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EFFICIENCY IN BUS STOP LOCATION AND DESIGN

by

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(The opinions, findings, and conclusions expressed in this report are those of the authors and not necessarily those of the sponsoring agencies.)

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ABSTRACT

The research reported here identified those elements associated with the location and design of bus stops that affect the efficiency of transit and traffic operations, and developed guidelines to assist transportation engineers and planners in technical and policy decisions concerning bus stops in urban areas. Two nationwide questionnaire surveys, one for city transportation officials and the other for bus transit operators, were conducted to establish a systematic definition of the operational dimensions of a bus stop which could be shown to influence the performance of the traffic and bus transportation systems. Criteria for evaluating the performance of bus stops were then derived and applied in practical situations in Arlington County, Virginia. It was found that the criteria used to determine the location and design of bus stops should be in the form of guidelines, not numerical warrants. In locating stops each should be treated individually. Finally it was found that right-turn-on-red and on-street parking conflict with bus stop operations.

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SUMMARY OF FINDINGS

This study examined selected strategies for improving the efficiency of locating and designing bus stops. The research comprised a review of the literature, two questionnaire surveys, and six case studies.

With regard to locating bus stops, the principal findings are listed below. The strategy used in spacing bus stops varies significantly from city to city.

- One-quarter mile is the acceptable maximum walking distance in both the CBD and outlying areas.

- Transfer points should be located at four corners of intersections and should be provided with bus shelters and benches.

- The factors which influence the selection of bus stop locations are listed, in order of priority, as follows:

  1. safety of passenger, bus, and other traffic;

  2. effect on transit operation;

  3. effect on traffic; and

  4. impact on adjacent land use and development.

The major findings relating to the elements considered in the design of bus stops are as follows:

- A minimum length for bus loading curb zones is necessary.

- Bus bays are most effective in cases where the adjacent roadway experiences moderate traffic volumes

- When a bus bay is employed, a preemption signal to permit the bus to immediately reenter the traffic stream is desirable.

- The number of bus riders boarding at or departing from a bus stop is the criterion employed to justify the construction of a shelter.

- The ridership and length of wait at a bus stop should be used in determining whether or not a bench should be provided.

Finally, it was found that the transportation system management actions of right turn on red and on-street parking conflict with bus-stop strategies.

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PURPOSE AND SCOPE

Numerous improvements to existing urban bus transit systems are being implemented to increase their speed and efficiency, including modifications in bus routes and schedules, express bus service, the preemption of traffic signals for buses, bus terminals, and simplified fare collection.[1] However, solutions to the traditional problems associated with the location of bus stops within the city block and along the bus route, as well as with the attractiveness of bus transit service related to the design of bus stops, are still being sought on an ad hoc basis. This is true because no general guidelines for locating and designing bus stops have been adopted by the transportation professions.

Accordingly, the study reported here was undertaken in an attempt to examine how parameters used in locating and designing bus stops influence the efficiency of the operation of urban bus and traffic systems and to recommend practices that will ensure the effective development and use of bus stops along transit routes. The specific objectives were to —

A. identify elements relating to the location and design of bus stops that should be integrated into a comprehensive planning strategy;

B. establish the interrelationships among the elements identified in (A) above;

C. make recommendations concerning each element;

D. show a set of prototype bus stop designs for specified design requirements such as adjacent land use, volume of buses served, volume of pedestrians serviced, etc.; and

E. show the significance of the location and design of bus stops to other actions in Transportation Systems Management (TSM) planning.

METHODOLOGY

To establish a systematic definition of the operational dimensions of a bus stop that influence the performance of traffic and bus transportation systems, a review of the literature and two nationwide questionnaire surveys were conducted. Moreover, case studies were conducted to substantiate the subjective responses to the questionnaires.

Literature Review

A file search of current literature available was made through the facilities of the Highway Research Information Service. Although the literature on the subject was limited, it provided sufficient information for designing the questionnaires.

Questionnaire Survey

Various strategies for locating and designing bus stops have been used in a number of cities to improve the efficiency of bus transit and diminish its interference with normal traffic flow, but a comprehensive survey of existing and planned applications of guidelines for the location and design of bus stops in the United States is not available. To examine the state of the art, two questionnaires were designed to gain relevant opinions of city transportation officials and transit operators. The specific purpose of the questionnaires was to obtain information that could be used to describe current practices, to identify criteria that are appropriate for evaluating the utility of bus stops, and to outline strategies for improving their utility.

Survey of Transportation Engineers

The survey questionnaire, was distributed to transportation engineers in 324 selected cities in the United States and Canada. A total of 117 questionnaires were returned, yielding a response rate of 36.2%. Appendix A lists the cities responding and Appendix B summarizes the survey results.

The distribution and return of the questionnaires by population of the cities is given in Table 1. This distribution indicates that each population category was proportionally represented by the responses (chi-square = 1.12 on 3 degrees of freedom, "p" value = 0.225).

Table 1

Survey of Transportation Engineers - Response by Size of City

City Population 1970 Census	Number Mailed	Number Returned	Response Rate, %
50,000 or less	54	20	37.0
50,001 to 100,000	78	32	41.0
100,001 to 200,000	102	38	37.2
200,001 or more	90	27	30.0
Totals	324	117	36.2

Survey of Bus Transit Firms

The survey questionnaire was sent to 176 bus transit firms in cities across the nation. Of the firms surveyed, 60% operated between 10 and 90 buses and 40% operated 91 or more buses. These firms were selected on the basis of peak-vehicle requirements as identified in A Directory of Regularly Scheduled, Fixed Route, Local Public Transportation Service in U. S. Urbanized Areas.(2)

A total of 67 questionnaires were returned by bus transit firms in 33 states, the District of Columbia, and Puerto Rico, for a response rate of 38.1%. The distribution and return of the questionnaires by peak-vehicle requirements of the cities is given in Table 2 and the survey results are summarized in Appendix C. The distribution in Table 2 shows that each category of firms by peak-vehicle requirements was proportionally represented by the responses (chi-square = 5.38 on 3 degrees of freedom, "p" value = 0.855); however, more firms with 91 or more buses returned the questionnaire than did smaller firms.

Table 2

Survey of Bus Transit Firms - Response by Vehicle Requirements

Peak-Vehicle Requirements 1976	Number Mailed	Number Returned	Response Rate, %
30 or less	36	7	19.4
31 to 60	39	12	30.8
61 to 90	29	11	37.9
91 or more	72	37	51.4
Totals	176	67	38.1

Case Studies

After the questionnaire data were reviewed, case studies were conducted to examine the operational and safety characteristics at seven urban bus stops in Arlington County, Virginia. These stops were selected by the Arlington County transportation planner to represent typical problems relating to bus and traffic turning movements, passenger and pedestrian activities, geometrical features, land use, and environmental characteristics.

To provide a comprehensive summary of the features of the bus stops, a form was prepared and is shown in Appendix D. This form was used to record observations at the selected bus stops and adjacent intersections.

REPORT FORMAT

The following discussion integrates the survey results with observations documented in the publications that were reviewed. An overview of the data is first presented to identify the status of bus stop strategies in general; then, the individual parameters relative to bus stop location and design are identified. Finally, case studies are presented to show how the individual location and design measures interact.

STATUS OF BUS-STOP STRATIEGIES: AN OVERVIEW

To gain an understnading of the appropriate role of bus stops in urbanized areas, the status of bus-stop strategies was examined through the questionnaire surveys. Of the 117 transportation engineers who responded to the survey, only 14% indicated that a standard policy for locating or designing bus stops had been used (item 1, Appendix B); while 27 bus transit operators (40%) reported that they had adopted a set of criteria for locating or designing bus stops (item 4, Appendix C), and many of them (70%) indicated that the criteria were merely derived from "A Recommended Practice for Proper Location of Bus Stops".(3) These responses show bus-stop strategies are not given consideration commensurate with their importance.

TSM Strategies

The use or nonuse of bus-stop strategies is interpreted as an indicator of the role assigned to bus stops as a TSM strategy. A proper bus stop location and design can yield beneficial effects, such as those listed in Table 3.(4) Although more than 70% of the transportation engineers reported that they had not considered bus-stop strategies in the areas' TSM plans, all respondents indicated that one or more TSM tactics had been used in the bus-stop decision process. For example, some small cities had prohibited curb parking in bus-stop zones to ensure the safety of bus operations.

As given in Table 4, the results of the survey showed that both transportation engineers and bus transit firms agreed that the primary TSM objective was to improve safety. However, bus transit firms felt that two other TSM objectives, to provide easy access to all major trip generators and to increase transit patronage, would be almost of the same importance as safety, while the transportation engineers thought that the next objectives in importance were to provide easy access to all major trip generators and to minimize interference with the traffic stream.

The implementation of TSM objectives should satisfy the various needs of different groups of people. Both the transportation engineers (item 4, Appendix B) and transit operators (item 7, Appendix C) who responded to the surveys agreed that the TSM objectives were influenced primarily by two interest groups; namely, bus riders and transit companies. However, as shown in Table 4, the transportation engineers felt that drivers in moving traffic would be the next interest group while transit operators felt it would be bus drivers.

Table 3

TSM Objectives Associated with Bus-Stop Location and Design Decisions

Decision	TSM Objective
Quality of Bus Transit Service	Reduce transit travel time Provide adequate service to the transportation-disadvantaged and transit-dependent Provide easy access to all major trip generators Improve bus rider convenience and comfort Improve safety Improve security
Efficiency of Existing Bus Transit System	Increase transit patronage Minimize interference with the traffic stream Minimize time for reentry into the traffic stream
Environmental Impact	Avoid blocking entry to adjacent business Ensure compatibility with adjacent development Reduce transportation system energy consumption Reduce interference with pedestrian flow
System Costs	Reduce transit travel costs Minimize implementation costs

Source: Reference 4

Table 4

TSM Objectives vs. Interest Groups for Transportation Engineers and Bus Transit Firms

TSM Objectives \ Interest Groups	Transportation Engineers: bus rider	bus driver	local business	transit company	pedestrians	moving traffic	other	Totals	Bus Transit Firms: bus rider	bus driver	local business	transit company	pedestrians	moving traffic	other	Totals
To reduce transit travel time	24	8	14	24	12	18	1	101	29	20	9	24	8	12	6	108
To reduce travel costs	12	4	7	12	6	10	2	53	17	9	6	15	4	9	3	63
To improve safety	52	23	30	52	30	38	6	231	55	33	18	43	18	30	10	207
To improve security	10	4	4	9	4	6	2	39	16	11	5	11	9	10	0	62
To increase transit patronage	47	17	16	42	14	19	5	160	54	31	19	44	17	26	9	200
To reduce transportation system energy consumption	8	3	3	9	4	7	1	35	16	10	3	20	4	12	0	65
To provide adequate service to the transportation-disadvantaged and transit-dependent	30	14	14	32	16	17	1	124	40	22	17	32	15	23	7	156
To provide easy access to all major trip generators	46	21	22	48	20	25	4	186	54	34	19	43	17	28	10	205
To minimize interference with the traffic stream	35	12	29	42	26	35	4	183	39	22	12	27	15	23	7	145
To minimize time for reentry into the traffic stream	19	7	13	20	15	20	3	97	32	20	10	25	15	21	6	129
To reduce interference with pedestrian flows	18	3	14	17	17	15	3	87	22	13	7	18	14	19	2	95
To avoid blocking entry to adjacent business	12	5	9	17	10	10	3	66	26	18	11	19	12	16	2	104
To ensure compatibility with adjacent development	17	3	10	16	9	11	3	69	22	14	6	18	11	15	3	89
Totals	330	124	185	340	183	231	38	1431	422	257	142	339	159	244	65	1628

1999

2000

Effects of Ordinances

To gain insight into how local ordinances affected decisions on bus-stop strategies, associated experiences and opinions were examined through the questionnaires (item 6 of Appendix B and item 9 of Appendix C). A total of 73% of the transportation officials reported that they did not feel that there were any local ordinances or state laws which affected bus stop strategies in their localities. However, more than half of the transit operators felt that they had to comply with all traffic laws unless specific exceptions had been given. Both groups agreed that the bus stop location and design had to be approved by the governing public works agency or traffic engineering department. In fact, some city codes delegated the authority for bus-stop installation to transportation officials.

CONSIDERATIONS IN BUS-STOP LOCATION

Criteria for locating bus stops along transit routes are derived from line and block and point considerations. These are discussed in the succeeding subsections.

Line Considerations

Three variables reflect the characteristics of bus-stop locations along bus routes: bus-stop spacing, bus-stop market area, and transfer points.

Bus-Stop Spacing

To improve bus service levels along a route transit operators can increase bus speed by restricting the number of stops. However, this strategy sometimes causes total revenue to decline.[5] Obviously, closely spaced bus stops provide short walking distances to public transit, but they tend to increase the jerkiness of the ride and bus travel times, and thus reduce total system capacity. Therefore, a standard for prescribing the minimum and or maximum distances between bus stops appears to be warranted. The purpose is to maximize safety, comfort, speed and capacity and at the same time to minimize the walking effort required to access the bus. Of the 67 bus transit operators responding to the survey, more than half (52%) reported that they specified the minimum and maximum distances between bus stops (item 11, Appendix C). In addition, two-thirds of the 25 bus transit firms with annual bus ridership in 1978 of 16 million or more indicated that the standards for the spacing of transit stops were helpful in providing guidelines to establish bus stops and zones.

As a rule of thumb, bus-stop spacing ranges from one stop per block where city blocks are 500 or more feet in length to stops in alternate blocks where blocks are shorter.(3) However, it is noted that in practice bus-stop spacing varies significantly from city to city. From examining the large transit systems in urbanized areas, it can be seen that they use different criteria for establishing distances between bus stops. For example, as given in Table 5, the spacing in commercial and business areas could be as long as 1,320 feet in Los Angeles, California, and as short as 440 feet in Richmond, Virginia. Nevertheless, all transit operators responding to the survey agreed that the spacing standards must be applied in a manner to locate bus stops at major generators such as schools, hospitals, employment centers, and densely populated neighborhoods.

Bus-Stop Market Area

An area within walking distance of the transit stop is considered to be a bus-stop market area. This market area, as identified by the transit operators, ranges from 160 feet (49m) to 2,640 feet (805m) in central business district (CBD) areas and from 320 feet (98m) to a mile in outlying transit areas (item 12, Appendix E). However, over 31% of the transit firms reported that they considered 1,320 feet (402m) as an acceptable walking distance in both CBD and outlying areas.

