Getting the Most on a Modest Budget — Santa Clara County Transit District LRV Maintenance Facility

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The Santa Clara County Transit District Guadalupe Corridor Light Rail Project is the longest new rail transit line to be built in 50 years in the United States. This project includes a facility that will house all vehicle and system maintenance and repair, parts storage, operations, and administrative functions. Because a modest budget was established for the facility, the planning and design process required following the most cost-effective approach. The various components of the facility are discussed and the cost conscious procedure that was followed in its development is detailed.

During the design phases of the Santa Clara County project the major items that were carefully analyzed included site selection, alternative layouts for yard and buildings, car spot studies, investigation of future expansion items, cost studies at various design levels for budget control, constant investigation of cost reduction items and their effects on maintenance and operations, and project phasing for early construction. The analyses and concepts were also subject to peer group reviews at two points in the design development process. A close consultant-client relationship was developed in which the client played an active role in design and decision making. This produced a product that will not require major modifications after completion and that stayed within the design budget.

The final plan selected accommodates 50 new light rail cars and allows for expansion to increase the fleet to 100 vehicles. Construction of the facility started in April 1984 and is scheduled to be completed in December 1985 at a total construction cost of $16.5 million. It was funded with UMTA, State of California, and local funds.

Final design of the maintenance facility was done by a consultant team led by the firm of Daniel, Mann, Johnson & Mendenhall under the direction of the Santa Clara County Transportation Agency. Other team members included Gannett Fleming Transportation Engineers, Ruth & Going, Fleet Maintenance Consultants, and Sanji Yano Associates.

SITE SELECTION

Alternative sites were analyzed during the system concept phase to select the best available location. Sixteen sites were initially identified and, after initial screening, the best six were selected for detailed analysis. The six sites and the selected Highway 17 site are shown in Figure 1. The selection criteria included physical characteristics of the site, cost, time required for environmental and property items, location, phasing and expansion, surrounding land use, supply and maintenance access, joint use of facility, and support of the site location by the city jurisdiction. Specific items that were investigated for each criterion are shown in Figure 2.

The evaluation of the criteria for each site was summarized in a matrix (Figure 3). The selected Highway 17 site was optimal with respect to the following items:

1. It is located along the earliest possible first phase main-line segment,
2. The property was publicly owned and thus acquisition did not require removal of private property from the tax rolls,
3. It has favorable deadheading costs and lost maintenance time costs,
4. The location is best if other light rail transit (LRT) corridors are built,
5. Sufficient land is available for future expansion,
6. Few environmental problems were involved with the site,
7. It is hidden from view--recessed from the main thoroughfare and located adjacent to two major highways,
8. It is compatible with the city jurisdiction's land use plans because it is zoned "Public/Quasi-Public,"
9. No residences are adjacent to the site, and
10. It is located close to the center of the LRT system and close to the downtown central business district (CBD).

The parcel comprises 22 acres. The facility will be developed on 18 acres, and the remaining 4 acres will be reserved for other uses.

