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SCRTD METRO RAIL PROJECT
Preliminary Engineering

YARDS AND SHOPS OPERATIONAL CRITERIA

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Prepared by
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CHAPTER 1 INTRODUCTION

The purpose of this report is to define the specific functional requirements and operational criteria associated with the yards and shops element of the SCRTD Metro Rail system. It identifies needs of the initial 18-mile segment for both the year 1995 and the ultimate system capacity and will serve as a guide for the layout and design of these facilities.

The term "yards and shops" generally refers to those facilities required for the support of revenue operations and for the maintenance of both vehicles and way and structures. This report focuses specifically on those criteria pertaining to the storage, servicing, and repair of revenue vehicles and the support of revenue operations.

CHAPTER 2
METRO RAIL SYSTEM CHARACTERISTICS

2.1 METRO RAIL SYSTEM DESCRIPTION

As currently proposed, the initial Metro Rail system will be a 18.6-mile line with 16 stations serving downtown, Wilshire Boulevard, Fairfax, Hollywood, and the San Fernando Valley via its northern terminus in North Hollywood. Service will be provided by electrically powered cars operating in trains of 4 to 6 cars. This study assumes that the revenue vehicles will be operated as coupled vehicle pairs, with performance, reliability, and maintainability characteristics consistent with those of vehicles on new or recently developed systems.

2.2 SYSTEM OPERATING CHARACTERISTICS

The preliminary operating plan for 1995¹ projects service 7 days per week, 20 hours per day. During the peak hour, 6-car trains will operate at headways between 3½ and 4 minutes in one direction and between 4 and 5 minutes in the other. Assuming a 90 percent availability rate, 140 cars will be needed in 1995—114 for revenue service, 12 for standby consists, and 14 for a maintenance margin.

The ultimate capacity of the initial line assumes that 6-car trains will operate at 2-minute headways, accommodating a 72 percent increase in ridership. At this capacity the fleet would expand to 214 cars (an increase of 53 percent), with 180 cars for revenue service, 12 for standby consists, and 22 for a maintenance margin.

¹SCRTD Metro Rail Project, Preliminary Operating Plan, prepared by Booz, Allen & Hamilton, Inc., June, 1982.

Pertinent operating statistics for both 1995 and ultimate capacity operations are given in Table 1. The 1995 statistics were taken from the preliminary operating plan; those for ultimate capacity operations were extrapolated, assuming the number of car hours and car miles per car remains constant.

2.3 FUNCTIONAL REQUIREMENTS OF YARDS AND SHOPS

The purpose of the revenue vehicle yards and maintenance shops is to support the mainline operation in providing dependable train service as prescribed in the operating plan. The yards and shops shall provide the following:

- . Storage of revenue consists when not in mainline service
- . Dispatch, receipt, and changes in consists of trains for mainline service
- . Interior and exterior cleaning of trains
- . Maintenance of cars, both for prevention and correction of failures
- . Testing of cars prior to acceptance for revenue service and following major repairs.

The yards and shops shall be capable of supporting train service dependability requirements by providing vehicles in prescribed consists at required intervals and in full operating condition to meet the mainline service schedule and gap train needs.

Operation of the yards and shops themselves shall be a primary consideration in the design of these facilities. To minimize the life cycle cost, the design shall consider the following:

- . Distances to be traveled by personnel and repair equipment

Table 1. Operating statistics.

Period	Train Trips*	Car Trips*	Train Hours	Car Hours	Car Miles
1995 operations					
Peak hour	15	90	17.5	105	3,366
Weekday	167	954	190.5	1,088	35,680
Annual	53,000	291,000	60,000	331,000	10,884,000
Ultimate-capacity operations					
Peak hour	26	156	30.5	183	5,834
Weekday	256	1,460	291.5	1,665	54,590
Annual	81,000	445,000	92,000	506,000	16,653,000

*Round trips.

- . Frequency of movement by personnel and repair equipment
- . Handling of equipment, material, and tools
- . Personnel needs
- . Time required to perform tasks
- . Equipment expenditures
- . Supervisory requirements
- . Flexibility for future changes
- . Availability of needed personnel, material, and machines
- . Non-revenue movement of passenger vehicles.