Theoretically, a bus-stop market area is half of the bus-stop spacing, provided a bus route along a straight road is used with bus stops spaced equal distances apart.(6) It seems that bus-stop spacing and the market area represent duplicated standards. However, the bus-stop market area provides a guideline by which transit operators can determine the distances between bus stops. As indicated by one-third of the transit operators who responded to the survey, the transit patrons desired to walk no more than one-quarter mile from their origins to a transit stop. This point, as shown in Table 5, had been used by the 25 large transit systems to establish the maximum distance between bus stops in commercial and rural areas.

Table 5

Bus-Stop Spacings of Selected Transit Systems in Large Urbanized Areas

Transit Systems & Serving Areas	Bus-Stop Spacing (S; in feet)	Description
WMATA Washington, D.C.	S = 880	More closely spaced in densely populated areas; less closely in rural areas
SCRTD Los Angeles, California	1 block $< S <$ 1320	Depends on population density and transit dependency
	1320 $< S <$ 2640	In rural or lightly developed areas
GRTC Richmond, Virginia	449 $< S$	In commercial and business areas
	600 $< S$	In residential areas
(all transits) Milwaukee, Wisconsin	600 $< S <$ 1250	660 feet standard spacing where practical

S = Spacing between stops

2002

Transfer Points

A basic assumption in public transit planning is that the transit system should provide direct service and through routing of buses between major traffic generators, and thus accommodate a majority of transit travel demands in a manner such that transferring will not be necessary.(6) However, a small number of transit passengers will always be required to transfer between routes. The bus stops serving as the connections of bus routes are transfer points. More than half (59%) of the transportation engineers (item 11, Appendix B) and 69% of the transit firms (item 10, Appendix C) felt that these transfer points between bus routes should be given special consideration regarding location.

To provide an easy, convenient and safe transfer, the transfer points should be located at major street intersections.(7,8) At the junction of two bus lines proceeding in the same direction, there should be a common bus stop to avoid the confusion of two loading points for the same direction of travel, or, if there is any transferring, to eilminate the transferree's walking effort. In fact, over 91% of the transit operators did use the same bus stops when bus routes overlapped on arterial streets (item 13, Appendix C).

Block and Point Considerations

Commonly, bus stops are served at the sidewalk curbs and classified in one of the following categories.(9)

1. Nearside-curb bus stops located at the approach to the intersection.
2. Farside-curb bus stops located at the exit from the intersection.
3. Mid-block-curb bus stops located in the middle of a block.*

In selecting which of these three general types of bus-stop locations to install, consideration should be given to several factors identified by the transportation engineers and transit

*If a crosswalk is provided in the middle of the block, the mid-block bus stop can be installed at the farside or nearside of the crosswalk and is referred to as a "farsided-mid-block"-or "nearsided-mid-block"-bus stop.

2009

operators responding to the surveys (item 2, Appendix B and item 6, Appendix C). Those given highest priority are the —

1. safety of passenger, bus, and other traffic;
2. effect on transit operation;
3. effect on traffic; and
4. impact on adjacent land use and development.

Safety

To consider the safety factor, four groups of movements — those of the passenger, bus, traffic, and pedestrian—were used to examine each of the seven bus-stop locations examined in the case studies. These movements are discussed below.

Passenger Movements

Passengers leaving a bus have a tendency to immediately walk across the street through the crosswalk. This practice poses hazards to the passengers if the bus stands at the nearside of the crosswalk, because motorists approaching from the rear of the bus cannot see the passengers crossing in front of it. Further, when the bus finishes discharging passengers and attempts to leave the stop, the crossing passengers constitute an unnecessary interference. At the farside of the crosswalk, however, these situations are not present.

Bus Movements

At farside stops, more access space is available for the bus to pull out of the through-travel lane into the curb lane and thus the potential for side-swiping parked vehicles is reduced.(10) To prevent the rear of a stopped bus from obstructing the traffic lane, the bus should be parked parallel to the curb and as close as possible to it. In terms of bus-operating characteristics, the farside stop has definite advantages in providing buses with maneuvering space.(10)

Traffic Movements

Because of the visual obstruction created by the standing bus, motorists may find sight conditions at nearside stops unfavorable. This is an important safety problem at the intersection, because the bus standing at the nearside stop sometimes blocks the motorists' view of traffic signals. Also, nearside stops pose hazards for other vehicles when a bus is loading or unloading passengers, because the following vehicles often attempt to bypass the standing bus and thus interfere with other traffic and the bus as it leaves the stop.(11) These stops also create a hazardous condition for vehicles making right turns in front of the bus standing at the stop.

Pedestrian Movements

A farside stop has a definite safety advantage because the stopped bus does not block a pedestrian's view of traffic approaching from behind the bus, and pedestrians do not conflict with the movement of the bus as it leaves the stop. A survey[12] was made in which data were collected on over 2,100 pedestrian accidents occurring over a 10-month period in 13 major cities in the country, and it was found that bus-stop-related pedestrian accidents were 3% of the total pedestrian accidents. Also, the survey indicated that one city involved had no bus-stop-related pedestrian accidents, and upon investigation it was determined that over 90% of its bus stops had been relocated to the farside. Accordingly, the report on the survey strongly recommended that bus stops be located at the farside of the intersection or at the farside of a mid-block pedestrian crosswalk to minimize visual interference.

Effect on Transit Operation

As identified by the transportation engineers and transit firms responding to the surveys, awkward bus movement on the arterial streets was one of the most important factors affecting transit system efficiency. The criteria selected to examine a bus-stop location included the bus driver's characteristics, bus turning movements, and bus travel delays.

Bus Driver's Characteristics

Both transportation engineers and transit operators, as shown in Table 4, did not feel that bus drivers were the important group influencing the location of bus stops; however, the characteristics and tendencies of the bus driver should be taken into consideration. At nearside stops drivers' attention is not diverted by cross traffic and turning vehicles when pulling into the stop, and while at the stop they have a direct view of three directions from which passengers may come. Furthermore, in comparison with the nearside stop, the farside stop tends to encourage the bus driver to maintain a greater approach speed

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near the intersection and to more frequently violate traffic signals in reaching the farside stop.[10]

Bus Turning Movements

In terms of bus movements, the bus stop generally can be installed at any one of the three types of locations, i.e., nearside, farside or mid-block. When any of the following conditions exist, however, the location of the bus stop should be given special consideration.

A. Bus right-turn movement.

If there is heavy right-turning traffic, a nearside stop before the turn should not be used; a farside stop after the turn is preferable. If a farside stop is unacceptable, a mid-block stop before or after the turn should be used.[13]

B. Bus left-turn movement.

For left turns, a nearside stop immediately prior to a turn should never be used since the abrupt, sharp turn may jeopardize vehicles in the traffic lane. A farside stop, in this case, is strongly recommended. If this farside stop is unavailable, then a mid-block stop after the turn should be used.[14,15]

Bus Travel Delays

There are three types of bus travel delays — bus dwelling time, traffic signal delay, and the waiting time for the bus to pull out of or reenter the normal traffic stream. A consideration of dwelling time, which is considered as necessary service time, was beyond the scope of this study. The other two delays will be discussed with reference to bus-stop location on the basis of experience.

A. Traffic signal delays.

In terms of traffic signal delay, a nearside stop has a definite time-saving advantage because a portion of the delay is combined with the bus-passenger-service operation;[9] but if there is a high volume of right-turning vehicles or cross-street pedestrians which might cause interference to the bus standing at the nearside stop, then a farside stop might be advisable.[11,16,17]

B. Waiting time for the bus to pull out of or reenter the normal traffic stream.

Usually, the bus driver has less trouble in pulling out of the normal traffic stream than he does in reentering it. At a farside stop, when the traffic light turns red behind the bus, the driver can find a gap to reenter the traffic stream without interference;(13) however, at a nearside stop, unless there is no vehicle in the traffic lane, as the bus leaves the stop it always conflicts with vehicles on the traveling route.

Priority treatment for buses can be used to reduce or eliminate the bus travel delays cited above. For example, the signal preemption treatment can reduce the waiting time during the traffic signal; and the exclusive bus-curb lane, through restricting the non-bus traffic flow, can provide the bus with an easy reentry and pullout and eliminate bus-vehicle interference. Of the 117 transportation engineers who responded to the survey, only 29% indicated that priority treatment had been given to buses over other vehicles in the service areas (item 13, Appendix B). Furthermore, one of them reported that unless there were tremendous bus travel delays, he would not sacrifice normal traffic flow to benefit the bus. This indicates that although the objective of a transportation system is to move people and freight, and not only vehicles,(18) most transportation engineers still look at the overall traffic volumes and delays.

Effect on Traffic

When a bus stands at the curb for passenger service, it impedes the normal traffic stream and increases the traffic delays. In some urban areas where the right-turn-on-red (RTOR) policy is allowed, the problems of bus-vehicle conflict become more pronounced and sound engineering judgement becomes critical.

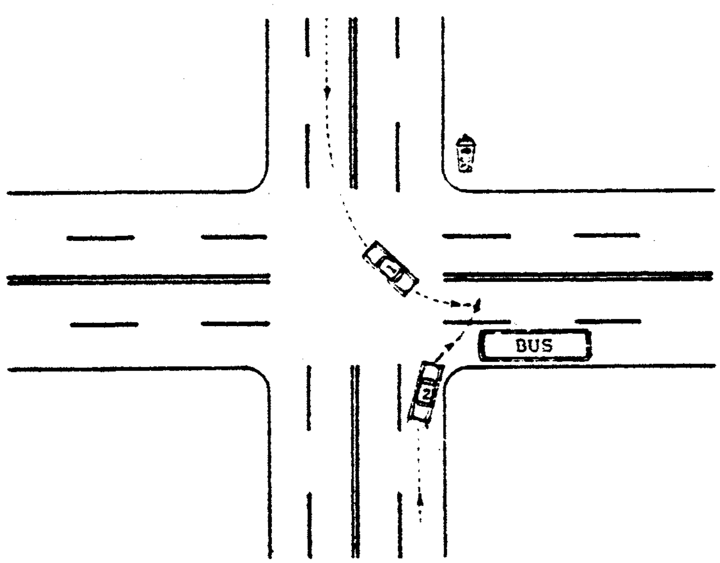
Bus-Vehicle Conflicts

Bus-vehicle and resulting vehicle-vehicle conflicts occurring when the bus stands at or leaves the stop cannot be eliminated unless bus-exclusive lanes are provided.

RTOR Movement

Over 92% of the transportation engineers reported that their cities permitted RTOR in the service areas (item 8, Appendix B), and only 15% of them felt that the RTOR policy had caused changes regarding bus-stop location (item 9). As a matter of fact, any installment of a bus stop within 200 feet of the intersection affects the RTOR movement.[9] Among those transportation officials who cited changes in bus-stop locations due to RTOR, 88% considered relocating the bus stop from the nearside to the far-side. Indeed, a farside stop has a definite advantage in keeping the bus from blocking the right-turning vehicles on the bus route. But, as discussed below, there are exceptions which cause reconsideration of nearside stops.

When a bus is standing at the farside stop and blocking the curb lane, RTOR vehicles from the cross street conflict with the left-turning vehicles from the opposite direction of the cross street. As shown in Figure 1, if the left-turning traffic is heavy, then a relocation to the nearside might be advisable.



The RTOR vehicle (No.2) conflicts with vehicle No. 1 making a left turn on a green signal, since the standing bus blocks the curb lane.

Figure 1. Opposing left-turn RTOR conflict.

When the percentage of right-turning vehicles approaching at the nearside stop is much less than that of the cross street vehicles approaching at the farside, a nearside stop might be better because the total delays of the RTOR vehicles might be smaller.

If either a farside or a nearside stop reduces the RTOR effects a great deal, then a mid-block stop should be used.

At any intersection where major bus routes cross and transferees are numerous RTOR should be prohibited.

RTOR policy and bus-exclusive curb lanes should not be implemented at the same intersection, regardless of the location of the bus stop.

Impacts on Adjacent Land Use and Development

For local development and public relations promotion, it is desirable to install bus stops at locations where they are compatible with commercial activities and parking needs, and where they cause least annoyance to adjacent property owners.

Commercial Activities

In congested CBD areas, it is advantageous to locate bus stops at the major establishments where the greatest amount of pedestrian traffic is generated so that the pedestrian crosswalk movements can be minimized.(3) Both transportation engineers and transit operators (item 3, Appendix B and item 6 Appendix C, respectively) responding to the surveys identified the proximity to passenger origins and destinations as the first-ranked factor considered in the bus-stop location process, and they also indicated that this factor would have quite often determined the proper location of the bus stop, whether it be located nearside, farside or at mid-block.

Automobile Parking

The lack of automobile parking space is a substantially serious problem in most urbanized areas. The installment of bus stops along any arterial street influences parking strategies significantly. In fact, 60% of the transportation engineers who responded to the survey indicated that parking needs would govern the establishment of a bus stop. In the interest of examining the effect, two factors were taken into consideration as noted below.

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A. Considerations of parking and intersection capacities

Due to bus maneuvering characteristics, the lengths of the bus loading zones at farside and nearside stops are much shorter than those at mid-block stops.* Therefore, the installment of bus stops at the intersection can provide better utilization of the curb to meet parking needs and, when the bus is not standing at the stop, the loading space can be used for additional capacity for right-turning vehicles so as to increase the capacity of the intersection.(8) However, if RTOR movements and the resulting capacity of of the intersection are reduced significantly due to the frequent bus service at the intersection, then mid-block stops can be used to reduce congestion.

B. Enforcement of parking regulations

The best engineered bus stop is of little use if parking regulations are not strictly enforced. Motorists are used to the standard parking regulations in effect on all sides of an intersection. Therefore, parking prohibitions ar nearside and farside stops can be enforced with comparatively little difficulty. The mid-block stops require a parking restriction at the loading areas where motorists are used to having parking privileges and this restriction is more difficult to enforce.(14)

Land Use

In terms of land use, the bus stop should be installed wherever there is a wide sidewalk and the stop will not block entrances of local businesses. If there is a broader road pavement on one side than on the other side at an intersection, the broader road pavement should be used for the bus stop so as to minimize traffic conflicts and enhance land use.(3)

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*The details of bus curb loading zones are addressed later under Elements of Bus Stop Design.

Summary

The bus stop location criteria identified above are summarized in Table 6. An "X" placed in Table 6 indicates which bus-stop-location choice best suits a specific criterion. However, the criteria only provide the guidelines and each stop location must be evaluated individually. In general, Table 6 shows that farside stops are preferable to nearside and mid-block stops.

