Coordinated Highway-Transit Interchange Stations

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The San Francisco Bay Area Rapid Transit project will consist of a 75-mile grade-separated regional rapid transit system, with schedule speeds of 45 to 50 mph and 33 rapid transit stations. Extensive planning and research have been conducted during the past 12 years on methods of attracting and accommodating the various access modes of travel to and from the stations. The objective of these studies was to provide the coordinated and integrated highway-transit interchange facilities necessary to the success of the system and to the alleviation of major corridor congestion.

An extensive postcard survey was conducted on the Bay Area Peninsula commute line of the Southern Pacific Company and additional data were provided by the Cleveland Transit System, with respect to access mode characteristics at outlying collector rapid transit stations. Other pertinent data have been evaluated and analyzed from other transit systems in America and abroad.

Station planning criteria and observations are presented in their several aspects. Access mode distributions, parking stall capacities, loading roadways, and facilities for walkers, feeder transit, taxis, kiss-riders, parkers, and bicycles are described and discussed. General aspects of highway-transit interchange station planning and design are reviewed. It is emphasized that system and station planning is a continuing process.

•CURRENT transportation planning interest is intensively focused on methods of coordinating, and providing interchange between, highways and public transit facilities in growing urban regions. These expanding needs are well understood by highway and transit planning officials. The objective is to optimize the utilization of each travel mode in its proper sphere and to minimize the critical peak period transportation capacity, investment, and operating costs required to serve major regional corridors and gateways properly.

Important provisions of the Federal-aid Highway Act of 1962, the Urban Mass Transportation Act of 1964, and the Federal Housing Acts of 1954 and 1961 require that urban planning assistance programs of the U.S. Bureau of Public Roads (BPR) and the Housing and Home Finance Agency (HHFA) give careful consideration to each mode of travel and emphasize the necessity for comprehensive, cooperative, and continuing transportation planning processes in all American urban regions. Before July 1, 1965, to be eligible for further Federal highway assistance, all American metropolitan areas of over 50,000 population must have such a recognized transportation planning process under way.

Since the initiation of planning and design studies for the San Francisco Bay Area Rapid Transit (BART) System in 1953, it has been recognized (1, 2) that a high degree

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of coordination and interchange will be essential between the growing street and highway facilities of the area and the rapid transit system. Present planning calls for over 23,000 parking stalls initially at 23 of the 33 rapid transit stations, careful coordination with feeder transit lines, and facilities for kiss-ride and taxi access to the stations. Figure 1 shows the three-county BART system which the voters approved for construction in November 1962.

On a rapid transit system, the stations themselves must be the foci to encourage the interchange of passengers with their automobiles and the street and highway facilities. During all of the past 12 years of planning for the BART system, and particularly during the past 6 years (3), this subject has been under intensive investigation. It is the purpose of this paper to discuss the research, planning, and proposed standards developed thus far in the program and to illustrate some interchange station concepts which are under consideration as BART enters the stage of final planning, design, and construction.

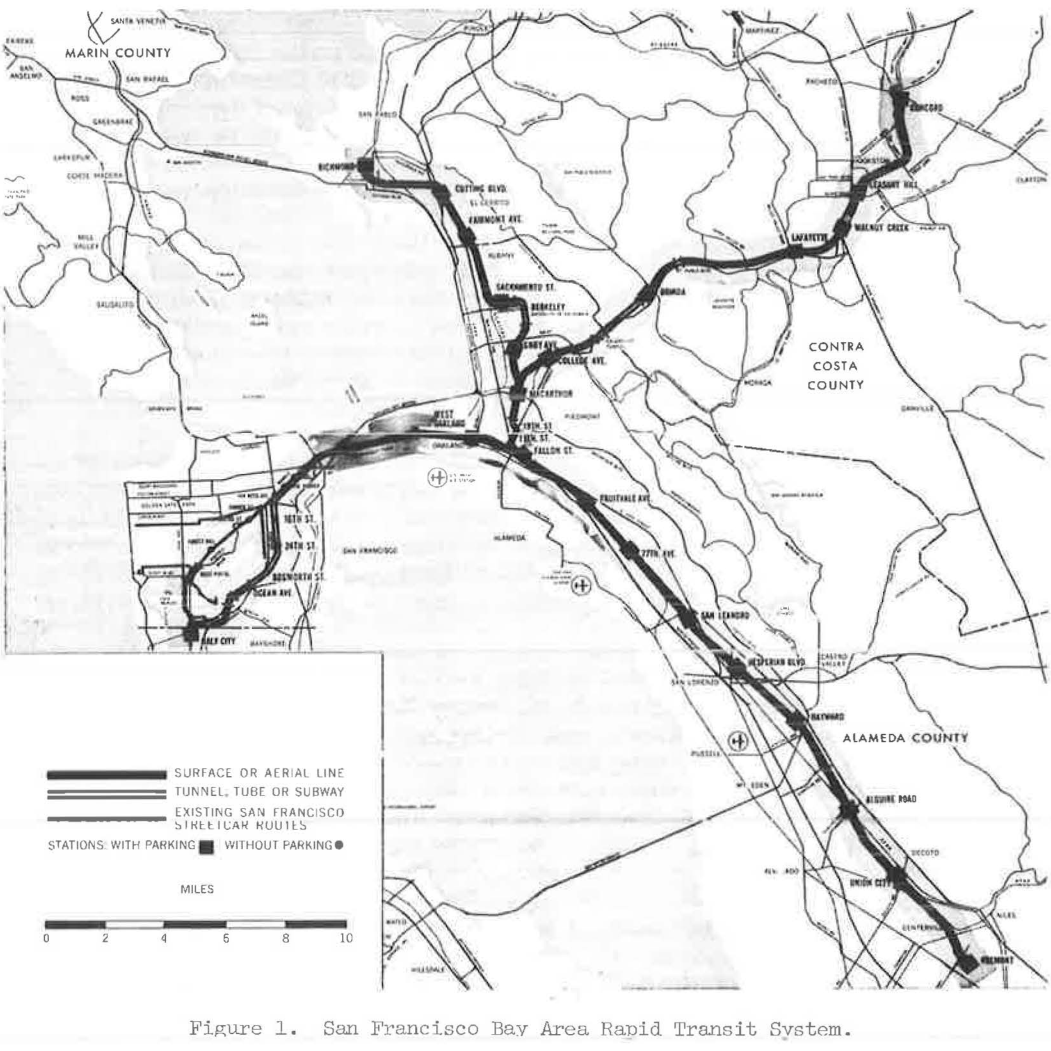

Figure 1. San Francisco Bay Area Rapid Transit System.

FIELD SURVEYS

To help determine the characteristics of Bay Area passengers arriving and leaving commuter stations, a 12,300-postcard survey was conducted on the Peninsula San Francisco-San Jose commute line of the Southern Pacific Co., which then carried approximately that number of riders in weekday round trips. Figures 2 and 3 illustrate the survey form distributed to all passengers on outbound S. P. trains from the San Francisco terminal on Tuesday, Jan. 19, 1960. Despite the length of the form, advance publicity and survey design enabled a 67 percent usable return to be obtained, which provided much valuable data on existing station access mode characteristics in the Bay Area. Tables 1 and 2 provide some of the results from this survey.

DEVELOPMENTS ELSEWHERE

During the past 7 years, the Cleveland Transit System (CTS) has conducted similar access characteristics studies at its outlying rapid transit stations, where 5,225 parking spaces are now provided (4). Through the courtesy of Donald C. Hyde, General Manager of CTS, acting as consultant to the BART project, pertinent CTS data were made available and used in BART system planning. Tables 3 through 6 present some of these data. A map of the CTS appears in Figure 4. Figures 5 and 6 illustrate the various external facilities at CTS' largest parking station, West Park, located at the present western terminal of the CTS rapid transit line.

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RAPID TRANSIT TRAVEL SURVEY

Parsons Brinckerhoff - Tudor - Bechtel
Room 1100
833 Market Street
San Francisco 3, California

YOUR HELP IS REQUESTED

Your San Francisco Bay Area Rapid Transit District is conducting engineering studies for the proposed regional rapid transit system. These studies are of great importance in planning the kind of rapid transit system you want.

You are being asked — as part of these studies — to give information concerning your trip via the S.P.R.R. today. Instead of delaying your trip by direct interviews, we ask only that you promptly:

1. **Fill out this questionnaire completely.**
2. **Fold along dotted lines shown.**
3. **Seal carefully along gummed edge.**
4. **Drop in any mail box.**

The questionnaire is self-addressed and postage paid.

Your cooperation is appreciated. Thank you.

Parsons Brinckerhoff - Tudor - Bechtel
General Engineering Consultants to the
San Francisco Bay Area Rapid Transit District

Nº 13757

Figure 2. Southern Pacific Co. commuter survey form: instructions side.

GUMMED EDGE. SEAL HERE

FOLD HERE

SAN FRANCISCO BAY AREA RAPID TRANSIT DISTRICT
POSTPAID MAIL QUESTIONNAIRE

of S.P. Commuters

It is important that YOU answer ALL questions below and RETURN this form promptly. Your answers will be of great help in improving traffic service in the Bay Area. This is YOUR PART in the rapid transit engineering studies.