Current plans call for the initial 18-mile Metro Rail line to have two yards and shops facilities, one at either end of the line. The downtown site will be the primary storage and service facility, and that in North Hollywood will be secondary. A summary of the functions to be performed at each facility is given in Table 2. The functional requirements may be varied to meet site constraints, but no heavy maintenance and repair will be performed at North Hollywood.

Table 2. Facility activities.

Function	Downtown	North Hollywood
Revenue train storage	x	x
Maintenance storage	x	x
Service and inspection	x	x
Light repairs	x	x
Major overhaul	x	
Major repair	x	
Vehicle turning	x	
Dispatch and recovery	x	x
Consist changing	x	x
Interior cleaning	x	x
Exterior washing	x	
Vehicle modification	x	x
Vehicle testing	x	
Component repairs	x	
Parts and materials inventory	x	x

CHAPTER 3
FUNCTIONAL REQUIREMENTS AND
OPERATIONAL CRITERIA OF STORAGE YARDS

This chapter discusses the functional requirements and operational criteria for the yards. Table 3 lists the yard elements for each site.

3.1 YARD CONTROL CENTER

Each yard shall have a yard control tower from which all authority for movement within yard limits will be directed and controlled. Provisions shall also be made for the remote control and supervision of North Hollywood yard by dispatchers and Central Control.

The tower at each yard shall be equipped with visual displays for monitoring the movement of consists, controls for regulating the movement of consists, and controls for switching and for removing power from the entire yard or selected yard tracks. The central control facility shall include similar capabilities for monitoring and control of the North Hollywood yard.

The control tower at each yard should be designed to provide a reasonably unrestricted view of the yard area.

At each location, a means of direct two-way voice communication with on-site and on-train personnel shall be provided as well as a means of public address. Direct two-way voice communications shall also be provided between those responsible for supervising yard movements and those responsible for mainline operations.

Table 3. Yard elements.

Element	Downtown	North Hollywood
Yard control center	x	x
Transfer zone	x	x
Revenue fleet storage	x	x
Exterior car wash	x	
Maintenance storage	x	x
Test track	x	
Train turning track	x	

At the downtown yard, a means of direct two-way voice communication between yard supervision and designated shop personnel shall be provided to coordinate movement of vehicles to and from the shop tracks.

3.2 TRANSFER ZONE

The transfer zone is that location where automatic train operation may be initiated for mainline service. Authority for train movement passes to and from Central Control at this location.

The transfer zone at the downtown yard shall be located between the yard lead tracks and the terminal platform tracks at Union Station. Direct access between the revenue storage tracks, maintenance storage, shop tracks, and car wash and the transfer zone shall be provided.

The preferred location of the transfer zone at the North Hollywood yard shall be between the yard lead tracks and the terminal platform tracks. If site space constraints will not permit this, the transfer zone shall be located at the terminal platform leads.

Design of the transfer zone shall include protection from single-point switch failures and permit dispatch and recovery operations to continue in the event a train is stalled on the yard leads or in the transfer zone.

3.3 REVENUE FLEET STORAGE

Storage tracks, of sufficient number and length to accommodate the cars required for weekday revenue service (including gap trains), shall be provided at the two yards. In 1995, revenue storage capacity at the two yards combined

shall total, at minimum, 126 cars;¹ when the line achieves its ultimate capacity, this total will be 192 cars². At least half and no more than two-thirds of these cars will be stored overnight at the downtown facility.

Revenue storage tracks shall be arranged to accommodate multiples of 6-car trains, with sufficient room to walk safely between adjacent trains.

The storage tracks shall be designed to avoid the need to move more than one train to gain access to another. If a revenue storage track is double-ended, with access to the yard leads from either end, then a maximum of three 6-car trains shall be permitted to be stored on that track. If a storage track is to be single-ended, the track shall be limited to a maximum capacity of two 6-car trains.

Direct access, via yard lead tracks, shall be provided between the revenue storage tracks and the mainline terminus. The design shall provide protection from single-point failures during movement from storage to yard leads. The design shall avoid the need to use yard lead tracks for any movement other than to or from the mainline; the one exception may be for movement from revenue storage to the car wash track.