Table 6

Criteria Used to Select Bus-Stop Location

	CHOICES			
			Mid-Block	
Criteria	Farside	Nearside	Farside	Nearside
Safety				
Passenger Movements	x		x	
Bus Movements	x		x	
Traffic Movements	x		x	
Pedestrian Movements	x		x	
Effect on Transit Operation				
Bus Driver's Characteristics		x		
Bus Turning Movements	x	x	x	x
Effect on Traffic				
Bus-Vehicle Conflicts	x			
RTOR Movement	x		x	x
Impacts on Adjacent Land Use and Development				
Commercial Activities	x	x	x	x
Land Use	x	x	x	x

ELEMENTS OF BUS-STOP DESIGN

A well-designed bus stop should provide passenger services with minimal interference to traffic and pedestrians and should assure the greatest comfort and safety of the passengers. This section identifies elements of bus-stop design that include bus-loading curbs, bus bays (turnouts), and bus shelters and benches.

Bus-Loading Curbs

According to the questionnaire response, more than 45% of the transportation engineers felt that curb length requirements for bus stops were necessary (item 14, Appendix B); while 78% of the transit operators indicated that the minimum desirable bus-loading curb lengths shown in Table 7 were required to provide a safe passenger service (item 14, Appendix C). Along with the minimum desirable curb length, there are two other important factors which ensure the safety and efficiency of bus-passenger operation; namely, the condition of the curb lane and the curb height, and the signs and markings in the loading zone.

Minimum Desirable Curb Lengths

In referring to minimum desirable lengths for bus curb loading zones, the <u>Highway Capacity Manual</u> notes different ranges of zones for various uses of buses.[9]

When the average bus volume in one direction exceeds 40 per hour,[11] the number of passengers to be loaded and the resulting time that each bus must spend in the bus curb loading zone increase, and it is necessary to provide a length for each bus expected to stop at any one time at any given bus stop. It is recommended that 45 feet (14m) of length be provided for each 40-foot bus (12m) and 5 feet (1.5m) between buses.[3] Considering bus maneuvering characteristics, the lengths for the curb loading zones should be adjusted to accommodate the turning radii.[3]

The survey responses of transit firms revealed that, in general, the adopted length requirements for curb loading followed the standards described in the <u>Highway Capacity Manual</u>, but that they were modified in some instances.

Some of the bus-transit firms reported that the curb-loading lengths were dependent upon on-street parking demands, and they could be as short as 60 feet (18m) for single-bus operations. For those cities with critical curb parking needs, an easy solution seems to be to provide room for only one bus and to restrict buses to a short length stop. But this solution is not recommended, because the provision of insufficient space for a second stopped bus will make it obstruct the through-travel lane, and also create hazardous and inconvenient loading and discharging conditions for the bus passengers. The provision of adequate loading-space is particularly important in light of recent federal requirements that new buses be equipped with wheelchair lifts or ramps. Proper operation of this equipment requires that the bus be parallel to the curb.(13)

It is recommended that at nearside stops an extra length be added for right-turning buses and vehicles.(9) For safety reasons, a nearside bus stop should allow adequate setback from a crosswalk to facilitate right-turn movements by buses and other vehicles and a clear sight path and walkway for pedestrians. Some transit operators indicated that this standard had been used at some intersections with heavy right-turning movements of buses and traffic and had proved successful through the years.

Condition of Curb Lane and the Curb Height

A good condition of the curb lane and an appropriate curb height are considered as to be essential to the efficient use of the curb lane. In various experiments, it was found that bus drivers avoided the poor pavement of the curb lane and stopped the buses away from the curb.(11) Boarding and alighting operations away from the curb were found more hazardous for riders than were curb operations, especially for the elderly and handicapped, and especially during inclement weather. The additional hazard would appear to result from the increased height from the ground to the first step of the bus and moving vehicles such as bicycles between the curb and the bus.(19)

An appropriate curb height for efficient passenger-service operation is from 6 to 9 inches (15cm to 23cm).(11) If curbs are too high, the bus will be prevented from moving close to it.

Signs and Markings

The primary functions of signs and markings on a bus-loading curb are to provide an easily identifiable location where passengers board and alight and to inform motorists of the restriction on parking.

Bus-Stop Sign

The placement of the bus-stop signs should be in line with traffic regulations and the signs should be visible to bus drivers as well as to bus riders. Wherever the same bus stop is used for bus routes that overlap on arterial streets, the bus-stop signs should indicate route designations for each line serving the stop.[20]

Curb Markings for Parking Restrictions

Curb bus zones should be posted with "No Parking — Bus Zone" signs in addition to solid yellow markings to identify parking restrictions. As recommended by the Manual on Uniform Traffic Control Devices (MUTCD), the two kinds of standard signs for parking regulations shown in Figure 2 are in general use by transit operators.[21]

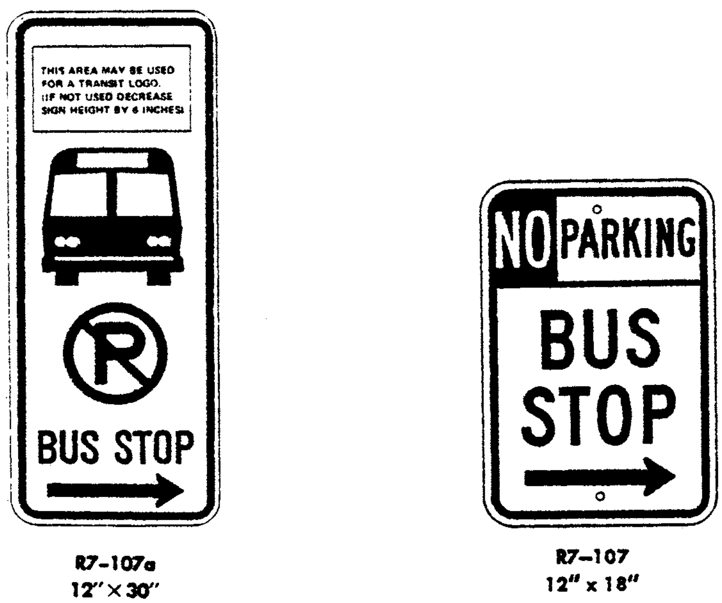


Figure 2. No-parking standard signs recommended by the MUTCD.

Further, some transit operators responded that they used solid red curb markings for parking regulations in bus loading zones. This marking is also noted as being acceptable in the MUTCD.[21]

Bus Bays or Turnouts

Primarily, the function of bus bays is to allow a stopped bus to stand completely out of the normal traffic stream and parking lanes while loading and unloading passengers. Wherever possible, these recessed bus bays should be used because the separation of buses and traffic enhances safety and improves bus-stop operations. A recent NCHRP investigation found, via simulation studies, that the use of bays has the most impact where moderate traffic volumes prevail.(22) This is because at low volumes the buses stopped in a moving lane can be easily bypassed, and at high volumes the traffic is so slow moving that the buses do not substantially impede the flow. The problems associated with bus bays concern strategy, effectiveness, and configuration.

Bus-Bay Strategy

The use of recessed bus bays was reported by 55% of the transportation engineers and 51% of the transit operators (item 15, Appendix B and item, 15 Appendix C). Those transit operators who did not use the bus bays said that with the bus bays the buses could not easily merge back into traffic. However, when asked about the preemption treatment given to the buses for easier reentry into traffic, only 2 transportation engineers out of 184 respondents reported that the actuated loop signals were used in conjunction with bus bays (item 17, Appendix B). These figures indicate that the bus-bay strategy is considered only a tool to get the buses out of the way of traffic flow, even though the result is delays to both buses and traffic when the buses reenter the flow. Whenever a bus bay is provided, special signing devices, which could possibly be simple flashers actuated by a presence detector at the exit of the bus bay, should also be provided to indicate to other traffic that it should yield to buses.(22)

Both transportation engineers and transit operators felt that an exclusive curb lane for buses was not an important factor in recommending a bus bay or turnout (item 16, Appendix B and item 16, Appendix C). Moreover, of the 16 transportation engineers who reported that bus exclusive curb lanes were in use, more than 37% indicated that bus bays were not used in conjunction with bus lanes (item 13 and 16 , Appendix B). Where both are not used bus travel-time savings through the use of bus exclusive curb lanes will be diminished by bus-bus conflicts when buses stand at stops for passenger operations.

Effectiveness of Bus Bays

Basically, bus bays apply wherever buses would potentially be forced to stop in the traffic lane. However, at some signalized intersections where right turns are heavy, nearside bus bays should generally be avoided, because the standing buses will increase delays and create conflicts to the right-turning vehicles. Furthermore, wherever bus bays are used, on-street parking should be prohibited to give buses enough room to pull out of the traffic lanes.

Configuration of Bus Bays

To be fully effective, bus bays should be as long and shallow as feasible;(23) they should be at least 10 feet (3m) wide to allow buses to stand completely out of the traffic stream; they should be long enough to accommodate a bus standing at the stop; and the transition distances, as shown in Figure 3, should be long enough to allow a bus to decelerate and accelerate at a comfortable rate. The design speed should be slightly greater than the non-peak hour approach speed, which is a function of the posted speed limit.(13)

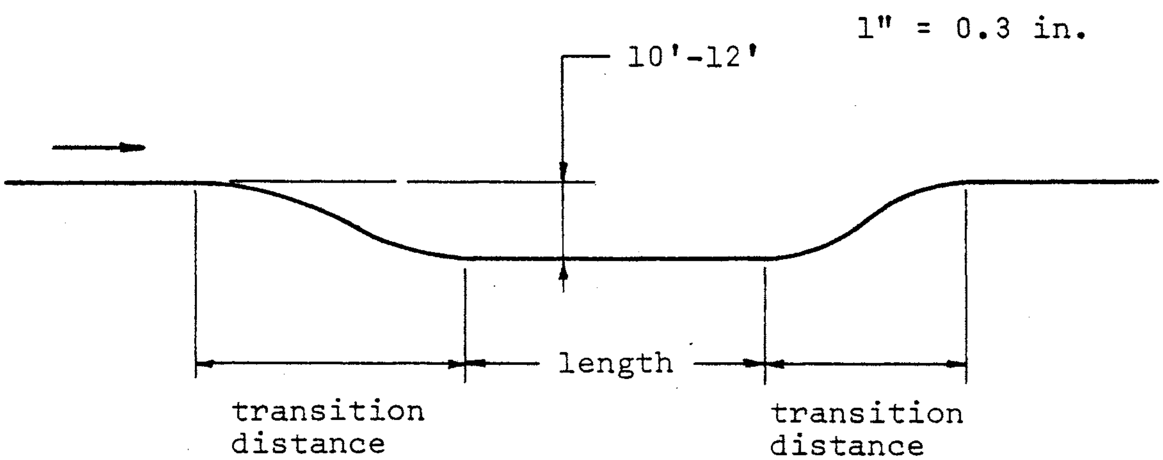


Figure 3. Configuration of bus bays.

Bus Stop Shelters

A bus stop shelter is considered to be a nonoperational bus improvement helpful in attracting people to bus use. In 1971, the Federal Highway Administration (FHWA) conducted a survey of transit operators to obtain information on their experiences with bus shelter programs and projects.(24) Of the 36 domestic transit operators replying, 61% said they provided some type of shelter. However, the 1979 survey conducted for this study revealed that of 67 transit operators, 84% used bus stop shelters to enhance the public image of the bus system (item 18, Appendix C). Among the problems associated with these shelters are those relating to applicability and design guidelines.

Applicability

As reported by the transit operators in the Research Council's survey, more than 77% indicated that the shelters were provided at fewer than 10% of the total bus stops and scattered throughout the systems (item 19, Appendix C). The criteria used for decisions about the installment of bus stop shelters, as identified by the respondents, are those of level of passenger demand, expected wait time, and elderly and handicapped patronage (item 20, Appendix C).

In the selection of the most effective and efficient sites for the bus shelters, locations with high passenger demands and low frequencies of bus service are given priority. Other factors, such as the percentage of elderly or handicapped passengers and the days of inclement weather, are also considered. In the selection process, priority should be given to locations at shopping malls, grocery stores, factories, etc., where people frequently carry packages onto the buses. Few shelters are needed at locations near buildings which could serve as temporary shelters.(25)

Design Guidelines

The primary functions of a bus stop shelter are to provide protection from the weather, offer basic passenger amenities, and enhance passenger safety.

Bus shelters should be highly visibile and meet the needs of the handicapped. Shelters located near hospitals, sanatoriums and residences for the aged should have facilities such as curb ramps and handrails.(24) Considering rider access, it is important for shelters to coordinate the entry and exit points with external pedestrian and vehicular traffic flows. At night, lighting facilities are necessary, especially in high crime areas where the passengers' safety may be in great jeopardy.[26]

Where the waiting time is relatively long and where there is a high percentage of elderly or handicapped boarders, it is important to provide seats or benches for the comfort of people waiting in the shelter. The FHWA survey in 1971 reported that only 50% of the 22 transit operators provided benches in bus shelters,[24] while the Research Council survey found that 81% of the respondents provided benches or seats at sheltered stops, and half of them stressed that benches should be provided as an integral part of shelters (items 21 and 22, Appendix C).

Summary

The major elements considered in the design of bus stops are as follows:

1. A minimum length for bus-loading curb zones is necessary, and parking restrictions within the bus zone should be enforced.

2. When a bus bay is employed, a preemption signal to permit the bus to immediately reenter the traffic stream is desirable. Bus bays should be implemented in traffic lanes that experience no direct volumes.

3. The number of bus riders, expected wait time, and percentage of elderly or handicapped patronage are the criteria employed in the decision to install a bus shelter or a bench.

CASE STUDIES

The objective of the case studies was to demonstrate how the evaluation criteria identified in the study applied and to provide alternatives for each of the study sites. For each site examined, a general description of the area and bus stop is given, specific problems associated with the stops are identified, and alternative solutions are examined.

The observations at the sites were made under normal conditions; i.e., roadways in the vicinity of the bus stops were not under repair or construction, buses were operating on a regular schedule, and traffic was as usual for normal weekdays. The six study sites were scattered throughout the southeast portion of Arlington County, Virginia. As shown in Figure 4, four of them (sites 1,2,3, and 5) were located at the intersections of major arterial streets and the other two (sites 4 and 6) were located on minor streets.

