SCRTD METRO RAIL PROJECT

Preliminary Engineering

PRELIMINARY OPERATING PLAN

WBS 13DAA

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SUMMARY

This preliminary operating plan defines initial service and operating characteristics for the SCRTD Metro Rail system in 1995. Its purpose is to provide a point of reference for the system design and for further analysis of operating alternatives.

Service has been planned for an 18-mile line between downtown Los Angeles and North Hollywood, with 16 stations and with train storage and maintenance facilities at each terminus. During the peak period, terminal-to-terminal travel time will be 31½ minutes; round-trip times will be 69 minutes, including terminal layover. During off-peak hours, these times will be slightly shorter due to shorter station dwell times.

Ridership in 1995 is expected to reach 309,000 trips daily. Of these, an estimated 28,400 will travel through the maximum load point in the morning peak hour: 15,600 inbound and 12,800 outbound.

It is recommended that the Metro Rail line operate 20 hours per day, 7 days per week. Expansion of service to 24 hours would not be precluded by system design.

Service frequency and train length would vary by time of day, as shown in the table on the following page.

Period		Maximum Schedule Headway (minutes)	Consist (Cars)
Weekdays			
Early morning	5:30 a.m. - 6:00 a.m.	15	6
	6:00 a.m. - 6:30 a.m.	7½	6
Peak periods	6:30 a.m. - 9:00 a.m.	3½-6	6
	3:30 p.m. - 6:30 p.m.	3½-6	6
Midday	9:00 a.m. - 3:30 p.m.	7½	6
Evening	6:30 p.m. - 7:30 p.m.	7½	6
Night	7:30 p.m. - 1:30 a.m.	15	4
Saturdays			
Morning	5:30 a.m. - 7:30 a.m.	15	4
Day	7:30 a.m. - 7:30 p.m.	10	6
Night	7:30 p.m. - 1:30 a.m.	15	4
Sundays and holidays			
All day	5:30 a.m. - 1:30 a.m.	15	4

Peak-period service would be scheduled to carry 170 passengers in each car through the maximum load point. Off-peak service would conform to established policy headways. On weekdays, 167 train trips would operate in each direction; 104 trips would operate on Saturdays, and 80 would operate on Sundays.

During peak periods, 6-car trains would be run. Daytime service on weekdays and Saturdays would also use 6-car trains to ensure that few riders in the off-peak would need to stand for more than one station stop. At other hours and on Sundays, 4-car trains would suffice to meet this standard.

A total of 140 cars (70 married pairs) would be required in 1995. This total includes a margin for maintenance needs and standby service. On an annual basis, this fleet would log 60,000 train hours, 331,000 car hours, and 11,000,000 car miles of service.

If the system is designed to operate at 2-minute headways, it will be capable of accommodating a 72 percent increase in peak-period ridership levels, assuming 6-car trains and 170 passengers per car. If this ultimate capacity is achieved prior to an expansion of the 18-mile system, 214 cars would be required to provide service at 2-minute headways.

CHAPTER 1
INTRODUCTION

This report contains a preliminary operating plan for the initial Southern California Rapid Transit District (SCRTD) Metro Rail system. Service and operating characteristics are described for the horizon year of 1995 to provide a point of reference for further analysis of the proposed system's design and operation. Service needs for the year 1995, recommended service levels and standards, a proposed train operating schedule, revenue fleet requirements, and pertinent operating statistics are presented, along with a preliminary analysis of the ultimate capacity of the initial line.

Development of this operating plan was based on an analysis of projected Metro Rail ridership and system characteristics, supplemented by examination of operations on other rail systems. Many of the data are preliminary and will be updated during the preliminary engineering phase of the Metro Rail Project. Future studies will analyze the operating plan's sensitivity to variations in service parameters and system characteristics. An updated operating plan will be prepared after the preferred system alternative has been selected during the preliminary engineering phase.

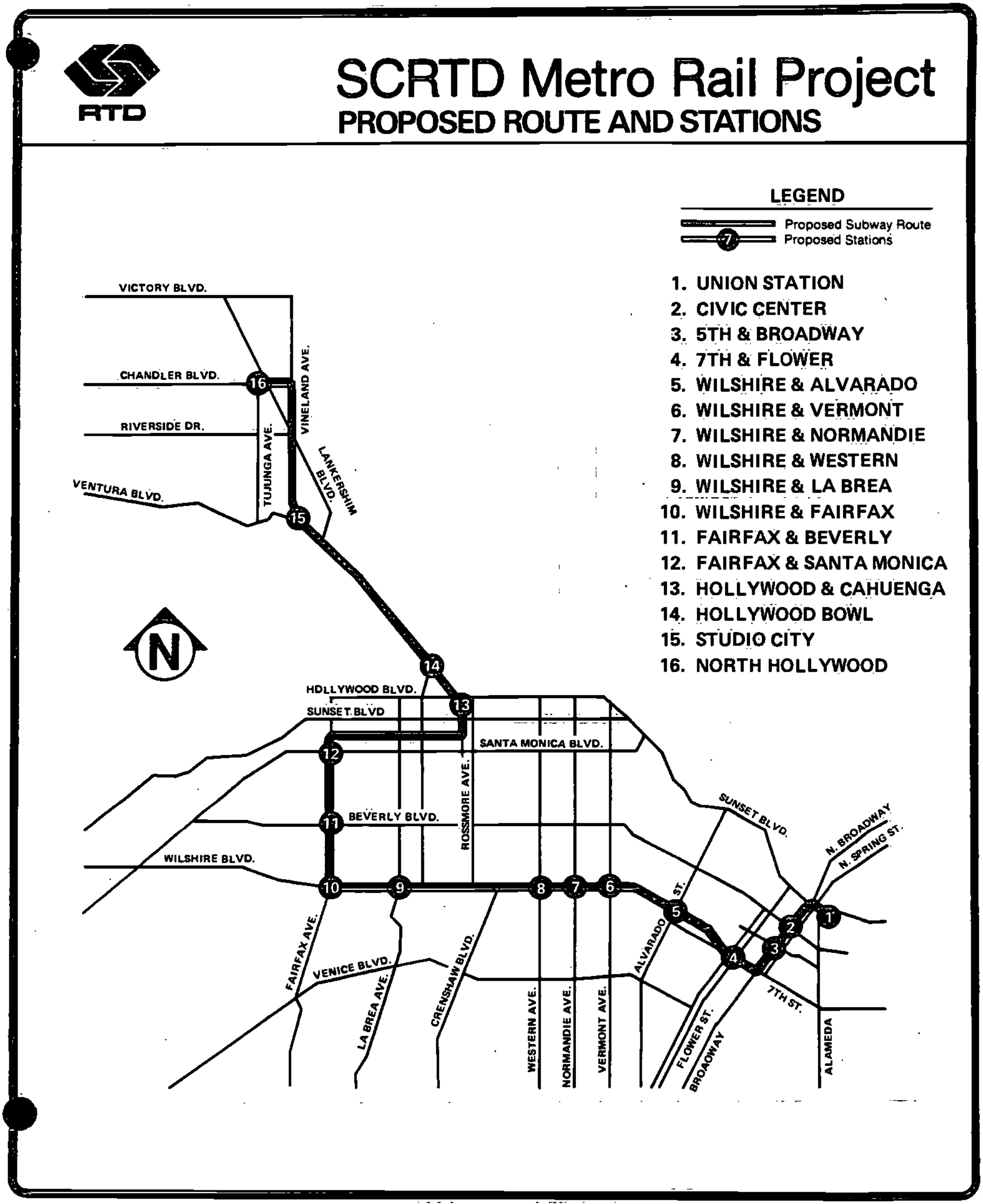
CHAPTER 2
SYSTEM DESCRIPTION

The Metro Rail line is currently planned to open in 1990. Plans are for the line to be 18.6 miles long and serve downtown Los Angeles, Wilshire, Fairfax, Hollywood, and the San Fernando Valley via its terminus in North Hollywood. It is anticipated that this will be the initial segment of a regional rail rapid transit system. Sixteen stations are contemplated, with station spacings varying from 0.5 miles downtown to 2.7 miles through the Santa Monica mountains. Figure 2-1 shows the planned horizontal alignment and station locations.

