Preliminary Progress Report of Transit Subcommittee, Committee on Highway Capacity

W. S. RAINVILLE, JR., *Chairman;*
WOLFGANG S. HOMBURGER, DONALD C. HYDE,
AND RICHARD I. STRICKLAND

• AN EARLY canvass of the membership of this subcommittee in 1960 revealed a belief, on the part of a majority of its members, that certain information regarding the capacity of bus lanes, bus stops and off-street bus terminals should be developed. For example, the committee believed that it would be of great benefit to traffic engineers and planners if some or all of the following information could be found in published form:

1. Capacity of a theoretical bus lane on freeways.
2. Capacity of reserved bus lanes on city streets.
3. Capacity of freeway bus stops.
4. Capacity of bus stops on city streets.
5. Capacity of bus loading and unloading platforms in off-street terminals.

With the possibility of producing something helpful and constructive, the subcommittee resolved itself into three working groups to investigate effective passenger capacities of transit vehicles under various conditions of operations, capacities of bus stops on city streets and on expressways, and capacities of off-street bus loading and unloading platforms.

EFFECTIVE PASSENGER CAPACITIES OF TRANSIT VEHICLES

In obtaining information as to volumes of transit passengers moved by transit vehicles under various conditions, the working group in this area of research purposely did not seek out cities with the largest passenger volumes anywhere in the United States. Rather, it selected its sample for preliminary study by seeking data from a dozen or so cities throughout the nation where things have happened recently in transit operations—where something new or unusual has been introduced on the streets and highways—for example, cities where bus operations on city streets have been accorded the use of reserved transit lanes, cities where express motor bus service has been instituted on expressways, and cities with recent rail rapid transit installations of the conventional type.

No attempt was made to obtain data from every such city. In the case of the cities selected for study, the data were obtained for the heaviest operation of the type specified in each city. The observed data collected are given in Tables 1, 2 and 3.

Local Bus Service on City Streets

Table 1a gives peak-hour passenger volumes for local buses on city streets with curb parking prohibited in the prevailing direction of travel except where otherwise indicated.

The 13 entries comprise the data submitted by ten cities. Maximum hourly transit passenger traffic flow, based on the heaviest 15- or 20-min period observed, ranges from 1,048 passengers per hour for Birmingham to 8,500 passengers per hour for Market Street in San Francisco.

The passenger movement given in Table 1 for Market Street, San Francisco, is that for the motor buses and trolley coaches using the regular street roadways and designated bus stops. In addition, the five streetcar routes traversing this stretch carry 9,376 additional transit passengers per hour, based on the maximum 15- or 20-min rate. The total transit movement over this stretch, therefore, occurs at a rate of nearly 18,000 passengers per hour, a substantial movement for local transit operations on city streets.

Local Bus Service on City Streets with Reserved Transit Lanes

Table 1b gives peak-hour passenger volumes for local buses on city streets with reserved transit lanes in the prevailing direction of travel.

The seven entries comprise the data submitted by six cities. Passenger movements in the peak hour (heaviest consecutive 60-min period) range from 1,435 passengers per hour on 20th Street in Birmingham to 4,982 passengers per hour in Rochester. Absence of data for the heaviest 15- or 20-min period in Rochester prevents expression of this range in terms of the maximum hourly rate of passenger traffic flow.

Express Bus Service on City Streets

Table 2a gives peak-hour passenger volumes for express bus service on city streets with curb parking prohibited in the prevailing direction of travel except where otherwise indicated. The six entries comprise the observations submitted by a corresponding number of cities. Maximum hourly transit passenger traffic flow, based on the heaviest 15- or 20-min period observed, ranges from 371 passengers per hour for the Baltimore entry to 4,185 passengers per hour for Gravois Street in St. Louis.

Express Bus Service on Expressways

Table 2b gives peak-hour passenger volumes for express bus service on expressways. The 14 entries are divided into two groupings: the first four, comprising "specialized" expressway lanes into or out of a unique metropolitan terminal center of very high passenger and traffic density; and the last ten, comprising what transit and highway engineers might more commonly regard as expressways in the usual sense of the term.

The specialized high-density lanes approaching Manhattan show observed rates of maximum hourly transit passenger traffic flow ranging from 9,468 passengers per hour on the George Washington Bridge to 28,556 passengers per hour for the bus ramps leading into the Lincoln Tunnel from The Port of New York Authority Bus Terminal during the outbound P.M. passenger movement.

The orthodox expressway operations observed in the last ten entries show passenger movements ranging from less than 200 per hour for the San Antonio entry to 2,700 maximum hourly rate (based on heaviest 15- or 20-min period) for the West Memorial Freeway in Cleveland, the Bayshore Expressway in San Francisco, and (2,640) the Hollywood Expressway in Los Angeles.

The following information pertaining to the modest passenger volumes reported for Richmond and San Antonio may be of interest in connection with Table 2:

Richmond—The expressway does not lie in a location where it can be used by transit buses for heavy movements. It does, however, afford the transit operator an opportunity to give a very good service to a number of persons in an outlying suburban community.

San Antonio—The expressway system has not yet been developed to a point where maximum use can be made of it for transit operations. The example shown is a small but interesting shoppers' special operation where the shoppers in a residential area are collected in six buses and taken downtown for shopping via expressway at a considerable saving in running time, which appeals to the passengers and the downtown merchants.

The effective passenger capacity of a transit motor bus service, within the limits of practical operating ability and safety, is a function of the size of vehicle, the peak carrying value assigned to it for scheduling purposes, and the frequency (headway) of operation. It is influenced, particularly as to the speed with which it performs its services, by the nature of the facility provided for its operation and the nature of the traffic engineering or other appropriate controls applied thereto.

Figure 1 shows the effective passenger capacity in passengers per hour (one-way) in relation to the number of vehicles per hour passing the maximum load point. The diagonal lines represent the effective capacities for various sizes of buses from 35 to 50 seating capacity at scheduled load factors of 150 percent of the seating capacity in the peak (solid lines) period, and 125 percent of seating capacity (dashed lines) in the pre- and post-peak periods.

The upper portion of Figure 1 relates the frequency of service to vehicles per hour.

For example, the effective passenger capacity of 110 40-passenger motor buses per hour in rush-hour service would be 6,700 passengers per hour in the prevailing peak direction, and would provide a headway or frequency of service of slightly more than ½ min.

The validity of the effective passenger capacity values shown in Figure 1 is demonstrated by plotting thereon the actual observed passenger volume given in Tables 1 and 2, representing data from more than a dozen cities. These observations show that the curves of Figure 1 are realistic, and in accord with fact.