2019

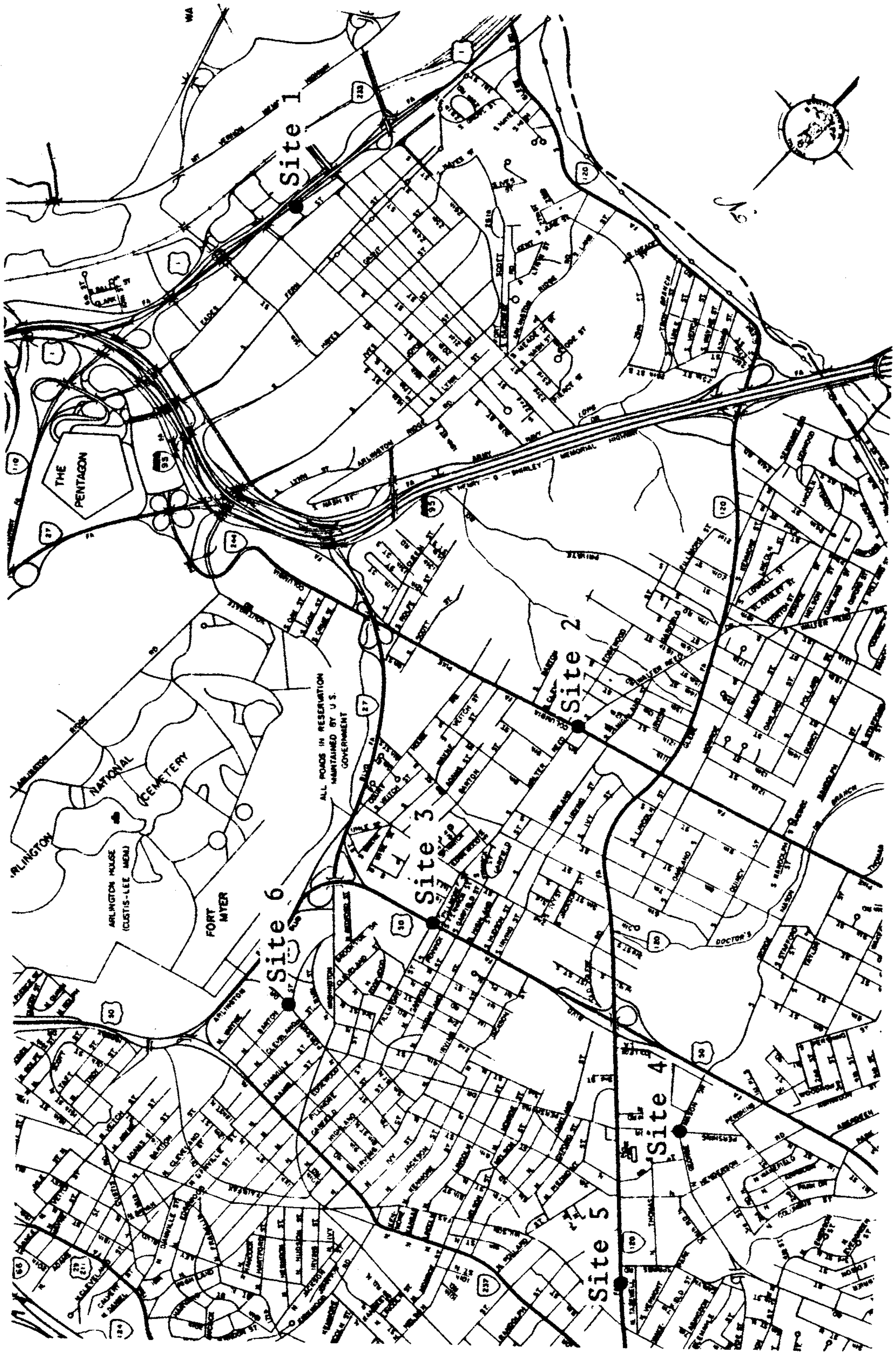
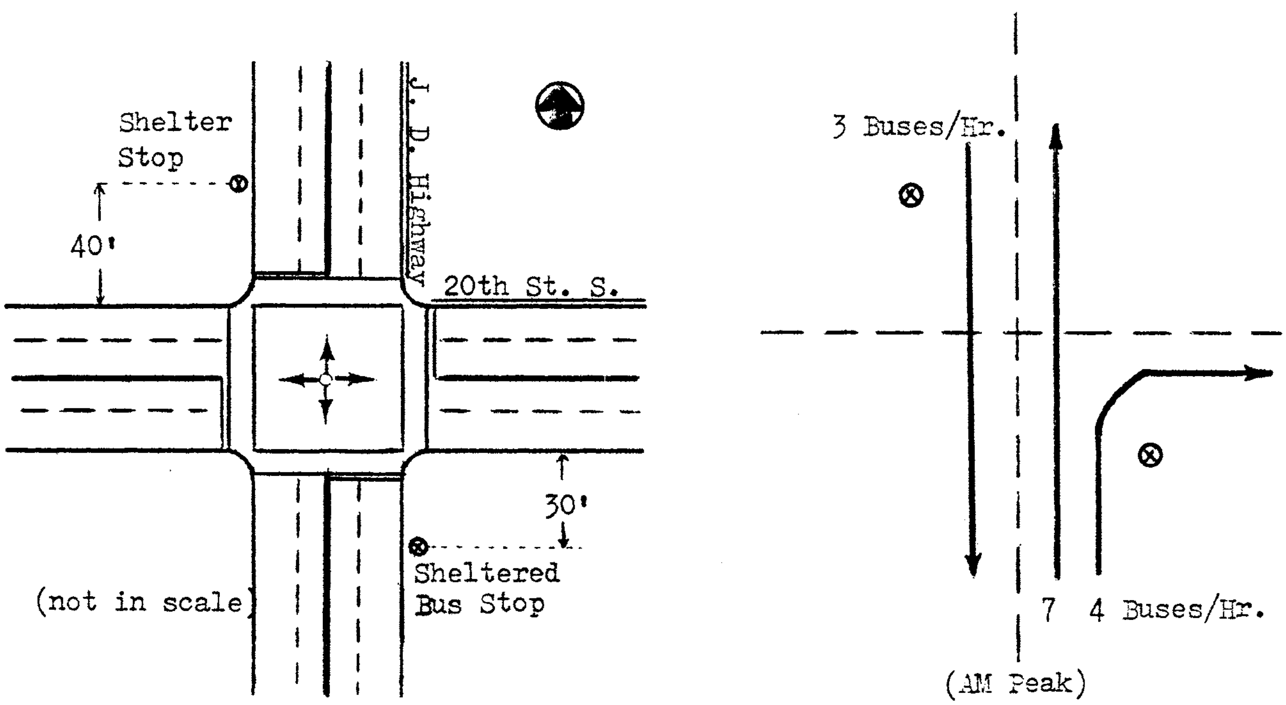


Figure 4. Location of six study sites in Arlington County, Virginia.

Site 1

Site Description

The first study examined two nearside bus stops on the Jefferson Davis Highway at its intersection with 20th Street South as shown in Figure 5. The major land use adjacent to the bus stops is commercial and residential development known as Crystal City. This area consists primarily of several high-rise apartment buildings, nine large hotels, a shopping mall, and a theater. Although no bus lane is provided in this area, the curb lane is wider than the left lane (approximately 14 to 10 feet [4-3m]) to benefit bus operations. RTOR is permitted while on-street parking is prohibited at the intersection. The traffic signal is a simple 2-phase one. Bus operations at the intersection include a high volume of pedestrian crossings and of through traffic on Jefferson Davis Highway. As scheduled, 36% of the bus arrivals from the south make a right turn and 64% of them go straight through the intersection after they leave the nearside stop, as shown in Figure 5.



Intersection Geometrics   Bus Movements and Volumes

Figure 5. Study site 1.

B. Bus Travel Delays

1. Buses conflict with the vehicles on the traveling route as they leave the stops.

2. Right-turning vehicles cause bus delays (left-turning vehicles from the opposite direction do also).

C. Traffic Delays

1. Standing buses diminish the RTOR effects.

2. Standing buses cause delays of the following vehicles.

3. Other vehicles are delayed when buses reenter the traffic stream.

Alternative Locations and Designs

For these nearside bus stops, there are several alternatives that can be used to reduce or eliminate the existing problems. Some of these alternatives may, however, introduce new problems. In order to examine the relative effectiveness of the alternatives, the problems associated with them must be identified. Table 7 shows the problems associated with five alternatives selected for consideration at this site. Based on the assumption that all criteria used to examine the problems are of equal weight, Alternative E is considered best. The result might be different if the severity of each of the cited problems is taken into consideration.

Existing Problems

The problems associated with these bus stops are those of safety, bus travel delays, and traffic delays, and are as described below.

A. Safety

1. Passengers (pedestrians) conflict with buses when they cross the street in front of the departing buses.

2. Standing buses block the motorists' view of crossing passengers and other pedestrians.

3. Right-turning vehicles interfere with departing buses.

4. Vehicles following the standing buses pose hazards to other vehicles in the left lane when they bypass the buses.

Table 7

Comparison of Alternatives — Site 1

Existing Problems	Original Bus Stops	Alternatives* A	B	C	D	E
Passenger conflict with leaving buses	x	x				
Standing buses block the motorists' view	x	x				
Right-turning vehicles interfere with departing buses	x	x				
Vehicle-vehicle conflicts occur with by passing buses	x		x		x	
Bus delays occur when waiting to reenter the traffic	x	x	x	x	x	x
Bus delays occur when vehicles turn right	x	x				
Standing buses diminish RTOR effects	x					
Standing buses cause delay of following vehicles	x		x		x	
Vehicle delays occur when buses reenter traffic stream	x	x	x	x	x	x
New Problems						
Increased traffic signal delays			x	x	x	x
Increased implementation costs				x		x

*Alternative A: Provide bus turnout at the original bus stops

Alternative B: Relocate bus stops to mid-block

Alternative C: Relocate bus stops to mid-block and provide bus turnouts

Alternative D: Relocate bus stops to farside

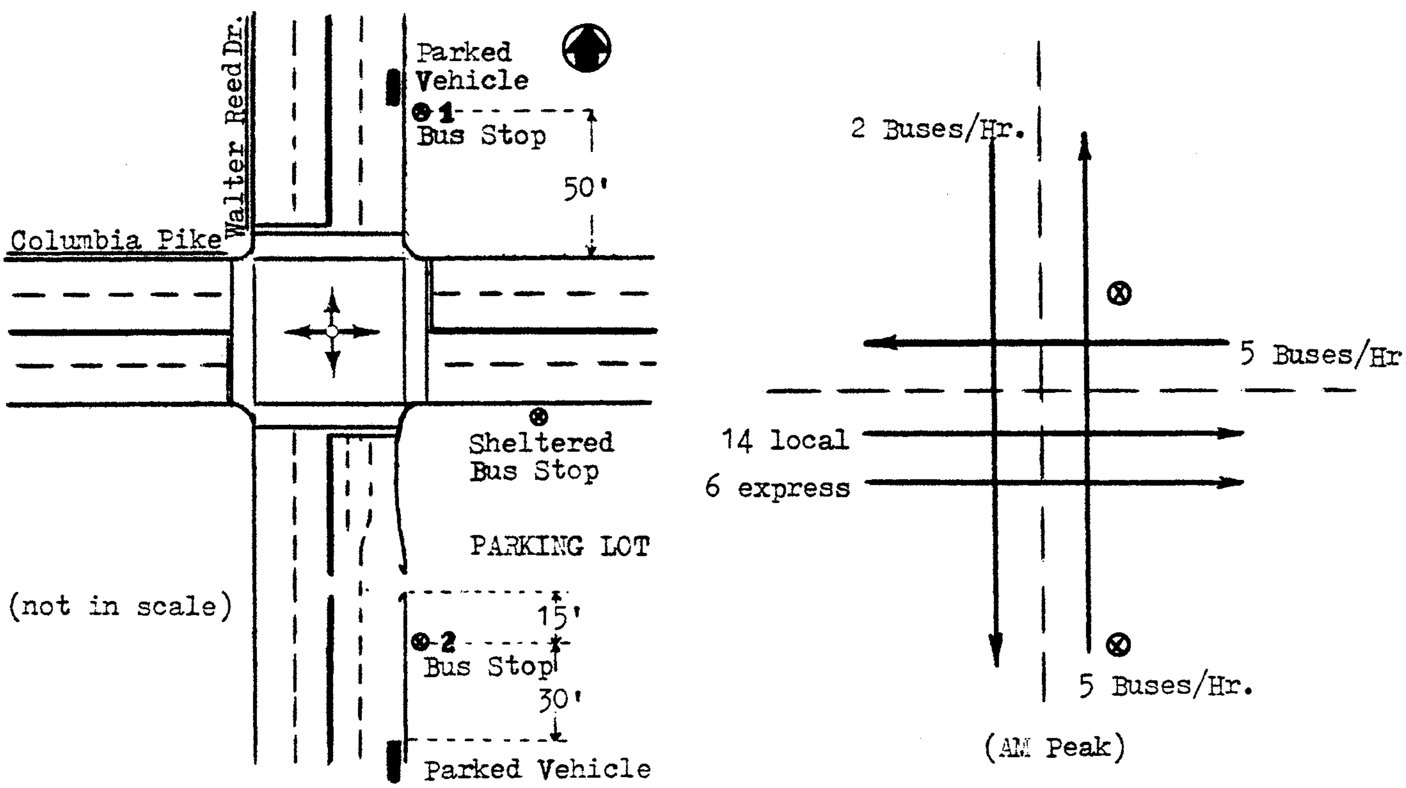
Alternative E: Relocate bus stops to farside and provide bus turnouts

2022

Site 2

Site Description

The second study examined two closely-spaced bus stops on Walter Reed Drive at its intersection with the Columbia Pike. One of these stops is located at the farside of the intersection and the other one at the nearside of a driveway near the intersection, as shown in Figure 6. The land use adjacent to the intersection is commercial, consisting of a cafeteria and some stores. Although a private parking lot is available for commercial needs, curb parking meters provide space for vehicles to park close to the bus stops. The roadway near the nearside stop is about 32 feet (10m) wide and is divided into two lanes: 20 feet (6m) for the curb lane and parking vehicles, and 12 feet (3.5m) for the left lane. As the road approaches the intersection, it is separated into three lanes of equal widths, and the left lane is for left-turning vehicles only. The traffic signal at this intersection is a 2-phase one with a split phase for left-turning vehicles; right-turning vehicles are permitted to turn only on green. Bus operations include a high volume of transfer activities between the intersecting routes, while the volume of through traffic on Walter Reed Drive is light to moderate. All buses serving these two stops go through the intersection with an average headway of 12 minutes during the morning peak periods, as shown in Figure 6.