Vehicle storage and maintenance facilities will be located at each end of the line. The yard in the downtown area will be an all-purpose facility capable of vehicle storage, inspection, service, and major repairs and overhaul. The North Hollywood yard will accommodate, at a minimum, vehicle storage and light repairs.

Metro Rail cars are expected to be similar to those used on other new or recently developed rail systems, such as Bay Area Rapid Transit (BART), Port Authority Transit Corporation (PATCO), Metropolitan Atlanta Rapid Transit Authority (MARTA), Washington Metropolitan Area Transit Authority (WMATA), Miami, and Baltimore. In accordance with SCRTD Board policy, the cars will be 75 feet in length. Other vehicle dimensions have been based on the Baltimore-Miami car currently under construction. It is anticipated that each Metro Rail car will have 76 seats and 310 square feet of standing area. Current plans are for operation of trains of up to 6 cars.

Figure 2-1. Metro Rail alignment and stations.



CHAPTER 3

BASELINE OPERATING PLAN FOR 1995

This chapter discusses proposed service standards for the Metro Rail line and the resulting service levels, operating statistics, and fleet requirements for the year 1995. The service standards are policies that set parameters for minimum service levels. Development of these standards was based on a review of the service levels on other systems and on estimates of 1995 ridership levels on the Metro Rail system. To estimate ridership levels by time of day, the average weekday volume of 309,000 one-way riders projected for Metro Rail was factored by available hourly bus ridership data and then adjusted to incorporate the peaking characteristics anticipated on the rail line.(1) A train schedule was developed to illustrate how demand levels and service standards would be met and to establish a basis for derivation of fleet requirements and operating statistics. The train schedule incorporated travel times based on characteristics of the route and the vehicle. A detailed discussion of ridership volumes and travel time derivations is in Appendix A.

3.1 SERVICE STANDARDS

Service standards establish minimum comfort and convenience levels for passenger service. The maximum vehicle loads, hours of service, and minimum frequency of service defined in this operating plan determine the maximum level of crowding and waiting time that a passenger can expect.

3.1.1 Vehicle Load Standards

Four vehicle load standards—seated, off-peak, peak, and crush—are defined in Table 3-1. The first standard shows the seated capacity of 76 passengers per car, which results in a load factor of 1.0 (one passenger per seat). The second and third standards are for scheduling purposes; the fourth is for analysis of failure management strategies. The use of two load standards for scheduling purposes provides a means of responding to the different effects of peak and off-peak service levels. Peak service requirements have a greater impact on capital and operating requirements than off-peak levels. Off-peak ridership, however, typically exhibits a greater sensitivity to service levels and ride quality. For a given service frequency and ridership level, the off-peak load standard will influence consist size.

Table 3-2 compares the proposed Metro Rail vehicle load standard with those of other rail systems having 75-foot cars. As the table shows, the proposed load standard is most similar to those of Washington and the systems under construction in Baltimore and Miami. It is lower than those of Toronto and New York, which are operating at or near capacity on some lines, and it is higher than those of BART and MARTA.

<u>Off-Peak Load</u>. The proposed off-peak load standard of 91 passengers per car corresponds to a load factor of 1.2. This standard will ensure that few passengers will have to stand for more than one station stop in off-peak periods. Analysis of station boarding and alighting patterns indicates that, with this standard, standing on off-peak trains would occur only between the Wilshire/Vermont and 5th/Broadway stations and that, with regular turnover of passengers at stations along Wilshire Boulevard, no passengers would need to stand for more than 3 minutes.

Table 3-1. Vehicle load standards.

Load	No. of Passengers	Load Factor	Area per Standee (sq ft)
Seated	76	1.0	--
Off-peak	91	1.2	20.7
Peak	170	2.2	3.3
Crush	232	3.0	2.0

Table 3-2. Comparisons of load factor standards.

System	Loading Standard (total passengers)	No. of Seats	Standing Area (sq ft)	Load Factor	Standing Density (sq ft per standee)
SCRTD proposed	170	76	310	2.2	3.3
Baltimore	166	76	310	2.2	3.4
Miami	166	74	320	2.2	3.5
WMATA	170	80	301	2.1	3.2
TTC	223	76	307	2.9	2.1
MARTA	136	68	288	2.0	4.2
NYCTA	220	72	328	3.1	2.2
BART	94	72	265	1.3	12.0

Peak Load. A peak-load standard of 170 passengers per car will provide adequate room for circulation among standees and thus aid in minimizing station dwell times. This standard comprises the seating capacity for 76 passengers plus space for 94 standees, based on a standing density of 3.3 square feet per passenger. A standing density of 3.0 square feet per passenger is considered the minimum required for adequate circulation.(4) In light of the boarding and alighting activity expected at stations near the maximum load point (typically 10 to 33 percent), this circulation is necessary to prevent undesirably long dwell times. A 10 percent contingency, resulting in 3.3 square feet per standee, was added to allow for imbalances in vehicle loading that occur during the peak period; such imbalances could result from established headway or average passenger flow deviations or from an uneven distribution of passengers on the train.

Crush Load. The crush load standard of 232 passengers per car is based on a 76-passenger seating capacity and 2.0 square feet per standee. This standing density, considered a minimum level for short-term queuing without physical or psychological discomfort, is defined here for analysis of operating strategies only; it should not be used for vehicle design purposes since denser loads are possible.

3.1.2 Hours of Service

Hours of service on other rail systems vary from 18 to 24 hours per day; weekend hours are shorter in some cases. Service hours recommended for the Metro Rail system are similar to those used by MARTA.

In light of the minimal demand anticipated for rail service between 1:30 and 5:30 a.m. and the availability of local bus service in the corridor during that period, a 20-hour service has been defined. Hours of service at the maximum load point would be approximately 5:30 a.m. to 1:30 a.m. daily, including Saturdays, Sundays, and holidays. Departure of the first train from the yard and arrival of the last train at the yard would occur slightly beyond these hours.

The period between 1:30 a.m. and 5:30 a.m. could be used for safe and efficient right-of-way maintenance. Although service hours and frequencies established in the Metro Rail System Alternatives Analysis assumed 24-hour service, the low demand for all-night service does not justify incurring the additional cost of operation and precluding an uninterrupted time for maintenance. Nothing in the design of the Metro Rail system, however, will rule out 24-hour operation if such service becomes appropriate.

3.1.3 Policy Headway

Policy headway defines the maximum waiting time for patrons at different times of the day. Headways shorter than policy are provided as required to satisfy other service standards (e.g., vehicle loadings) or to relay equipment to points where it is needed. Deadheading will be restricted to disabled trains.

The policy headways recommended for Metro Rail are given in Table 3-3. Their definition took into consideration anticipated demand levels along the Metro Rail corridor and service levels on other systems. Table 3-4 shows a comparison of Metro Rail service levels (hours, frequencies, and anticipated train lengths) with those of other rail systems.

Table 3-3. Recommended policy headways.

Period		Maximum Schedule Headway (minutes)
Weekdays		
Early morning	5:30 a.m. - 6:00 a.m.	15
	6:00 a.m. - 6:30 a.m.	7½
Peak periods	6:30 a.m. - 9:00 a.m.	6
	3:30 p.m. - 6:30 p.m.	6
Midday	9:00 a.m. - 3:30 p.m.	7½
Evening	6:30 p.m. - 7:30 p.m.	7½
Night	7:30 p.m. - 1:30 a.m.	15
Saturdays		
Morning	5:30 a.m. - 7:30 a.m.	15
Day	7:30 a.m. - 7:30 p.m.	10
Night	7:30 p.m. - 1:30 a.m.	15
Sundays and holidays		
All day	5:30 a.m. - 1:30 a.m.	15

Table 3-4. Comparison of service levels.