Any departure test that is required of trains for revenue service shall be performed in the yard prior to entering the transfer zone. This test may include a safety check of status annunciators, a standing air-brake test, a cycling of doors, a check of headlights and taillights, and a test of reverse control. Provision may also be required

¹Per the Preliminary Operating Plan, 114 cars for revenue service and 12 cars for gap trains.

²Per the Preliminary Operating Plan, 180 cars for revenue service and 12 cars for gap trains.

for a standing test of speed control by use of either car-borne or wayside test equipment.

3.4 MAINTENANCE STORAGE

Storage tracks shall be provided for those trains or vehicles that have been removed from service and are scheduled for maintenance and for those trains or vehicles that have undergone maintenance and are awaiting testing or further maintenance. These maintenance storage tracks shall have direct access to both the yard leads and the shop tracks. In 1995, capacity for a minimum of two 6-car trains will be needed at the downtown facility and for one train at the North Hollywood facility.

In addition, at the downtown yard, an additional long-term maintenance storage track, capable of accommodating a minimum of one vehicle pair, shall be provided for inoperative cars requiring prolonged storage before repairs can be scheduled. This track may be stub-ended and should not be used for any other yard or shop function. Direct access to the shop from this long-term storage track is desirable but not essential.

3.5 CAR-CLEANING TRACK REQUIREMENTS

At the downtown yard, trains will be washed with an automatic exterior car wash facility approximately once every week, preferably as they are removed from service. If required, trains will also be washed from storage. Therefore, direct access to the wash track from the transfer zone will be necessary, as well as access from the revenue storage tracks with a minimum of reverse movements. A minimum clear lead track for one 6-car train on each end of the car wash shall be provided to prevent interference

with the recovery of other trains from mainline service and with other operations of the yard.

Daily interior car cleaning is to be performed at the revenue storage tracks in both the downtown and North Hollywood yards for all vehicles to be returned to revenue service. This cleaning will consist of trash removal and the performance of similar housekeeping work, such as wiping down of interior surfaces, on an as-needed basis. Design of the revenue storage area shall consider the need for access to a side door of each car by utility vehicles used to transport personnel, cleaning equipment, and trash; alternative track centers of a minimum of 19 feet are recommended for this purpose. An enclosed area will also be required at each site for storage of the utility vehicles and equipment.

Weekly light interior cleaning, to include window washing and carpet vacuuming, shall be performed at both yards on a track alongside a special cleaning platform of car-floor height. This track may be one of the revenue storage tracks.

Heavy interior cleaning will include the washing of interior walls, handrails, upholstery, and windows, as well as the heavy vacuuming and shampooing of the carpet. This activity shall be performed at least once every 2 months on a track alongside a platform of car-floor height; this track may be one of the revenue storage tracks or a track near the shop building with direct access to the yard.

3.6 TEST TRACK

A test track adjacent to the downtown yard and shop facility shall be provided to permit the testing of vehicular equipment. This track shall be used for testing purposes only and will not become a section of the mainline as long

as it is designated for test-track activities. Direct access to the test track shall be provided from the downtown yard and shop facility without requiring use of mainline track, yard lead track, or yard tracks dedicated to other activities. The test track will be used for production vehicle acceptance testing, post-maintenance testing, malfunction diagnosis, evaluation of engineering modifications to vehicle and wayside equipment, and operations and maintenance personnel training. Trains to be tested on the test track will consist of one vehicle pair.

The track shall be of sufficient length to permit a test of all speed codes. Provision shall also be made for full simulation of a station stop. The speed achievable on the test track must at a minimum exceed station entry speed by 10 mph. The track must have a means of physical retardation (e.g., sand boxes) at each end to prevent serious injury or damage in the event of a brake malfunction.

3.7 TRAIN-TURNING TRACK

A means of periodically reversing the direction a vehicle faces shall be provided in the downtown yard. A loop track is preferred for this activity, but a wye track may be used if site constraints dictate. The turn track shall be capable of accommodating a 6-car train.