Intersection Geometrics   Bus Movements and Volumes

Figure 6. Study site 2.

2024

Existing Problems

The problems at these two closely spaced stops are those of transfer accessibility, safety, bus operations, traffic delays, and bus curb-loading zone designs. In the listing below, the bus stop located at the farside of the intersection is referred to as Stop 1 and that at the nearside as Stop 2.

A. Transfer Accessibility

1. Most transferees depart from Stop 1 and cross Columbia Pike to gain access to the stop on the other side.

2. Access time for transferees from Stop 2 is relatively long.

B. Safety

1. Potential for buses to side-swipe parked vehicles when pulling into the curb of Stop 2.

2. Potential for buses to side-swipe parked vehicles when pulling away from the curb of Stop 1.

3. Standing buses block the motorists' view of vehicles coming out of the parking lot; also, they block the view of the motorists coming from behind.

4. Vehicles following the buses standing at Stop 2 pose hazards to other vehicles in the left lane when they bypass the buses.

5. Vehicles turning into or out of the parking lot interfere with buses leaving Stop 2.

C. Bus Operations

1. The bus driver's view is restricted when the bus stands right behind the parked vehicles at Stop 1.

2. Buses waiting to reenter the traffic stream are delayed.

3. Buses are delayed by vehicles turning into and out of the parking lot at Stop 2.

D. Traffic Delays

1. Buses fail to pull out of the traffic lane completely at Stop 2 and thus obstruct following vehicles.

2. In order to get into the traffic lane easily, buses stand away from the parked vehicles at Stop 1 and block the cross traffic.

3. Buses standing at Stop 1 make following vehicles queue up to the intersection and block cross traffic.

4. There are traffic delays when buses reenter the traffic stream.

E. Bus curb-loading zone designs

1. Bus curb-loading zones are inadequate.

2. Passengers waiting at Stop 1 block business entrances.

3. Passengers waiting at Stop 1 interfere with pedestrian movements.

4. Parked vehicles are too close to the loading curb.

Alternative Locations and Designs

As mentioned for site 1, the introduced alternatives cannot eliminate all the existing problems. An x placed in the appropriate box in Table 8 shows where a problem exists. Of the two alternatives in Table 8, alternative B, which relocates Stop 2 to the farside of the driveway and the nearside of the intersection and eliminates Stop 1, is recommended.

Table 8

Comparison of Alternatives — Site 2

Problems	Original Bus Stops	Alternatives* A	Alternatives* B
Existing Problems			
Transferees cross the street	x	x	
Transferee's access time is long	x	x	
Buses have potential of side-swiping parked vehicles	x		
Standing buses block motorists' view	x	x	
Vehicle-vehicle conflicts occur with by passing buses	x	x	x
Right-turning vehicles interfere with departing buses	x	x	
Bus driver's view is restricted	x		
Bus delays occur when waiting to reenter the traffic	x	x	x
Bus delays occur when vehicles turning right into parking lot	x	x	
Standing bus blocks the intersection	x		
Standing bus blocks vehicles on the traveling route	x		x
Standing bus makes vehicles queue up and block intersection	x		
Traffic delays when buses reenter traffic stream	x	x	x
Bus curb-loading zones are inadequate	x		
Passengers block business entrances	x		
Passengers interfere with pedestrian movements	x		
Parked vehicles are too close to loading curb	x		
New Problems			
Decreased intersection capacity			x
Decreased curb-parking capacity		x	
Construction of a shelter (no building nearby can serve as temporary shelter as with Stop 1)			x

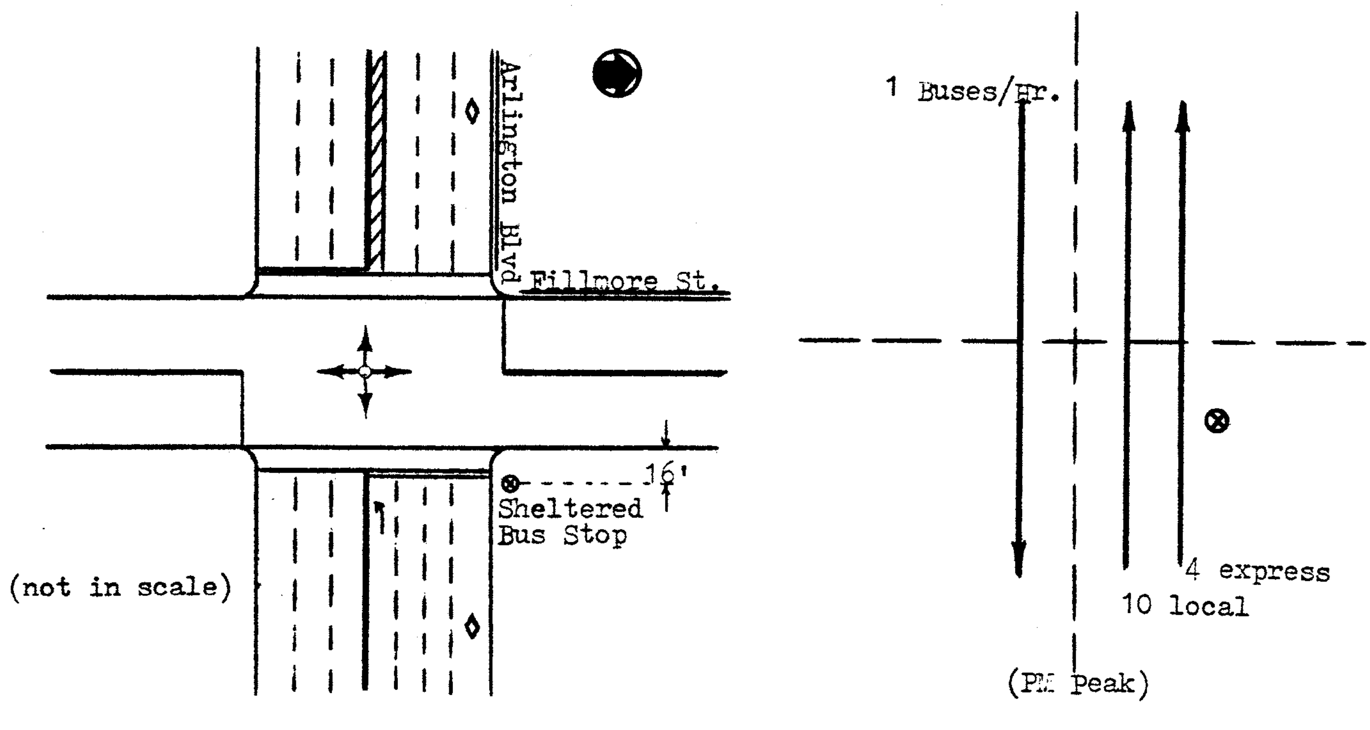
*Alternative A: Replace the "No-Parking" Signs 30 feet away from Stop 1 and 60 feet away from Stop 2. (According to the minimum bus loading-curb zone recommended by the Highway Capacity Manual)

Alternative B: Relocate Stop 2 to the farside of the driveway and the nearside of the intersection and eliminate Stop 1

Site 3

Site Description

The third site examined was located on Arlington Boulevard at its intersection with Fillmore Street. The sheltered bus stop located at the nearside is about 16 feet (5m) from the intersection, as shown in Figure 7. The land use adjacent to the intersection is residential, consisting of single- and multifamily dwellings. Arlington Boulevard, which serves as State Route 50, is divided into six lanes. In each direction, the curb lane is reserved for high occupancy vehicles including buses and vehicles with 2 or more passengers during peak evening periods (4 - 6:30 pm) and the other two lanes are for normal traffic. The traffic signal at this intersection is a 2-phase one with actuated detectors on Fillmore Street. Bus operations at the bus stop include a high volume of through traffic, and pedestrian crossings on Route 50 are light to moderate. All the westbound buses, including 10 local and 4 express buses for every hour during the evening peak, go straight through the intersection after they leave the nearside stop, as shown in Figure 7.



Intersection Geometrics

Bus Movements and Volumes

Figure 7. Study site 3.

Existing Problems

The problems at this nearside bus stop, as listed below, relate to safety, bus travel delays, and traffic delays.

A. Safety

1. Right-turning vehicles interfere with the buses as they leave the stop.

2. Vehicles following the standing buses pose hazards to other vehicles in the adjacent lanes when they bypass the buses.

B. Bus Travel Delays

1. As they depart the stop, buses conflict with car-pool vehicles and express buses on the reserved lane.

2. Right-turning vehicles from the adjacent lanes cause bus delays (left-turning vehicles from the opposite direction do also).

C. Traffic Delays

1. Right-turning vehicles are delayed by buses departing the stop.

2. Following car-pool vehicles and express buses are delayed by standing buses.

3. Car-pool vehicles and express buses are delayed by buses reentering the traffic stream.

D. Bus-Loading Curb

1. The bus-loading curb is too close to the intersection.

2. The bus-loading curb is inadequate for passenger operations.

Alternative Locations and Designs

The alternatives for solving the problems of this nearside stop on the car-pool lane require a relocation of the bus stop and provision of a bus turnout. The farside block of the intersection is too short and not feasible for locating the bus stop and providing a turnout. A comparison of these alternatives is shown in Table 9 where an x box shows that a problem exists.

Of the alternatives in Table 9, alternative C, which relocates the bus stop to mid-block and provides a bus turnout, is recommended.

Table 9

Comparison of Alternatives — Site 3

Problems	Original Bus Stop	Alternatives* A	B	C
<u>Existing Problems</u>				
Right-turning vehicles interfere with departing buses	x	x		
Vehicle-vehicle conflicts occur with by-passing standing buses	x		x	
Bus delays occur when waiting to reenter the car-pool lane	x	x	x	x
Bus delays occur when vehicles turning right from medium lane	x	x		
Standing buses block the carpooling vehicles and express buses	x		x	
Traffic on car-pool lane delays when buses reenter	x	x	x	x
Delays of right-turning vehicles occur when buses depart	x	x		
Bus-loading curb is too close to intersection	x			
Bus-loading curb is inadequate for passengers	x			
<u>New Problems</u>				
Increased traffic signal delay			x	x
Increased implementation costs				x

*Alternative A: Provide bus turnout at the stop and set the original stop back from intersection about 70 feet (21m) (according to the minimum bus curb-loading zone recommended by the Highway Capacity Manual)

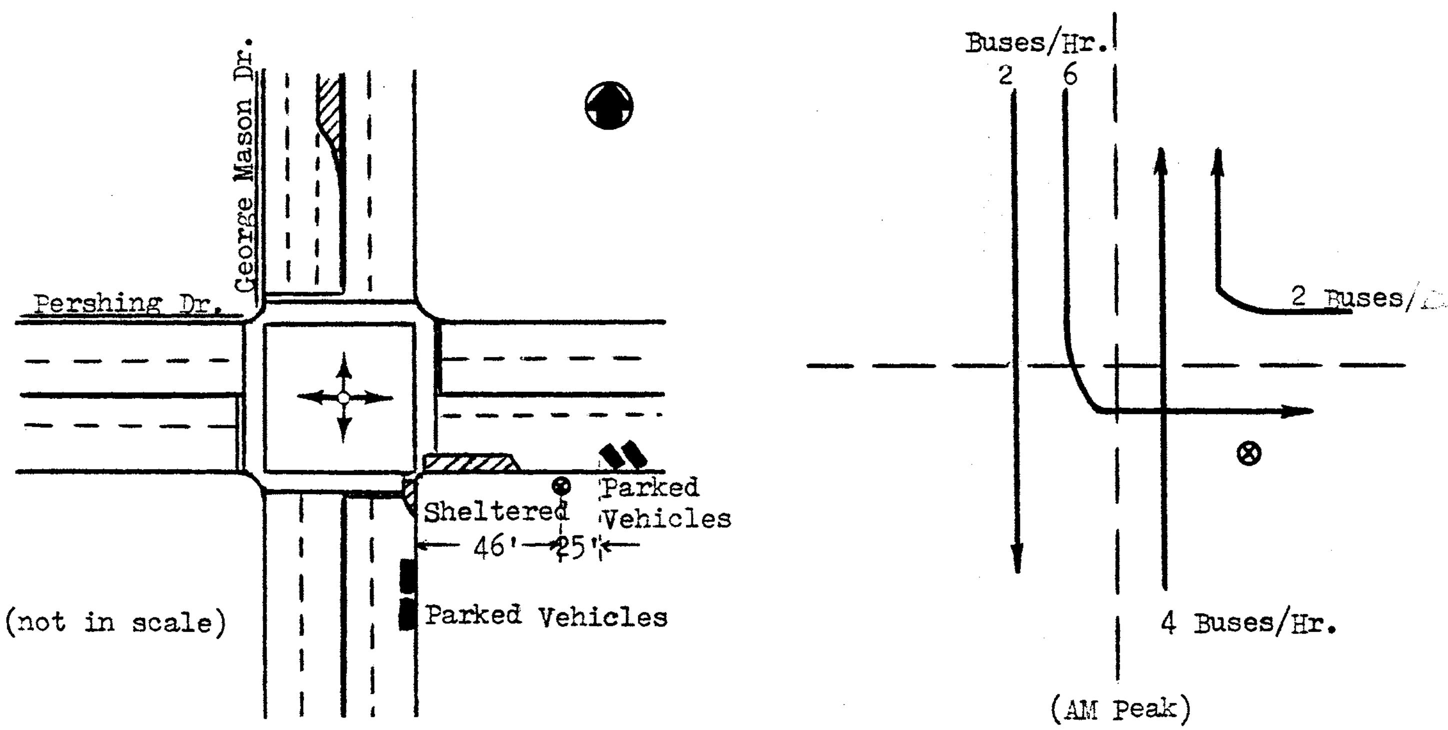
Alternative B: Relocate bus stop to mid-block

Alternative C: Relocate bus stop to mid-block and provide bus turnout

Site 4

Site Description

The fourth study examined a farside bus stop on Pershing Drive at its intersection with George Mason Drive, as shown in Figure 8. Surrounding this intersection, some two- or three-story appartment buildings provide insufficient off-street parking spaces and create a critical need for curb parking. Bus operations at this intersection include moderate traffic on George Mason Drive and light to moderate pedestrian crossings on Pershing Drive. The traffic signal at this intersection is a 2-phase one with a split phase for left-turning vehicles on the left-turn lane. A bus turnout is provided and all buses serving at the stop make left turns through the intersection before they reach the stop, as shown in Figure 8.



Intersection Geometrics

Bus Movements and Volumes

Figure 8. Study site 4.