Service Factor	WMATA Red Line	PATCO	CTA North Line	MARTA	BART Daly City	SCRTD AA/EIR	SCRTD Op. Plan
Hours of service							
Weekday	18	24	24	20	18	24	20
Begin	6 a.m.			5:30 a.m.	6 a.m.		5:30 a.m.
End	12 mid.			1:30 a.m.	12 mid.		1:30 a.m.
Saturday	16	24	24	20	18	24	20
Sunday	8	24	24	20	15	24	20
Service headway (weekday), minutes							
Morning peak	5	2-6	3-4	10	3.75	3½	3½-6
Midday	10	7½	5	10	5	7	7½
Evening peak	5	2-6	3-4	10	3.75	3½	3½-6
Evening	10	7½-10	6	10	5	15	7½
Late night	15	60	7½-15	15	20	30	15
(Late-night start)	10:30 p.m.	10:35 p.m.	10:00 p.m.	7:30 p.m.	7:20 p.m.	1:00 a.m.	7:30 p.m.
Train consists (weekday)							
Peak period	6	6	8	6	4-10	6	6
Midday	6	2	4	4	3-6	4	6
Late evening	4	1	2	2	5-6	2	4

Service frequencies on other systems range from 2 to 10 minutes between peak-period trains and from 5 to 10 minutes between midday trains. Weekday service frequencies are similar to those specified in the Alternatives Analysis; recommended weekend service levels, however, are less frequent than those recommended in the earlier study.(5) Service hours and off-peak frequency may be adjusted following the initiation of service as actual ridership characteristics become apparent.

3.2 OPERATING REQUIREMENTS

This plan is based on the following operating philosophy:

- All trains will operate the full length of the line, stopping at each station.
- Train service will be provided at the minimum service frequency unless vehicle loading or vehicle relaying (positioning) requires additional service.
- Minimum schedule headways will be determined by the capacity needs of the peak 20-minute period. Peaking within that period has been assumed to be minimal.

3.2.1 Peak-Hour Service

During peak periods, 6-car consists will be required. With a peak load of 170 passengers per car, these 6-car trains can carry 1,020 passengers. To accommodate projected ridership levels, it will be necessary to carry 15,600 inbound passengers traveling through the maximum load point in the morning peak hour. As Table 3-5 shows, 16 inbound train trips must be scheduled in that 1-hour period. Similarly, a minimum of 6 train trips must be scheduled to accommodate the 5,900 inbound passengers at the maximum load point in the peak 20-minute period. Assuming a relatively constant passenger flow during the 20-minute peak, this latter re-

Table 3-5. Service requirements for morning peak period.

Time Period	Maximum Load Ridership	Minimum No. of Trains	Required Headway (minutes)
Inbound			
Peak 20 minutes	5,900	6	3½
Remainder of peak hour	9,700	10	4
Remainder of peak 2 hours	11,200	11	5½
Outbound			
Peak 20 minutes	4,900	5	4
Remainder of peak hour	7,900	8	5
Remainder of peak 2 hours	9,200	9	6*

*Policy headway

quirement means that, at the height of the peak, a schedule headway of 3½ minutes will be necessary. In the outbound direction, with 4,900 passengers in the peak 20 minutes, 4-minute headways will suffice.

A proposed operating schedule for weekday morning service is shown in Table 3-6; derivation of travel times used in development of the schedule is discussed in Appendix B. The table illustrates how peak-hour service needs in both directions influence overall service levels and revenue fleet requirements. Service has been scheduled to peak simultaneously in both directions at the maximum load point. Train service and revenue equipment must meet the needs of the peak in each direction. Nineteen 6-car consists would be required to operate the peak-period schedule.

Service levels outside the peak hour are also influenced by vehicle storage locations. In general, train hours of weekday service will increase with the number of consists stored overnight at the downtown yard and/or midday at North Hollywood. More inbound service will be required in the morning peak hour since inbound peak ridership is higher than outbound. Peak inbound service will also be dispatched earlier because the maximum load point is near downtown.

In the operating schedule shown in Table 3-6, overnight storage is shared equally between the two yards. As a result, some consists will be relayed as revenue trains to North Hollywood for the inbound peak. Peak-period train hours would be minimized if approximately two-thirds of the revenue fleet were stored overnight at North Hollywood. However, other considerations—such as overnight vehicle servicing, vehicle maintenance, and North Hollywood site constraints—make this impractical.

Table 3-6. Proposed weekday morning schedule.

Train No.	Depart Union Station	Arrive North Hollywood	Depart North Hollywood	Arrive Union Station
17			* 5:13½	5:43
18			* 5:28½	5:58
3			* 5:43½	6:13
7			* 5:51	6:20½
8			* 5:58½	6:28
10	* 5:28	5:57½	6:06	6:35½
12			* 6:13½	6:43
13	* 5:43	6:12½	6:18½	6:48
15			* 6:23½	6:53
16			* 6:28½	6:58
17	5:59	6:28½	6:31½	7:03
18	6:04	6:33½	6:36½	7:08
1	* 6:08½	6:38	6:41	7:12½
2	* 6:12½	6:42	6:45	7:16½
3	6:16½	6:46	6:49	7:20½
4	* 6:20½	6:50	6:53	7:24½@
5			* 6:56½	7:28
6	* 6:24½	6:54	7:00	7:31
7	6:29	6:58½	7:03½	7:35
8	6:33	7:02½	7:07	7:38½@
9	* 6:37	7:06½	7:10½	7:42
10	6:41	7:10½	7:14	7:45
11	* 6:44½	7:14½	7:17½	7:49
12	6:48	7:18½	7:21½	7:53@
13	6:51	7:22½	7:25½	7:57
14	* 6:55	7:26½	7:29½	8:01
15	6:59	7:30½	7:33½	8:05@
16	7:03	7:34½	7:37½	8:09
17	7:07	7:38½	7:41½	8:13@
18	7:11	7:42½	7:45½	8:17
19	* 7:15	7:46½	7:49½	8:21
1	7:19	7:50½	7:53½	8:25@
2	7:23	7:54½	7:57½	8:29
3	7:27	7:58½	8:01½	8:33
5	7:31	8:02½	8:05½	8:37@
6	7:36	8:07½	8:10½	8:42
7	7:41	8:12½	8:15½	8:47
9	7:46	8:17½	8:20½	8:52
10	7:51	8:22½	8:25½	8:57
11	7:57	8:28½	8:31½	9:03
13	8:03	8:34½	8:37½	9:09

Table 3-6, continued

Train No.	Depart Union Station	Arrive North Hollywood	Depart North Hollywood	Arrive Union Station
14	8:09	8:40½	8:43½	9:13½@
16	8:15	8:46½	8:49½	9:19½
18	8:21	8:52½	8:55½	9:25½
19	8:27	8:58½	9:01½	9:31
2	8:33	9:04½	9:07½	9:37
3	8:39	9:10½	9:13½	9:43@
6	8:45	9:16½	9:19½	9:49
7	8:51	9:22½	9:25½	9:55
9	8:57	9:28½	9:31½	10:01
10	9:03	9:34	9:37½	10:07
11	9:09	9:39½	9:43½	10:13@
13	9:15½	9:45½	9:49½	10:19
16	9:23	9:52½	9:56½	10:26
18	9:30½	10:00	10:04	10:33½
19	9:38	10:07½	10:11½	10:41
2	9:45½	10:15	10:19	10:48½
6	9:53	10:22½	10:26½	10:56
7	10:00½	10:30	10:34	11:03½
9	10:08	10:45	10:41½	11:10½
10	10:15½	10:37½	10:49	11:18½
13	10:23	10:52½		

* departs from yard

@ enters yard

3.2.2 Off-Peak Service

During the off-peak period, train lengths must satisfy the load factor standard of 1.2 times seated capacity, or 91 passengers per car. For the estimated 3,300 hourly midday passengers traveling through the maximum load point in each direction, 6-car trains will be necessary for the specified headways of 7½ minutes. On Sundays and holidays and in the early mornings and evenings on weekdays and Saturdays, when low ridership levels are anticipated, 4-car trains will be operated at the specified 15-minute headways.