1. At which station did you **board** the outbound S.P. train on which you received this questionnaire? (Check one.)
   - ☐ Third & Townsend Depot (S.F.)
   - ☐ Other: ______ (Specify)

2. At which station did you get off that train? ______ (Specify)

3. Where were you going to on that trip?
   ______ (Nearest Street Corner, or Address) ______ (City or Town)

4. How did you travel **between the station** where you got off train (Q. 2) and your ultimate destination (Q. 3)? (Check one.)
   - ☐ Walked
   - ☐ Feeder Bus
   - ☐ **Passenger** } in an auto parked at or near Sta.
   - ☐ **Driver** } in an auto parked at or near Sta.
   - ☐ Picked up at Sta. by auto not parked there
   - ☐ Taxi (rode alone)
   - ☐ Taxi (shared ride)
   - ☐ Bicycle
   - ☐ Other ______ (Specify)
   - ☐ Combination of above ______ (Specify)

FOLD HERE

5. **IF YOU** were the **DRIVER of** an auto parked at or near the R.R. Station (Q. 4):—(Do not answer if **not driving** car away from station **on THIS** trip.)
   (a) **Where** was this auto parked? (Check one.)
   - ☐ S.P. Station Lot
   - ☐ Private Lot or Garage
   - ☐ At Curb
   - ☐ Other ______ (Specify)

   (b) How far was auto parked from station platform? (Check one.)
   - ☐ Less than 200 ft.
   - ☐ 200-500 ft.
   - ☐ 500-1000 ft.
   - ☐ 1000-1300 ft. (quarter mile)
   - ☐ ¼ to ½ mile
   - ☐ Over ½ mile

   (c) What is the size of this car? (Check one.)
   - ☐ Standard-Size American
   - ☐ American "Compact"
   - ☐ "Small Foreign"
   - ☐ Other ______ (Specify)

6. On your trip **inbound towards San Francisco** today, how did you travel **between your starting point (origin) and the S.P. station where you boarded train? (Check one.)**
   - ☐ Walked
   - ☐ Feeder Bus
   - ☐ **Passenger** } **in an auto parked at or near Sta.**
   - ☐ **Driver** } **in an auto parked at or near Sta.**
   - ☐ Dropped off at Sta. by auto **not** parked there
   - ☐ Taxi (rode alone)
   - ☐ Taxi (shared ride)
   - ☐ Bicycle
   - ☐ Other ______ (Specify)
   - ☐ Combination of above ______ (Specify)
   - ☐ Did not travel inbound today

7. On your inbound trip today, please give:
   (a) Station boarded train ______ (Write in)
   (b) Time train was due to leave ______ (Write in) A.M. P.M.
   (c) ☐ Did not travel inbound towards S.F. today.

FOLD HERE

8. For **these** same **S.P. trips today**, could you have **driven** or **shared** a ride in an auto, if you had **chosen** and **arranged** to do so? (**Check one.**)
   ☐ Yes ☐ **No; no** auto transportation could have been available.

9. What was the **purpose** of each of these trips today? (Check one in each line.)

		Work or Business	Home	Shop	Social or Recreation	Other
Inbound to S.F.	From	☐	☐	☐	☐	☐
	To	☐	☐	☐	☐	☐
Outbound from S.F.	From	☐	☐	☐	☐	☐
	To	☐	☐	☐	☐	☐

10. **Ordinarily, how many times a week do you make these same trips? (Check one in each line.)**

	Over 7	7	6	5	4	3	2	1	Under 1
Inbound to S.F.	☐	☐	☐	☐	☐	☐	☐	☐	☐
Outbound from S.F.	☐	☐	☐	☐	☐	☐	☐	☐	☐

11. Brief comments and suggestions on the proposed regional rapid transit system: (optional answer) ______

Please fill out this questionnaire completely. Fold along dotted lines. Seal carefully along gummed edge. Drop in any mailbox. Your cooperation is appreciated. Thank you.

Figure 3. Southern Pacific Co. commuter survey form: questionnaire side.

TABLE 1

ACCESS MODES AT OUTLYING STATIONS, S. P. COMMUTER SURVEY[a]

Access Modes	Alighting, Outbound		Boarding, Inbound	
	No.	Percent	No.	Percent
Walked	1,997	15.5	2,272	17.6
Feeder bus	562	4.4	410	3.2
Passenger in parked auto	1,012	7.9	1,016	7.9
Driver of parked auto	5,019	39.2	5,224	40.2
"Kiss-ride" (picked up)	3,854	30.1	3,770	29.1
Taxi				
Alone	55	0.4	44	0.4
Share	26	0.2	22	0.2
Bicycle	74	0.6	79	0.6
Other	20	0.2	23	0.2
Combination of modes	193	1.5	76	0.6
Total	12,812	100.0	12,936	100.0

[a]Commuters outbound from San Francisco, Tuesday, Jan. 19, 1960, excluding only San Francisco terminal station.

TABLE 2

CHARACTERISTICS OF STATION PARKERS, S. P. COMMUTER SURVEY[a]

Characteristic	No.	Percent
Parked at:		
S. P. Co. lot	3,409	69
Private lot	342	7
Street curb	1,131	23
Other	58	1
Total	4,940	100
Parking distance from station platform:		
<200 ft	1,635	33
200-500 ft	1,938	40
500-1,000 ft	1,091	22
1,000-1,300 ft	207	4
1/4-1/2 mi	48	1
>1/2 mi	4	—
Total	4,923	100
Parked Auto Size:		
Standard American	4,271	89
American compact	126	3
Small foreign	383	8
Other	32	—
Total	4,812	100

[a]Commuters outbound from San Francisco, Tuesday, Jan. 19, 1960, excluding only San Francisco terminal station.

TABLE 3

CLEVELAND RAPID TRANSIT STATION INTERCHANGE FACILITIES, 1963

Station	No. Feeder Transit Lines	No. Parking Spaces	Kiss-Ride Loop
West Park	6[a]	2,000	Yes
Triskett	2[a]	1,200	Yes
W. 117th—Madison	4[a]	575	Yes
W. 98th—Detroit	3[a]	315	Yes
W. 65th—Madison	4	0	No
W. 25th—Lorain	14	0	No
Union Terminal (public square)		0	No
E. 55th St.	2	85	No
E. 79th St.	3	0	No
E. 105th—Quincy	2	0	No
University—Cedar	10[a]	0	No
Euclid—E. 120th	4	0	No
Superior	3[a]	150	Yes
Windermere	6[a]	900	Yes
Total	—	5,225	

[a]Off-street bus transfer facilities.

TABLE 4

CLEVELAND RAPID TRANSIT ACCESS MODES PERIODICITY

Time Period	Parking			Kiss-Ride			Feeder Transit[b]		Walking[c]	Total
	Autos	Psgrs.	Percent[a]	Autos	Psgrs.	Percent[a]	Psgrs.	Percent[a]	Psgrs.	Psgrs. to R. T.[d]
					(a) West Park Station[e]					
6- 7 AM	209	247	37.6	72	76	11.6	332	50.6	1	656
7- 8 AM	807	924	35.2	397	453	17.2	1,226	46.6	27	2,630
8- 9 AM	325	412	32.8	174	183	14.5	638	50.7	25	1,258
9-10 AM	120	150	42.1	45	48	13.5	152	42.7	6	356
10-11 AM	101	116	35.5	40	52	15.9	158	48.3	1	327
11-12 AM	76	87	39.5	30	32	14.6	101	45.9	—	220
12- 1 PM	58	67	41.6	22	23	14.3	70	43.5	1	161
1- 2 PM	50	57	30.8	17	21	11.4	105	56.7	2	185
2- 3 PM	23	26	16.4	19	19	11.9	110	69.2	4	159
3- 4 PM	34	38	14.9	24	27	10.6	183	71.8	7	255
4- 5 PM	24	25	5.8	40	52	12.0	345	79.9	10	432
5- 6 PM	9	10	3.2	47	52	16.6	249	79.6	2	313
Total	1,836	2,159	31.1	927	1,038	14.9	3,669	52.8	86	6,952
					(b) Triskett Station[f]					
6- 7 AM	86	99	41.8	16	16	6.7	112	47.3	10	237
7- 8 AM	516	652	49.3	153	171	12.9	493	37.3	6	1,322
8- 9 AM	305	358	52.3	89	100	14.6	222	32.4	5	685
9-10 AM	64	74	49.7	30	30	20.1	43	28.9	2	149
10-11 AM	70	85	60.3	24	26	18.4	28	19.9	2	141
11-12 AM	63	75	65.2	19	21	18.3	18	15.6	1	115
12- 1 PM	62	73	65.8	15	19	17.1	18	16.2	1	111
1- 2 PM	60	71	68.3	14	16	15.4	15	14.4	2	104
2- 3 PM	17	21	36.9	15	15	26.3	21	36.8	0	57
3- 4 PM	35	42	46.1	16	24	26.4	24	26.4	1	91
4- 5 PM	23	28	36.8	14	18	23.7	27	35.5	3	76
5- 6 PM	20	24	34.3	14	17	24.3	26	37.1	3	70
Total	1,321	1,602	50.7	419	473	15.0	1,047	33.2	36	3,158

[a] Of R.T. passengers via mode shown to total passengers to R.T.