The train-turning function must be accomplished without interference with mainline or yard lead activity. The loop or wye track may, however, provide a secondary means of access to the transfer zone from the revenue storage tracks, in the event the primary means of access is blocked. For a wye track to be suited to this function, the stub-ended turn track at the end of the wye will need a train-length platform at car-floor height to permit the efficient drop-back of train operators.

CHAPTER 4
FUNCTIONAL REQUIREMENTS AND OPERATIONAL CRITERIA OF THE
VEHICLE MAINTENANCE FACILITY

This chapter discusses the functional requirements and operational criteria for the shop elements to be incorporated at each site. As currently planned, the downtown facility will be all-purpose, capable of performing all vehicle maintenance activities. The facility at North Hollywood will be a secondary facility, capable at a minimum of performing light repairs and maintenance. Table 4 lists the shop elements required for each site.

4.1 VEHICLE MAINTENANCE SHOP

This section presents criteria for the vehicle maintenance shops in three categories: general (pertaining to the entire shop); major repair tracks; and service and inspection tracks. An analysis of shop maintenance capacity requirements is presented in the Appendix.

4.1.1 General Criteria

Vehicle maintenance shops shall be located in close proximity to the mainline and the revenue and maintenance storage yards to minimize the time required to move vehicles to the shop. Access to shop tracks from the yard lead tracks and all storage tracks shall be provided, with direct access from the maintenance storage tracks and a minimum of reversing required for other movements.

Vehicle maintenance will include:

- . Service and inspection: the replacement of vehicle consumables and routine observations of equipment condition and operation

Table 4. Shop elements.

Element	Downtown	North Hollywood
Vehicle maintenance shop		
Service and inspection area	x	x
Major repair and overhaul area	x	
Component repair shops	x	
Parts and supplies storage	x	x
Maintenance administrative offices	x	

- . Light repair: the correction of vehicle failure through component adjustment or replacement, generally requiring one eight-hour shift or less to perform
- . Major overhaul: the scheduled replacement and adjustment of major vehicle components
- . Major repair: correction of vehicle wear, damage or failure that requires specialized equipment or personnel, and/or more than one eight-hour shift to perform
- . Modifications: a special fleet-wide program of component replacement or alteration.

At North Hollywood, the vehicle shop shall be capable of service and inspection and light repair work. The downtown facility shall be capable of service and inspection, light repair, major repair, and major overhaul. Design of the downtown shop shall permit a functional separation of work positions corresponding to the type of work. Service and inspection and light repairs shall be conducted on the service and inspection tracks. Major overhaul, major repair, and extensive modifications shall be conducted on the major repair tracks. The acceptance testing of newly-arrived vehicles shall also be performed on the major repair tracks.

4.1.2 Major Repair Tracks

Major repair tracks shall be provided at the downtown facility only. The activities to be performed on these tracks will include major overhaul, major repair, extensive modifications, and acceptance testing. These activities are time consuming and will require the use of specialized equipment and/or personnel.

A total of four major repair work stations, each with space for one vehicle pair, shall be required at the downtown

facility for the 1995 fleet. Five stations shall be necessary when the ultimate capacity of the initial 18-mile line is achieved.

In general, most work will be performed on individual vehicle pairs. The preferred layout of the major repair area would provide for direct access of a vehicle pair to each work station from the shop lead tracks, without interfering with work on other vehicles. Each shop track shall accommodate no more than three vehicle pairs. Access shall be provided from the yard to either end of the shop track..

Most of the floor space in the major repair area will be at rail level, with large areas allocated for work on vehicles retained in the shop for prolonged periods of time. All floor-level work stations shall be provided with a means of raising coupled vehicle pairs for extended periods of time. The rails shall be flush with the floor to permit access of heavy-duty lift vehicles for servicing under-car components.

At least two major repair work stations shall be provided with detrucking equipment. In addition, one position shall be provided with wheel truing equipment that permits truing of all wheels while on the vehicle. The wheel-truing machine shall be positioned at the entrance side of the work station to permit the truing of any wheels of a vehicle pair without interfering with other work stations. One work station shall be provided with a work pit for visual inspection, testing, and repair of undercar components.