With an average dwell time of 20 seconds at the intermediate stations during the off-peak, nominal round-trip times will be 65 minutes. Nine trains will be required for this off-peak service.

3.2.3 Operating Statistics

Table 3-7 summarizes the service to be provided during the 20-hour operating period on weekdays. Differences between the headways in Table 3-7 and the policy headways specified in Table 3-3 are due to equipment relay requirements and peak-period demand levels that exceed minimum service capacity.

Operating statistics are summarized in Table 3-8. Train and car hours are based on average, not nominal, round-trip times for different times of the day (70 minutes for the peak period and 67½ minutes for the off-peak).

On a typical weekday, 167 trains will be operated, logging 190 train hours, 1,088 car hours, and 35,680 car miles. On an annual basis, the system will log 60,000 train hours, 331,000 car hours, and 11,000,000 car miles.

Table 3-7. Summary of weekday service.

Period	Headways (minutes) Inbound	Headways (minutes) Outbound	Train Trips Inbound	Train Trips Outbound
5:30 a.m. - 6:00 a.m.	15	15	2	2
6:00 a.m. - 6:30 a.m.	7½	4	4	7
6:30 a.m. - 7:00 a.m.	5	4	6	7
7:00 a.m. - 7:30 a.m.	3½-4	4	8	7
7:30 a.m. - 8:00 a.m.	3½-4	4-5	8	7
8:00 a.m. - 8:30 a.m.	4	6	7	5
8:30 a.m. - 9:00 a.m.	6	6	6	5
9:00 a.m. - 9:30 a.m.	6	6	5	5
9:30 a.m. - 10:00 a.m.	6	7½	5	4
10:00 a.m. - 3:00 p.m.	7½	7½	40	40
3:00 p.m. - 3:30 p.m.	7½	5	4	6
3:30 p.m. - 4:00 p.m.	6	5	5	6
4:00 p.m. - 4:30 p.m.	5	4	6	7
4:30 p.m. - 5:00 p.m.	4-5	3½-4	7	8
5:00 p.m. - 5:30 p.m.	4-5	3½-4	7	8
5:30 p.m. - 6:00 p.m.	4	5	7	6
6:00 p.m. - 6:30 p.m.	4	6	7	5
6:30 p.m. - 7:00 p.m.	7½	7½	5	4
7:00 p.m. - 7:30 p.m.	7½	7½	4	4
7:30 p.m. - 1:30 a.m.	15	15	24	24
			167	167

Table 3-8. Summary of operating statistics.

Period	Days per Year	No. of Trains	No. of Car Trips	Train Hours	Car Hours	Car Miles
Weekdays	255	167	954	190.5	1,088	35,680
Saturdays	52	104	560	117.0	630	20,994
Sundays and Holidays	58	80	320	90.0	360	11,968
Annual	365	52,633	290,950	59,830	331,080	10,884,232
Annualization Factor (Annual/ Weekday)		315	305	314	304	305

3.2.4 Fleet Requirements

A total fleet size of 140 cars will be required for 1995 service:

- 114 cars for revenue service (peak-hour service of 19 6-car trains)
- 12 cars for terminal spares (two gap trains) to replace in-service failures or to fill gaps resulting from significant service delays
- 14 cars for maintenance spares, assuming 90-percent availability

Terminal Spares. One standby (or gap) train will be located at each terminal to enter service in the event that another train must be removed from service due to hardware failure or if additional equipment is required because of passenger volume irregularities. WMATA, MARTA, and PATCO each position gap trains on or near the main line for those occasions when they are needed for such reasons.

It is anticipated that at least one 6-car gap train will be needed two to four times each week during peak periods. This estimate is based on the mean-time-between-service-failures (MTBSF) experience of existing properties and the probability of vehicle failure during the 2-hour peak period.(6)

Because both terminals will be dispatching trains into revenue service, one spare train at each terminal will permit rapid response to equipment failure and limit the resulting impacts on service.

Maintenance Spares. Unavailability due to corrective maintenance is determined by vehicle reliability (mean-time-between-failures, or MTBF) and shop maintenance capacity. It is also influenced by fleet composition; lower availability can be expected with a fleet of married pairs than with one of single cars, since two cars are made unavailable by most failures. In addition, for planning purposes, the availability factor should consider the potential prolonged loss of equipment from active service due to unforeseen car damage.

PATCO and MARTA typically achieve availabilities of about 90 percent; CTA achieves approximately 87 percent; WMATA achieves 88 percent. BART has recently been achieving an availability of approximately 85 percent of its active fleet, although equipment availability was previously much lower.

During the early years of operation, lower levels of availability should be anticipated. The 90 percent availability level may not be achieved during the first 3 to 5 years. Once the Metro Rail system has matured, the targeted 90 percent availability factor should provide adequate contingency for vehicle loss and maintenance requirements provided that: (a) stringent vehicle specification and procurement procedures are implemented to ensure that reasonable reliability and maintainability goals can be achieved; and (b) maintenance facilities have sufficient capacity and are properly staffed for quick repairs and servicing.

CHAPTER 4
ULTIMATE SYSTEM CAPACITY

The Metro Rail system must be designed to accommodate growth in demand beyond the 1995 horizon year, without requiring major reconstruction. This chapter examines several design alternatives for defining the maximum capacity that could be provided on the initial 18-mile system.

Three variables determine throughput capacity: schedule headways, vehicle capacity, and train length. Table 4-1 summarizes the hourly capacity possible under various assumptions. For example, 6-car trains would have an hourly maximum load capacity of 30,600 persons at 2-minute schedule headways, if loadings are no higher than 170 passengers per car; the capacity of 8-car trains under similar conditions would be 40,800 passengers per hour.

Table 4-2 compares the ultimate capacity under various alternatives to the peak 20-minute demand levels forecast for 1995. These figures show that a 72 percent increase in ridership over 1995 levels could be accommodated by 6-car trains with 170 passengers per car operating at a minimum 2-minute schedule headway. A 135 percent increase could be accommodated if crush load conditions were permitted. Eight-car trains with 170 passengers per car and operating at 2-minute headways would accommodate a 129 percent increase in ridership.

Fleet requirements for each capacity alternative are for the initial 18-mile line alone and assume ridership peaking characteristics similar to those anticipated in 1995. With 6-car trains at 2-minute headways and 170 passengers per car, 214 cars would be required.

Table 4-1. Hourly maximum load capacity.

Maximum Passengers Per Car	Hourly Capacity (Passengers)			
	6-Car Trains		8-Car Trains	
	2-Minute Headway	2.5-Minute Headway	2-Minute Headway	2.5-Minute Headway
170	30,600	24,500	40,800	32,600
200	36,000	28,800	48,000	38,400
232	41,760	33,400	55,700	44,500

Table 4-2. Design capacity alternatives.