[b] Latest available data (West Park 1963-1964, Triskett Feb.-March 1964) adjusted to turnstile reading of survey day.

[c] Walking passengers somewhat underreported, but not so much as to affect greatly the other modal percentages shown.

[d] Inbound turnstile count.

[e] Inbound toward CBD, Tuesday, March 24, 1964.

[f] Inbound toward CBD, Wednesday, March 25, 1964.

TABLE 5

DISTANCES OF TRIP ORIGINS TO FOUR WEST SIDE RAPID TRANSIT STATIONS[a]

Airline Dist. to Stations[b] (mi)	October 1959		March 1964	
	No. Parked Autos	Percent	No. Parked Autos	Percent
0.0- 0.5	126	5.00	123	3.95
0.6- 1.0	411	16.21	429	13.79
1.1- 1.5	402	15.89	447	14.38
1.6- 2.0	314	12.42	343	11.03
2.1- 3.0	249	9.87	272	8.74
3.1- 4.0	373	14.75	637	20.49
4.1- 5.0	80	3.15	82	2.63
5.1- 6.0	82	3.25	115	3.69
6.1- 7.0	407	16.04	523	16.80
7.1- 8.0	39	1.52	47	1.53
8.1- 9.0	20	0.76	50	1.57
9.1-10.0	23	0.92	36	1.15
>10.0	6	0.22	8	0.25
Total	2,532	100.00	3,112	100.00

[a]West Park, Triskett, W. 117th, and W. 98th (data expanded from average 75 percent sample).
[b]Avg. travel distance: Oct. 1959, 2.97 mi; March 1964, 3.22 mi.

TABLE 6

DISTANCES OF TRIP ORIGINS TO TWO WEST SIDE RAPID TRANSIT STATIONS, MARCH-APRIL 1958[a]

Airline Dist. to Stations (mi)	Parked Autos (%)			Kiss-Ride Autos (%)			Total Passengers[b]		
	W. 117th	W. 98th	Total	W. 117th	W. 98th	Total	W. 117th	W. 98th	Total
0-1	10.7	12.9	11.7	20.1	28.6	21.4	13.9	28.6	18.0
1-2	29.1	18.0	24.1	37.5	28.6	36.1	40.3	25.2	35.9
2-3	8.8	23.2	15.4	11.4	22.4	13.1	14.7	21.7	16.6
3-4	17.2	12.9	15.2	14.4	4.1	12.8	18.3	13.3	17.0
4-5	9.3	9.5	9.4	4.2	4.1	4.2	4.2	3.2	4.1
5-6	4.1	8.6	6.1	2.7	2.0	2.5	3.6	2.3	3.2
>6	20.8	14.9	18.1	9.7	10.2	9.9	5.0	5.7	5.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Avg. Travel Dist. (mi)	3.8	3.7	3.8	2.7	2.7	2.7	2.6	2.4	2.5

[a]Before opening of Triskett and West Park Stations; data from Gilman and Co. (5).
[b]Total boarding passengers at W. 117th and W. 98th Streets rapid transit stations.

Additional work on this subject has been conducted by the Delaware River Port Authority in connection with its Philadelphia-Kirkwood rapid transit line, now under construction. Table 7 indicates the amount and type of parking, kiss-ride, and other facilities presently proposed to be provided at stations along the Kirkwood line in New Jersey.

Significant progress in developing coordinated highway-transit interchange stations has been made in the past few years by several state highway departments in connection with express bus services on freeways and expressways, by the Metropolitan Transit Authority of Boston, the New York City Transit Authority, the rapid transit systems in Chicago and Toronto, several commuter railroads, and various cities (6), rapid transit systems, and state railroads in Europe (7).

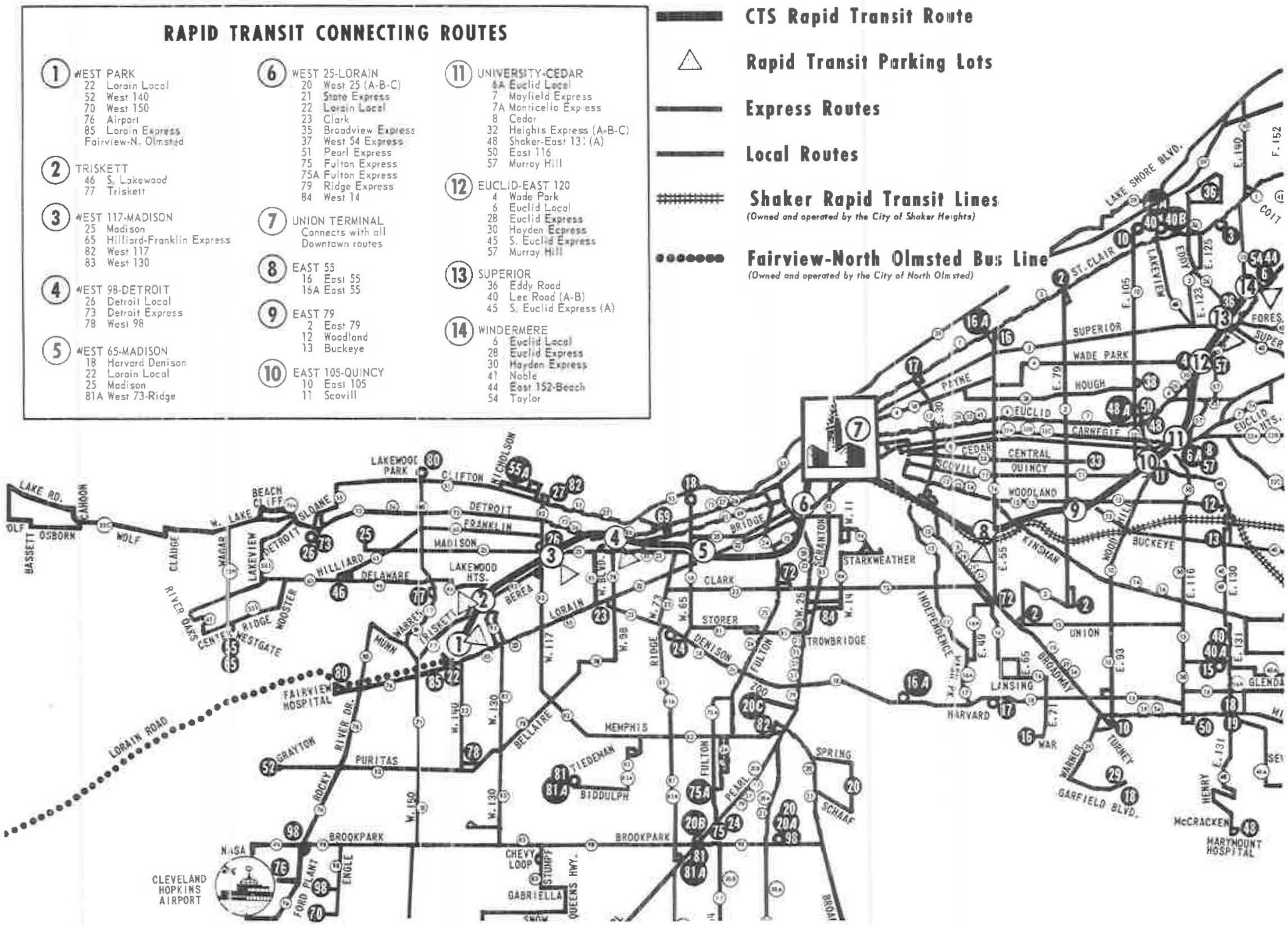

Figure 4. Cleveland Transit System routes, 1963.