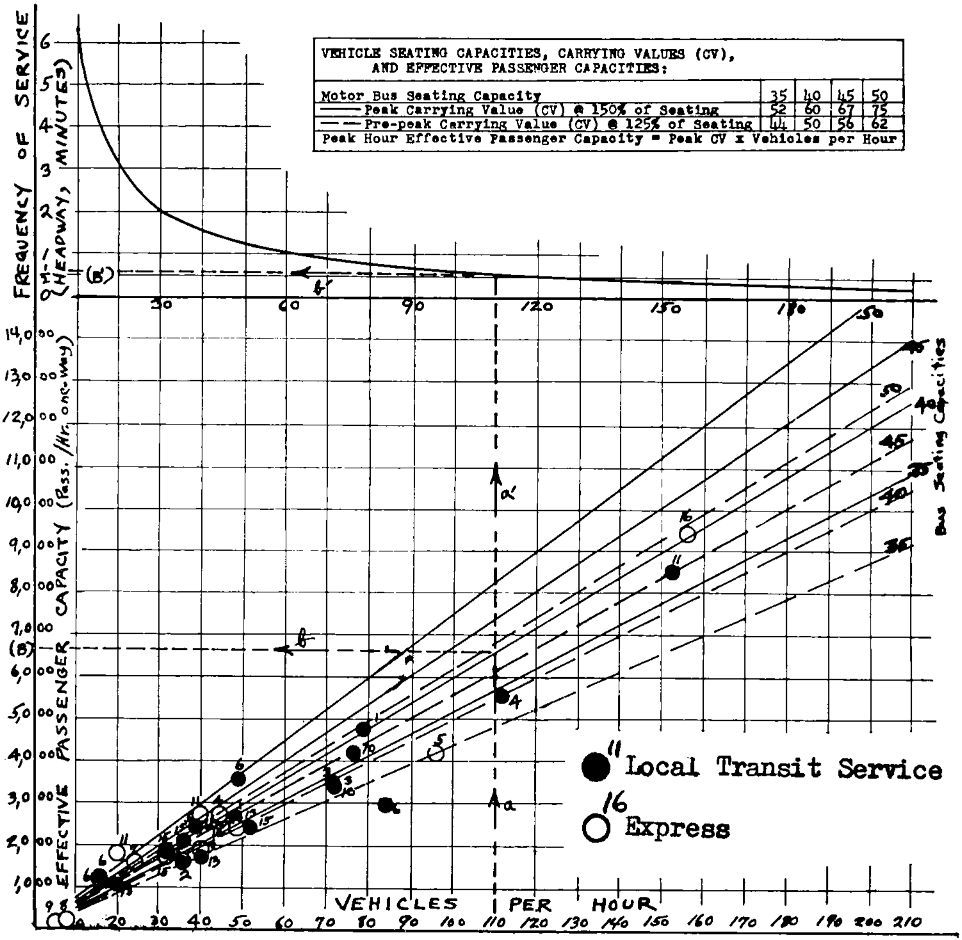
It is apparent from Tables 1 and 2 and Figure 1 that many of the transit facilities observed are not operating up to fully effective capacity at this time, and that they can be readily expanded through improved headways to handle more of the total movement in their respective urban areas as the desirability of doing so, from an over-all community standpoint, becomes apparent to public officials and the general public.

Rail Rapid Transit

Table 3 gives peak-hour passenger volumes for three recent conventional rail rapid transit installations on the North American continent. Selected for study were the Yonge Street subway in Toronto, the center mall rail service on the Congress Street Expressway in Chicago, and the private right-of-way and subway rail installation in Cleveland.

Maximum hourly transit passenger traffic flow, based on the heaviest 15- or 20-min period observed, ranges from 8,349 for the Cleveland entry to 39,840 passengers per hour for the Yonge Street subway in Toronto.

The Toronto installation is characterized by a large interchange of surface transit passengers at its outer terminus. Ten transfer platforms at street level for incoming and departing trolleycoaches and motor buses facilitate the process. Vehicles are unloaded at the approach end of each platform, moving forward after passenger discharge to pick up their loads at the other end of the platform.



Cities represented in the transit volume observations:

1. Baltimore	5. St. Louis	9. San Antonio	13. Birmingham
2. Rochester	6. Chicago	10. Dallas	14. Toronto
3. Atlanta	7. Philadelphia	11. San Francisco	15. New Orleans
4. Cleveland	8. Richmond	12. Los Angeles	16. New York

Figure 1. Effective peak-hour passenger capacity of transit bus service on city streets and expressways, with related frequencies of service. Plotted values are hourly rates based on heaviest observed 15- or 20-min period.

The terminal station at Eglinton handles about 18,000 passengers per maximum hour, with 15,000 in the heavy direction.

The Chicago installation shows interesting possibilities for the incorporation of rail rapid transit in urban expressways, using the center mall for trains in both directions flanked by parallel automobile roadways on either side. Ramps connect the station platforms to interchange stations at the level of the surface street overpass, where pedestrians, motorists and transferring bus passengers may enter and leave the rail service.

The Cleveland installation, although lower in peak passenger vol-

TABLE 1

PEAK HOUR PASSENGER VOLUMES BY LOCAL BUSES ON CITY STREETS WITH PARKING PROHIBITED

City	Facility	Length of Section (mi)	Traffic Lanes in One Direction (no.)	Transit Routes Using Street (no.)	Service Stops in Section (no.)	Capacity of Buses (no.)		Bus Movement		Automobiles (no.)	Passenger Movement (no.)				Average Speed (mph)	
											Buses		Autos			
						Seats	Total	Trips (no.)	Headway (min)		Peak Hour	15–20-Min Rate per Hr	Peak Hour	15–20-Min Rate per Hr	Buses	Autos
(a) Locations with Parking Prohibited																
San Francisco	Market St.[a]	1.1	3	8	8	46	69	130	0.5	730	7,553	8,500	1,095	1,208	5.2	10.0
Cleveland	Euclid Avenue	1.0	3	7	10	51	68	90	0.7	860	4,316	5,600	1,200	1,200	6.0	8.3
Baltimore	Baltimore St.	0.8	2	3	11	47	62	76	0.8	—	4,387	4,758	—	—	5.2	—
Dallas	Commerce St.	0.6	5	10	8	47	70	68	0.9	—	3,497	4,200	—	—	3.7	7.5
Chicago[b]	63rd St.[c]	10.3	2	2	93	51	80	40	1.5	904	2,748	3,540	1,356	—	12.2	14.2
Atlanta	Peachtree St.	0.3	2	6	3	45	65	66	0.9	770	2,668	3,440	1,400	1,476	3.1	4.3
St. Louis	Washington St.[d]	1.5	3	4	13	45	62	30	2.0	572	1,750	2,424	887	—	10.5	15.4
New Orleans[b]	Baronne St.	0.7	2	3	6	48	62	45	1.5	722	2,001	2,400	1,277	1,676	6.9	9.1
	Tulane Avenue	0.7	3	1	7	48	62	30	2.0	1,398	1,613	2,064	2,502	2,992	8.9	13.4
	N. Rampart St.	0.7	2	1	7	48	62	30	2.0	1,212	1,740	1,900	1,963	2,236	9.6	10.7
Rochester	State St.	0.8	3	2	8	—	—	27	2.2	—	1,080	1,576	—	—	8.7	—
Chicago[e]	Western Ave.[f]	15.8	2–3	1	134	51	80	17	3.5	1,140	1,060	1,268	1,710	—	9.5	13.6
Birmingham	Tuscaloosa Ave.	1.8	2	3	19	43	57	15	4.0	1,155	838	1,048	1,852	2,292	17.1	25.3
(b) Locations with Reserved Transit Lanes																
Rochester	Main St.	0.5	3	9	7	44	66	93	0.6	932	4,982	—	1,398	—	6.2	9.5
Atlanta	Peachtree St.	0.3	3	6	3	45	65	67	0.9	1,100	2,807	3,504	1,900	2,240	5.8	10.5
Dallas	Commerce St.	0.6	5	10	8	47	70	67	0.9	—	3,069	3,444	—	—	4.2	8.1
Chicago	Washington Bd.[g]	0.5	5	5	8	51	80	84	0.7	995	2,711	2,942	1,493	—	6.0	12.7
Birmingham	2nd Ave. North	0.8	4	8	7	43	57	44	1.4	1,413	2,301	2,712	2,308	2,548	5.5	13.7
Baltimore	Charles Street[h]	2.1	3	2	22	45	58	38	1.6	—	2,056	2,625	—	—	6.3	—
Birmingham	20th Street	0.4	3	7	4	43	57	35	1.7	500	1,435	1,708	810	904	3.4	14.5