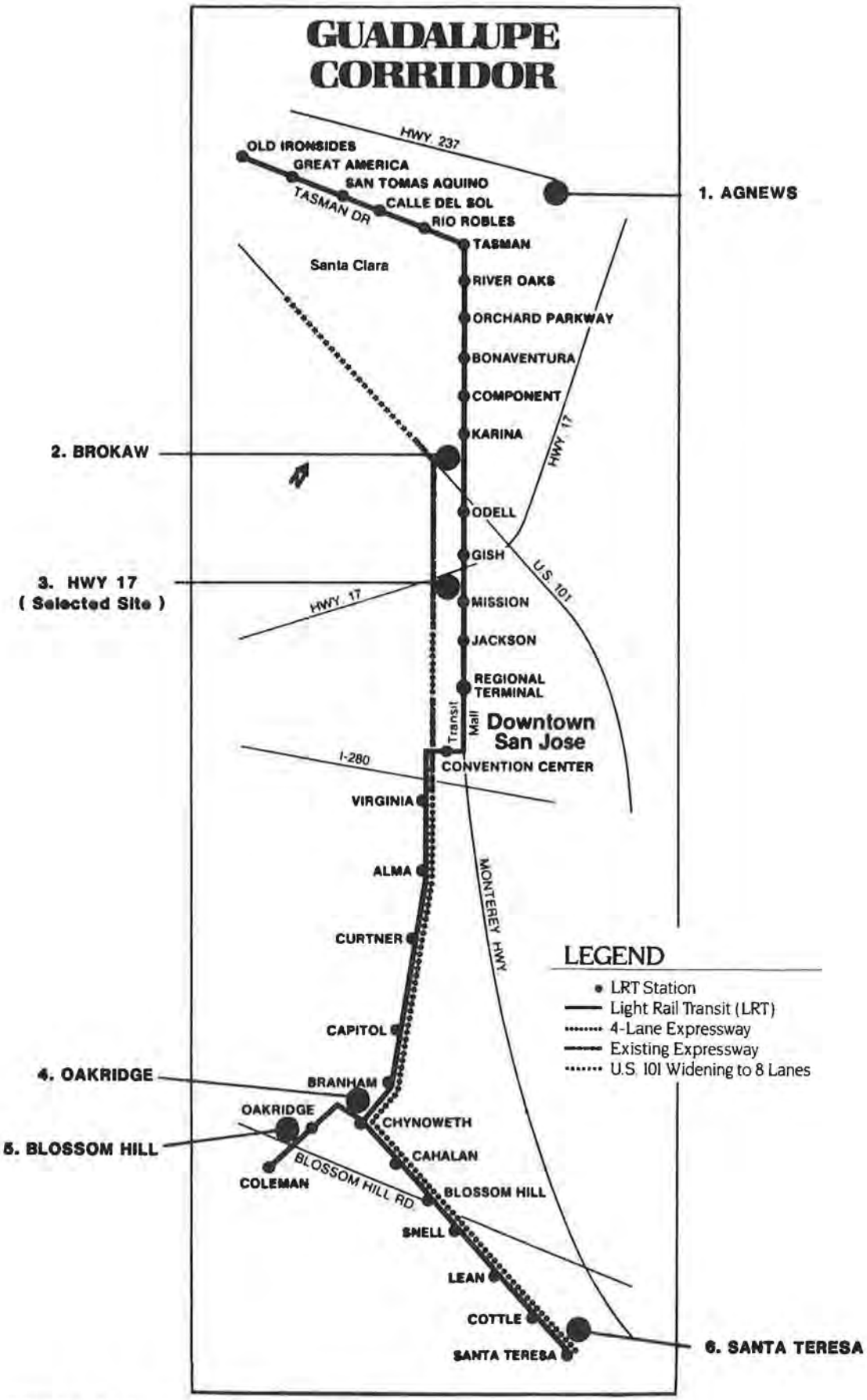

FIGURE 1 LRV maintenance facility site locations.

I. Physical Characteristics
   A. Size and shape of site
      1) Minimum size (15 acres absolute minimum; 20+ acres desirable)
      2) Site configuration suitability
      3) Topography, easements, restrictions, etc.
      4) Expansion potential
      5) Existing utilities
II. Cost
   A. Land
   B. Existing improvements to be removed
   C. Costs associated with accessing the site (see IV.)
   D. Costs associated with the time to acquire the site (see III.)
   E. Costs asociated with utility service hook-ups, especially electrical
III. Time
   A. Environmental clearances
      1) Archeological
      2) Historical
      3) Other
   B. Mitigation measures (costs to be entered under II.)
   C. Relocation studies, alternatives (costs to be entered under II.)
   D. Any r/w required to access the site
   E. Cost of time (the costs associated with time to be entered under II.)
IV. Location
   A. LRT Access
      1) Access track and roads to be constructed (costs to be entered under II.)
      2) Access deadhead time.
      3) LRT operations/disruption of auto traffic (N. First St., Tasman Dr. or Route 87, etc.)
   B. Phasing and Expansion
      1) Compatibility with proposed phasing plans (costs?)
      2) Compatibility with potential LRT expansion plans (other corridors)
         a) Locations of proposed expansions
         b) Deadhead time
   C. Surrounding Land Use
      1) Appropriate zoning and use of land
      2) Likelihood of neighborhood acceptance
   D. Supply and Maintenance access
      1) Rail/truck access for receiving/shipping vehicles, components, etc.
V. Joint Use Facility (existing bus or SPRR maintenance facility?)
   A. Operating cost savings, if any
   B. Maintenance cost savings, if any
   C. Other joint use advantages/disadvantages
   D. Impacts on existing facility, if any
VI. Support of Site Location by City
   A. City restrictions

FIGURE 2 LRV maintenance facility site selection criteria.