Existing Problems

The problems at this farside bus stop relate to the bus-loading curb design, safety, bus travel delays, and traffic delays.

A. Bus-Loading Curb Design

1. Length of the bus-loading curb is insufficient (approximately 50 feet (15m), between a 6-foot (2m) wide, expanded curb and parked vehicles).

2. Passenger waiting areas are inadequate.

B. Safety

1. Access space is not enough for the left-turning buses to pull out of the through-travel lane into the curb area.

2. The rear of a stopped bus obstructs the traffic lane.

3. Buses conflict with the vehicles in the adjacent lane when they leave the stop (due to the insufficient turning radius provided).

4. Vehicles bypassing the standing buses pose hazards to the vehicles in the adjacent lane.

C. Bus Travel Delays

1. The bus waits to get into the traffic stream.

2. The turning bus waits to pull out of the traffic due to the conflict with right-turning vehicles from the opposite direction.

D. Traffic Delays

1. Standing buses make following vehicles queue up to the intersection and block cross traffic.

2. There are traffic delays when buses reenter the traffic stream.

3. Buses block the vehicles on the traveling route when they stand for passenger operations.

E. Potential Problems

1. A new northbound bus route on George Mason Drive is going to be established.

2. Transfer walking accessibility should be taken into consideration.

Alternative Locations and Designs

Primarily, the alternatives used to improve the efficiency of this farside stop are related to parking and intersection geometrics. A comparison of the original bus stop to its alternatives is shown in Table 10.

Among those in Table 10, alternative A, which recommends removal of the parked vehicles, is preferable. However, considering the establishment of the new northbound route on George Mason Drive, alternative B is recommended. With the removal of the expanded curb, a nearside stop can be installed and transferees' access efforts can be minimized.

Site 5

Site Description

The fifth study examined the mid-block bus stop located on Glebe Road between Carlin Springs Road and Randolph Street, as shown in Figure 9 . The area is in an outlying business district consisting of drug stores, department stores, a gas station and automobile dealers. On four-lane Glebe Road, no bus lane is provided and on-street parking is prohibited. At the intersection of Glebe Road and Carlin Springs Road, there are heavy right-turning and left-turning traffic movements into and out of the parking garage, and a 3-phase traffic signal is designed to give the right-of-way to those turning vehicles. Bus operations at the sheltered mid-block stop include a high volume of through traffic on Glebe Road, and there are light to moderate pedestrian crossings. All the northbound buses go straight through the intersection with an average headway of 8 minutes during the morning peak period, as shown in Figure 9

Table 10

Comparison of Alternatives — Site 4

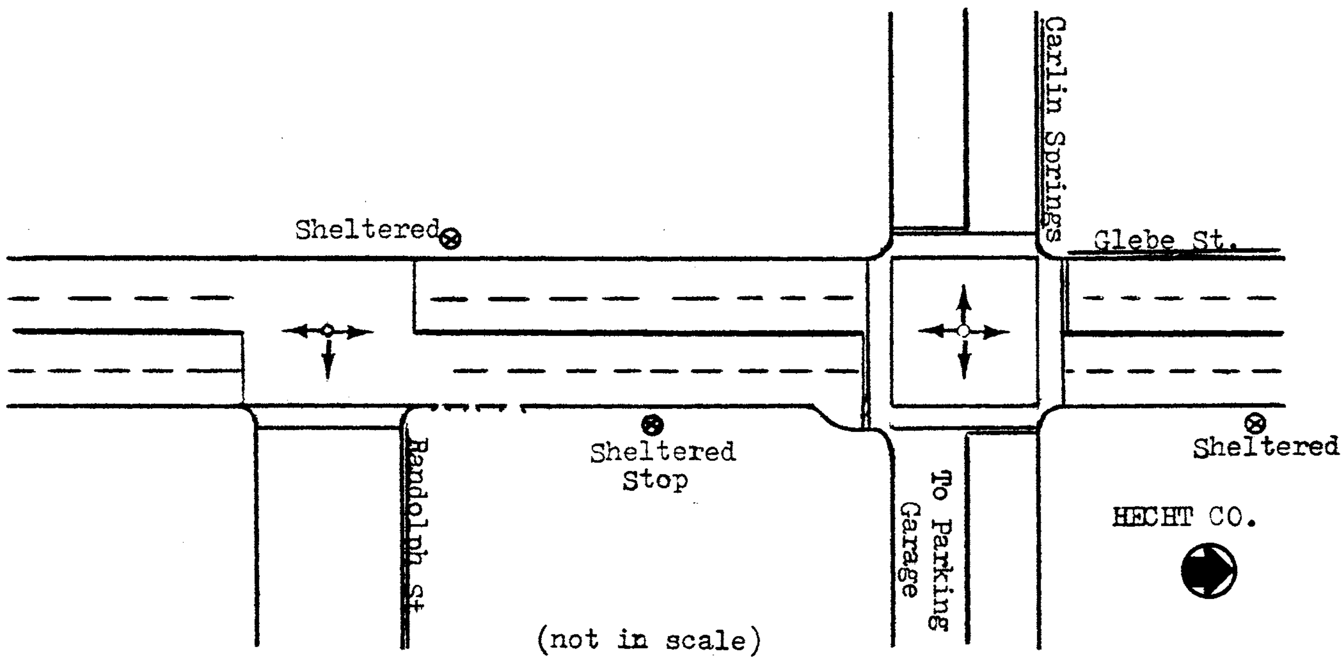
Problems	Original Bus-Stop	Alternative* A	Alternative* B
Existing Problems			
Length of bus loading curb is insufficient	x		
Passenger's waiting areas are inadequate	x		
Access space is not enough for left-turning buses	x		
Rear of Stopped bus obstructs traffic lane	x		
Bus-vehicle conflicts occur when buses leave the stop	x	x	x
Vehicle-vehicle conflicts occur with by passing standing buses	x		
Bus delays occur when waiting to reenter the traffic	x	x	x
Buses wait for right-turning vehicles to clear the way	x	x	x
Standing buses make following vehicles block cross traffic	x		
Traffic delays occur when buses reenter	x	x	x
Standing buses block the vehicles	x		
No site is available for new route**	x		
Transfer walking accessibility**	x		
New Problems			
Decreased curb-parking capacity		x	x
Increased implementation costs (to remove the expanded curb)			x

*Alternative A: Remove the parked vehicles away from the intersection 120 feet more for bus loading

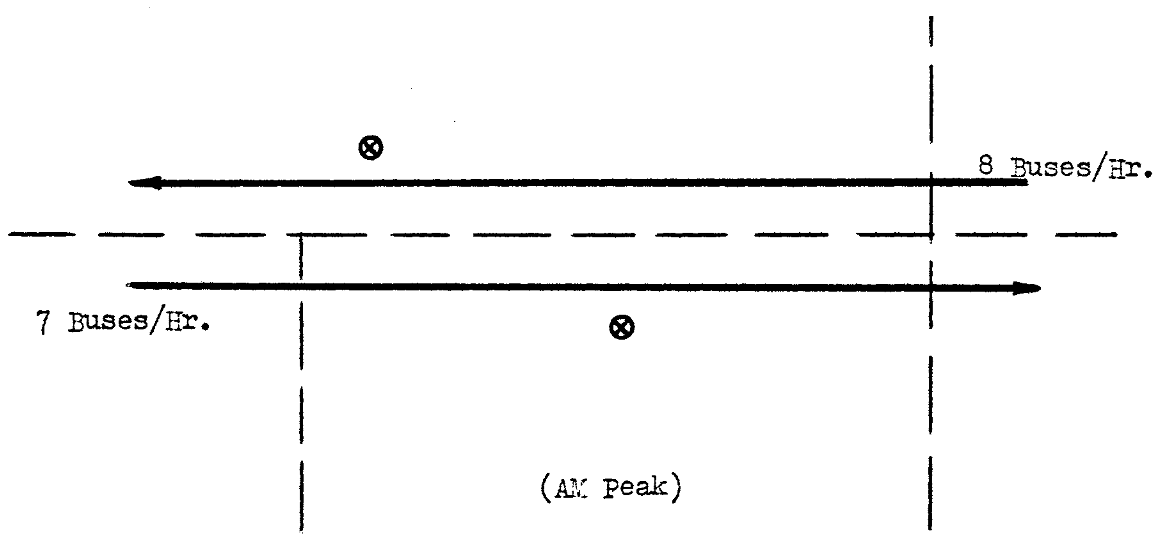
Alternative B: Remove the expanded curb and parked vehicles for at least 20 ft. (6m) (These lengths are recommended by Highway Research Board in NCHRP Report #155; p. 133)

**These two potential problems are eliminated if the expanded curb is removed and a nearside stop for the northbound buses is installed.

2033



Intersection Geometrics



Bus Movements and Volumes

Figure 9 . Study site 5.

Existing Problems

The problems associated with this mid-block bus stop are those of safety and bus and traffic delays as listed below.

A. Safety

1. Vehicles bypassing the standing buses pose hazards to the vehicles on the adjacent lane.

B. Bus Travel Delays

1. Buses must wait to get into the traffic stream when leaving the stop.

2. Buses must wait to pull out of the traffic for passenger operations due to congested traffic ahead.

C. Traffic Delays

1. Buses loading and unloading passengers block the vehicles on the traveling route.

2. Traffic is delayed by buses reentering the traffic stream.

Alternative Locations and Designs

Within the immediate vicinity, there is no feasible alternative location for this mid-block bus stop. This statement is based on the following facts.

A. At the intersection of Glebe Road and Randolph Street —

1. there is heavy right-turning traffic onto Randolph Street, and a nearside stop would increase traffic delays; and

2. the three driveways along the farside block make the installment of a farside stop impossible.

B. At the intersection of Glebe Road and Carlin Springs Road —

1. the provision of a right-turn lane and the heavy right-turning traffic prohibit the installment of a nearside stop; and

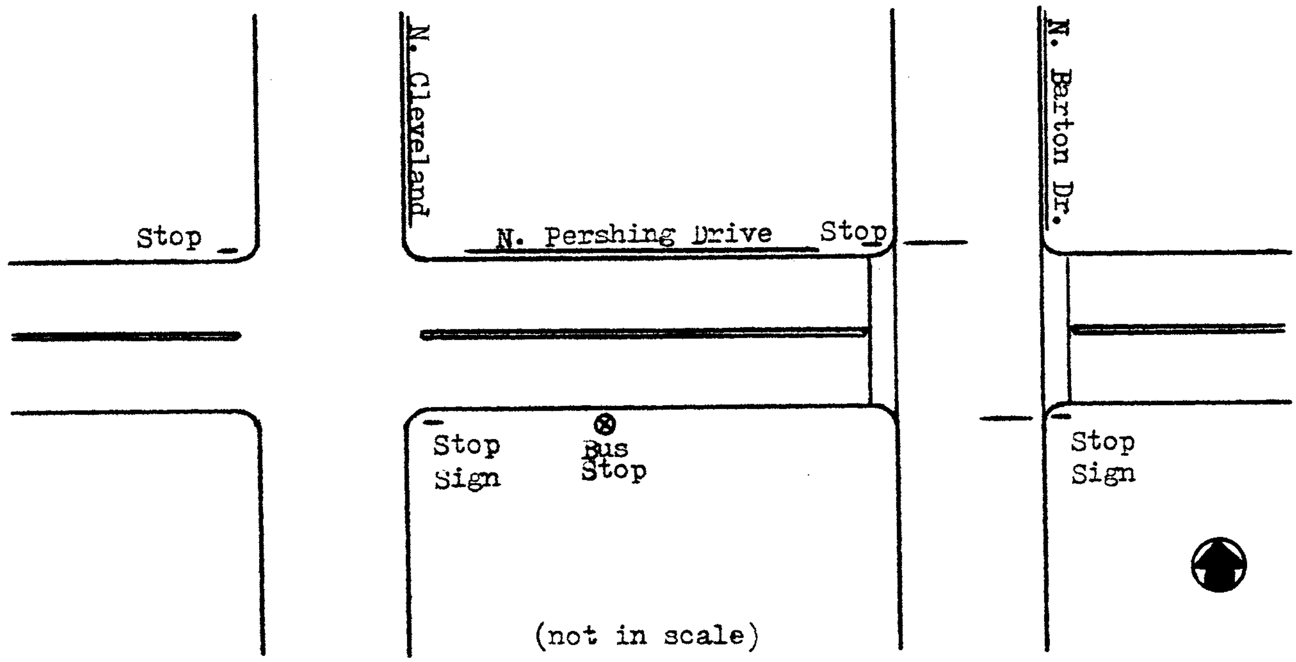
2. a farside stop would be too close to the other mid-block stop.

The only effective solution to the problems caused by congestion at the bus stop is to provide a turnout at the original location. With the provision of a turnout, most delays would be eliminated. To prevent the buses from increasing the delays when reentering the traffic stream, special signing devices such as a "Yield to Buses" sign and an actuated flasher at the exit of the turnout should be provided.