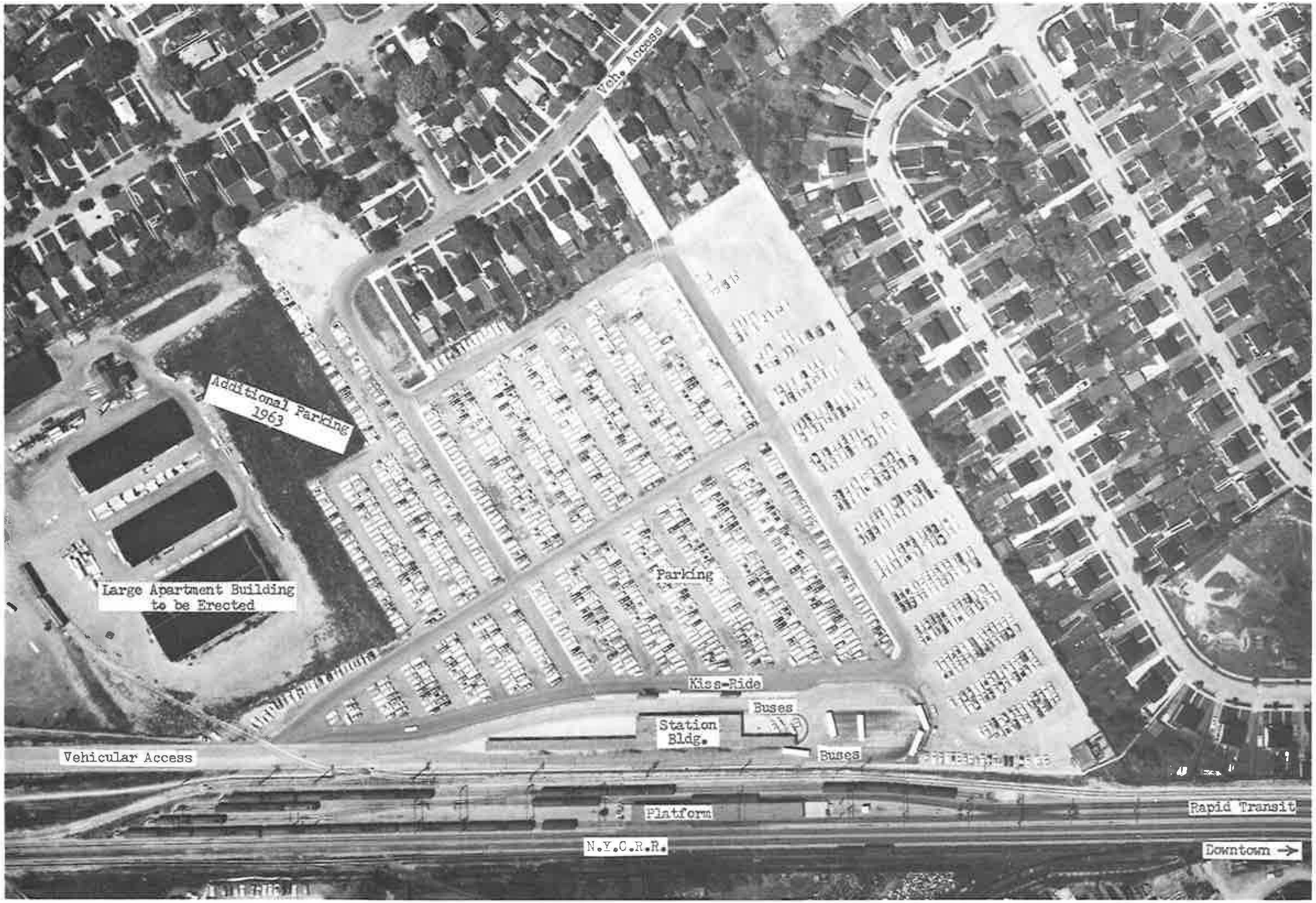

Figure 5. Station facilities, West Park Station, CTS, 1961.

Figure 6. Feeder bus and kiss-ride loading areas, West Park Station, Cleveland.

TABLE 7

PHILADELPHIA-KIRKWOOD PROPOSED RAPID TRANSIT STATION FACILITIES[a]

Station	Kiss-Ride Positions	Paid Parking Stalls	Free Parking Stalls	Total Spaces
Ferry Ave.	73	283	642	998
Collingswood	30	64	429	523
Westmont	23	217	540	780
Haddonfield	47[b]	187	687	921
Ashland	11	158	384	553[c]
Kirkwood	31	282	868	1,181[d]
Total	215	1,191	3,550	4,956

[a] Loading and unloading positions for feeder buses and taxis provided at all stations.
[b] 35 15-min parking; 12 kiss-ride.
[c] Additional land to be purchased for 350 spaces to be provided in the future when traffic increases.
[d] Additional land to be purchased for 367 and 440 spaces to be provided in two stages when traffic increases.

The Demonstration Grant program, administered by the HHFA in accordance with the Housing Act of 1961, has also provided active assistance in this field. Of particular interest is an HHFA Demonstration Grant to the Tri-State Transportation Committee, in which a new station along a major Pennsylvania Railroad commute line was constructed at the outskirts of New Brunswick, N. J. The new station was opened on Oct. 24, 1963, and observation under the grant was to continue for an 18-month period.

The old station in the center of New Brunswick had been difficult to reach by automobile because of traffic congestion and insufficient parking facilities. The new station has a 300-car parking lot and is located about 1.5 miles from the center of New Brunswick. It is intended to demonstrate whether a station conveniently located outside a city's center and equipped with adequate parking facilities can attract enough commuters and other daytime passengers to be feasible.

HIGHWAY-TRANSIT INTERCHANGE STATION CRITERIA

Extensive BART studies have been and are being conducted on travel times, travel patterns, modal split, rapid transit patronage, fare levels and structure, gross revenue, operations planning, train schedules, operating expense, net revenue, rolling stock requirements, and parking facilities requirements.

Based on these studies, specific planning and research investigations for the BART stations, and data available from other existing and planned rapid transit systems, proposed planning criteria have been developed for highway-transit interchange facilities in this area. It should be emphasized that the planning process is continuous and subject to further development as the project proceeds through the stage of final design before construction.

ACCESS MODE DISTRIBUTIONS

Table 8 gives current estimated station access mode volumes for the BART stations on a 1975 annual average weekday. A careful evaluation of the potential characteristics of each of the 33 stations and their tributary areas was involved in these estimates. These characteristics included forecasts of future land uses, of the geography and quality of access routes and facilities, demography and economy, station site development considerations, and the ranking of the service functions attributable to each station. Also used in this preparation were the analyses and results of the rapid transit patronage studies and comparisons with the January 1960 S. P. postcard survey and the Cleveland data referred to previously. The station sector studies, described later, were important in refining the estimates.

PARKING CAPACITY

From the data of the foregoing studies and Table 8, the number of parking stalls required at each rapid transit station was estimated, taking into consideration several important factors. Initial estimates were prepared of potential stall demand by 1980 and 2000. The parking stall and area estimates were scaled to fit that part of the BART $792,000,000 general obligation bond resources budgeted for external station facilities. In scaling to this budget level, the distribution of numbers of stalls among the 23 stations selected by study for parking facilities was further evaluated and modified to account for several elements. Early trials of these distributions considered, successively, the potential demand estimates and relative demand variously modified by relative parking capital costs per square foot among the parking stations. Later trials added consideration of two other significant factors: (a) an evaluation of the relative magnitude of property acquisition problems likely to be encountered at the 23 parking stations; and (b) attraction to the system of the longest possible lengths of passenger trip, with the objective not only of increasing rapid transit revenues but also particularly of relieving major parallel highway facilities of the greatest possible amount of congesting vehicle-miles of automobile travel.

The latter objective involved emphasizing the outer, more regional stations of the system where auto and parking access is proportionately of much greater importance. It is to be noted, for example, that of all existing North American rapid transit systems, the largest station parking capacities are generally placed at or toward the outer ends of rapid transit routes. Where several outlying stations on one route will have parking, it is not always necessary to provide well-above-average amounts of parking at the route's terminal station. It is apparent that parking is not generally provided at central stations in downtown areas, principally because they are delivery rather

TABLE 8

ESTIMATED ACCESS MODE VOLUMES, SAN FRANCISCO BAY AREA RAPID TRANSIT STATIONS[a]