ALT.	LOCATION	SIZE	COSTS				PHASING & EXPANSION					LAND USE		COMMENTS
			CAPITOL [1]		O & M [2]		EARLY OPER. [7]		FUT. EXTENSION [8]					
		ACRES	SITE [3]	ACCESS IMPR. & R/W [4]	ANNUAL [5]	DISCOUNTED [6]	SAN CARLOS TO TRIMBLE	OAKRIDGE TO TRIMBLE	NORTHERLY [9]	SOUTHERLY [10]	TOTAL [11]	EXISTING USE	ZONING NEIGH. ACCEPT.	
1	AGNEWS	27±	$7.2 [12]	$4.3	$657	$6.4	2.7	2.7	6	40	54	VACANT	+	
2	BROKAW	20.0	$7.6	—	$502	$6.2	✓	✓	7	30	42	AGRI.	o	
3	HWY 17	10±	$6.3	—	$485	$6.0	✓	✓	11	25	40	PARKING	o	
4	OAKRIDGE	14.5	$5.1	—	$399	$4.9	N.C.	✓	35	7	47	AGRI.	—	RESID. RELOCATIONS REQUIRED
5	BLOSSOM HILL	10±	$6.6	—	$430	$5.3	N.C.	0.7	37	8	53	VACANT	—	RESID. DEVELOPMENT PENDING
6	SANTA TERESA	20.0	$5.2	—	$454	$5.6	N.C.	4.3	48	11	69	VACANT	o	

1) MILLIONS of 1982 DOLLARS.
2) Access Deadhead Costs Plus Peak Maintenance Period Relative Costs Due to Deadheading.
3) Acquisition Costs Including Ex. Improvements.
4) Includes Special Site Preparations.
5) Thousands of 1982 Dollars.
6) Present Worth in Millions of 1982 Dollars at 20 Years and 5%.
7) ✓=Compatible With Early Operations Phase.
   2.7=Miles of Track Needed to Access M.Y. Site With Early Operations Phase.
   N.C.=Not Compatible With Early Operations Phase.
8) Sum of Miles to M.Y. From Branch Junctions.
9) BART, Lockheed & Central Extensions.
10) Morgan Hill, Rte. 85 & Eastridge Extensions.
11) Above Extensions Plus Vasona to Los Gatos Extension.
12) Opportunity Cost - Value of This Site if Sold on the Open Market (Now Owned by CTD).

FIGURE 3 LRV maintenance facility site evaluation.

PEER GROUP REVIEWS

To assure that the maintenance facility plans were leading to an efficient design, experts from the light rail vehicle (LRV) field were invited to critique the plans. Two peer group review sessions were held--one at the completion of systemwide preliminary engineering and one after completion of the 35 percent design development plans for the final design of the maintenance facility. The peer group participants included those with knowledge of operational, maintenance, trackwork, traction power, and maintenance-of-way aspects of facilities. The topics discussed included critiques of the site and building plans, trackwork, traction power, scheduling, leferrable items, and other topics. Specific items are shown in Figure 4.

Comments received from the first peer group review meeting resulted in a modified concept that compressed the layout of the site from 22 acres to 18 acres, provided more space for vehicle storage, reduced the amount of trackwork, and changed maintenance functional relationships within the shop building. This concept became the starting point for the final design team.

The second peer group meeting at the 35 percent final design level provided input that eliminated single-point failures on the site; recommended deferring or reducing areas for maintenance of way, blowdown, daily inspection, vehicle storage tracks and paved areas for cost reduction; recommended shifting daily maintenance areas for better vehicle flow; and suggested staging construction projects to allow for a quicker start of construction.

Topic #1 (Site Plan & Operation Plan)

1. General Critique of Site Plan.
2. General Critique of Operations Plan.
3. The run-around/test track is designed for a maximum speed of 15 MPH. Is this sufficient for testing?
4. Is it feasible for the perimeter road at the northerly boundary of the facility to share space with the test track?
5. Is coupling/decoupling area or track needed in the car storage area?
6. Is yardmaster/quality control person needed to direct LRV cars into proper areas? Should this person be at a fixed location or should he "roam" yard?
7. Should a pit be located on test track so tht undercar adjustments can be made without bringing vehicle into shop?
8. Is a yard run-around track needed in addition to test track?