4.1.3 Service and Inspection Tracks

Service and inspection (S&I) tracks shall be provided at both the downtown shop and the North Hollywood shop.

The activities to be performed on these tracks will include scheduled inspections and servicing, light repairs, and minor modifications. These activities require a vehicle or train to remain in the shop for a relatively short period of time (generally no more than one 8-hour shift).

A total of six S&I work stations, each for one vehicle pair shall be required at the downtown facility for the 1995 fleet. Nine stations shall be provided for the ultimate capacity of the initial 18-mile line.

Each S&I shop track shall be configured to accommodate either full 6-car trains or three individual vehicle pairs with enough space between pairs to allow safe movement of equipment between the pairs. Each shop track shall be a run-through track, with access at either end to the storage tracks via the shop lead tracks.

The configuration of the downtown shop shall be as follows:

- . For the 1995 fleet (70 pairs)
 - One S&I track of three work stations with each located over a pit for undercar inspection and repairs
 - One S&I track of three work stations with one located over a pit and the other two with rails flush with the floor
 - Of the two non-pit work stations, one to be equipped to provide a means of raising a coupled vehicle pair and for removal and replacement of any truck on the pair
- . For the ultimate capacity fleet (107 pairs)
 - Two S&I tracks as described above
 - One S&I track of three work stations with one located over a pit and the other two with rails flush with the floor

- Of the two non-pit work stations on the third track, one to be equipped to provide a means of raising a coupled vehicle pair.

The North Hollywood yard shall have an S&I track with an inspection pit to accommodate a 6-car train for routine inspection and light repairs. The S&I track shall be located so as not to interfere with yard dispatch and recovery of revenue trains. Space shall be allocated for a small workshop and parts storage area. The S&I track shall be constructed for the 1995 fleet. Additional trackage will not be required as fleet size increases.

4.2 COMPONENT REPAIR SHOPS

Repair of passenger vehicle components will be performed at centralized service and apparatus repair shops located in the downtown facility. These shops may be augmented to accommodate the repair of components from other elements of the Metro Rail system (i.e., fixed facilities).

The functions of the component repair shops include receipt, inspection, and storage of spare parts; repair, overhaul, and testing of parts and components, including failure analysis; distribution of new and repaired components to the vehicle maintenance shops and other non-vehicle facilities; and component disposal decisions, including warranty. The component repair shops shall be capable of the following activities:

- . Electronic repair: repair, maintenance, and testing of electronic assemblies, modules, and components for the vehicle, including those for vehicle propulsion, train control, door control, friction brake control, destination signs, and communications
- . Electrical repair: repair, inspection, and overhaul of non-electronic electrical equipment, including

motors, electrical couplers, relays, switches, motor alternators or generators, and third-rail collector assemblies

- . Friction brake repair: repair, inspection, and overhaul of friction (air) brake systems and pneumatic equipment
- . Machinery, welding, and sheet metal working: repair of mechanical components and fabrication of new or replacement metal components
- . Battery maintenance: discharging, charging, testing, and cleaning of batteries
- . Air conditioning repair: servicing, repair, and testing of air conditioning system components
- . Upholstery and glass repair: replacement and storage of passenger vehicle door and window glass; fabrication and repair of vehicle seat upholstery
- . Truck overhaul: overhaul of vehicle trucks, replacement of components, and storage of spare truck assemblies
- . Wheel and axle overhaul: inspection, servicing, and replacement of wheel and axle assembly components, including journal bearings and drive gears
- . Painting and parts cleaning: painting of components and cleaning of truck frames and various other components by use of steam, solvents, detergents, and compressed air.

Rail access shall be provided between the detrucking station, wheel truing station, truck shop, and steam cleaning area for movement of trucks.

4.3 MATERIALS AND PARTS STORAGE

A storeroom and disbursement center for spare parts and materials shall be located adjacent to the vehicle maintenance shop in the downtown facility where all expendable parts and materials shall be stored along with most repairable

and reuseable components and subassemblies. Large equipment, such as truck assemblies, may be stored at the responsible component repair shop.