Station	Total Boarding and Alighting	Walk		Feeder Transit		Taxi		Kiss-Ride		Parked Auto		Total Auto	
		Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.
Daly City	14,800	9	1,330	50	7,400	1	150	14	2,070	26	3,850	40	5,920
Ocean Ave.	10,700	15	1,600	64	6,850	3	320	18	1,930	0	0	18	1,930
Bosworth	9,400	22	2,070	59	5,550	3	280	16	1,500	0	0	16	1,500
24th St.	15,800	41	6,480	47	7,430	2	310	10	1,580	0	0	10	1,580
16th St.	9,500	64	6,080	31	2,940	2	190	3	290	0	0	3	290
Civic Center	22,200	63	13,990	34	7,550	2	440	1	220	0	0	1	220
Powell St.	31,600	66	20,850	32	10,110	1	320	1	320	0	0	1	320
Montgomery St.	66,200	66	43,690	32	21,190	1	660	1	660	0	0	1	660
W. Oakland	8,900	28	2,490	51	4,540	1	90	5	440	15	1,340	20	1,780
12th St.	39,900	68	27,130	27	10,770	2	800	3	1,200	0	0	3	1,200
19th St.	39,600	73	28,910	23	9,110	1	390	3	1,190	0	0	3	1,190
MacArthur Blvd.	16,500	17	2,810	50	8,250	1	160	17	2,810	15	2,470	32	5,280
College Ave.	7,700	15	1,150	45	3,470	1	80	14	1,080	25	1,920	39	3,000
Orinda	4,700	5	240	15	700	2	90	28	1,320	50	2,350	78	3,670
Lafayette	6,500	8	520	14	910	2	130	26	1,690	50	3,250	76	4,940
Walnut Creek	6,100	9	550	15	920	2	120	24	1,460	50	3,050	74	4,510
Pleasant Hill	5,300	12	640	14	740	2	100	22	1,170	50	2,650	72	3,820
Concord	4,700	10	470	15	710	2	90	21	990	52	2,440	73	3,430
Richmond	8,100	10	810	41	3,320	2	160	16	1,300	31	2,510	47	3,810
Cutting Blvd.	10,900	5	550	35	3,810	1	110	19	2,070	40	4,360	59	6,430
Fairmont Ave.	5,700	10	570	40	2,280	1	60	18	1,030	31	1,760	49	2,790
Sacramento St.	8,700	10	870	45	3,910	1	90	16	1,390	28	2,440	44	3,830
Berkeley	24,000	47	11,280	34	8,160	4	960	15	3,600	0	0	15	3,600
Ashby Ave.	16,400	21	3,450	50	8,200	1	160	12	1,970	16	2,620	28	4,590
Oak St.	19,800	30	5,940	41	8,120	2	400	19	3,760	8	1,580	27	5,340
Fruitvale Ave.	30,600	11	3,360	58	17,750	1	310	22	6,730	8	2,450	30	9,180
73rd Ave.	23,000	10	2,300	55	12,650	1	230	22	5,060	12	2,760	34	7,820
San Leandro	16,900	16	2,700	42	7,100	1	170	21	3,550	20	3,380	41	6,930
Hesperian Blvd.	9,800	5	490	35	3,430	1	100	22	2,150	37	3,630	59	5,780
Hayward	10,100	12	1,210	34	3,440	3	300	17	1,720	34	3,430	51	5,150
Tennyson Rd.	3,400	10	340	24	820	1	30	23	780	42	1,430	65	2,210
Union City	4,200	7	290	14	590	2	80	28	1,180	49	2,060	77	3,240
Fremont	5,100	4	200	16	820	2	100	29	1,480	49	2,500	78	3,980
Total (Aug. 1965)	516,800	38	195,360	37	193,540	2	7,980	11	59,690	12	60,230	23	119,920

[a]24-hr 1975 annual average weekday; data subject to continuing reevaluation as project planning and development proceed.

TABLE 9

SAN FRANCISCO BAY AREA RAPID TRANSIT STATION PARKING STALLS, INITIAL PROGRAM[a]

Station	Total Stalls
Daly City	1,250
W. Oakland	600
MacArthur Blvd.	900
College Ave.	800
Orinda	950
Lafayette	1,150
Walnut Creek	1,350
Pleasant Hill	1,250
Concord	1,350
Richmond	1,050
Cutting Blvd.	1,450
Fairmont Ave.	950
Sacramento St.	1,050
Ashby Ave.	900
Oak St.	450
Fruitvale Ave.	850
73rd Ave.	1,050
San Leandro	1,150
Hesperian Blvd.	1,550
Hayward	1,250
Alquire Road	850[b]
Union City	850[b]
Fremont	850[b]
Total	23,850

[a]Preliminary, subject to continuing reevaluation as project planning and development proceed.
[b]Of which initially 500 would be constructed and land would be provided for remaining 350.

than collector stations and because parking capital costs in these areas are relatively high.

These studies, together with preliminary location studies, indicated that between 23,000 and 24,000 parking stalls could initially be provided at the 23 parking stations, with capacities varying between 450 and 1,550 stalls at the individual stations.

During subsequent design, property acquisition, and actual construction, changes in the cost factors involved, in specific problems of community planning and acquiring land, and other elements may affect the number and distribution of stalls at individual stations. Table 9 shows the initial number of parking stalls presently planned for each station, subject to these qualifications.

TRANSPORTATION DESIGN

External Station Layouts

Figure 7 illustrates, and supplements the following discussion of, criteria proposed for external station layouts at the 23 stations where parking space is planned ("parking stations"). Figure 7 is based on a capacity of 1,200 stalls, the approximate average number of lot (single-level) stalls shown in the engineering plans referenced to the May 1962 BART Composite Report (8). Specific conditions encountered during subsequent design, property acquisition, and actual construction at each of these 23 parking stations may cause marked variations from this optimal layout. Figure 7, however, provides an important illustrative basis for the external station functions and criteria subsequently described (9, 10, 11).

At the 14 other stations of the system (10 for rapid transit and four for express streetcars) where parking is not provided because they are purely downtown delivery, internal urban, or express streetcar stations, the rapid transit route is usually in subway under city streets. There are not likely to be extensive external station facilities involved at these 14 stations, other than loading-unloading space for autos, taxis, and feeder transit vehicles, arranged in accordance with the street geometry, building development, and access needs in the immediate vicinity of each station. It is expected that this loading-unloading space will usually be included within the existing general street geometry, with possibly some curb setbacks and other relatively minor modifications.

Initial Considerations

The BART station structures will be approximately 700 ft long and 50 to 60 ft wide. The 700-ft length will provide for 10-car trains of about 70-ft long cars. Optimally, external parking and circulation facilities should be grouped around the long, narrow station (a) to provide the closest access to the train platforms for the most efficient

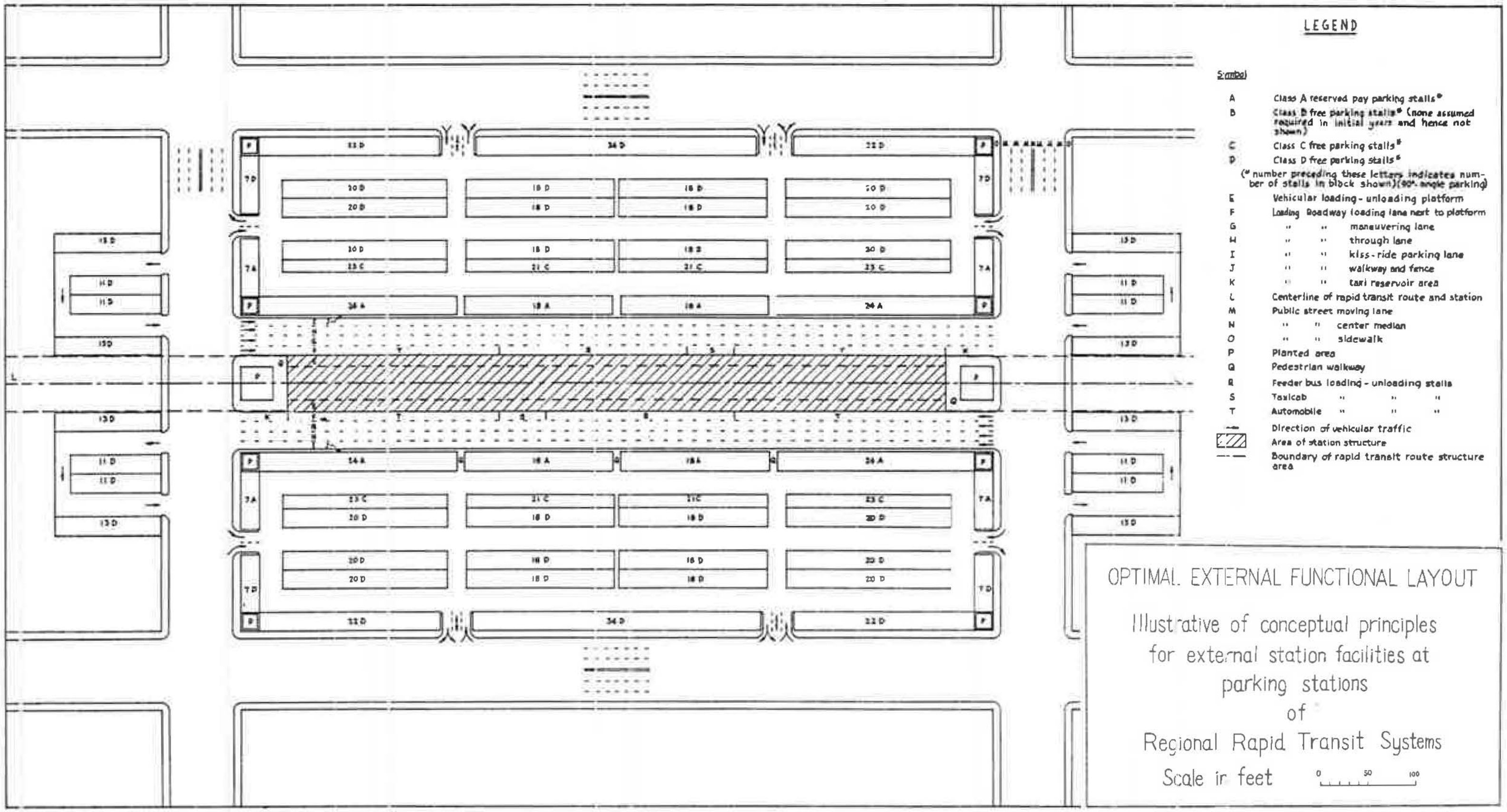
LEGEND
Symbol
A Class A reserved pay parking stalls*
B Class B free parking stalls* (none assumed required in initial years and hence not shown)
C Class C free parking stalls*
D Class D free parking stalls*
(* number preceding these letters indicates number of stalls in block shown)(90°-angle parking)
E Vehicular loading-unloading platform
F Loading Roadway loading lane next to platform
G " " maneuvering lane
H " " through lane
I " " kiss-ride parking lane
J " " walkway and fence
K " " taxi reservoir area
L Centerline of rapid transit route and station
M Public street moving lane
N " " center median
O " " sidewalk
P Planted area
Q Pedestrian walkway
R Feeder bus loading-unloading stalls
S Taxicab " " "
T Automobile " " "
Direction of vehicular traffic
Area of station structure
Boundary of rapid transit route structure area
OPTIMAL EXTERNAL FUNCTIONAL LAYOUT
Illustrative of conceptual principles for external station facilities at parking stations of Regional Rapid Transit Systems
Scale in feet
0 50 100

Figure 7.

access modes to encourage use of these modes, (b) to minimize walking distances between train platforms and all parking stalls, (c) to optimize the number of vehicular entrances from and exits to the street-highway network, and (d) to optimize automobile, taxi, and feeder transit loading, unloading, ingress, and egress (Fig. 7). From the station operation standpoint, the most efficient access modes are, in descending order, walk, feeder transit, bicycle, taxi, auto kiss-ride, miniature auto parked, small foreign auto parked, and standard American auto parked.

