use to designers of new facilities in determining which amenities to provide.

Parking-Area Amenities

Amenities provided at existing lots in Texas are shown in Table 9. Certain features, such as trailblazer signing, are common to most lots. Provision of of other amenities varies greatly.

As would be expected, the exclusive park-and-ride facilities provide more amenities. At those lots, pedestrian walkways, specially designated parking areas, and extensive landscaping are typically included in the design.

Shared-use lots are generally less capital intensive and, consequently, offer fewer amenities. Indeed, amenities, such as lighting, that are provided

Table 9: Amenities Provided at Park-and-Ride Lots in Texas

Park-and-Ride Location	Parking Lot Design Feature							
	Designated Kiss-and-Ride Parking Area	Designated Parking for Handicapped	Security Attendant	Lighted Parking/ Transfer Areas	Sidewalks to Loading Areas	Designated Pedestrian Walkways in Lot	Trailblazers on Adjacent Streets	Exclusive Bus Access-way
New, Exclusive Park-and-Ride Lots								
Garland South	X	X		X			X	
Garland North	X	X	X	X	X	X	X	X
San Antonio Wonderland	X			X	X	X	X	X
Shared-Use Park-and-Ride Lots								
Dallas Oak Cliff (Redbird)	X		X	X			X	
Dallas North Central	X		X	X			X	
Dallas Pleasant Grove			X				X	
Austin Fox Theater				X			X	
Austin Woolco/Westgate				X			X	
Houston Sage (Gulf Fwy)			X	X			X	
Houston Sage (Meyerland)			X	X			X	
Houston Sharpstown			X				X	

frequently existed in the parking area before the park-and-ride service was implemented.

It might be noted that many of the park-and-ride lots provide some form of security. Provision of security personnel is believed to reduce vandalism and increase confidence in the service. Security personnel may also function in other roles such as information attendants or parking fee collectors.

Bus Boarding-Area Amenities

Bus boarding-area amenities provided at existing park-and-ride lots in Texas are shown in Table 10. As would again be expected, more amenities are provided at the exclusive park-and-ride facilities. Many of the amenities at the shared-use lots are features that were available at the site before park-and-ride service was implemented.

Table 10: Bus Boarding-Area Amenities Provided at Park-and-Ride Lots in Texas

Park-and-Ride Location	Boarding-Area Amenity												
	Type of Shelter Provided			Services Provided									
	Bus Stop, No Enclosed Shelter	Semi-Enclosed Shelter	Enclosed Waiting Area	Seating	Information	Restrooms	Newspaper Vending	Beverage/Cigarette Vending	Water Fountain	Telephone	Heating	Air Conditioning	Trash Receptacles
New, Exclusive Park-and-Ride Lots													
Garland South		X		X			X			X			X
Garland North			X	X	X	X	X	X	X	X	X	X	X
San Antonio Wonderland		X		X			X	X		X	X		X
Shared-Use Park-and-Ride Lots													
Dallas Oak Cliff (Redbird)			X	X	X	X	X	X	X	X	X	X	
Dallas North Central			X	X	X	X	X		X	X	X	X	
Dallas Pleasant Grove		X		X	X								
Austin Fox Theater	X												
Austin Woolco/Westgate	X												
Houston Sage (Gulf Fwy)	X			X			X	X					X
Houston Sage (Meyerland)	X			X			X						X
Houston Sharpstown	X			X									X

CONCLUSIONS

In many respects, the design of a park-and-ride lot is similar to the design of a typical parking lot; considerations such as parking space width, depth, aisle width, etc., will not vary appreciably. However, certain considerations do arise in the layout of a park-and-ride lot that do not necessarily arise in designing a typical parking lot. This report is intended to address those design aspects that are somewhat unique to the park-and-ride lots.

The report has developed guidelines for locating a park-and-ride lot as well as for identifying the desirable range of sizes for these lots. Information pertaining to access/egress needs, kiss-and-ride space requirements, bus-loading space needs, and bus-shelter requirements has been developed. Certain guidelines for the layout of various internal lot features (location of bus-loading area, location of handicapped/kiss-and-ride/park-and-ride parking area, pedestrian flow patterns, and parking-lot amenities) also have been set forth.

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