[a] Steuart to Turk.
[b] Parking permitted.
[c] Naragansett to Stony Id.
[d] 18th to Grand.
[e] 8 percent restricted curb parking.
[f] Berwin to 79th.
[g] Wacker to State.
[h] Reserved transit lane for 0.87 mile.

TABLE 2

PEAK HOUR PASSENGER VOLUMES FOR EXPRESS BUS SERVICE

City	Facility	Length of Section (mi)	Traffic Lanes in One Direction (no.)	Transit Routes Using Street (no.)	Service Stops in Section (no.)	Capacity of Buses (no.)		Bus Movement		Automobiles (no.)	Passenger Movement (no.)				Average Speed (mph)	
											Buses		Autos			
						Seats	Total	Trips (no.)	Headway (min)		Peak Hour	15–20-Min Rate per Hr	Peak Hour	15–20-Min Rate per Hr	Buses	Autos
						(a) On City Streets										
St. Louis	Gravois [a]	1.3	5[b]	7	2	40	48	66	0.9	1,531	2,918	4,185	2,373	—	20.0	20.0
Cleveland	Clifton Blvd.	5.0	3	1	22	51	68	32	1.9	1,803	1,872	2,700	2,524	2,884	11.0	18.0
Chicago [c]	Archer Avenue	11.0	4	1	33	51	80	29	2.1	700	1,896	2,500	1,050	—	13.3	—
S. Francisco [d]	Van Ness-Brdy-Stockton	1.9	1–3	1	1	48	72	17	3.5	1,540	1,234	1,784	2,310	2,576	14.0	10–15
New Orleans [d]	Earhart Blvd.	2.0	2	2	0	51	65	25	2.4	1,357	1,267	1,620	2,198	2,424	20.2	24.4
Baltimore	Calvert Street	3.4	4	1	13	45	58	5[e]	8.0[e]	—	200[e]	371	—	—	11.2	—
						(b) On Expressways										
New York [f]	P.A. Bus Terminal	0.3	2	53	0	46[g]	64[g]	511	0.12	—	23,187	28,556	—	—	20.0	—
Union City, N.J.	Route 3	0.4	3	50	0	46[g]	64[g]	397	0.15	2,753	17,800	23,000	4,630	5,161	35.0	35.0
New York	Lincoln Tunnel	1.5	2	50	0	46[g]	64[g]	480	0.13	1,365	21,600	22,860	2,321	2,734	25.0	25.0
	George Wash. Bridge	1.1	4–5	28	0	46[g]	64[g]	136	0.44	3,659	6,936	9,468	6,220	7,766	35.0	35.0
Cleveland [h]	Shoreway W.	3.2	4	1	1	51	68	32	1.9	6,340	1,872	2,700	8,800	9,520	24.0	24.0
S. Francisco	Bayshore Exp'y	2.8	3–4	3	0	48	72	35	1.7	6,800	2,270	2,700	10,880	13,056	25.0	25.0
Los Angeles [h]	Hollywood Freeway	4.0	4	5	1	45–51	60	41	1.5	8,010	2,268	2,640	—	—	20.0	22.0
Atlanta	North Exp'y	1.5	3	6	0	45	55	19	3.2	4,915	803	1,892	8,500	—	31.0	31.0
Dallas	Central Exp'y	1.2	3	6	0	44	66	30	2.0	4,380	1,567	1,848	7,008	6,388	30.0	30.0
St. Louis	3rd St. Exp'y	1.3	3	4	0	40	48	30	2.0	1,265	1,349	1,584	1,961	—	38.0	40.0
Philadelphia	Schuylkill Exp'y	6.0	3	1	0	50	65	18	3.3	4,335	1,080	1,521	—	—	40.0	40.0
Chicago	N. Lake Shore Dr.	5.8	6	1	0	51	76	14	4.3	10,007	838	1,200	15,011	20,016	21.0	—
Richmond	Turnpike	5.1	3	1	0	45	67	4	15.0	686	166	240	1,029	—	34.0	55.0
San Antonio	N.W. Int. 10	2.0	2	2	1	32	48	6	10.0	2,959	158	—	4,439	—	25.0	33.0

[a] Dolman to Juniata.
[b] Includes one reversible lane.
[c] 80 percent restricted curb parking.
[d] Curb parking permitted.
[e] For 40-min period only.
[f] Bus lane.
[g] Rough average seating capacities range 41–51, total capacities range 48–80.
[h] Some stops.

TABLE 3

PEAK HOUR PASSENGER VOLUMES FOR THREE RECENT CONVENTIONAL RAIL RAPID TRANSIT INSTALLATIONS

City	Facility	Length of Section (mi)	Traffic Lanes in One Direction (no.)	Transit Routes Using Street (no.)	Service Stops in Section (no.)	Capacity of Buses (no.)		Bus Movement		Automobiles (no.)	Passenger Movement (no.)				Average Speed (mph)	
											Buses		Autos			
						Seats	Total	Trips (no.)	Headway (min)		Peak Hour	15–20-Min Rate per Hr	Peak Hour	15–20-Min Rate per Hr	Buses	Autos
Toronto	Yonge St. subway	4.6	—	1	10	496	1,360	28	2.0	1,110[a]	35,166	39,840	1,800	1,870	17.6	12.3
Chicago	Center-Congress Exp'y	1.0[b]	5[b]	2	2	294	600	25	2.5	5,150	10,376	14,542	7,722	—	24.5	—
Cleveland	Private R/W and subway	7.0	—	1	6	238	450	20	3.0	—	6,211	8,349	—	—	28.0	—

[a] Automobile operation on Yonge Street, above the subway.
[b] Stretch represents densest "transit" mile of rail rapid transit operation, where two routes converge; consists of track and four auto lanes.

ume, is of great interest because of the growth of park-and-ride and kiss-and-ride activities. This operation illustrates the desire of many motorists to use their automobiles for part of the journey to the central business area, completing it via public rapid transit, thus avoiding driving in the more congested areas and the problem of finding a downtown parking space. Automobiles are left at the rapid transit parking lots, or with another member of the family for use during the day.