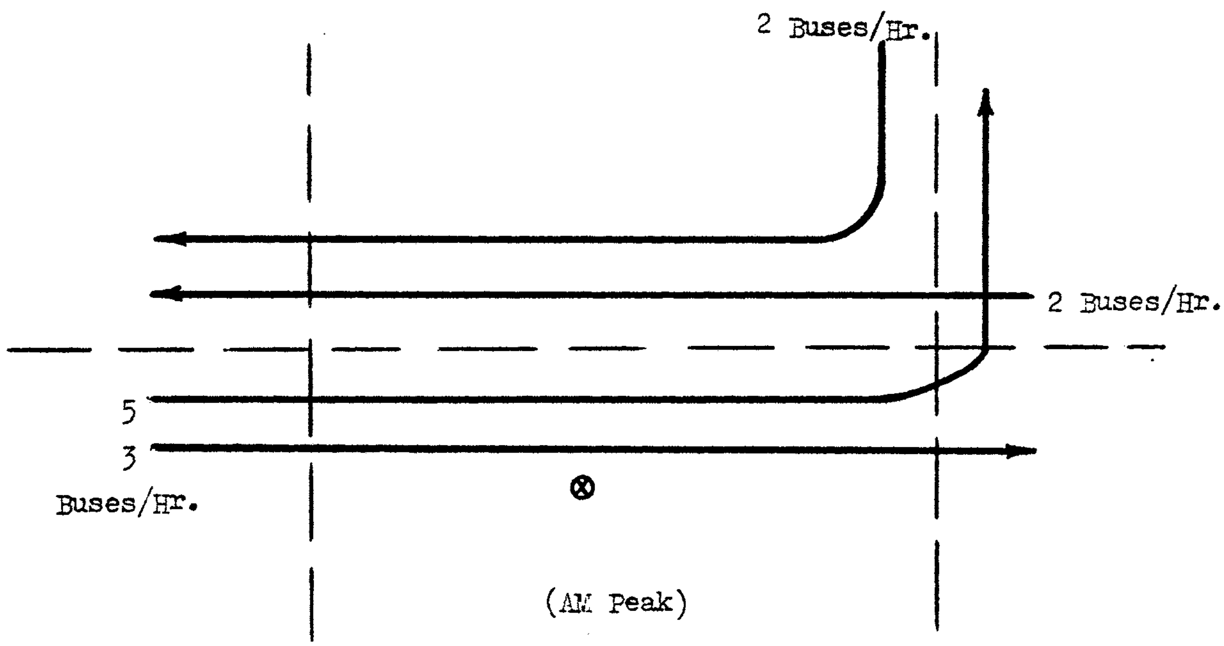
Site 6

Site Description

The study of site 6 was concerned with the environmental characteristics of a mid-block bus stop located on Pershing Drive between North Barton Drive and North Cleveland Drive. The land use adjacent to the bus stop is residential, consisting of single- and multifamily dwellings. The traffic control devices used at the intersections are simple 2-way stop signs located on North Barton and North Cleveland Drives, as shown in Figure 11. Also, on these two streets curb parking is permitted, but it is prohibited on Pershing Drive. Except for crosswalk and centerline markings on Pershing Drive, there is no traffic marking. Bus operations at the stop include moderate traffic and pedestrian crossings on Pershing Drive. As scheduled, 63% of the bus arrivals from the west make a left turn and 37% of them go straight through the intersection after they leave the mid-block stop, as shown in Figure 10.



Intersection Geometrics



Bus Movements and Volumes

Figure 10. Study site 6.

2 2

Existing Problems

The existing problems at this location are those of safety, bus travel delays, traffic delays and environmental impacts.

A. Safety

1. Buses leaving the stop conflict with vehicles in the traffic lane.

2. Buses moving wide to make left turn conflict with vehicles in the traffic lane.

B. Bus Travel Delays

1. Buses must wait to get into the traffic stream after finishing passenger operations at the stop.

2. Buses wait to get to the left side of the lane before making left turns.

C. Traffic Delays

1. Traffic is blocked by buses loading and unloading passengers.

2. Traffic must wait for buses to complete left turns.

D. Environmental Impacts

1. Owner of the property adjacent to the stop complains that passengers wait on his lawn for buses and requests a relocation of the stop.

2. Sight distance is short for an eastbound bus approaching the crest of the hill at the intersection of Pershing and Cleveland Drives.

Alternative Locations and Designs

The alternatives for this site require a relocation of the bus stop. A comparison between the alternatives is given in Table 11. Of these alternatives, a relocation to the farside or mid-block on North Barton Drive after buses make left turns is recommended.

Table 11

Comparison of Alternatives — Site 6

Problems	Original Bus Stop	Alternatives* A	B	C
Existing Problems				
Bus-vehicle conflicts occur when buses depart	x	x	x	x
Bus-vehicle conflicts occur when buses make left turns	x	x	x	
Buses wait to reenter the traffic	x	x	x	x
Buses wait to move to left side for making turns	x	x	x	
Buses block the moving traffic behind	x	x	x	x
Traffic delays occur when buses reenter the traffic	x	x	x	x
Traffic delays occur when buses make left turns	x	x	x	
Property owner complains	x		x	
Sight difficulty exists	x	x	x	
New Problems				
Decreased curb-parking capacity				x
Increased right-turning vehicle delays		x		

*Alternative A: Relocate at the nearside of the intersection of N. Cleveland Drive and Pershing Drive

Alternative B: Relocate at the farside of the intersection of N. Cleveland Drive and Pershing Drive

Alternative C: Relocate at the farside or mid-block on N. Barton Drive after the buses make left turns

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APPENDIX A

Cities Responding to the Questionnaire Surveys

STATE/CITY	1970* Population in 1000's	1976** No. of Passenger Buses
Alabama		
Birmingham	301	143
Huntsville	138	
Alaska		
Anchorage	175	
Arizona		
Phoenix	582	
Scottsdale	68	
Tucson	263	83
California		
Anaheim	167	
Burbank	89	
Chula Vista	68	
Downey	88	
Fresno		78
Long Beach	359	
Los Angeles		1860
Modesto	62	
Norwalk	92	
Oakland	362	628
Richmond	79	
Riverside	140	
San Bernardino	104	
San Diego		284
San Francisco		420
San Francisco		227
San Jose	446	171
Santa Rosa	50	
Stockton	108	
West Covina	68	
Whittier	73	
Colorado		
Colorado Springs	135	
Fort Collins	43	
Connecticut		
New Haven	138	
Stamford	109	
Delaware		
Wilmington		81
District of Columbia		
Washington DC		1567
Florida		
Clearwater	52	
Jacksonville	529	
Pensacola	60	
St. Petersburg	216	47
Georgia		
Athens		13
Atlanta	497	703
Hawaii		
Hilo		15
Honolulu		320
Illinois		
Des Plaines		106
Evanston	80	
Joliet	80	
Moline	46	
Rock Island	50	
Urbana		30
Chicago	3367	2172
Indiana		
Fort Wayne	178	
Gary	175	
Hammond	108	
Indianapolis	745	
Muncie	69	
South Bend	126	

STATE/CITY	1970* Population in 1000's	1976** No. of Passenger Buses
Iowa		
Ames	40	
Iowa City		14
Kansas		
Wichita		42
Kentucky		
Lexington		57
Newport		76
Louisiana		
Baton Rouge	166	
New Orleans	593	384
Maine		
Portland	65	60
Maryland		
Annapolis	30	
Baltimore	906	855
Hagerstown		14
Montgomery	590	
Rockville	42	
Massachusetts		
Cambridge	100	
Springfield	164	
Worcester		62
Michigan		
Dearborn	104	
Detroit	1511	217
Grand Rapids	198	
Saginaw	92	
Warren	179	
Minnesota		
Bloomington	82	
Duluth		87
Minneapolis	434	
St. Paul		856
Rochester	54	

STATE/CITY	1970* Population in 1000's	1976** No. of Passenger Buses
Missouri		
Independence	112	
Kansas City	507	253
Nebraska		
Fremont	23	
Lincoln		46
Omaha	347	178
Nevada		
Las Vegas	126	
New Hampshire		
Concord	30	
Nashua	56	
Manchester		30
New Jersey		
Bayonne	73	
Bergenfield		138
Trenton	105	
Woodbridge	99	
New Mexico		
Las Cruces	38	
Santa Fe	41	
New York		
Albany	116	185
Buffalo	463	368
Mineola	-	250
Westchester	296	
North Carolina		
Chapel Hill		19
Greensboro	144	
Raleigh	122	35
Wilmington	46	
Winston-Salem	133	

STATE/CITY	1970* Population in 1000's	1976** No. of Passenger Buses
<u>North Dakota</u>		
Bismarck	35	
<u>Ohio</u>		
Akron	275	64
Canton		73
Columbus		228
Middletown	49	
Parma	100	
<u>Oklahoma</u>		
Oklahoma City	366	
<u>Oregon</u>		
Eugene	76	
Portland		435
<u>Pennsylvania</u>		
Allentown		46
Altoona		35
Bethlehem	73	
Lancaster		32
Philadelphia		1027
Pittsburgh	520	761
<u>Puerto Rico</u>		
San Juan		411
<u>Rhode Island</u>		
Pawtucket	77	
Providence	179	188
<u>South Carolina</u>		
Columbia	114	
Florence	26	
Greenville	61	
Spartansburg	45	
Sumter	24	
<u>South Dakota</u>		
Sioux Falls	72	

STATE/CITY	1970* Population in 1000's	1976** No. of Passenger Buses
<u>Tennessee</u>		
Chattanooga	119	
Knoxville		71
Memphis	624	
<u>Texas</u>		
Arlington	91	
Beaumont	116	
Dallas		389
Fort Worth	393	86
Galveston	62	
Houston		372
Lubbock	149	
San Antonio		313
Waco	95	
<u>Utah</u>		
Salt Lake City		191
<u>Virginia</u>		
Alexandria	111	
Arlington	174	
Chesapeake	90	
Hampton	121	83
Lynchburg	54	
Newport News	138	
Norfolk		138
Petersburg	36	
Richmond		168
Roanoke	92	35
Staunton	25	
<u>Washington</u>		
Bellingham		15
Seattle	531	574
Tacoma		106
<u>Wisconsin</u>		
Eau Claire	45	
Madison	173	
Milwaukee	717	465
Racine	95	

* Source: U.S. Census Bureau
** The number of passenger buses is the peak requirement of the particular transit firm in 1976; provided by Urban Mass Transportation Administration, DOT, February, 1977.

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APPENDIX B

Results of Questionnaire Survey of City Transportation Engineers

All Responses: 117 Cities

1. Has your organization adopted a standard policy and/or set of criteria for locating and/or designing bus stops? a. 16 yes b. 92 no c. 9 No Reply
   If you answer yes, please attach a copy of your criteria and/or policy.
   Follow guidelines/policy, compromising where necessary; Essentially operating under an intersection bus stop policy while no formal policy has been adopted.

2. What specific objectives are associated with bus stop location decisions in your jurisdiction?

	Primary Objective	Secondary Objective	Not an Objective	No Reply
a. To reduce transit travel time	34	42	15	26
b. To reduce travel costs	17	37	36	27
c. To improve safety	82	12	4	19
d. To improve security	13	31	46	27
e. To increase transit patronage	62	24	10	21
f. To reduce transportation system energy consumption	12	43	34	28
g. To provide adequate service to the transportation disadvantaged and transit dependent	42	37	15	23
h. To provide easy access to all major trip generators	64	23	5	25
i. To minimize interference with the traffic stream	65	25	6	21
j. To minimize time for reentry into the traffic stream	35	45	12	25
k. To reduce interference with pedestrian flows	29	48	15	25
l. To avoid blocking entry to adjacent business	24	50	19	24
m. To ensure compatibility with adjacent development	23	40	26	28
n. Other (please specify)				

3. What specific transportation planning and engineering factors are considered in your bus stop location process?

	Primary Consideration	Secondary Consideration	Not a Consideration	No Reply
a. Frequency of stops per length of route	33	32	25	27
b. Availability of curb loading space	57	26	10	24
c. Proximity to passenger origins and destinations	80	14	4	19
d. Traffic volume	39	39	13	26
e. Width of sidewalks	15	36	39	27
f. Intersection capacity	35	37	18	26
g. Turning movements	50	35	7	25
h. Pedestrian movements	39	41	12	25
i. Interference with traffic	58	27	8	24
j. Visibility of signals	27	43	19	28
k. Automobile parking	29	23	20	25
l. Traffic flow delays	44	38	10	25
m. Bus travel delay	34	42	15	26
n. Adjacent development	24	51	14	28
o. Population density	20	38	33	26
p. Security of traveler	20	43	25	29
q. Visibility of stop	42	37	11	27
r. Safety of bus, passengers, and other traffic	65	15	8	29
s. Other (please specify)				

4. What interest groups influence your bus stop location process?

	Strong Influence	Secondary Influence	Not Influential	No Reply
a. Bus rider	65	28	7	17
b. Bus driver	27	48	20	22
c. Local business	35	56	6	20
d. Transit company	72	21	5	19
e. Pedestrians	32	43	19	23
f. Moving traffic	41	33	18	25

g. Other (please specify)
Political people; Requestors of on-street parking space; Private property owners; Municipal government.

5. What measures are used by your department as indices of performance of a particular bus stop location?

	Primary	Secondary	Not Used	No Reply
a. Delay to traffic flow	50	25	17	25
b. Time lost attempting to reenter traffic	25	43	21	28
c. Number of boardings and departures at stop	60	17	12	28
d. Local air quality	4	20	61	32
e. Pedestrian conflicts	26	43	20	28
f. Distance between stops	44	29	17	27
g. Accidents	51	16	17	33

h. Other (please specify)
Number of complaints from bus rider, citizen and adjacent business.

6. Are there any local ordinances or state laws which affect bus stop location in your locality?
a. 25 Yes
b. 85 No
If yes please describe appropriate laws.
City code delegates bus stop installation authority to traffic engineers.
c. 7 No Reply

7. Do parking needs ever govern the establishment of a bus stop?
a. 71 Yes
b. 31 No
c. 15 No Reply

8. Does your jurisdiction permit right turns on red?
a. 108 Yes When was this policy initiated? From 1960 to July, 1979
b. 2 No
c. 7 No Reply

9. Has Right Turn on Red caused any changes regarding your agency's approach toward locating bus stops? a. 16 Yes b. 92 No c. 9 No Reply
If you answer yes, please briefly describe the changes.
If heavy right turns, far side bus stops are encouraged; RTOR prohibited at intersections where major routes cross and transferees are numerous.

10. Are any changes in your bus stop location policy being considered as a result of experience with RTOR? a. 2 Yes b. 103 No c. 12 No Reply
If answer is yes, please describe anticipated changes.
Possibility of changing several bus stops to allow RTOR traffic to flow unimpeded; identification of fixed route more accurately.

11. Are bus stops which serve as transfer points between different bus routes given special consideration regarding location. a. 69 Yes b. 37 No c. 11 No Reply
If yes, please specify additional considerations.
Ease of transfer and distance for passengers to walk are of prime concern; Adequate waiting space; Bus shelters; Pull-off bus lanes.

12. Is bus stop location a consideration in your areas' transportation system management (TSM) plan?
    a. 20 Yes
    b. 83 No
    If yes please send a copy or furnish the name of the agency from which the TSM plan may be obtained. ______
    c. 14 No Reply

13. Indicate all measures taken in your service area that give buses priority treatment over other vehicles.
    a. 76 none
    b. 5 signal preemption
    c. 16 exclusive curb lanes
    d. 3 priority lanes for express service
    e. 10 other (please specify) Preemption from many at-intersection turn prohibitions.

14. Does your city have curb space length requirements for bus stops?
    a. 54 Yes
    b. 54 No
    c. 9 No Reply

15. Indicate where you employ recessed bus bays (turnouts) on your streets?
    a. 53 None employed (go to number 18 if you answer none employed)
    b. 8 On downtown local streets
    c. 25 On heavily traveled sections of arterial highways
    d. 14 At bus transfer points
    e. 28 Other (please specify) Where curb lane width is less than 19'; where right of way is adequate.