4.4 MAINTENANCE ADMINISTRATION

Facilities shall be provided for maintenance personnel needed to operate the yard and shops, including technical, supervisory, and administrative personnel.

4.5 COMMUNICATIONS

At the downtown shop, a means of direct two-way voice communication shall be provided between yard supervision and designated shop personnel to coordinate movement of vehicles to and from the shop tracks. Similarly, a means of two-way communication between on-site shop personnel and the North Hollywood yard and dispatchers at Central Control must be provided.

At the downtown shop, direct two-way communication shall also be provided between maintenance administrative offices and the vehicle shop floor and maintenance support areas (e.g., parts storage, component repair). A means of public address from the offices to the floor shall also be provided.

Direct two-way communication shall be provided between maintenance personnel at each facility.

APPENDIX
SHOP CAPACITY ANALYSIS

Shop capacity must be sufficient to regularly achieve fleet availability requirements.

For an initial fleet in 1995 of 140 cars (70 vehicle pairs), a downtown shop capacity for 10 vehicle pairs will be required. For an ultimate fleet of 214 cars (107 vehicle pairs), a downtown shop capacity of 14 vehicle pairs will be required.

A light-repair track long enough to accommodate a 6-car train will be required at the North Hollywood yard.

A general assignment of the maintenance functions to be performed at each track position is given in Table A-1.

Four key elements were examined for sizing the shop facility:

1. Amount of revenue service to be provided (car-hours, car-miles)
2. Frequency of occurrence requiring maintenance
3. Time required to perform a maintenance action
4. Time available to perform a maintenance action

Maintenance actions include preventive maintenance and light repairs, to be performed on the service and inspection tracks, and major overhaul, major repair, and wheel truing, to be performed on the major repair tracks.

For preventive maintenance and major overhaul, the Metro Rail Subsystems Division defined the anticipated

Table A-1. Shop capacity analysis.

Function	Shop Capacity, Vehicle-Pair Positions			
	Initial Capacity for 70-Pair Fleet		Ultimate Capacity for 107-Pair Fleet	
	Downtown	North Hollywood	Downtown	North Hollywood
Service and inspection area				
Preventive maintenance	3	-	4	-
Light repair	3	3	5	3
Major repair area				
Major overhaul	2	-	3	-
Major repair	<u>2</u>	<u>-</u>	<u>2</u>	<u>-</u>
Total by location	<u>10</u>	<u>3</u>	<u>14</u>	<u>3</u>
Total by system	13		17	

inspection interval (miles between inspections) and time required to perform (shop hours). This was used to determine the annual number of inspections and the total shop hours incurred for these inspections.

Unscheduled maintenance levels were determined by defining possible reliability and maintainability levels. These estimated levels were based on the experience and projections of other systems. Wheel-truing frequency was also based on the experience of other systems.

Time available to perform (work-shifts and days of week assigned to maintenance) was based on the work schedules of other systems.

SCHEDULED MAINTENANCE

The preliminary scheduled maintenance program is summarized in Table A-2. The effect of this program is to place a vehicle pair in the shop every 5,000 miles for a period between 4 and 8 shop hours. At 100,000 miles, the vehicle pair is sent to the shop for 16 hours. At 350,000 and 700,000 miles, the vehicle pair is sent to the shop for 40 and 80 hours, respectively, for major overhaul. The number of times each level of maintenance is to be performed on a vehicle pair over a 700,000-mile interval is given in Table A-3. The annual frequency of inspection for the entire fleet in 1995 is also shown.

Scheduled maintenance activity was analyzed in three steps: (a) frequent routine or preventive maintenance performed on service and inspection tracks, (b) major overhaul performed on major repair tracks, and (c) wheel truing performed on the wheel-truing machine in the major repair area.

Table A-2. Scheduled maintenance program.*

Revenue Miles Interval	Preventive Maintenance Class	Shop Hours
5,000	A	4
10,000	B	4
20,000	C	8
30,000	D	8
50,000	E	8
100,000	F	16
350,000	G	40
700,000	H	80

*Provided by Metro Rail Subsystems Division.

Table A-3. Frequency of scheduled maintenance.