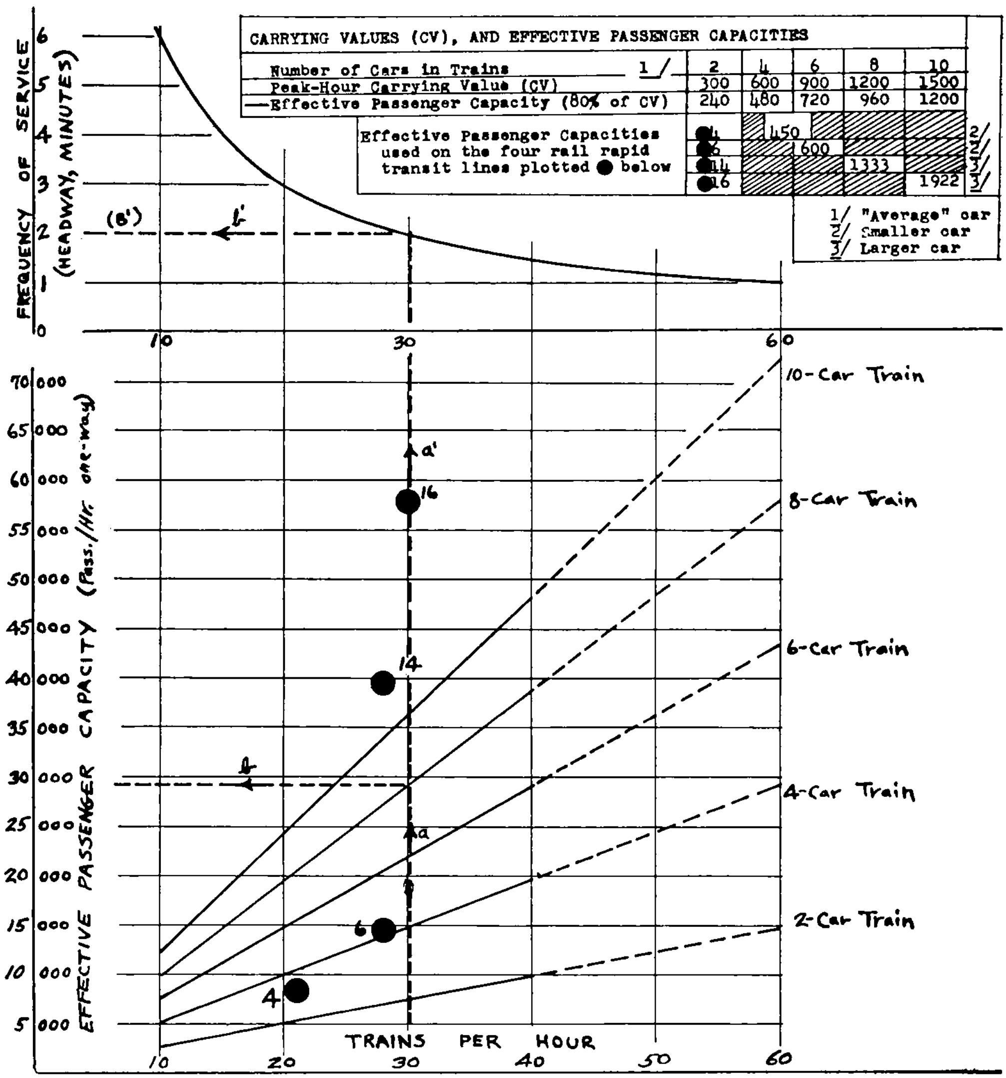
The effective passenger capacity of a rail rapid transit service, within the limits of practical operating ability and safety, is a function of the size of car, the peak carrying value assigned to it for scheduling purposes, the number of cars in the train, and the frequency (headway) of train operation. Track and signal capacities, station platform lengths and arrangements, and the capacities of station stairways, ramps and escalators are important factors in determining the limits of practical operating ability and safety.

Figure 2 shows the effective passenger capacity in passengers per hour (one-way) in relation to the number of trains per hour passing the maximum load point. The diagonal lines represent the effective capacities of trains of various lengths, based on an assumed "average" car as defined at the top of the chart.

The upper portion of Figure 2 relates the frequency of service to vehicles per hour.

For example, the effective passenger capacity of 40 10-car trains per hour of average car size would be 48,000 passengers per hour in the prevailing direction, while providing a headway or frequency of service of 1½ min.

The validity of the effective passenger capacity values shown in Figure 2 is demonstrated by plotting thereon the actual observed passen-



Cities represented in the transit volume observations:

4. Cleveland
6. Chicago
14. Toronto
16. New York

Figure 2. Effective peak-hour passenger capacity of rail rapid transit service on private right-of-way, expressways, and subways, with related frequencies of service. Plotted values are hourly rates based on heaviest observed 15- or 20- min period.

ger volumes given in Table 3. Making due allowance for the fact that the rapid transit cars in Cleveland and Chicago are smaller than the "average" car of the chart, and that the Toronto car is larger, these observations indicate that the values shown in Figure 2 are realistic and susceptible of achievement.

It is apparent from Table 3 and Figure 2 that the three rail installations depicted are not operating up to fully effective capacity at this time, and that they can be readily expanded through improved headways to handle more of the total movement in their respective areas as the desirability of doing so, from an over-all community standpoint, becomes apparent to public officials and the general public.

Figure 3 shows the morning inbound passenger flow for the maximum hour (60 consecutive minutes) on a typical weekday in May 1959 on the Yonge Street subway. This value reaches 24,774 passengers per hour over the heaviest section of the route.

The corresponding value for the maximum rate of hourly passenger flow over this same section, based on the heaviest 15-min period, was 29,164 passengers per hour. From this point on, alighting passengers exceed boarding passengers as transit riders reach their destinations near or within the central business district. The locations of parking lots and the distances between stations are indicated on the diagram.

The greatest volume of boarding passengers, more than 50 percent of the total riders accumulating over the heaviest section, occurs at Eglinton Station (A), where 13 surface transit routes connect with the terminal of the subway rail line. Studies at this point show the following breakdown of the 15,613 passengers entering the subway at this point during the maximum A.M. rush hour:

Passenger Type		Number of Passengers	Percent of Total Passengers
Transfer from transit lines		13.041	83.5
Pedestrian entering on foot		2.572	16.5
Including:			
Taxi pass.	14		
Kiss-n-ride pass.	254 [1]		
Park-n-ride pass.	5 [2]		
Sub-total	273		(1.7)

[1] Passengers brought to rail line by automobile.
[2] Although there are only five park-n-ride passengers at this station during the maximum hour, there are 34 passengers from 9:30 to 10:30 A.M., indicating a willingness to pay a relatively high parking fee for short-term parking close to the subway, but not for all-day parking. There are probably 200 to 300 all-day park-n-ride motorists who park up to ¼ mile from this station. but cannot be identified as such on entering the station.