Topic #2 (Bldg. Layout Plan/Service Lane/Blow Shed)

1. General Critique of Building Layout Plan.
2. General Critique of Maintenance Plan.
3. Can track with wheel truing be used for Preventive Maintenance/Running Repair (PM/RR) during peak hours and wheel truing during off hours?
4. Is the layout and design of pits in the major repair area effective?
5. Should a freight elevator be included in the 2nd floor shops? Is a crane sufficient in lieu of freight elevator?
6. Do you agree with the inspection times, frequencies, and overall hours to perform inspections? Is the plan adequate for 100-car fleet? Can one of the future tracks between building and inspection area be eliminated?
7. We have assumed use of "stingers" and winches to move vehicles on certain track; is our plan effective?
8. What form of building isolation do you recommend to protect against stray current corrosion?
9. Can an overhead line or stinger be used in paint booth?
10. What type of overhead doors are best?
11. How much space is needed for truck storage?
12. Is the crane coverage for material handling adequate? Is it excessive?
13. Is a blowshed needed? Can it be deferred? Can a vacuum be used to remove dirt from motors instead of blowshed?
14. Can fiberglass work be done in paint booth? If not, where?
15. Does battery shop need direct access to interior of shops?
16. Are clearance above, below and around vehicles adequate?
17. Is it feasible to perform interior cleaning in car storage area?
18. Is single catwalk adequate?

FIGURE 4 Peer group discussion questions.

Topic #3 (Trackwork/Traction Power/Maintenance of Way (M.O.W.))

1. General critique of trackwork and traction power.
2. Are # 4 switches and frogs OK?
3. Is girder rail or strap guard rail best to use in yard?
4. Is it feasible to backfeed electric power from the mainline substation to yard substation if yard substation fails?
5. How much space is needed in M.O.W. area? What areas are needed in M.O.W. building? What should be included?

Topic #4 (Scheduling/Costs/Deferable Items)

1. Is it best to construct trackwork systemwide?
2. Is it best to design and construct traction power systemwide?
3. Assuming budget is a problem, which of the following items would you defer? And in what priority?
   A. Wheel Truing Machine
   B. Blow Down Shed
   C. Daily Inspection Building
   D. Paint Booth
4. Do you think it is reasonably cost effective to substitute a "bubble" pit for daily inspection?
5. What other items could be deferred to reduce first cost of project?

FIGURE 4 continued.

The peer group review and discussions were significant factors in maintaining the established budget and schedule as well as in developing a site and shop building layout with efficient circulation and relationships between maintenance and operations functions.

CRITERIA DEVELOPMENT

During the concept development phase of final design for the maintenance facility, a number of technical memorandums were developed that outlined design criteria and operations plans for departmental responsibilities and activities. These memorandums established the basis for final design and evaluation in the context of the available budget and existing design standards used in other Santa Clara County Transit District facilities.

The design criteria developed for functional areas included the following items:

A. General. Initial capacity of a facility for 50 double-ended, articulated light rail cars with future expansion provisions for a 100-car fleet.

B. Sitework

1. Double-track entrance and exit to prevent single-point failures.
2. Storage tracks with capacity for six cars per track plus an additional bypass track for circulation and testing cars. Yard ladders at each end for through operation.
3. Double-ended maintenance shop tracks permitting run-through operation. Track lines in the facility for
   a. Body shop and paint booth,
   b. Future overhaul,
   c. Overhaul and component charge-out,
   d. Wheel truing,
   e. Running repair,
   f. Preventive maintenance,
   g. Future running repair,
   h. Blowshed,
   i. Daily inspection, and
   j. Car wash.
4. Overhead contact traction power wire over all tracks.
5. Paving between alternate storage track lines, in the apron area around the buildings, and in the employee parking lot.
6. Perimeter security fencing with gates for light rail cars, delivery trucks, and staff vehicles.
7. Perimeter landscaping and irrigation.

C. Shop Building

1. Industrial-type metal-sided building housing all maintenance and repair facilities, parts storage, operations, and administrative spaces. Operations areas for dispatch and drivers.
2. Major repair area with run-through tracks, maintenance pits, overhead power, turntables for truck movement to truck shop, body shop, paint booth, and wheel truing.
3. Preventive maintenance (PM) and running repair (RR) with run-through tracks, depressed floor for access to side-car equipment, maintenance pits, monorail crane for rooftop equipment, overhead power, and an inspection platform.
4. Administrative and support area in a two-level central core between heavy repair and PM and RR including
   a. Parts storage;
   b. Maintenance personnel lunch room, restrooms, and lockers;
   c. Schedule and supervisor's office;
   d. Truck repair shop;
   e. Electric shop;
   f. Machine shop;
   g. Pneumatic shop;
   h. Electronic shop;
   i. Pantograph and air conditioning shop;
   j. Operations area including dispatch office, ready room, quiet room, and restrooms; and
   k. Administrative area including general office, supervisors' offices, meeting room, and computer room.