Loading Roadway

Because the stations are about 700 ft long, analysis indicates that a single loading roadway and vehicular loading-unloading platform of that length, along one side of a station, should be adequate to meet 1980 peak requirements for momentary loading and unloading of automobiles, taxis, and feeder transit buses. By the nominal year 2000, this single loading roadway and platform may still be adequate at most of the parking stations, but at others there should be a loading roadway and platform along both sides of each station. One 700-ft long loading-unloading platform provides space, for example, for three large transit buses, two taxis, and 11 automobiles at the platform curb.

As a general criterion, at most interchange stations, it is considered desirable, if found practicable at specific sites, to provide a vehicular loading roadway and loading-unloading platform along both long sides of each of the parking stations, in order to minimize peak vehicular concentrations entering and leaving the stations, even though the vehicular loading-unloading requirements themselves do not always indicate an absolute need for two such roadways. At a number of the stations, however, physical and site planning considerations will not make such double loading roadways practicable.

As shown in Figure 7, the vehicular loading-unloading platform should be 12 ft wide, the adjacent vehicle loading lane 10 ft wide, the maneuvering lane 11 ft wide, and the through lane 11 to 12 ft wide. There should be an 8.5-ft wide kiss-ride parking lane adjacent to the through lane and a 3-ft wide walkway and fence separating the parking lane from the main parking areas beyond. (The functions of these last two elements are described below.)

The loading, maneuvering, through, and parking lanes, and the walkway-fence strip, altogether make up approximately 43 to 45 feet of width and are termed the loading roadway. At aerial and subway stations the 12-ft wide loading-unloading platform is assumed to fall within the 50- to 60-ft width of the station structure itself, since the track level will be above or below the surface level where the vehicular loading-unloading platform is situated. At surface stations the width required for two train tracks with side platforms, fare collection equipment and fencing, and a vehicular loading-unloading platform on each side of the station, will approximate 96 ft.

Walking

Patrons walking to and from the 23 parking stations are, with few exceptions, not expected to be more than 20 percent of all patrons, and usually only 5 to 15 percent. Adequate pedestrian walkways should be provided from all areas of the station structure itself to various desirable points beyond the precincts of the external station facilities. These walkways should usually be at least 2 lanes or 60 in. wide. A pedestrian lane width of 27 in. is considered as a minimum, with 30 in. desirable. Walkways will be required as access to and possibly through station parking lots.

In most cases, special pedestrian undercrossings or overcrossings of adjacent streets and of the loading roadway(s) will not be justified, at least in the earlier years of operation. As patron walking volumes increase with the growth of residential, commercial, and industrial developments adjacent to the stations, more such separated crossings may later be required. Of particular concern will be the walking and parking patrons who must cross the loading roadway(s) to reach the station structures; here pedestrian conflicts with vehicular loading-unloading movements may be severe enough to warrant separated crossings, either later on or at the opening of service, depending on particular analysis of individual cases.

Bicycles

Patrons arriving and leaving by bicycle, motor bicycle, scooter, etc., are not expected initially to be a significant percentage of the total access volume. Consideration should, however, be given to their access movements and to the possible later provision of bike and other racks in a special storage area if this access mode were to develop to any degree.

Feeder Transit

At the 23 parking stations, all or virtually all feeder transit services will be provided by self-powered buses. In some cases, these buses will merely make curbside stops along streets at or near stations. In other cases, however, the buses will enter and leave via the loading roadway, and load and unload at the vehicular loading platform.

Analysis indicates that, until at least 1980, three or four bus platform stalls can be expected to meet the feeder bus loading requirements at most stations. A marked-off 200-ft center section of the 700-ft long loading platform, for example, would best accommodate three larger feeder transit buses for this purpose. By the nominal year 2000, more platform bus berths may be required at several of the parking stations; in those instances it would be desirable, if practicable, to distribute the feeder bus platform loading-unloading onto two vehicular loading platforms. Feeder bus layovers could be accommodated at these loading stalls, and at curbsides and other locations near the stations as desirable. By 1980 at these 23 stations, between 14 and 58 percent of total patron access volumes are expected to be by the feeder transit mode. The proportions of these which will board (a) at nearby curbside street bus stops, and (b) at the station access roadway loading platforms has been evaluated and will vary at each station.

Taxis

Patrons using taxicabs as their loading mode at the 23 parking stations are not expected usually to be more than 1 to 3 percent of total patronage. Until at least 1980 two taxi loading stalls, occupying a total of 50 ft of loading platform length, should adequately meet all requirements at these stations. In the nominal year 2000, four taxi loading stalls are indicated for most of these stations; again, it would be desirable, if practicable, to divide this requirement between two loading platforms located along each long side of the stations.

A small taxi reservoir area holding a maximum of four cabs would be desirable along the loading roadway at the end of the 700-ft long loading platform. A 4-cab reservoir would be about 100 ft long with the cabs in a single file; if in two files, about 1,000 sq ft of space would be required.

Kiss-Ride

Family members driving husbands and others to and from stations (with the automobiles involved not being parked there) are expected to account for about 5 to 30 percent of all patrons arriving and leaving the 23 parking stations. Patrons arriving at a station will be driven in via the loading roadway(s), discharged at the loading platform(s), and the automobiles involved will then be driven away from the station. Of the 700-ft length of loading platform, typically 200 ft would be taken up by three central bus loading stalls, 50 ft by two taxi loading stalls, and the remaining 450 ft would be available for about 11 kiss-ride automobile stalls. These latter stalls will be most intensively used in the weekday inbound morning peak periods, during which analysis indicates that by 1980 one loading roadway with its 11 kiss-ride platform unloading stalls would be sufficient. However, as indicated above, if practicable it would be highly desirable to de-concentrate these loading roadway vehicular peaks onto two, rather than just one, loading roadway at each station. By the nominal year 2000, two such loading roadways, along both long sides of each station structure, may be required at least at some of the 23 parking stations.

Patron egress by the kiss-ride mode requires additional external station facilities. In the minority of cases where the patron reaches the vehicular loading platform before the kiss-ride automobile appears, the vehicular arrival process is simply repeated and the patron is driven away to his home. Most family members picking up husbands and others at the stations to drive them home will, however, by prearrangement, arrive at the station before patrons alight from their trains. These kiss-ride automobiles must, therefore, be parked for a relatively short period until the patrons appear for the trip home. As shown in Figure 7, one lane of kiss-ride parking, accommodating about 30 stalls, is located along the side of the loading roadway opposite the loading platform and next to the through lane. Since the short-term waits of kiss-ride autos picking up patrons are concentrated in the weekday outbound evening peak periods, it would be wasteful of space and capital funds to provide much more than one file or lane of these stalls along each loading roadway; these stalls may be used conveniently for this purpose throughout the day. At all 23 parking stations in 2000 and at most of them in 1980, however, the estimated requirement for kiss-ride short-term parking stalls in the evening peaks is several times higher than the loading roadway stalls which can economically be provided for this purpose.

The remainder of this evening peak kiss-ride stall requirement could be met conveniently in another manner. By regular prearrangement, the family member driving the automobile to the station to pick up a kiss-ride patron could select a first and a second parking choice among alphabetically lettered small sections of the station parking area shown in Figure 7. The kiss-ride patron, knowing that his auto pickup would be parked in one of two adjacent lettered parking sections, walks to the first-choice section and finds his auto there or, if not there, locates it in the second section. Because, in each lettered small section, some automobiles parked there all day will already have been driven away by parker patrons early in the afternoon peak, the family member driving the pickup auto into this section, by regular prearrangement, would be able to find a vacant stall for her use for short-term parking while awaiting the kiss-ride patron. A special colored pennant attached to the auto aerial while waiting for the kiss-ride patron might aid his identification of his automobile. The family member waiting for the kiss-ride patron might also park in the aisle while awaiting a stall vacancy, if two-lane two-way aisles are provided. The transit system could assist the lettered-area selection process by providing prearrangement duplicate forms (one copy for the kiss-ride patron and the other for the driver) and recommending which lettered sections should be used to balance the demands for this type of short-term-waiting parking. In addition, some curbside space on streets adjacent to the stations may also be suitable for this kiss-ride vehicle waiting function.