Figure 4 shows the morning inbound passenger flow for the maximum hour on a typical weekday in May 1959 on the center mall rail operation of the Congress Street Expressway. This value reaches 6,282 passengers per hour over the heaviest section of the Congress Street "leg," and 12,391 passengers per hour on Congress Street below the point of convergence with the Douglas Park Branch.

The corresponding values for the maximum rates of hourly passenger flow over these same sections, based on the heaviest 15-min period, were 7,140 and 14,080 passengers per hour, respectively. The locations of parking lots and the distances between stations are indicated on the diagram.

Volumes of inbound automobile passengers on the parallel roadways for the corresponding 60-min period are shown to scale on the drawing. These data were furnished by the Cook County Highway Department, based on three locations where vehicle counters are operated. Highway department counts of November 9, 1960, were used. An earlier count would have given a distorted figure because the stretch of expressway between Des Plaines and Central Avenues was only recently (October 12, 1960) opened to traffic.

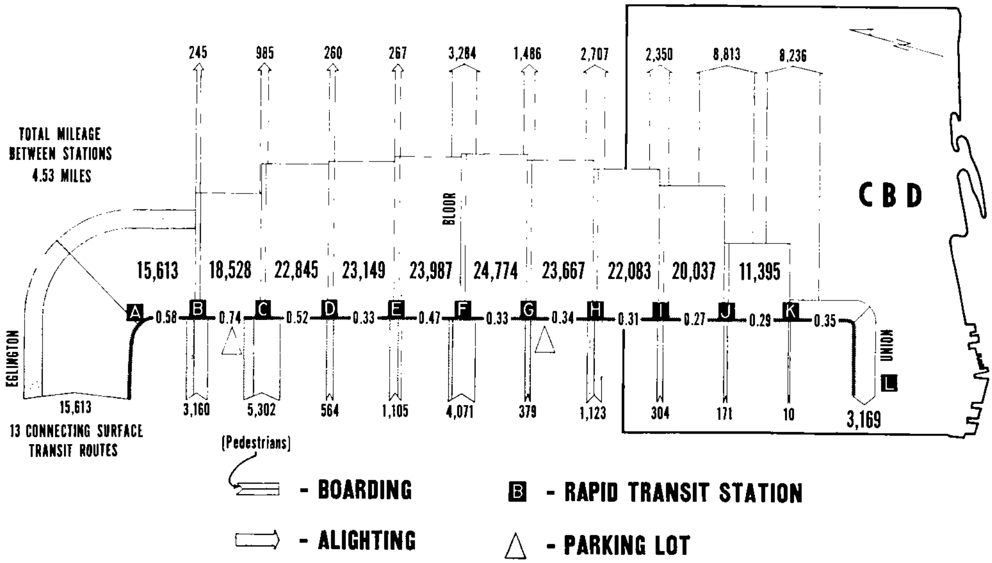


Figure 3. Inbound rail rapid transit peak-hour passenger flow, Toronto; typical weekday (May 1959) A.M. rush.

A significant volume of park-and-ride and kiss-and-ride movement characterizes this rapid transit route. Figure 4 shows a breakdown of boarding passengers at each station according to their methods of arrival.

Figure 5 shows the morning inbound passenger flow for the maximum hour on a typical weekday in January 1960 on the rail rapid transit route in Cleveland. This value reaches 6,015 passengers per hour over the heaviest section of the west-side route, before it enters the central business district.

The corresponding value for the maximum rate of hourly passenger flow over this same section, based on the heaviest 15-min period, was 6,860 passengers per hour.

The locations of parking lots and

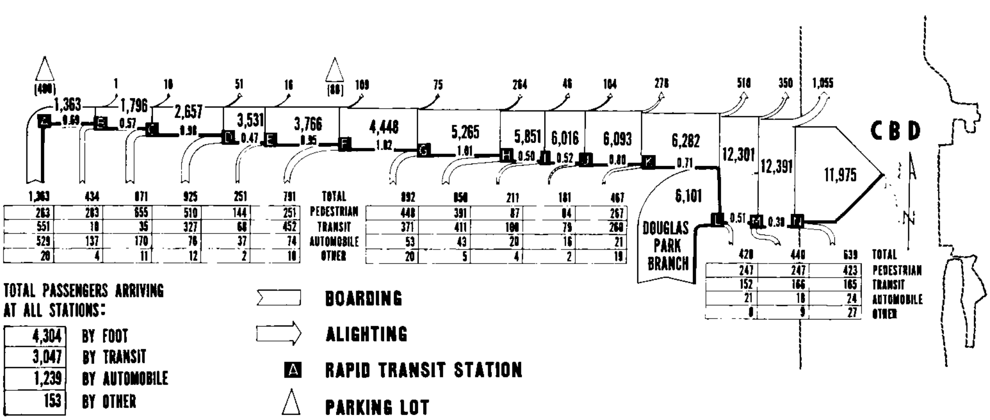


Figure 4. Inbound rail rapid transit peak-hour passenger flow, center mall rail operation in Congress Street Expressway, Chicago, typical weekday (May 1959) A.M. rush.

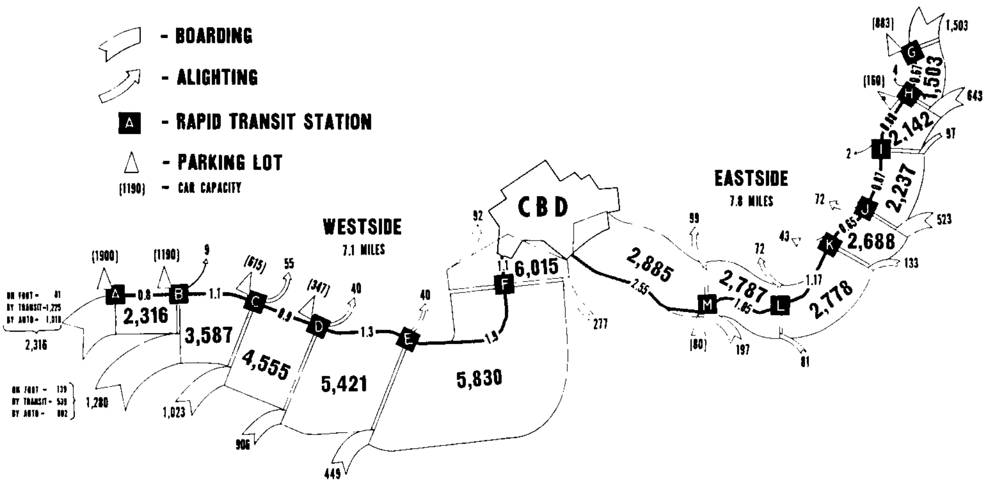


Figure 5. Inbound rail rapid transit peak-hour passenger flow, Cleveland; typical weekday (January 1960) A.M. rush.

the distances between stations are indicated on the diagram. Several of the lots have rather high car capacities. (Those at stations A, B, C and G, for example, have capacities in excess of 500 automobiles. The largest lot at the westside line terminal, shown in Figure 5 at 1,900 cars in early 1960, now has a capacity of 2,200 autos.)