D. Daily inspection building. Inspection area with maintenance pit, inspection platform, overhead power, and sanding equipment.

E. Blowdown building. Undercar cleaning area with maintenance pit and compressed air cleaning equipment.

F. Exterior car wash. Car cleaning equipment to

wash front, sides, and back of cars with recyclable wash system.

G. Trackwork

1. Track alignment to accommodate 5-mph speed, 10-mph yard bypass and test track speed, and minimum track centerline radius of 100 ft.

2. Track centerline spacings in storage area alternating at 13 ft and 16 ft.

3. Ballasted track standard on site consisting of 115 American Railway Engineering Association (AREA) welded rail.

4. Embedded track used where rail vehicles share trackway with rubber-tired vehicles.

5. Shop track embedded in building slab and on steel column supports in depressed PM and RR area.

6. Track gauge of 4 ft 8 1/2 in.

7. Track design to minimize stray currents from use of rails as negative return for system. Building structure and shop rails to be grounded for safety and corrosion protection.

8. Track materials consisting of subballast and timber ties.

H. Overhead Traction Power System

1. Direct suspension contact wire system on poles and bridges.

2. Contact wire material of 300 MCM, grooved, hard-drawn copper.

3. Minimum wire height in yard and buildings at 19 ft per California Public Utilities Commission standards.

I. Traction Power Distribution System

1. DC substation building with all incoming and outgoing positive and negative connections underground.

2. 750 volt DC power operation.

J. Maintenance of Way

1. Defer maintenance-of-way building until program is developed in the future. Provide utility stub-ends for future building.

2. Maintenance-of-way vehicle storage track for line cars and the like.

3. Materials storage area for rail, ties, ballast, and so forth.

In addition to these design criteria, a detailed operations plan was developed to establish departmental responsibilities and procedures for the maintenance of equipment, operations, parts/stores, and maintenance of way departments. The operations plan is outlined in the Appendix.

REFINEMENT OF THE CONCEPT

The next step in the final design process required refinement of the facility concept to be consistent with the peer group recommendations and the design criteria. Cost reduction, operating efficiency, and future expansion capability were paramount considerations in that concept refinement.

Shop Track Spot Requirements

A spot analysis was conducted to assure that all necessary functions could be provided and that the size of the initial shop building could be held down to reduce cost. The spot analysis was based on the recommended schedule for periodic inspections provided by Metro Canada, the vehicle supplier for the Guadalupe Corridor Project. Table 1 gives the recommended schedule.

In the analysis it was assumed that overhaul would be accomplished in the heavy repair area and that all other inspections would occur in the PM and RR area. Six spots were provided in the heavy repair area with initial operations on the 50-car fleet scheduled to be performed primarily on the main day shift. Three spots were dedicated to paint, wreck repair and paint preparation, and wheel truing. The remaining three spots accommodate all truck work, major component change-out, overhaul, and so forth. All six spots were programmed for inclusion in the initial building. As the fleet expands, or for unforeseen repair requirements, multiple shift operation will be employed.

The key issue related to building size was the number of PM and RR spots to be provided. On the basis of the proposed operating plan, and assuming that miles per vehicle will be balanced over a yearly schedule, each vehicle in the 50-car fleet will operate an average of 171.4 mi per day. At that rate, the "A" inspection would occur at 29.2 days, the "B" inspection at 87.5 days, and so on, which produced the following inspection schedule for each vehicle in the fleet.