Parking

General Layout. —Generally between 10 and 50 percent of all patrons at the 23 parking stations are expected to arrive and leave these stations as either drivers or passengers in automobiles parked at the stations. Figure 7 shows an optimum parking layout for a typical station requiring 1, 200 lot stalls. It is to be noted that the parking stalls are distributed in an equidistant manner from all points along the edge of the 700-ft long by 60-ft wide station structure to minimize stall walking distances and peak vehicular concentrations at parking entrances and exits.

For most large parking lot sizes and shapes, 90-deg-angle parking, with stalls and aisles wide enough to permit convenient one-maneuver stall entry and exit, and generally two-lane two-way aisle movement, provides the most economical use of space, the most efficient arrangement of stalls, and the most efficient internal vehicular circulation (Fig. 7). Almost 100 percent of the Cleveland rapid transit system's 5, 225 station parking stalls are right-angle (4), and this is common, although not exclusive, practice on other commuting systems.

Access Dispersion. —It is essential to disperse the entrance and exit of parking vehicles onto as many different streets and highways as possible in the vicinities of the stations to minimize peak vehicular congestion on these feeding streets and in the station parking facilities. At least one entrance lane and one exit lane should be provided for every 300 (and preferably every 250) station parking stalls. Where more than 2,000 parking stalls may be provided in the future in one facility, a rate of up to 500 stalls per entrance and per exit lane may have to be tolerated, provided the feeding streets-highways involved will then have reasonably high individual capacities. These entrance and exit lanes should be dispersed throughout the parking facility and not concentrated in just one or two places or onto just one street. At stations with more than 1,000 stalls, it will be important to disperse parking entrances and exits onto several feeding streets of relatively low individual capacity, directly onto at least one or two highways or streets of high capacity, or onto an adequate combination of the two.

These vehicular dispersal criteria are essential to avoid overtaxing the available capacity of one or more feeding streets adjacent to the station parking facilities, since these streets have more community traffic-moving functions than just those related to an individual rapid transit station. Similar comments were made previously with respect to the station loading roadways.

Comprehensive functional traffic engineering studies are being made at each station site to insure that all elements of station access and parking are in close harmony with then-present and future land use, traffic circulation, and planning in the general vicinity of each individual station. This work is being accomplished in close coordination with the interested local planners and engineers.

Classes. —It is proposed that the station parking area itself be divided for use by four classes of parker (A, B, C, and D) as shown in Figure 7. This proposal is subject, however, to further review and has not yet been adopted as a policy for the BART system. Class A parkers are those who are willing to pay about $0.25 a day for a reserved standard-size stall (8.75 by 20 ft, aisle width of 25 ft) located as close as possible to train platforms. About 15 to 25 percent of all stalls at each station may be of this type. The revenue from Class A parkers pays for the maintenance and operation of the entire parking facility.

Class B parkers are free parkers who drive miniature vehicles or go-carts which can be parked in a miniature-size stall (about 6.5 by 11 ft, aisle width of about 16 ft). They are given second preference in propinquity to train platforms (after Class A) because of the small spaces they occupy. For design purposes it is assumed that by 1980 there will not be enough miniature vehicles on the market to make this class of parker a significant enough customer to warrant special Class B stalls. Nevertheless, it is known that some manufacturers are experimenting with miniature cars of low capital cost for home-to-station commuting and for family "second cars" to be used in local neighborhood travel (school, shopping, and other local trips). It is estimated that these may represent 10 percent of all parkers by the nominal year 2000. Because of their economy in parking space usage, they should be given every encouragement.

Class C parkers are free parkers who drive small foreign cars which can be parked in a small-size stall (about 7.5 by 14 ft, aisle width of about 20 ft). They are given third preference in propinquity to train platforms (after Class B). Small foreign car usage has been growing and already represented 8 percent of all cars parked at Southern Pacific Peninsula commuter stations in 1960. It is estimated that at the rapid transit stations they may represent 15 percent in 1980 and 25 percent in 2000.

Class D parkers are free parkers who drive standard-size American cars which can be parked in a standard-size stall (8.75 by 20 ft, aisle width of 25 ft). In 1980 they are estimated to represent 85 percent and in 2000, 65 percent of all cars parked at the 23 parking stations. They will occupy the remainder of the parking area as shown in Figure 7.

Portions of Class D space may be set aside for short-term (3 to 5 hour) parking for off-peak users, particularly women shoppers.

Flexible Periodic Layout Readjustments. —It is apparent, from the changing circulation requirements and proportions of different classes of parkers, likely to occur in the future, that the parking stalls and aisles, as well as the entrances, exits, and access roadways, should be constructed and delineated so that they may be conveniently and flexibly readjusted to meet changing conditions. This criterion does not preclude the landscaping and other architectural treatments which are most necessary in all of the external station facilities to create a pleasing impression for rapid transit users and the general community involved. It is also to be observed that the aisle and stall dimensional requirements of each parking class tend to create modules which limit such readjustments and may tend in some cases to limit the effectiveness of small or miniature stalls and aisles.

Operation. —Parking revenue collection for Class A parkers should be separated from train fare collection because of the great expense of maintenance and capital cost of installation, as an alternative, additional system fare collection equipment out-of-doors at the several entrances and exits of all station parking facilities. Actuated gates and fee payment at parking entrances and exits are also expensive and relatively impractical for these applications. Parking meters are relatively expensive to maintain and operate under these conditions. Instead, a much simpler and more economical method of Class A parker revenue collection has been proposed for consideration. The station agent at each parking station and/or the system's several Customer Service Centers would issue, on proper payment and identification, window stickers for automobiles showing date of expiration of validity, station valid at, and class of parker. The parkers affix the stickers at a directed specific place inside a specific window of their automobiles.

On presentation of proper information, Class B, C, and D parkers would obtain free, from the same sources, stickers showing similar information. Roving checkers would periodically check the stickers on all parked vehicles for validity; repeating offenders would be towed away. The sticker identification system would be necessary at most, if not all, parking stations to insure that the parking stalls will be available to and used by bona fide rapid transit parker patrons. General parking demand near these stations might otherwise cause these stalls to be occupied by nonusers.

Rapid transit fares are dedicated for purposes other than the expenses of maintenance and operation of parking facilities. Therefore, revenues from Class A parkers should be sufficient to cover the expenses of the entire parking facilities, which include maintenance, cleaning, window-sticker checking and issuing, lighting, insurance, accounting, administration, and miscellaneous expenses.

Lot vs Multi-Deck. —At most of the 23 parking stations, present plans are that all stalls initially provided will be in lot-type facilities. It is possible that the point may be reached in certain cases, however, where it would be less expensive to construct initially some multi-deck rather than single-level lot parking facilities.

All station parking facilities will be developed to permit the future addition of multiple parking decks. The sizes and shapes of the initial parking facilities, and their stall-aisle modules, must permit the possible subsequent vertical expansion of parking capacity. A frequent advantage of multi-deck parking structures is the marked reduction in average walking distances between auto stall and train platform. It is also then possible to consolidate large parking capacities into multi-deck structures to avoid sprawling the entire capacity over huge single-level lots.

As a general guide, the following walking distance standards have been provided for parking stalls, expressed in terms of radius from the station structure: a desirable maximum of 300 ft and an absolute maximum of 500 to 600 ft. These radii are measured from along the edges of the 700- by 50- to 60-ft station structures. The boundaries indicated by these radii, in effect, form around the station a type of oval in which all of the parking stalls should be located if practicable.

TRANSIT AND TRAFFIC OPERATIONS

Feeder Transit Operations

As shown in Table 8, the vast majority of patrons will reach the outlying parking stations by modes other than walking because of the access distances involved. During the critical peak periods, the passenger occupancy ratio of one bus will be typically 30 times that of one automobile reaching the station. Preferential treatment should be given to feeder transit buses, therefore, in planning station layouts. All present transit operations in the Bay Area have been inventoried and reviewed in past studies to ascertain their potential value as transit feeders to the rapid transit stations. This review process will continue during future stages of the project.

There are important potential economies to the existing transit systems in the conduct of feeder services to BART, especially on routes where feeder patronage is attracted above minimum levels. Feeder trips typically will be short, usually less than 2.5 miles in length and seldom over 6 miles. The bus mileage and operating expense required to serve them, therefore, will be relatively lower than when (as is now the case) such passengers must be hauled by bus all the way to their destinations, often with transfers between buses.

Most feeder transit routes to BART stations will be less than 4 miles in length, and on such routes a feeder bus can be recycled so as to carry two to five peak direction loads during the same crest peak period. There are also important opportunities for balancing the peak directional feeder volumes with additional patronage gained in the reverse direction. At a number of the stations, for example, not only will patrons be boarding rapid transit to commute to work elsewhere, but also commuters will be arriving at these stations for work in the general vicinity.