A high volume of park-and-ride movement, together with some kiss-and-ride activity, characterizes this rail operation, which is routed over private right-of-way in outlying sections and in subway in the center city. Figure 5 shows a breakdown of boarding passengers at stations A and B on the westside operation, according to their methods of arrival.

CAPACITIES OF BUS STOPS ON CITY STREETS AND ON EXPRESSWAYS

For efficient and convenient transportation in, through, or around congested urban areas, adequate provision must be made for parking, and for loading and unloading persons and goods. The movement of automobiles, public transit vehicles, and trucks must be given precedence over the need for parking and loading and unloading of goods.

The National Committee on Urban Transportation, in its working manual 7A, entitled "Standards for Street Facilities and Services," urges the following order of preference in allocating curb space:

1. Loading and unloading of persons.
2. Loading and unloading of goods.
3. Parking.

Bus Stops on City Streets

Experience indicates the desirability, in local motor bus operations, of the following frequency or spacing of service stops:

In ordinary residential areas the number of local surface transit stops should not exceed seven per mile.

In commercial and industrial areas the number and location of local surface transit stops should be determined in each case by (a) the character of commercial or industrial development and (b) concentrations of people and their demonstrated dependence upon transit services.

In crowded downtown areas where there are concentrations of stops of several transit routes on a few major streets, consideration may be given to the possibilities of (a) expanded peak-hour bus stop lengths, (b) reserved transit lanes, and (c) provision of alternate stops for the several routes.

In determining bus stop locations consideration must be given to such items as bus routing, frequency of service, traffic volumes, pedestrian movements, transit rider origins and destinations, transfer movements between lines, and the nature and location of traffic control devices.

The optimum location of bus stop zones will depend on conditions prevailing at each intersection, and should be determined only after adequate study. Objectives include convenience and safety of passengers, avoidance of serious conflicts with other traffic, minimizing pedestrian movements across high-volume streets, safe and expeditious movement of buses into and out of stop zones, and adequate capacity (length) of bus stops to meet the scheduled requirements of all routes using them without undue traffic delay or excessive passenger interchange time.

For example, when buses are required to make a left turn in traversing their routes, bus stops should not be located on the near side of the turn, but should be placed on the far side of the street entered. Where buses turn right on a short curb radius, other conditions being equal, a mid-block stop has certain advantages. At intersections where many vehicles turn right, far-side stops may be preferred to avoid conflicts. On the other hand, far-side stops might not prove satisfactory where accumulations of buses even occasionally exceed the capacity of the bus stop zone.

Location of bus stops near side, so that passenger interchange periods are more or less coincident with traffic signal timing, helps minimize delays to transit and general traffic.

Generally speaking, traffic specialists say that (a) where parking is prohibited, higher street capacities are achieved when bus stops are located on the far side in downtown areas, and on the near side in other areas, and (b) where parking is permitted, except in the bus stop zone, street capacity is increased when bus stops are located on the near side of the intersection.

Regardless of their position—near side, far side, or mid-block—adequate bus stop zone length must be provided to handle the accumulation of buses likely to use the zone at the same time. Table 4 gives the minimum desirable length for bus curb-loading zones. Lengths should be adjusted upward from this minimum standard in the light of local experience as headway intervals between vehicles using a zone decrease.

Adequate provision must be made in all areas—residential, commercial and industrial—for safe and convenient pedestrian access to bus stop zones.

Expanded Peak-Hour Bus Stops

Table 1 shows a high volume of travel by motor bus and trolley coach on Market Street, San Francisco. Transit headways during the heaviest peak hour are closer than ½ min, and the actual passengers carried in that hour exceed 7,500. Rate of passenger flow in the heaviest schedule period reaches 8,500 passengers per hour.

The arrangement of bus stops on Market Street has been a major factor in achieving such capacities. The eight bus stops in the heaviest stretch (Steuart to Turk Streets) average normally 130 ft in length. During the heaviest peak hour "advance stop bars" are used at five of these stops to increase temporarily their capacity for buses and passenger in-

TABLE 4
MINIMUM DESIRABLE LENGTHS FOR BUS CURB-LOADING ZONES[1]

Approx. Bus Seating Capacity	Approx. Bus Length (ft)	Loading Zone Length[2] (ft)					
		One-Bus Stop			Two-Bus Stop		
		Near Side[3]	Far Side[4]	Mid-Block	Near Side[3]	Far Side[4]	Mid-Block
30 and less	25	90	65	125	120	90	150
35	30	95	70	130	130	100	160
40–45	35	100	75	135	140	110	170
51	40	105	80	140	150	120	180

[1] Source: American Transit Assn.
[2] Measured from extension of building line, or from an established "stop" line, whichever is appropriate. Based on side of bus positioned 1 ft from curb; if bus is positioned as close as 6 in. from curb, 20 ft should be added to near-side stops, 15 ft to far-side stops, and 35 ft to mid-block stops.
[3] Increase 15 ft where buses are required to make a right turn. If there is a heavy right-turn movement of other vehicles, near-side stop zone lengths should be increased 30 ft.
[4] Based on roadways 40 ft wide, which enable buses to leave the loading zone without passing over centerline of street. Increase 15 ft if roadway is 36 ft wide, and 30 ft if roadway is 32 ft wide.

terchange. The advance stop bars are painted in the pavement 40 to 50 ft beyond the head ends of the regular stop zones. The first bus pulls up to that point, thus permitting the loading and unloading of three or four buses simultaneously at each of the expanded stops along this busy stretch during the heaviest hour.

Reserved Transit Lanes

A number of cities have taken steps to assure adequate bus stop capacity at peak periods by adopting "reserved transit lanes." Among these are the six cities listed in Table 1b. In the case of Chicago, the reserved lane is the center lane of a one-way street. In all other cases the reserved transit lane is the curb lane. Such lanes are reserved exclusively for the use of transit buses in movement and passenger interchange.

In each instance where the reserved transit lane has been adopted, a significant improvement has been noted in both transit and general traffic speeds (see Table 5) over the stretch of street involved. The advantages of the reserved transit lane have aroused the interest of the Institute of Traffic Engineers, whose Technical Committee 3-D on Reserved Transit Lanes has reviewed experience and operating data from cities with transit lanes, and has developed warrants and operating criteria for the establishment and operation of such lanes.