Miles	Time (days)	Inspection
5,000	29	A
10,000	58	A
15,000	88	B
20,000	117	A
25,000	146	C
30,000	175	A
35,000	204	A
40,000	234	B
45,000	263	A
50,000	292	D
	Cycle Starts Over	
55,000	321	A
60,000	350	A
	One Year	
65,000	380	B

Total inspections = 8 A, 2 B, 1 C, 1 D, and 1/2 B

On that schedule, the total spot-hours per vehicle per year would be

$$8(2) + 2(4) + 1(8) + 1(16) + 1/2(4) = 50 \text{ hr per vehicle.}$$

Therefore, assuming a one-shift operation for inspections, the total number of spots necessary for

TABLE 1 Recommended Inspection Schedule

Designation	Frequency (miles/time)	Inspection Type	Person-Hours to Perform	Time on Spot[a]
A	5,000/30 days	Safety	3	2
B	15,000/90 days	Safety + Scheduled	8	4
C	25,000/6 mo	Safety + Scheduled	20	8
D	50,000/1 yr	Safety + Scheduled + Heavy lube	30	16
E	250,000/5 yr	All above + Overhaul	100	

[a]Assumes that more than one person is involved in inspections.

periodic inspections on the initial fleet of 50 vehicles would be

[(50 hr/vehicle)/(2,080 hr/spot)] x 50 = 1.2 spots.

Two cars spots were provided for periodic inspection operations, which also allows about 1,660 hr per year for running repair operations on these spots. Assuming an average of 4 hr per running repair, some 415 repairs per year or about 8 per vehicle will be possible. However, because air conditioning equipment, pantographs, and the like are carried on the top of the vehicle, a second track line with two car spots was determined necessary to assure spot availability for change-out of these components. These spots will also be available for running repair. On the same basis of 4 hr per repair, that would provide up to 20 repairs per vehicle per year. The analysis also recognized that minor repair and service, such as wiper blades and lights, that require 1 hr or less would be accomplished in the yard, and should actual operating experience show that running repairs were needed more frequently, a second shift could be implemented. In addition, the daily inspection line could be used for several hours per day for periodic inspection or running repair, or both, if necessary.

On the basis of this analysis, the initial shop building was established with six heavy repair spots plus four periodic inspection and preventive maintenance spots.

Future Expansion

Design requirements included provisions to expand the facility to store and maintain up to 100 vehicles as the system expands in the future. This requirement affected the layout of both the yard and the various maintenance buildings. Particular emphasis was placed on being able to expand with minimal interference to existing operations and on ensuring that future expansion would not require major rework of existing facilities or replacement of equipment.

In the case of the main shop, future expansion will add six car spots in the PM and RR bay. The north wall of the initial building has been designed to accommodate that expansion through removal of the metal siding and concrete panels that form the lower 10 ft of the wall and extension of the roof structure. Floor height at the north wall was set at the intermediate step level to facilitate expansion of the pits into the future addition leaving an uninterrupted floor line. Similarly, all utility and service lines have been stubbed at the north wall to allow for expansion.

Placing the daily inspection building on line with the future shop building expansion and adopting the same bay and column spacing also allows an "in-fill" of the structure to complete the building when the expansion is accomplished. The expansion incorporating the initial daily inspection building also increases future flexibility. The "in-filling" for expansion will allow the trackline next to the initial daily inspection line to be extended to accommodate inspection of a three-car train if that is found desirable or necessary. That possibility has been reflected in the layout of future track and overhead and in the positioning of the car wash facility.

In the storage yard, the necessity of storing an additional 50 articulated vehicles dictated a tight layout of storage tracks with alternating track centerlines of 13 ft and 16 ft in order to provide the total number of storage tracks necessary. That layout will require car cleaning operations to be done from the 16-ft aisle, servicing cars on both sides of the aisle. Layout of both track and overhead has included all necessary provisions for future expansion, and track turnouts will be installed during initial construction to preclude disrupting operations to "cut in" switches when the expansion occurs.

Cost Reduction Measures

In addition to the peer group review conducted of the initial facility concept prepared during an earlier phase of the Guadalupe Corridor Project, the final design team prepared an early concept cost estimate as one of its initial tasks. On the basis of that estimate, it was determined that significant cost reductions would be necessary to stay within the prescribed construction budget. As a result of that estimate and the peer group review, a thorough reevaluation of facility requirements was done to determine deferrable items or other areas of possible cost reduction that would not seriously affect the mission of the facility.

The car spot analysis discussed earlier was used to determine the minimum building size. An analysis of in-house versus contract services for various service functions resulted in deferral of the purchase of several pieces of major equipment, such as wheel and axle presses and provision for traction motor rebuilding, although shop space for this equipment was included. The daily inspection building was reduced from a three-car capability to two-car length because operations in the early years were anticipated to be built around two-car trains. The blowdown facility was also reduced to service one truck at a time instead of the entire vehicle. Another major cost reduction deferred the maintenance-of-way building pending a more complete definition of the distribution of these functions between the LRT operations and other county departments. However, all utility services for the future building will be stubbed into the storage area so as not to disturb track and operations when the building is built.