Design Parameters	Alternative 1	2	3	4	5	6	7	8
Operating standards								
Minimum schedule headway	2 min	2 min	2 min	2 min	2.5 min	2.5 min	2.5 min	2.5 min
Maximum train length	6-car	6-car	6-car	8-car	6-car	6-car	6-car	8-car
Maximum car load	170	200*	232*	170	170	200*	232*	170
Hourly passenger capacity (through maximum load point)	30,600	36,000	41,760	40,800	24,480	28,800	33,408	32,640
Maximum ridership								
Peak 20 minutes	10,200	12,000	13,920	13,600	8,160	9,600	11,136	10,880
Peak hour	26,842	31,579	35,789	21,474	21,474	25,263	29,305	28,632
Service needs (trains)								
Peak 20 minutes	10	10	10	10	8	8	8	8
Peak hour	27	30	30	27	22	24	24	22
Fleet requirement								
Revenue service	180	210	210	240	150	168	168	200
Total (including spares)**	214	248	248	280	180	200	200	236
Peak 20-minute ridership as a percentage of 1995 projections	172%	202%	235%	229%	138%	162%	188%	184%

* Minimum headway operated until vehicle loads fall below 170 passengers.

** Two spare consists at terminals, 90 percent availability.

No North American systems outside the New York area and Toronto currently carry peak-hour loads that exceed 30,000, although many can accommodate a higher capacity with 2-minute headways. Table 4-3 shows current demand levels on selected systems. Given the experience of these systems, an ultimate service capacity of 30,000 passengers per hour is a reasonable design target.

Table 4-3. Current ridership on other rail lines—
peak hour at inbound maximum load point.

Service Factor	NYCTA Queens-Ind Line	TTC Yonge Line	WMATA Red Line	BART Transbay Service	SCRTD Metro Line
Trains	29	28	12	16	16
Cars	232	168	82	143	96
Passengers	55,700	33,000	12,000	13,055	15,600
Cars Per Train	8.0	6.0	6.8	8.9	6.0
Passengers per Car	240	196	146	91	162

APPENDIX A
RIDERSHIP FORECASTS

Daily ridership forecasts, shown in Table A-1, indicate that many stations will be significant traffic generators for trips in both directions. Of the estimated 309,000 daily one-way riders:

- 164,300 (53 percent) will travel through the maximum load points,
- 39,500 (13 percent) will travel between downtown stations, and
- 105,200 (34 percent) will not enter the downtown area at all.

Weekday peaking is expected to be similar to levels experienced on other rail transit systems, but the unique characteristics of the Wilshire corridor will result in the weekday peak being less heavily weighted in a single direction. As currently experienced by the bus service, at the maximum load point 45 percent of total traffic will be traveling outbound in the morning peak period; the maximum load point will occur between the Wilshire/Vermont and Wilshire/Alvarado stations. Peak-hour ridership at this point will be 15,600 inbound and 12,800 outbound; these volumes represent 9.5 percent and 7.8 percent of the daily total of 164,300. Of these peak-hour volumes, 38 percent will be travelling in the peak 20 minutes.

The distribution of trip origins and destinations and the directional balance of traffic during the peak periods should result in the opportunity for high ratios of both passenger trips and passenger miles per seat mile.

To provide a more complete profile of ridership by time of day, bus ridership characteristics in Los Angeles were examined to estimate (a) distribution of ridership over the entire peak period, (b) relationship of the second peak hour to the peak hour, and (c) midday ridership levels.

Existing route-specific data precluded analysis of hourly distribution of bus ridership in the Metro Rail corridor; therefore, readily available cordon count data were used to approximate the distributions.(2,3) These cordon counts for all service entering and leaving downtown Los Angeles are shown in Figures A-1 and A-2. The high reverse peaking levels projected for the Metro Rail line were taken into account in the development of an hourly distribution of rail ridership. Based on this analysis, the following estimates were made:

- Ridership in the peak hour will account for approximately 58 percent of that in the peak 2 hours.
- Ridership in the evening peak period will be similar to that in the morning.
- Midday hourly ridership at the maximum load point will account for approximately 4 percent of the total daily maximum load ridership.

Daily ridership forecasts are shown in Table A-1. The derived distribution is shown in Figure A-3.

Figure A-1. Bus ridership by time of day, downtown cordon count, November 1980 (6).

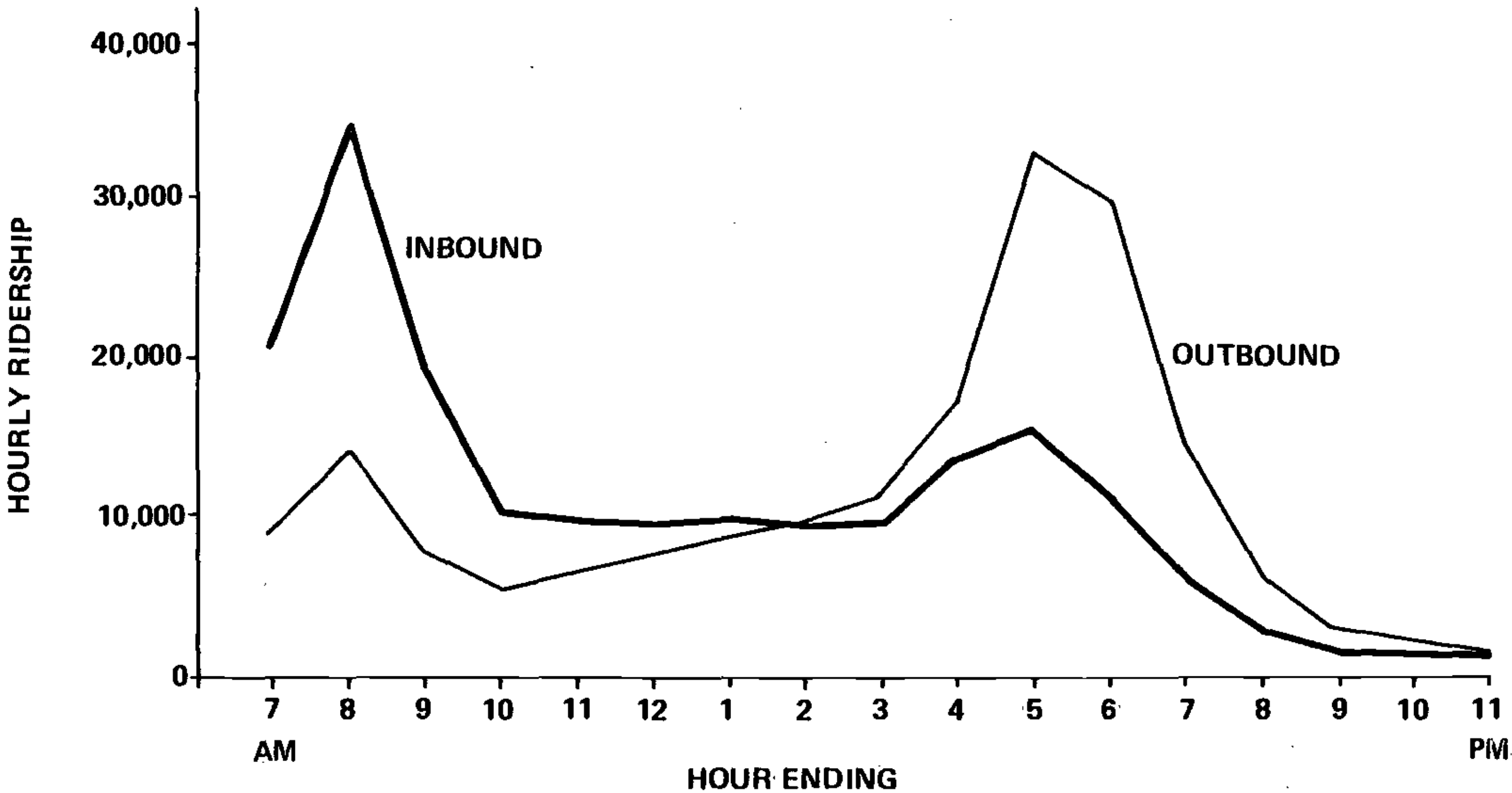


Figure A-2. Bus ridership by time of day, downtown cordon count, May 1978 (5).