The ITE Committee has concluded that a curb transit lane is practical, under normal circumstances, at hours or under access conditions when curb

TABLE 5
IMPROVEMENT IN SPEEDS THROUGH RESERVED TRANSIT LANES

City	Speeds, Heaviest Hour (mph)				Improvement (%)	
	Before Reserved Lane		After Reserved Lane			
	Transit	Auto	Transit	Auto	Transit	Auto
Baltimore[1]	4.9	10.3	6.9	13.6	40.8	32.0
Rochester	5.8	5.7	6.2	9.5	7.0	67.0
Atlanta	4.6	6.3	5.8	10.5	26.0	67.0
Dallas	3.7	7.5	4.2	8.1	13.5	8.0
Birmingham	5.2	11.4	6.6	16.4	27.7	44.0

[1] From report to The Baltimore Transit Company by the Department of Transit and Traffic, City of Baltimore.

access of vehicles to service abutting property can reasonably be prohibited, and justified if the flow of transit vehicles is 60 per peak hour, or 400 per 12-hr period. Other conditions are stipulated in its report (*1*), which suggests a minimum of 75 transit vehicles per hour and 500 transit vehicles per 12-hr period per transit lane to justify a full-time reserved center transit lane.

In a foreword to the report, the Committee says: "It should not be concluded that the Committee does not recommend the establishment of a transit lane under circumstances that do not meet the suggested warrants, or under operational criteria which are at variance with those listed (in the report) if such establishment may be otherwise justified with official and public support."

Bus Stops on Expressways

Table 2 indicates that most of the reported express bus operations on expressways operate nonstop on the expressway portions of the transit route. In three of the reported instances there is a single service stop in the freeway stretch.

At this stage of experience, the operation of express and rapid transit services on urban expressways is essentially in its infancy. Students of the problem visualize the following future possibilities (*2*):

1. Express bus operation on expressway.
   - (a) Stops at surface level.
   - (b) Bus turnouts and stop facilities at freeway level.
   - (c) Separate bus roadways as central business area is approached.
   - (d) Special bus roadways and appropriate stop facilities throughout.
   - (e) Special bus roadways and automated bus trains.
2. Rail rapid transit service in expressway right-of-way.

Development of any or all of these forms will require provision of adequate and appropriate stop facilities for express transit service.

Freeway Bus Stop Capacity

Opportunity for freeway buses to stop for the purpose of discharging, loading and transferring passengers may be provided either within or outside the freeway right-of-way. A number of schematic layouts of bus stops have been given by the American Association of State Highway Officials (*2*).

If the layout of a freeway bus stop is of the type which does not require the bus to cross any other vehicle stream at grade, its capacity will be affected primarily by the dimensions of the loading area and the problem of reentry into the freeway.

Loading Area. Capacity principles applicable to off-street terminal loading areas are equally applicable to freeway loading areas where such areas are physically separated from all other roadways. The capacity is dependent on the number of loading stations, and on the design of the vehicles (rate of discharging and loading). The situation differs from that of an off-street terminal only in that the coaches, instead of being completely cleared or loaded, receive and discharge only a few passengers each. Hence, the number of alighting and boarding passengers per bus should be estimated to calculate the length of time each bus will be at a loading station (see Tables 6 and 7, and Figure 6).

Reentry to Freeway. Although no data are available to show the extent to which problems of reentry of a bus into a crowded freeway lane may reduce capacity of the bus stop, it is assumed that this will not become a major factor if the acceleration lane from the bus stop is designed to permit the bus to achieve full running speed before arriving at the merging

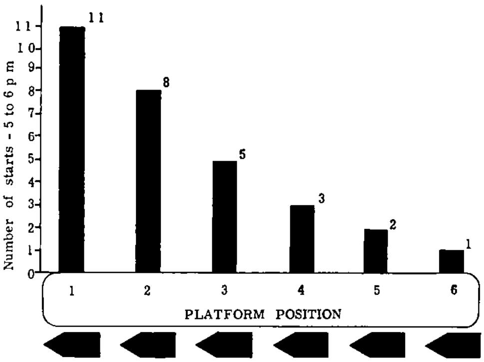


Figure 6. Rush-hour starts per berth as related to platform loading position, Port of New York Authority Bus Terminal.

area. This is equally applicable whether the buses merge into an on-ramp or into the freeway itself.

If the layout of a freeway bus stop involves crossing another vehicle stream at grade (for example, if the bus stop is at the cross-street level), the capacity of the bus stop will be further limited by the capacity of such an intersection. The intersection must be analyzed with general capacity principles in mind. There will be almost no reduction in capacity if buses always have the right-of-way at such an intersection (either through STOP signs on the cross street or through a preempting traffic-actuated signal). Capacity reductions will be more substantial if the buses must wait for a green phase in a traffic signal cycle, or for a gap in the crossing stream where the latter has the right-of-way.

Freeway bus stop capacities may also be reduced if the bus roadway at the loading stations does not permit one bus to pass another. Where two or more loading stations are required and heavy discharging and loading of passengers is anticipated, the same geometric principles as used in the island type of off-street terminal layout should be used.

TABLE 6

PASSENGER HEADWAYS ON AND OFF BUSES: TYPICAL WEEKDAY RUSH HOUR, TO AND FROM WORK

Condition	Item	Time (sec)
Unloading	Little hand baggage and parcels; few transfers.	1½–2½
	Moderate hand baggage or many transfers.	2½–4
	Considerable baggage from racks . .	4–6
Loading	Single coin or token fare box	2–3
	Odd-penny cash fares	3–4
	Mult.-zone fares:	
	Prepurch. tickets and regis. by driver.	4–6
	Cash including regis. by driver	6–8

CAPACITIES OF OFF-STREET BUS LOADING AND UNLOADING PLATFORMS

In order that bus loading and unloading operations do not restrict the capacity of streets and highways, it is often necessary to provide off-street station facilities. At transfer points of high passenger density, and at terminal points in central areas, layouts must be carefully planned to provide adequate facilities.

The design of off-street facilities involves many factors. It is beyond

TABLE 7

BUS POSITIONS REQUIRED FOR VARIOUS PASSENGER AND BUS HEADWAYS

Sched. Bus Headway (min)	Bus Positions Required								
	Pass. Hdwy. 3 Sec.			Pass. Hdwy. 5 Sec.			Pass. Hdwy. 7 Sec.		
	30 Pass.	45 Pass.	60 Pass.	30 Pass.	45 Pass.	60 Pass.	30 Pass.	45 Pass.	60 Pass.
2	1	2	2	2	2	3	2	3	4
5	1	1	1	1	1	1	1	2	2
10	1	1	1	1	1	1	1	1	1

the scope of this paper to consider these in detail, but the following outline indicates the many considerations:

Factors Affecting the Capacity of Bus Loading and Unloading Platforms

Physical Layout of Platform Areas
- Platform width, length, and pedestrian access and egress.
- Bus runway width; bypass possibility around standing buses.
- Arrangement of passenger queueing.
- Common or separate loading and unloading platforms.
- Free-flowing bus access and egress to platforms.
- Roadway connections to street system.