Preventive Maintenance Class	No. of Inspections During 700,000-mile Interval	No. of Inspections, Average per Year, 1995
A	70	544
B	14	109
C	21	163
D	21	163
E	6	47
F	6	47
G	1	8
H	1	8
	<u>140</u>	<u>1,089</u>

Preventive maintenance would be performed during the third shift (11 p.m.-7 a.m.) 5 days per week. (Undercar blowdown, performed at the blowdown pit prior to inspection, would be performed during the second shift.) Major overhaul and wheel truing would be performed during the first shift (7 a.m.-3 p.m.).

Preventive maintenance requirements are analyzed in Table A-4. The analysis shows that 2.7 vehicle-pair track positions would be required in 1995 and 4.2 positions would be required when the system achieves ultimate capacity. (Final determination of the integral number of positions was deferred until all activity could be examined simultaneously.)

Analysis of major overhaul in Table A-5 shows that 0.8 vehicle-pair positions would be required in 1995 and 1.2 positions would be required when ultimate capacity is achieved.

Analysis of wheel-truing capacity requirements was based on an estimate of 60,000 miles between truing and 300,000 miles between wheel replacements, in accordance with PATCO experience. The analysis in Table A-6 shows that 0.6 position would be required for wheel truing in 1995, increasing ultimately to 0.9 positions.

UNSCHEDULED MAINTENANCE

Unscheduled maintenance activity was analyzed for the light repairs to be performed on the S&I shop tracks and for heavy repairs and extensive modifications to be performed on the major repair shop tracks.

Table A-4. Preventive maintenance analysis.

Preventive Maintenance Class	Inspections per Year, 1995	Shop Hours per Inspection	Total Annual Shop Hours, 1995
A	544	4	2176
B	109	4	436
C	163	8	1304
D	163	8	1304
E	47	8	376
			<u>5,596</u>

Analysis

	Total shop hours per year, 1995	5,596
÷	Work days per year	255
÷	Work hours per day	8
=	Vehicle-pair positions required in 1995	<u>2.74</u>
x	Adjustment for ultimate fleet size	<u>1.53</u>
=	Vehicle-pair positions required at ultimate capacity	<u>4.19</u>

Table A-5. Major overhaul analysis.

Preventive Maintenance Class	Inspections per Year, 1995	Shop Hours per Inspection	Total Annual Shop Hours, 1995
F	47	16	752
G	8	40	320
H	8	80	640
			<u>1,712</u>

Analysis

	Total shop hours per year, 1995	1,712
+	Work days per year	255
+	Work hours per day	8
=	Vehicle-pair positions required in 1995	<u>0.84</u>
x	Adjustment for ultimate fleet size	<u>1.53</u>
=	Vehicle-pair positions required at ultimate capacity	<u>1.28</u>

Table A-6. Wheel-truing analysis.

	Annual vehicle pair miles	5,442,000
+	Wheel-truing frequency (miles)	<u>60,000</u>
=	Wheel-truing per year (vehicle pairs)	90.70
	Annual vehicle pair miles	5,442,000
+	Wheel replacement (instead of trued)	<u>300,000</u>
=	Wheel replacement per year (vehicle pairs)	18.40
	Wheel-truing per year	90.70
-	Less wheel replacement per year	<u>18.40</u>
	Net wheel truing per year (vehicle pairs)	72.30
x	Trucks per vehicle pair	<u>4</u>
	Trucks trued per year	289.2
x	Shop hours required per truck	<u>4</u>
	Annual shop hours	1156.8
+	Work days per year	225
+	Work hours per day	<u>8</u>
	Wheel truing units required	0.57

Because the timely performance of light repairs is critical to maintaining specified fleet availability levels, these will be performed 24 hours per day (3 shifts), 7 days per week. Major repairs and modifications will be performed during the first shift, 5 days per week. Should the completion of a fleetwide modification be of critical nature, it could be performed on an expanded work schedule.

Light repairs were analyzed to ensure that sufficient capacity will be provided on a daily basis to meet availability goals for each peak period. The evening peak period is the more critical because of the higher level of revenue service and correspondingly higher number of failures occurring before this peak period than before the morning peak.