A significant number of local routes can with few changes be adapted as BART feeders. The operating ratio (expenses to revenues) on many of such routes may be susceptible to marked improvement over present levels. Patronage on such routes could be substantially increased by BART feeder demands; passenger trips, fare revenues, and net revenues per bus-mile could well be improved. The logic and economy of feeder transit operations, where patronage levels are sufficient, point strongly in this direction.

Further potential economies are possible for each local transit system as a whole. At present, usually for $0.15 or $0.20 these local systems must haul their patrons for much longer average distances (at much slower speeds than BART) over the whole lengths of their patrons' trips. They must also provide numerous presently uneconomic feeder bus routes to feed their main trunk routes. For one $0.15 or $0.20 fare today, therefore, their transferring patrons ride on two or even three different buses. One bus gets this fare and the other one or two collect only paper (i.e., the transfer). Such local transferring trips today are typically from 3 to 6 miles in total length.

With BART in operation, the bus patrons who transfer to BART rather than going all the way locally by bus will have typical feeder bus trip lengths of only 1 to 3 miles—less than half their present typical total trip length by bus. Furthermore, their feeder trips will almost always involve one bus to the BART station, rather than two or three when transferring as at present. In addition, these passengers will ride through the most critical (service-determining) transit maximum-load points and along the most congested urban corridors on high-capacity rapid transit, which can carry loads more economically at three to four times surface transit speeds.

These are factors of profound importance to local transit systems in areas served by rapid transit. They are the principal reasons why the general manager of the Cleveland Transit System can state that the introduction in 1955-1958 of the 15-mile East-West rapid transit line has improved the operating economy of the whole CTS bus and rail system and has retarded periodic needs for systemwide fare increases.

Vehicular Traffic Operations in Station Vicinities

In rapid transit station facilities, certain other general traffic operational considerations are important. As in most traffic planning, efforts should be made to deconcentrate potentially critical areas or points of congestion and conflict. Left turns across opposing vehicle flows should be eliminated as much as possible and right turns emphasized where appropriate.

It is desirable to prepare special estimates of the arriving and departing volumes of station vehicular and person trips, by each mode of access, during the design-determining peak periods. For this purpose, the effective tributary patronage territory of each station should be determined and divided into relatively small zones sectored or oriented toward the station itself. Such sector studies, with their estimated peak volumes arriving and departing by each access mode, are being prepared for each of the rapid transit and express streetcar stations of the BART system. These studies are essential to developing proper internal and external station area layouts, access roadways, and connections to the adjacent street and highway system. The sector studies also are essential to determine the impact of station-generated vehicular and pedestrian traffic on the feeding streets and highways in the vicinity.

Although feeder transit operations can, as indicated above, be conducted economically in many cases, there will be portions of some tributary patronage areas where potential feeder transit volumes will be light. It will often be less expensive, therefore, from the standpoint of overall regional and local transit operations to provide at the stations adequate parking stall capacity and kiss-ride facilities to reduce the needs for feeder transit services in cases where they are, in fact, uneconomical. The Cleveland Transit System has found this principle to be most effective at outlying stations where feeder transit patronage may be relatively light. It is less expensive for CTS to provide parking stalls in such cases than the equivalent feeder bus service. Obviously, the provision of the even less land-consuming and less costly kiss-ride auto facilities compares in this respect even more favorably.

GENERAL PLANNING CONSIDERATIONS

Population Densities and Rapid Transit

It is often advanced that urban areas of relatively low population density do not justify grade-separated rapid transit. Rather than the average population densities in each urban region involved, a more significant test is the relation between measured peak traffic volume-pattern demands and the transportation capacities available to meet these demands separately for each of the major corridors of the urban region. Although the overall population densities of a region, or the part of it proposed to be served by a rapid transit line, may be relatively low, the principal test is the ability of the proposed rapid transit facility to attract enough major corridor traffic of sufficient length to minimize effectively the total transportation facilities and costs required to meet total peak corridor demands.

Table 5 shows the parking-passenger trips attracted to four westside Cleveland rapid transit stations from their tributary patronage territories, and the lengths of those trips between place of residence and the rapid transit interchange stations used. It is significant to note from Table 5 that in October 1959 the weighted average access length of these trips was 2.97 miles, and that by March 1964 this average distance had increased by 8.4 percent to 3.22 miles. In fact, 25.0 percent of these trips reached the stations from distances of greater than 5 miles in 1964. The present West-Side rapid transit line serves ten suburban communities with an average population density of only 1,378 persons per square mile or 2.1 persons per acre (12). This line is being extended farther westward into outlying areas of low density.

Table 6 shows similar Cleveland rapid transit data for each access mode in March-April 1958. Although the West-Side Cleveland rapid transit line was only opened late in 1955, and by March-April 1958 extended west only to the W. 117th St. Station with less than adequate initial interchange facilities, even by 1958 24.2 percent of parker trips and 8.4 percent of all trips to and from the W. 117th and W. 98th St. Stations involved access distances of greater than 5 miles.

It is apparent that, with properly designed highway-transit interchange stations, the effective tributary patronage territory of rapid transit systems offering fast, convenient service may feasibly extend at least 4 to 6 miles in outlying areas. Even 6-mile trips to rapid transit stations typically involve only 15 to 20 min of travel time. A 4-mile auto access trip might typically involve 10 to 15 min of travel time to the station. Large portions of such station tributary areas may have very low suburban or exurban population densities. The important points are the amount of passengers attracted to the stations themselves and aggregated through the critical transit maximum load points of the major corridors served, as well as the lengths of the heavy-volume portions of those corridors.

Adequate well-designed provision must be made for potential patrons who will drive to collector stations and park there, enabling them to proceed over the most congested portions of their routes via rapid transit. From the standpoint of station economy, patrons who reach the station by kiss-ride vehicles and feeder buses require much less station facilities, capital investment, and area than do patrons parking automobiles there. Therefore, in planning and design, every encouragement should be given to the nonparking access mode categories.

Station Spacing and Location

In addition to emphasizing the needs for high standards in the planning and design of coordinated highway-transit interchange stations, these data illustrate that such collector stations usually should not be spaced closer together than every 2 to 3 miles in the outlying tributary residential areas of high-speed regional systems. A variety of access travel modes are usually available to prospective rapid transit patrons whose homes, or even places of work, are beyond normal walking distance from the station (1,300 to 2,600 ft). Long station spacings of 2 to 4 miles in the tributary residential areas are essential to insure high schedule speeds (45 to 50 mph) along the BART system. It is estimated (Table 8) that generally much less than 20 percent of all passengers reaching the 23 principal BART residential collector stations in outlying areas will do so on foot. The "reach" of the station, with proper feeder transit, parking, and kiss-ride facilities, is, therefore, vastly extended beyond the limited walking range, to effective distances of 4, 6 and, in some cases, 10 miles.

Station location, closely tied as it is to the general subject of rapid transit route location, is also influenced by a hierarchy of other considerations which can appropriately be the focus of a separate paper. Important among these considerations are the forecast characteristics of each potential station site and its tributary or service area, as discussed previously. Of considerable importance is the ranking of the service functions assigned to each station under study. Such functions include those of residential passenger collection and those of passenger delivery within regional subcenters and centers. The proportions of the collection and delivery functions will vary between stations. The best collector stations are usually those which strongly emphasize or solely possess this function, to the deemphasis or exclusion of central delivery functions.

Therefore, in rapid transit route location, the aim is often to locate some stations between or away from regional subcenters or centers to optimize coordination with access streets and highways, provide adequate station interchange facilities with minimum congestion, and thus serve well residential tributary areas which are usually spread out in composition. Other stations along the same route will emphasize the delivery function to regional subcenters and centers and may or may not also function as residential collectors.

CONCLUDING OBSERVATIONS

In the total transportation planning process under way in urban regions, it is evident that private and public transportation must be coordinated effectively to minimize the aggregate investment in transportation facilities and costs of operation, as well as to minimize urban congestion and travel times.

People must first get to public transit stations and stops if they are to make use of these facilities and not always travel all of the way in automobiles. The attraction of potential passengers to transit stations and stops is, therefore, of paramount importance. Not only must the transit systems themselves be fast, economical, convenient, and comfortable; the interchange facilities required to attract patrons at stations and stops must also be abundant and well-designed. The transit stations, therefore, become critical elements of transition between highway and transit travel.

There are important areas for further research and development within this general subject. Additional studies are desirable with respect to the characteristics of tributary station territories, patronage volumes, feeder transit operations, vehicular traffic operations, modes of access, and volume periodicity. Unfortunately, to date, rapid transit stations with parking, feeder transit, and kiss-ride facilities available for such studies, are relatively limited in number. Until the new generation of rapid transit systems are in operation in the Bay Area, Philadelphia, and elsewhere, further research must be concentrated principally at the rapid transit and commuter railroad stations having such facilities in Cleveland, Boston, New York, Philadelphia, Chicago, and a few pioneering cities abroad.

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