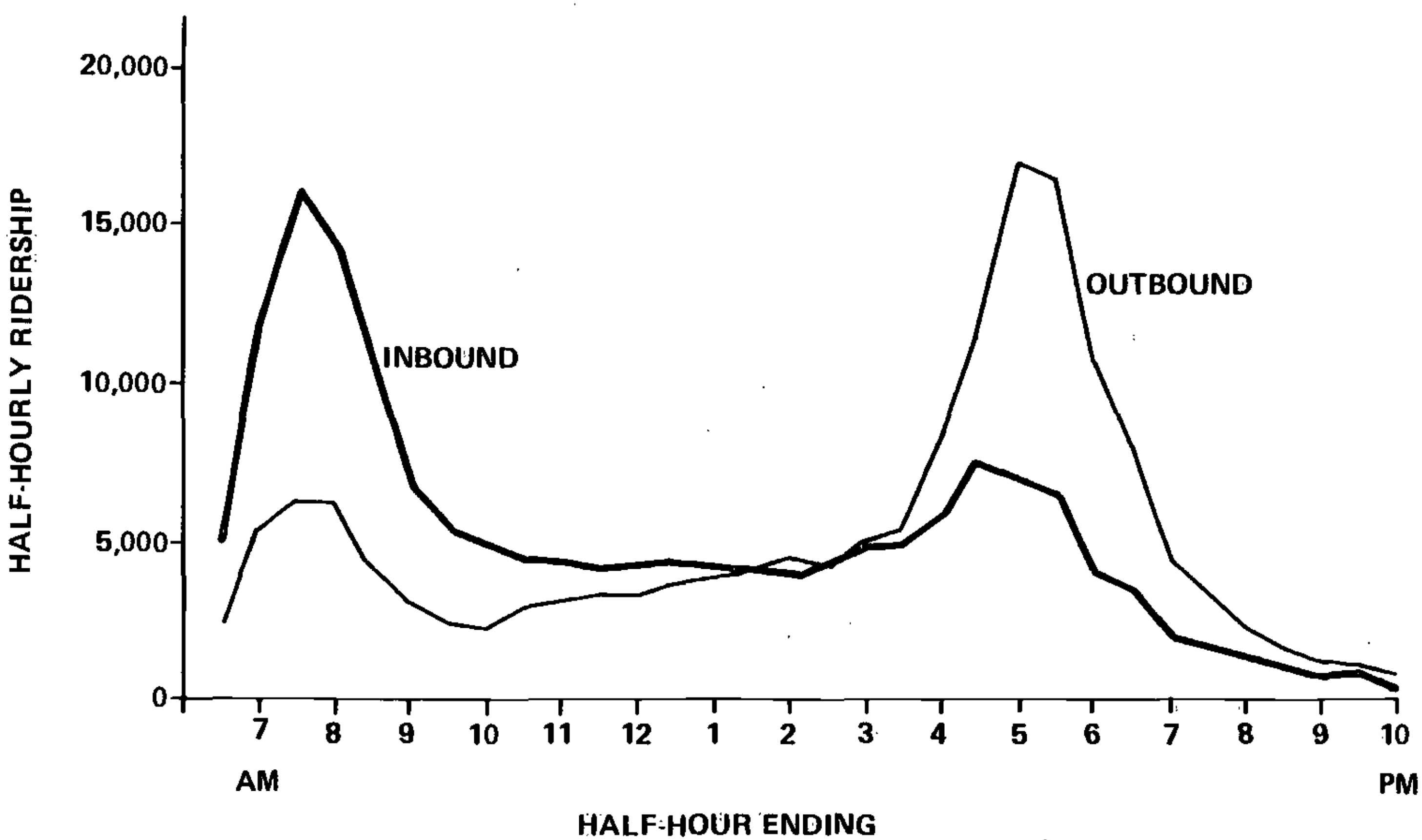
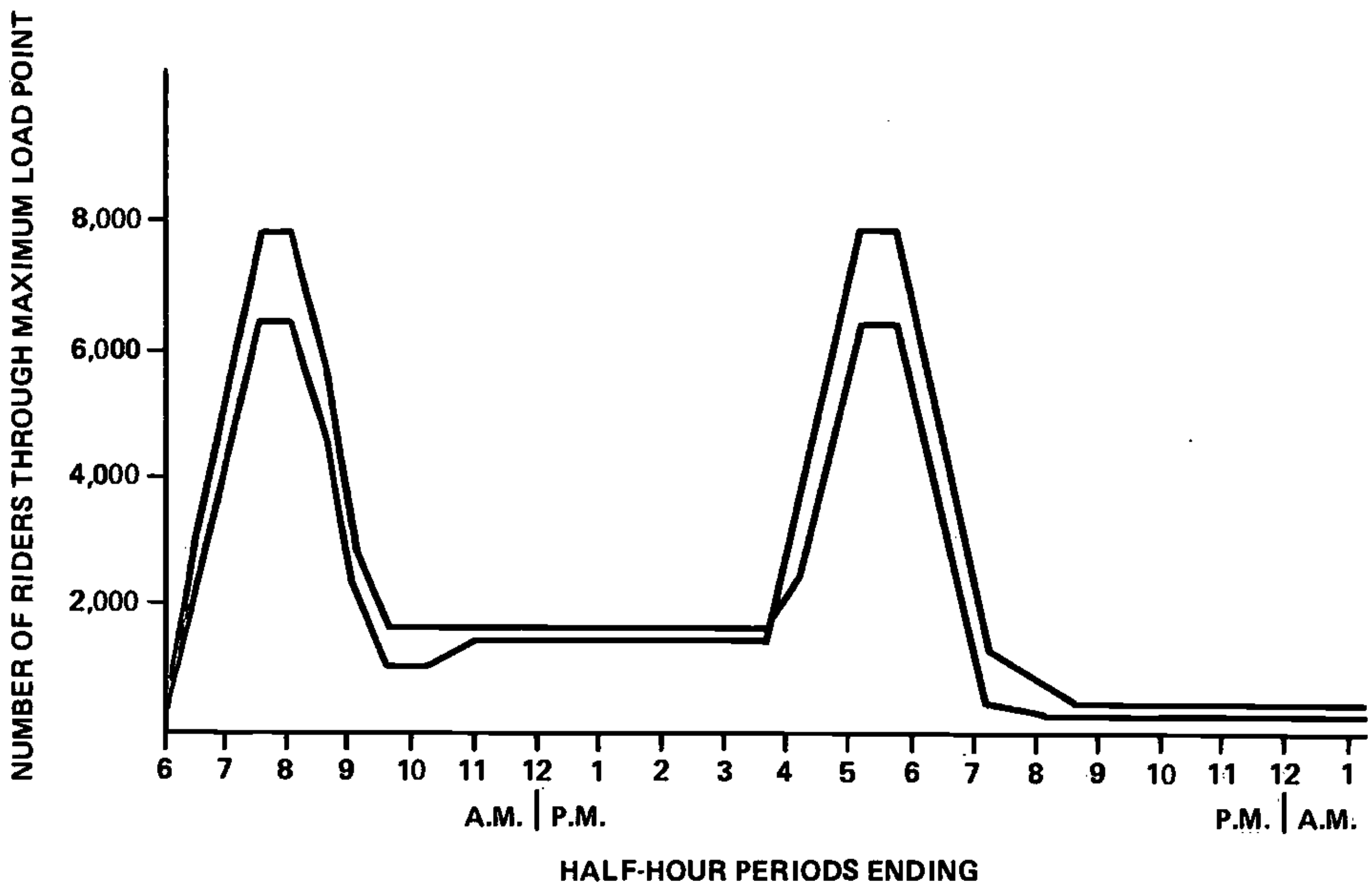


Table A-1. Metro Rail ridership daily volumes, 1995.