16. Indicate all factors that are used to recommend a turnout?
    a. 26 high number of boardings and departures
    b. 42 high traffic volumes on street
    c. 3 exclusive curb lane in use for buses
    d. 18 other (please specify) Consideration of accident experiences; Length of bus dwelling time; narrow street width; volume of buses.

17. Are traffic signals employed in conjunction with bus turnouts to lessen the delay to buses when reentering the traffic stream?
    a. 2 Yes
    b. 56 No
    If yes briefly describe the characteristics of stops where priority signals are provided. Actuated loop used to control bus exit.
    c. 59 No Reply

18. Does your agency provide bus stop shelters?
    a. 61 Yes
    If answer is yes check items below that apply
    1. 0 at all stops
    2. 4 at CBD stops
    3. 6 at suburban stops
    4. 51 at other selected stops (please specify) Where heavily used and space available; long duration between bus arrivals; transfer points.
    b. 49 No
    If answer is no check the item below that applies and then go to #23.
    1. 28 none provided in system
    2. 21 provided by bus operator
    c. 7 No Reply

19. What percentage of your bus stops are sheltered?
    a. 66 0-10%
    b. 12 10-25%
    c. 1 25-50%
    d. 0 over 50%
    e. 38 Not Applicable

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20. Indicate all factors that are used to recommend that a shelter be provided at a bus stop.

a. 12 suburban location
b. 25 no other shelter in vicinity of stop
c. 66 level of demand
d. 25 other (please specify) Transfer points; traffic generators; Elderly & handicapped consideration; width of side-walks.

21. Are benches or seats provided at sheltered bus stops?

a. 54 Yes
b. 6 No
c. 20 Sometimes
d. 37 No Reply

22. If you answered yes or sometimes to question 21 what criteria are used to recommend that seats be provided at bus stops?

a. 20 length of average wait
b. 23 transfer point
c. 19 volume of buses
d. 24 elderly and handicapped considerations
e. 20 available space
f. 37 other (please specify) Benches are the integral part of shelters; level of demand; specific requests by transit users.

23. Would you like to receive a copy of the final report related to this study?

a. 92 Yes
b. 18 No

If yes include your name and mailing address to insure proper delivery.

____

____

____

c. 7 No Reply

Return Completed Questionnaire To:

Michael J. Demetsky
Faculty Research Engineer
Virginia Highway & Transportation Research Council
P.O. Box 3817 - University Station
Charlottesville, Virginia 22903

APPENDIX C

Results of Questionnaire Survey of City Transit Firms

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All Responses: 67 Cities

1. Annual Bus Ridership Range: 385,340 to 533,097,489

2. Annual Bus Revenue Range: $149,000 to $138,892,460

3. Annual Bus Vehicle Miles of Service Range: 225,000 to 83,815,000

4. Has your organization adopted a standard policy and/or set of criteria for locating and/or designing bus stops? a. 27 yes b. 31 no c. 9 no reply
If you answer yes, please attach a copy of your criteria and/or policy.

5. What specific objectives are associated with bus stop location decisions in your jurisdiction?

	Primary Objective	Secondary Objective	Not an Objective	No Reply
a. To reduce transit travel time	30	19	16	2
b. To reduce travel costs	19	25	21	2
c. To improve safety	58	7	0	2
d. To improve security	16	28	21	2
e. To increase transit patronage	58	8	0	1
f. To reduce transportation system energy consumption	9	31	25	2
g. To provide adequate service to the transportation disadvantaged and transit dependent	42	18	4	3
h. To provide easy access to all major trip generators	58	5	2	2
i. To minimize interference with the traffic stream	40	23	2	2
j. To minimize time for reentry into the traffic stream	34	23	8	2
k. To reduce interference with pedestrian flows	22	27	16	2
l. To avoid blocking entry to adjacent business	27	28	10	2
m. To ensure compatibility with adjacent development	23	30	12	2

n. Other (please specify)
To minimize complaints from residents.

6. What specific transportation planning and engineering factors are considered in your bus stop location process?

	Primary Consideration	Secondary Consideration	Not a Consideration	No Reply
a. Frequency of stops per length of route	32	18	11	6
b. Availability of curb loading space	45	13	5	4
c. Proximity to passenger origins and destinations	62	2	1	2
d. Traffic volume	28	30	7	2
e. Width of sidewalks	9	36	19	2
f. Intersection capacity	17	28	20	2
g. Turning movements	44	13	8	2
h. Pedestrian movements	30	26	8	3
i. Interference with traffic	44	18	3	2
j. Visibility of signals	29	25	11	2
k. Automobile parking	25	31	9	2
l. Traffic flow delays	31	29	4	3
m. Bus travel delay	41	20	4	2
n. Adjacent development	36	24	5	2
o. Population density	39	20	5	3
p. Security of traveler	28	25	12	2
q. Visibility of stop	46	14	5	2
r. Safety of bus, passengers, and other traffic	53	10	1	3

s. Other (please specify)

7. What interest groups influence your bus stop location process?

	Strong Influence	Secondary Influence	Not Influential	No Reply
a. Bus rider	62	4	1	0
b. Bus driver	36	25	5	1
c. Local business	21	40	5	1
d. Transit company	49	8	3	7
e. Pedestrians	19	32	15	1
f. Moving traffic	31	26	7	3

g. Other (please specify)
Private property owners adjacent to bus stop, various citizens' groups, municipalities, local government agencies & police department.

8. What measures are used by your firm as indices of performance of a particular bus stop location?

	Primary	Secondary	Not Used	No Reply
a. Delay to traffic flow	20	26	15	6
b. Time lost attempting to reenter traffic	27	24	11	5
c. Number of boardings and departures at stop	58	3	3	3
d. Local air quality	0	15	47	5
e. Pedestrian conflicts	20	29	13	5
f. Distance between stops	42	15	5	5
g. Accidents	42	13	8	4

h. Other (please specify)
Number of complaints from bus rider, citizen and adjacent business.

9. Are there any local ordinances or state laws which affect bus stop location?
a. 32 Yes
b. 34 No
If yes please describe appropriate laws.
Compliance with all traffic laws unless specific exception given; Approvals required from traffic engineering department; parking regulations.
c. 1 No Reply

10. Are bus stops which serve as transfer points between different bus routes given special consideration regarding location?
a. 46 Yes
b. 21 No
If yes please specify these additional considerations.
Use four corners: Minimization of the number of street crossings and distance walked by transferees; Availability of adequate bus loading zone for simultaneous passenger activities; Availability of shelter.

11. Does your agency prescribe minimum and/or maximum distances between bus stops?
a. 35 Yes
b. 32 No
If yes please specify. Greater than 660 feet and less than 1250 feet; Conventional rule of thumb is that no more than 8 stops per mile be utilized beyond CBD, within CBD a bus stop, when possible, at every corner.

12. What is the range (miles) of walking distance considered to be served by a bus stop in your system?
a. 45 in CBD 9 0.10 mile; 21 0.25 mile; 15 else
b. 55 at outlying points 22 0.25 mile; 10 0.5 mile; 23 else
c. 4 no reply

13. Do different bus routes that overlap on arterial streets
a. 61 use the same stops
b. 1 alternate stops
c. 4 other (please specify) Only when there is a heavy boarding terminal or one or more routes are making a left turn at an intersection, the alternate stops will be used.
d. 1 No Reply

14. Does your organization have curb space length requirements for bus stops?
 a. 52 yes
 b. 15 no
 If yes please specify. ITE recommended practice for bus stop location.

15. Do you employ recessed bus bays (turnouts)?
 a. 33 No (If answer is no go to number 18)
 b. 10 On downtown local streets
 c. 17 On heavily traveled sections of arterial highways
 d. 6 At bus transfer points
 e. 13 Other (please specify) Where Right of Way is adequate; where the curb space permits.

16. Indicate all factors that are used to recommend a turnout?
 a. 23 high number of boardings and departures
 b. 28 high traffic volumes on street
 c. 3 exclusive curb lane in use for buses
 d. 8 other (please specify) High number of buses; Availability of adequate right of way.

17. Are traffic signals employed in conjunction with bus turnouts to lessen the delay to buses when reentering the traffic stream?
 a. 0 Yes
 b. 41 No
 If yes briefly describe the characteristics of stops where priority signals are provided.
 c. 26 No Reply

18. Does your agency provide bus stop shelters?
 a. 56 Yes
 If answer is yes check items below that apply
 1. 0 all stops
 2. 7 CBD stops
 3. 1 suburban stops
 4. 48 other selected stops (please specify) Transfer points and other heavy boarding areas where public requests.
 b. 11 No
 If answer is no check the item below that applies and go to number 23.
 1. 9 none provided in system
 2. 2 provided by city

19. What percentage of your bus stops are sheltered?
 a. 52 0-10%
 b. 6 10-25%
 c. 2 25-50%
 d. 0 over 50%
 e. 7 No Reply

20. Indicate all factors that are used to recommend that a shelter be provided at a bus stop.
 a. 10 suburban location
 b. 25 no other shelter in vicinity of stop
 c. 56 level of demand
 d. 29 other (please specify) Transfer points; Traffic generators; Elderly & Handicapped patronage; Right of way availability.

21. Are benches or seats provided at sheltered bus stops?
 a. 46 yes
 b. 8 sometimes
 c. 6 no (if answer is no go to number 23)
 d. 7 No Reply

22. If you answered yes or sometimes to question 21 what criteria are used to recommend that seats be provided at bus stops?
 a. 16 length of average wait
 b. 16 transfer point
 c. 11 volume of buses
 d. 24 elderly and handicapped considerations
 e. 17 available space
 f. 36 other (please specify) All shelters are designed with benches as an integral part; considerations of passengers' comfort and convenience; Level of demand.

23. Would you like to receive a copy of the final report related to this study?

a. ___66___ Yes

b. ___1___ No

If yes include your name and mailing address to insure proper delivery.

____

____

____

<u>Return Completed Questionnaire to</u>:

Michael J. Demetsky
Faculty Research Engineer
Virginia Highway & Transportation Research Council
P.O. Box 3817 - University Station
Charlottesville, Virginia 22903

APPENDIX D

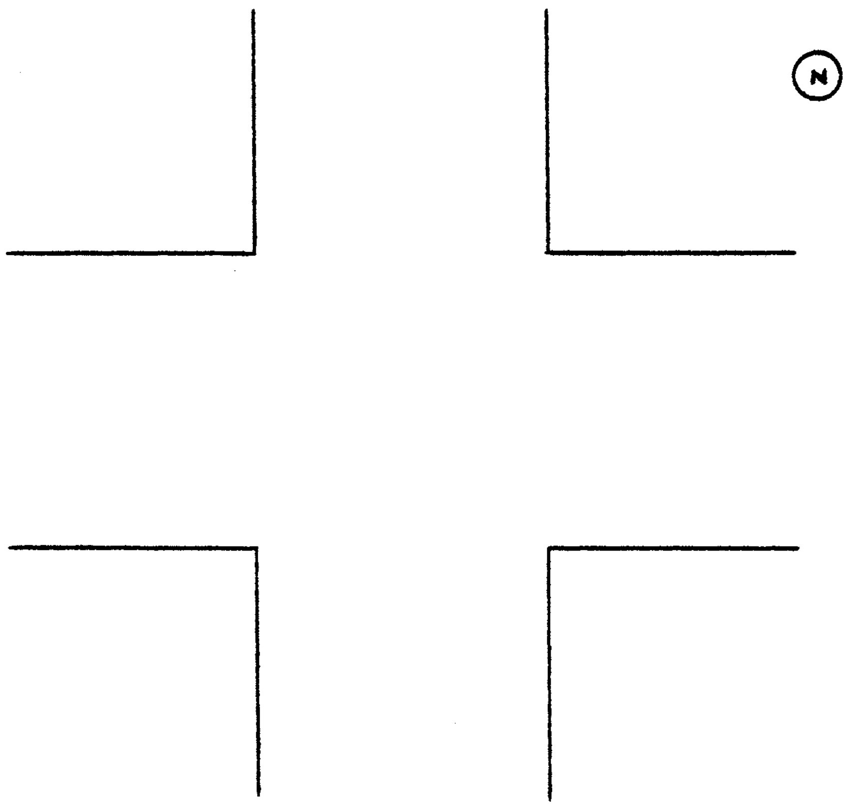
CASE STUDY DATA: BUS STOP LOCATION & DESIGN

Date: ________________

PART A: Physical Features

INTERSECTION GEOMETRICS (not in scale)

LOCATION OF BUS STOP: On ____________ St. at its intersection with ____________ St.



(Mark:(1) street names (2) no. of traffic lanes & widths (3) bus stop location (4) distance between bus stop and the intersection)

Examined Items	Yes	No
Bus Lane Provided?		
Right Turn Lane Provided?		
Left Turn Lane Provided?		
Bus Loading Zone Marked?		
Traffic Lane Marking?		
Crosswalk Marking?		
Stop Line Marking?		
Bus Turnouts Provided?		
RTOR Permitted?		
Bus Shelter Provided?		
Benches Provided?		

Sidewalk Features

Shoulder Curb & Gutter

Width ____________

REMARKS:

TRAFFIC CONTROL: Signal (cycle ______) Stop-Sign

Yield - Sign None

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Part B: Evaluation Criteria

TRAFFIC MOVEMENTS	APPROACH TRAFFIC	Heavy Moderate Light
	% OF RIGHT TURNS	High Medium Low
	ONE-WAY CROSS STREET	From Right From Left
BUS MOVEMENTS	BUS FLOW BUSES/HR	
	MOVEMENTS	Thru ___(%) R/T ___(%) L/T ___(%)
PASSENGER MOVEMENTS	NO. OF PASSENGERS	Heavy Moderate Light
	TRANSFER ACTIVITIES	Yes No
	BUS LOADING CURB	Sufficient Insufficient
	SIDEWALK WIDTH	Sufficient Insufficient
LOCAL DEVELOPMENT	LAND USE	Business Residential Public Open Space Undeveloped Other
	LOCAL PEDESTRIAN TRAFFIC	Heavy Moderate Light
	BUS STOP DESIGN	Compatible Incompatible
	CRITICAL NEEDS FOR CURB PARKING, TRUCK LOADING ZONES, STORAGE LANE, ETC.	Yes No
	PARKING IN BUS ZONES	Eliminated Permitted Prohibited but not Eliminated
	LOCAL BUSINESS ENTRANCE BLOCKED BY BUS STOP	Yes No
OTHERS(PLANNING & DESIGN DATA)		
COMMENTS		