Coupled with the reduction in track and overhead necessitated by the more compact site, these various measures reduced the cost to fit within the predetermined budget. Aside from some loss of flexibility, particularly in daily inspection, the reductions were realized without reducing the overall capability of the facility. Cost control remained a primary factor throughout the final design program.

SITE LAYOUT

The original maintenance facility concept developed during previous phases of the Guadalupe Corridor Project provided a 22-acre, irregularly shaped site at the approximate midpoint of the corridor. As indicated earlier, the peer group review produced an alternative layout concept on a more compact site with stub-end storage tracks. That concept was further developed by the final design team during concept refinement to eliminate the stub-end storage and provide an emergency entrance and exit capability. Figure 5 shows the final site layout.

Concept refinement also relocated the daily inspection building from the south side of the shop building to a location in line with and north of the shop. That relocation had two purposes. It provided the queueing space necessary to avoid possible blocking of West Younger Street by trains waiting to go through inspection and wash. The relocation also offered increased operational flexibility because

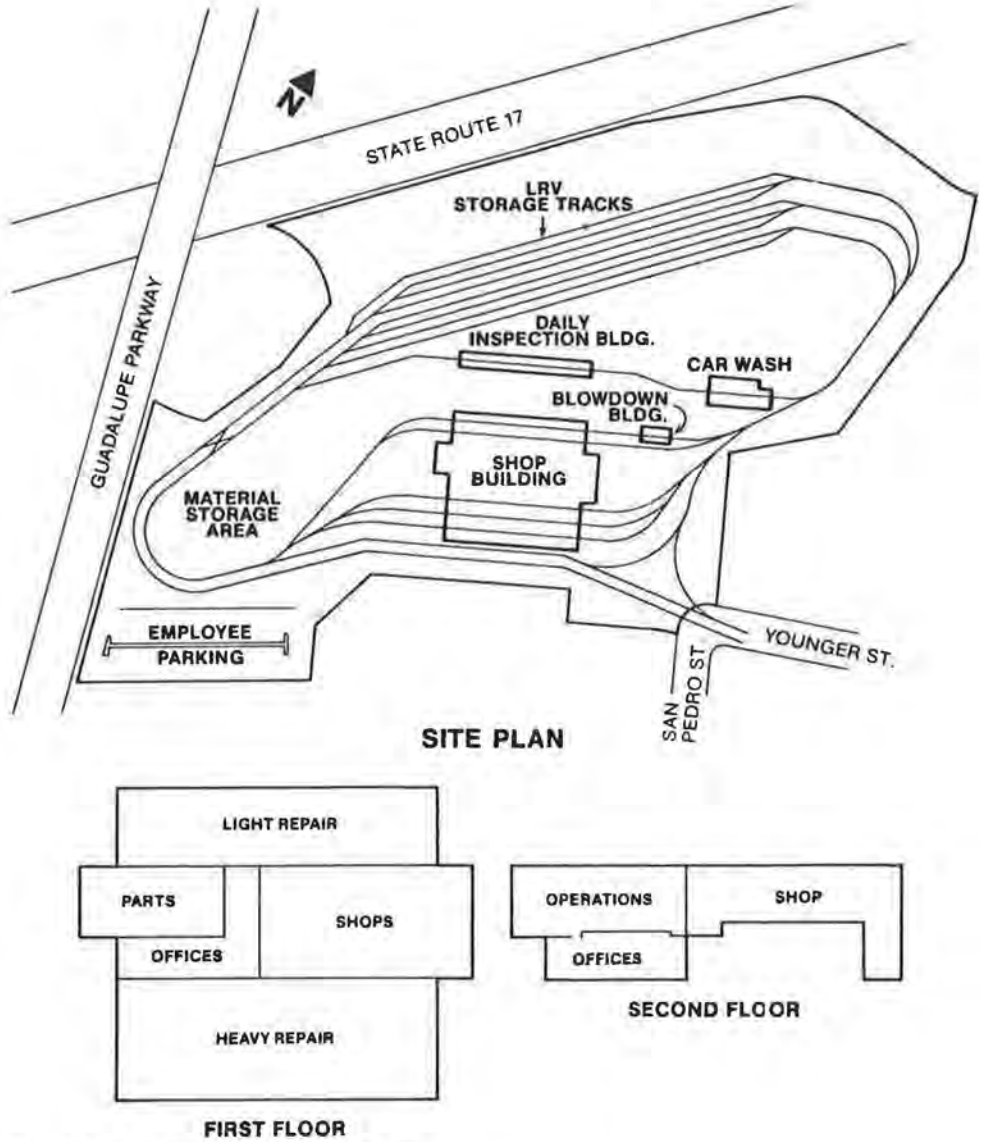

FIGURE 5 Site plan and shop building plan.