Analysis of repair activity and required capacity is given in Table A-7. This analysis focuses on the critical 8-hour period affecting the ability to meet revenue fleet requirements for the evening peak period. During this period (5:30 a.m.-1:30 p.m.), 50 percent of the total daily car-miles are logged.

Vehicle subsystem reliability and maintainability requirements specified in the Baltimore-Miami car specifications were used to analyze anticipated repair activity on Metro Rail. Adjustments to the resulting shop hours were then made to account for (a) the lower reliability levels currently experienced on rail vehicles than those levels specified, (b) the potential synchronization of repair time with shift changes and work breaks, and (c) the trouble-shooting of incidents that result in "No Trouble Found."

The 140 hours of MTBF (mean time between failure) specified for the Baltimore-Miami car was adjusted to 100 hours

Table A-7. Corrective maintenance analysis.

Major Subsystem	MTBF (hours)	Average 8-Hour Failures*	MTTR (hours)	Shop Hours
Car body, miscellaneous car body	699	0.39	1.5	0.58
Couplers and draft gear	1223	0.22	2.2	0.49
Door operation and control	920	0.30	0.5	0.15
Heating, ventilation, cooling	1336	0.20	1.6	0.33
Miscellaneous electrical equipment	294	0.93	1.5	1.39
Power and traction	490	0.56	2.2	1.22
Trucks and suspension	950	0.29	1.5	0.43
Friction brakes	548	0.50	1.0	0.50
Communications	1174	0.23	1.5	0.35
Train control	2034	0.13	2.0	0.27
Lighting	2300	0.12	0.7	<u>0.08</u>
				5.79

Analysis

	Total vehicle-pair hours in shop (unadjusted)	5.79
x	Adjusted for lower reliability levels	1.4
x	Adjustment for synchronization with breaks and shifts**	3.6
x	Contingency for "No Trouble Found"***	<u>1.25</u>
=	Total vehicle-pair hours in shop (adjusted)	36.47
÷	Hours per day for corrective maintenance (3 shifts)	<u>8</u>
=	Vehicle-pair positions required in 1995	4.56
x	Adjustment for ultimate fleet size	<u>1.53</u>
=	Vehicle-pair positions required at ultimate capacity	6.98

* based on 272 vehicle-pair hours in 8-hour period.

** based on simulation results for Baltimore shop.

*** based on BART reported experience.

to reflect current reliability experience with similar cars. The synchronization adjustment was based on a simulation analysis of the Baltimore shops, which examined the impact of work breaks, shift changes, and other interruptions to continuous work flow on the total shop hours required to perform repairs on a typical workday. The percentage of "No Trouble Found" incidents was based on the levels reported by BART.

The analysis shows that, for a 70-pair fleet, 4.5 vehicle-pair positions would be required for repairs and, for a 107-pair fleet, 7.0 positions would be required.

MAJOR REPAIR AND MODIFICATIONS

For major repair activity and extensive fleetwide modifications, one vehicle-pair position for every 50 vehicle pairs was allocated. Thus, 1.4 positions would be required for a 70-pair fleet and 2.1 would be required for a 107-pair fleet.

CAPACITY REQUIREMENTS

All maintenance activity was examined simultaneously to determine overall capacity requirements so as not to oversize the system. Sums of the number of work stations required for each type of maintenance activity indicate that a minimum of 10.0 work stations would be needed for the 70-pair fleet and 15.4 for the 107-pair fleet. Additional spaces were allocated to the system in light of the following considerations:

- . The analysis was based on average requirements, which will be exceeded on occasion.

- . The location of vehicles in need of repair will vary between the two yards from day to day.

As Table A-1 shows, 10 vehicle-pair positions have allocated downtown for the 70-pair fleet, and 14 for the 107-pair fleet. A 3-pair track for minor repairs would be provided at North Hollywood.

Within the S&I and major repair areas, each track position will be flexible as to its use. Because preventive maintenance and light repair activity will peak at different times of the day, the S&I tracks will be available for both uses. In the major repair area, the shop supervisor will use his judgment to coordinate repair, overhaul, and modification activity.