Station	Boardings Inbound	Boardings Outbound	Boardings Total	Link Volume
Union Station	--	28,500	28,500	
				28,500
1st/Broadway	--	12,200	12,200	
				40,700
5th/Broadway	7,100	28,800	35,900	
				62,400
7th/Flower	3,900	22,400	26,300	
				80,900
Wilshire/Alvarado	8,700	10,000	18,700	
				82,200
Wilshire/Vermont	20,500	10,700	31,200	
				72,400
Wilshire/Normandie	10,000	6,400	16,400	
				68,800
Wilshire/Western	15,400	9,600	25,000	
				63,000
Wilshire/La Brea	11,500	3,800	15,300	
				55,300
Wilshire/Fairfax	21,600	8,200	29,800	
				41,900
Fairfax/Beverly	4,400	3,200	7,600	
				40,700
Fairfax/Santa Monica	7,800	4,700	12,500	
				37,600
Hollywood/Cahuenga	15,500	5,300	20,800	
				27,400
Hollywood Bowl	1,300	100	1,400	
				26,200
Studio City	12,400	600	13,000	
				14,400
North Hollywood	14,400	--	14,400	
TOTAL	154,500	154,500	309,000	

Source: Barton-Aschman Associates, Patronage Impact of Possible Future Line Extensions, Phase II, March 1982.

Figure A-3. Estimated rail ridership by time of day, initial Metro Rail line—1995.



APPENDIX B

CALCULATION OF TRAIN ROUND-TRIP TIMES

Round-trip time was calculated to permit an analysis of operations and fleet requirements for the service schedule developed in this operating plan. Based on an analysis of station-to-station run times, station dwell times, and terminal turnback times, a peak-period nominal trip time of 69 minutes for the 18-mile line has been used for scheduling purposes. A round-trip schedule is given in Table B-1. The 31½-minute terminal-to-terminal travel time for the line includes dwell times and implies an average speed of 35½ mph in the peak period. Derivation of the components of this round-trip time is discussed in the following sections.

STATION-TO-STATION RUN TIMES

Run times between stations were calculated by a train peformance simulator, using the profile shown in Figure B-1 and the vehicle performance characteristics shown in Figure B-2. Because definition of the performance characteristics for the Metro Rail car were not complete at this writing, those of the BART car were utilized for analysis of run times, with the added specification of nominal acceleration and braking rates of 2.7 mphps and 2.2 mphps, respectively. A maximum allowable speed of 70 mph was assumed as most appropriate for station spacings of 1 to 2 miles.(7)

Speeds through curves were based on the Preliminary Design Criteria, which defined superelevation and unbalance.(8) Grades dictated by differences in station elevation were included in the simulation; however, gravity-assisted profiling was not included.

Table B-1. Peak-period round-trip time.

Milepost	Station	Inbound	Outbound
0.0	North Hollywood	Depart 0:00	Arrive 1:06
2.3	Studio City	0:03	1:03½
5.0	Hollywood Bowl	0:06½	1:00
5.9	Cahuenga/Hollywood	0:08	0:58½
8.3	Fairfax/Santa Monica	0:11½	0:55
9.3	Fairfax/Beverly	0:13½	0:53
10.7	Wilshire/Fairfax	0:16	0:50½
11.7	Wilshire/La Brea	0:17½	0:49
13.7	Wilshire/Western	0:20½	0:46
14.2	Wilshire/Normandie	0:22	0:44½
14.7	Wilshire/Vermont	0:23	0:43½
15.7	Wilshire/Alvarado	0:25	0:41½
16.9	7th/Flower	0:27	0:39½
17.4	5th/Broadway	0:28½	0:38
17.9	Civic Center	0:30	0:36½
18.7	Union Station	Arrive 0:31½	Depart 0:34½

Note: Round-trip times include 3-minute layovers at each terminal.

Figure B-1. SCRTD Metro Rail line preliminary route profile.

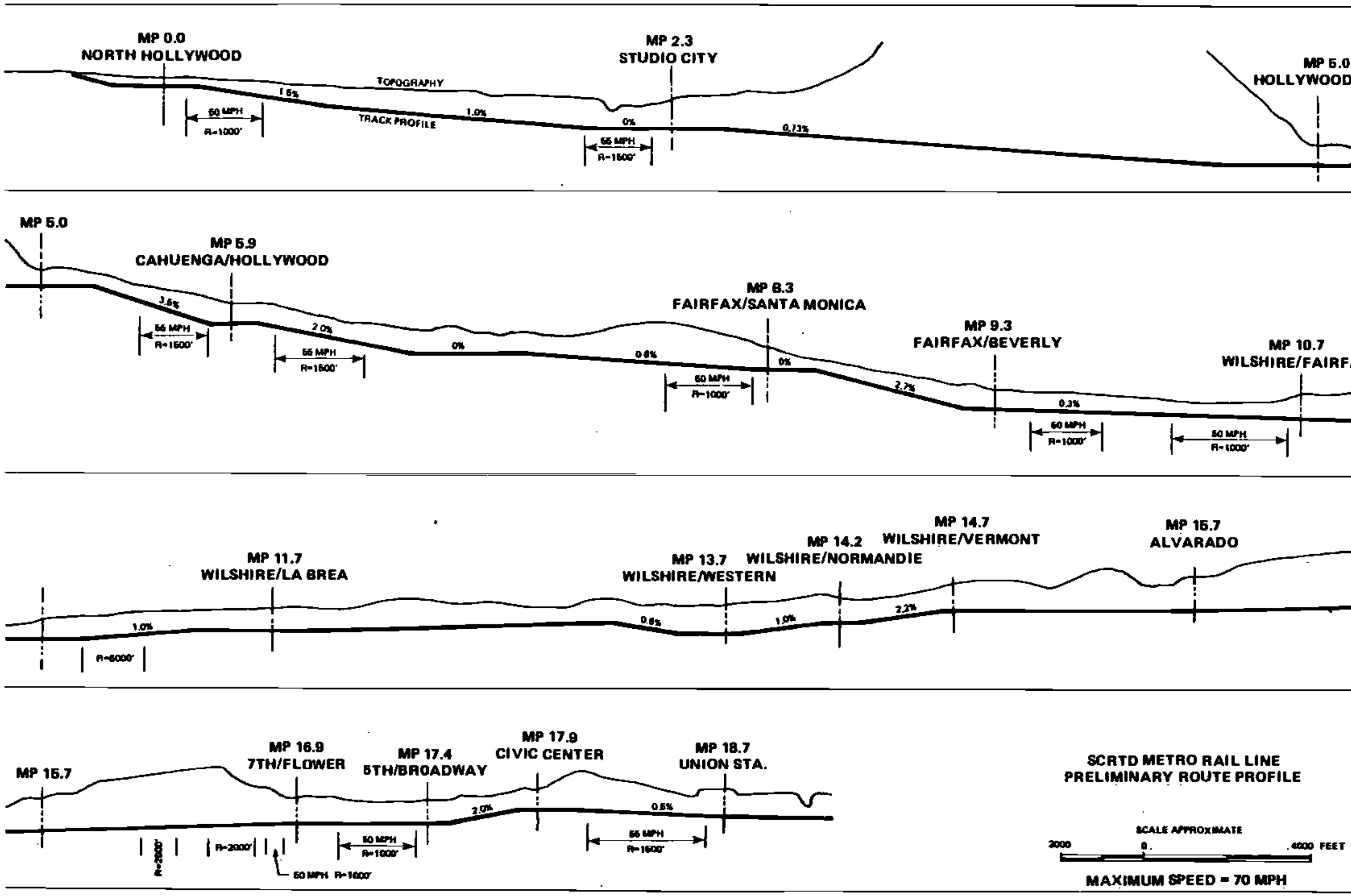
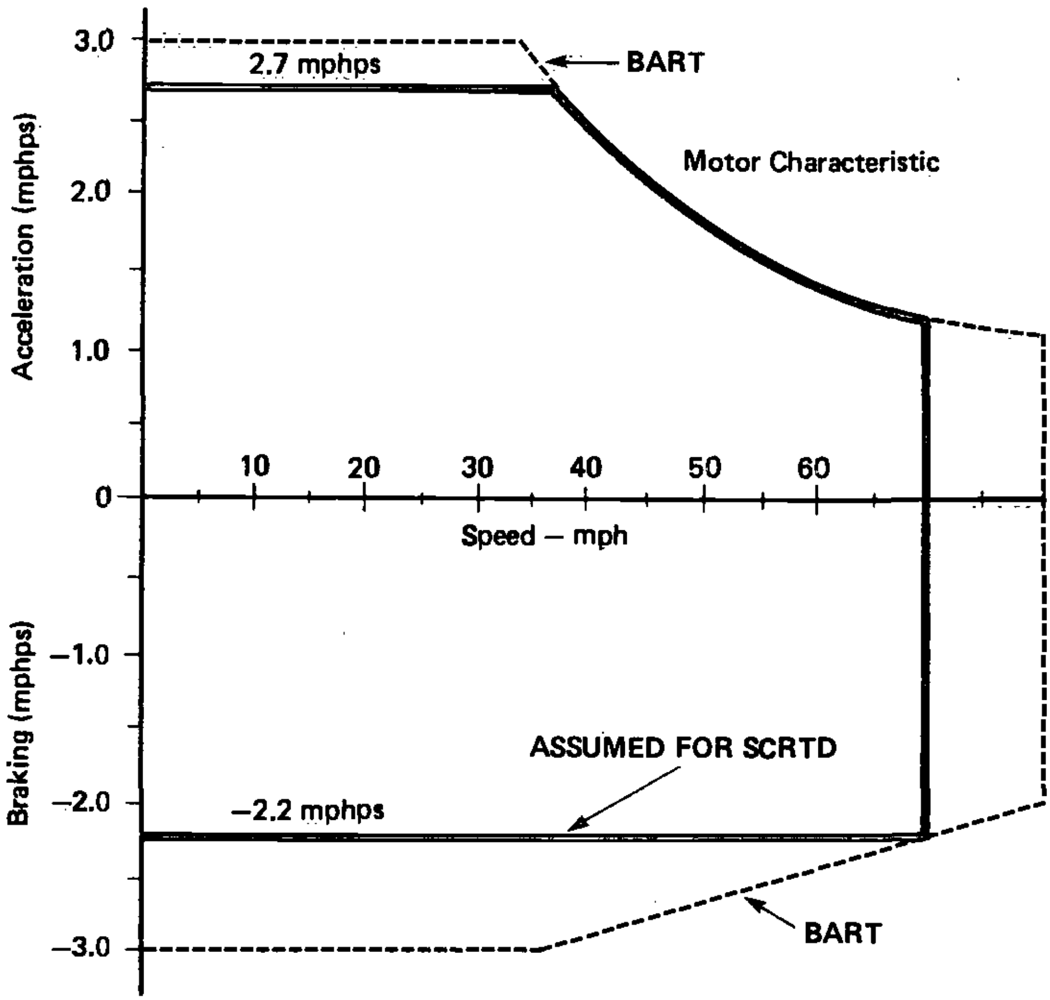