Nature of Bus Operations
- Bus headways; number of different routes at platforms.
- Enroute station or end-of-line station.
- Size of buses and door provisions.
- Dispatch efficiency, communications and holding areas.
- Express or local buses.

Passenger Considerations
- Fare collection system.
- Regular users or occasional users.
- Amount of baggage.
- Shelter provided for queued passengers.

From observations of bus loading and unloading operations, basic design information has been gathered (Tables 6 and 7, and Figure 6).

The values shown in Table 6 for loading and unloading operations indicate the wide range of passenger headways, depending on the amount of baggage and the fare collection procedure. For example, loading time can increase threefold with complicated multi-zone fares. The headways shown are purely for the passenger movements, and platform provisions must allow for off-schedule variations. For example, a bus load of 50 passengers leaving the bus on a 2-sec headway would require less than 2 min to unload. If similar bus loads arrived on a 2-min headway, theoretically one berth would be adequate. In practice, however, schedule or running time variations would make two berths necessary even under good operating conditions.

Table 7 presents the requirements for available loading positions for various combinations of bus headways, passenger loading headways, and passengers loaded per bus. These requirements are based only on the passenger loading time, and additional berths would be required to allow for bus movement delays.

Figure 6 presents actual operating data from the 72 loading berths of the suburban bus level of the Port Authority Bus Terminal in New York City. This level is used by 14 different bus lines and has 15 separate loading platforms of from two to seven berths each. Four- and five-berth platforms are most common and all bus runways are single-lane except at one platform. Multiple routes are operated by most of the bus lines and have varying headways to meet route loads. The loading platforms are operating essentially at capacity during the evening rush hour. Figure 6 shows the actual average bus starts, or departures, per hour by platform berth position. Readily apparent is the sharp drop in starts per hour for the rear berth positions: the first berth had as many starts as the 3, 4, 5 and 6 berths combined.

It is noted that the first berth position, where the shortest headway routes are placed, averaged a headway of 5.5 min, whereas the actual loading time for the bus (say 50 passengers at 3 sec each) was less than 3 min. In other words, under the operating conditions prevailing, the actual headway for the most active position was about twice the normal loading time.

A last comment on Figure 6 concerns its implication as to the optimum number of berths per platform. Obviously, if space and cost considerations are ignored, single-berth platforms would produce the most starts per berth. However, in most station locations, efficient space utilization is a major requirement. The space required for the platform and bus runway for a single berth is about 22 ft by 41 ft, or 900 sq ft. For access to this berth, a portion of the platform circulation roadway must be assigned to each platform. In this particular terminal layout an area 22 ft by 50 ft is required at each end of the platform, or a total of 2,200 sq ft. Based on these two space requirements and the starts-per-hour data from the various berth positions in Figure 6, the following calculations have been developed:

No. of Berths per Platform	Area (sq ft)			Peak-Hour Starts	Area per Start (sq ft)
	Platform and Runway (sq ft)	Circul. Roadway	Total		
1	900	2,200	3,100	11	282
2	1,800	2,200	4,000	19	210
3	2,700	2,200	4,900	24	204
4	3,600	2,200	5,800	27	214
5	4,500	2,200	6,700	29	231

Thus, the calculations show a requirement of from 204 to 282 sq ft per peak-hour start. Under the particular conditions at this terminal, it appears that platforms of from two to four berths give better space utilization. It is noted that the peak-hour start data were gathered from predominantly four- and five-berth platforms where loading at the fourth and fifth positions occasionally interferes with use of the leading positions. Consequently, the data somewhat minimize the efficiency of operation in the leading berths. To generalize, two- and three-berth loading platforms appear most desirable for a central area terminal of this type.

The general layout or arrangement and size of platforms and runways for off-street bus terminals should be determined from studies of the types previously described, as well as many others, depending on the particular problems of the project involved.

REFERENCES

1. "Report of Institute of Traffic Engineers' Technical Committee 3-D on Reserved Transit Lanes." *Traffic Eng.* (July 1959).
2. "A Policy on Arterial Highways in Urban Areas." Amer. Assn. of State Highway Officials, pp. 289-293, 357-370, 435-437 (1957).

DISCUSSION

GEORGE W. HOWIE, *Director of Public Utilities, Cincinnati, Ohio*:—Exclusive bus lanes, mentioned favorably in this report, have merit under some circumstances, but are not invariably beneficial to traffic flow or even to transit movement.

Tests in Cincinnati (1958) indicated that when traffic in peak hours is moving at or close to the practical capacity of the street, introduction of an exclusive bus lane reduces the total capacity of the street and, conlays in the traffic stream. This effect sequently, may result in increased de- was so severe on Fourth Street (Cincinnati) that the bus movement itself was retarded.

This test, made on a downtown one-way street, 40 ft curb-to-curb width over a 5-block length of about 2,400 ft, showed an average increase of 10.5 percent in bus travel time in the 4 to 6 P.M. peak. During the morning peak, when congestion was less severe, bus travel time decreased 2.2 percent.

At the same time, average travel time for the traffic stream as a whole was much more severely increased by use of an exclusive bus lane in the right-hand curb lane. Average travel time for all traffic increased 25.3 percent in the afternoon peak and 20 percent in the morning peak.

Setting aside one of the four available lanes for the exclusive use of buses resulted in overloading the three remaining lanes, thus creating additional delays in the general traffic stream. Buses in the curb lane were prevented by heavy traffic from passing other buses stopped for loading, turning, or other reasons, with the result that delays in the exclusive bus lane tended to become cumulative.

Observations of exclusive bus lane trials in other cities indicate that these efforts usually include other traffic improvements which may constribute more to expediting the traffic stream than may be derived from the bus lane itself. Such improvements include street markings, parking controls, traffic signal retiming, and "No Standing" regulations in curb lanes.

This point of view also is supported by W. A. Carsten, Director of Traffic, Dallas, Tex., who writes: "The greatest reason, undoubtedly, for our increase in speeds was due to the elimination of a 'scramble system,' which previously had taken up 17 seconds of the total cycle length for a walk interval. At the same time the bus lanes were put into effect, 'walk' and 'don't walk' signals were installed at several locations on the streets and also certain turns, both right and left, were prohibited."

Cincinnati's experience seems to indicate that exclusive bus lanes are no substitute for over-all good traffic management. The principal objective should be to improve movement of the total traffic stream, thus effectively increasing working capacity of the street. No element in the traffic stream can move much better than the stream itself. Setting aside part of the street for a specialized use reduces capacity of the street; therefore, if the full capacity of the street is needed for traffic movement at peak times, an exclusive bus lane may produce negative results.

A strict "no-standing-or-parking" regulation in downtown right-hand curb lanes on bus routes is being enforced in Cincinnati. This, coupled with other good traffic controls, has been found to be most effective in expediting peak-hour bus movement as well as total traffic movement.