Figure B-2. Preliminary vehicle performance curve.



Source: BART Specification modified by Booz·Allen.

Run times under full performance conditions and the time spent at maximum speed are listed for each station pair in Table B-2.

TERMINAL TURNBACK TIMES

Terminal turnback times include the time required to unload and load passengers and to change train direction. They are measured from the time the doors open to discharge inbound passengers to the time the doors close and the train departs outbound. A minimum turnback time of 3 minutes was established as a reasonable planning assumption for a 2-track terminal with front-end crossovers, as is anticipated on the Metro Rail line. Short turn times will be made possible by adopting the technique used by PATCO and WMATA of scheduling train operators to "drop back" and depart the terminal on the next train to enter the terminal, rather than on the train in which the operator arrived. This procedure gives the operator time to leave the inbound train and move into position to board the next inbound train at its outbound front end. In preparing the operating schedule in Table 3-6, a longer turnback time was used when necessary to assign equipment to a particular run.

The 3-minute minimum turnback time provides a reasonable opportunity for recovery from delays; this was determined in an analysis for the Baltimore Regional Rapid Transit System.

AVERAGE DWELL TIMES

An average peak-period dwell time of 30 seconds at intermediate stations was used in calculating round-trip times. Peak dwell times are expected to range between 15 and 50 seconds. During the off-peak, average station dwell times are expected to be 20 seconds or less. These estimates are

Table B-2. Run times between stations.

Station	Distance (miles)	Run Time (min: sec)	Time at Maximum Speed (min: sec)
North Hollywood			
	2.3	2:37	0:54
Studio City			
	2.7	2:46	1:41
Hollywood Bowl			
	0.9	1:16	
Cahuenga/Hollywood			
	2.4	2:48	0:48
Fairfax/Santa Monica			
	1.0	1:21	0:16
Fairfax/Beverly			
	1.4	1:54	
Wilshire/Fairfax			
	1.0	1:22	0:16
Wilshire/La Brea			
	2.0	2:13	1:08
Wilshire/Western			
	0.5	0:55	
Wilshire/Normandie			
	0.5	0:55	
Wilshire/Vermont			
	1.0	1:26	0:18
Wilshire/Alvarado			
	1.2	1:29	0.24
7th/Flower			
	0.5	1:00	
5th/Broadway			
	0.5	0:55	
Civic Center			
	0.7	1:16	
Union Station			

supported by an analysis of the boarding and alighting activity expected to occur at each station and the experiences of other properties.(3,9)

The dwell time analysis assumed three door openings per side, two door lanes per door opening, and a 2-second-per-passenger boarding or alighting time.(7)

A fixed minimum dwell time of 11 seconds was defined for door operation; this includes time to assure that all doors are clear, a 2-second warning chime, and time to start the train. A contingency was also added to account for the effects of loading imbalances and of train and passenger delays.

REFERENCES

(1) Barton-Aschman Associates, Patronage Impact of Possible Future Line Extensions, Phase II, for SCRTD Metro Rail Project, March 1982.

(2) Los Angeles Department of Traffic, Corridor Count—Downtown Los Angeles, May 1978.

(3) Southern California Rapid Transit District, Summary Report of Los Angeles Central Business District Corridor Check, 1980.

(4) John J. Fruin, Pedestrian Planning and Design, Metropolitan Association of Urban Designers and Environmental Planners, Inc., New York, 1971.

(5) U.S. Department of Transportation, Urban Mass Transportation Administration, Alternatives Analysis/Environmental Impact Statement/Report on Transit System Improvements in the Los Angeles Regional Core, April 1980.

(6) Booz, Allen & Hamilton, Inc., Special Study of the Appropriate Fleet Size, Parts I and II, BRRTS, Section A, April 1979.

(7) U.S. Department of Transportation, Urban Mass Transportation Administration, Alternatives Analysis Procedure and Technical Guidelines, Appendix A: Estimation of Transit Supply Parameters, December 1980.

(8) Southern California Rapid Transit District, Metro Rail Project, Preliminary Design Criteria.

(9) U.S. Department of Transportation, Urban Mass Transportation Administration, and Southern California Rapid Transit District, Summary of Peer Review Board Comments on Operational Features, August 13 and 14, 1981.