inspection could be scheduled for either the morning or the evening pull-in and trains not scheduled could bypass inspection and go directly to storage.

In normal operation, trains going into service will leave the storage yard in a westerly direction, proceed through the west loop, and enter West Younger Street. Entering the yard, trains will normally proceed through the west loop, through daily inspection and wash, and then through the east loop into storage. If not scheduled for inspection, the train proceeds directly into a storage track from the west loop, bypassing inspection. Emergency operations are provided by the wye connection between the run-around track and the entrance track at West Younger Street.

The space inside the east and west loops is designated for maintenance-of-way storage. Future vehicle storage will be to the north of the initial vehicle storage tracks. Shop expansion will occur by "in-filling" the area between the initial shop and daily inspection. Employee parking has been sited in the southwest corner of the site, making use of an otherwise unusable area.

Shop access may be had at either end of the two-vehicle length shop so that no car spot is blocked by a vehicle being serviced. Run-around capability has also been provided to check out vehicles after service or repair.

Overall, this layout makes maximum use of the available site and produces minimum on-site vehicle travel. At the same time, it reserves 4 acres of land fronting on North First Street (east of the site) for alternative uses. Figure 6 shows architectural renderings of the facility.

BUILDING LAYOUT

The layout of the main shop building also reflects maximum utility of all shop spots and minimum distance from stores, central services, shops, lunchroom, and other employee facilities with minimum interference between functions. As shown in the space diagrams in Figure 5, the central service core separates the heavy repair area and the light repair area on the first floor. That separation serves two purposes. First, it permits direct unimpeded access to parts storage and shop areas from both repair areas. Second, it allows multiple-shift operation in one or the other repair area with that area secured, which reduces supervision requirements.

FIGURE 6 Architect's rendering of facility (a) from Younger Street and (b) from Guadalupe Parkway.

All major component shops, including truck shop, future wheel and axle shop, machine shop, and electrical shop, are located on the first floor and shared by light and heavy repair. Office space for maintenance foremen and schedulers is located on the first floor to facilitate direct access to and supervision of the work areas.

The second floor provides space for general administrative offices and the operations department in addition to pantograph repair, air conditioning, and electronic shops. The operations area houses all dispatch, communications, and operators' facilities, all of which are separated from the maintenance activities. Separate entrances are provided so that operators and other operations personnel do not have to pass through maintenance areas. The pantograph and air conditioning shops located on the second floor are serviced by a monorail crane over a PM and RR track. This arrangement reduces time required to remove or replace a rooftop component because the components can simply be lifted off the vehicle and moved directly to the appropriate shop area by the monorail crane.

COST CONTROL PROCEDURES

Cost control during design was a critical aspect of this project to assure a high level of maintenance capability and, at the same time, remain within the established budget. This was accomplished by monitoring the design through increasingly detailed cost estimates. The concept refinement estimate clearly identified the need to carefully examine the site and building requirements. At the 30 percent design level, the cost estimate became a "design-to" figure and at subsequent 50 to 85 percent design levels cost estimates were compared to prior estimates and any variation analyzed.

Throughout the design program each cost reduction measure suggested was analyzed for its impact on the efficiency of maintenance operations. For example, in the concept refinement stages, one cost reduction item suggested was to single track the entrance and exit lane between West Younger Street and the west crossover near the storage yard, even though the single track could produce added delay during pull-ins. As the design progressed it was found that the suggestion required installation of a block signal system costing about $80,000 to satisfy California Public Utilities Commission safety requirements. This reduced the total savings available. In this case, it was concluded that the net savings did not compensate for the loss of operations flexibility and the potential for delay. Therefore, the single-track suggestion was abandoned. Similar comparisons of cost-effectiveness were made for any cost reduction measure that could affect operations.

PHASING CONSTRUCTION CONTRACTS

As the contract documents for the maintenance facility were being put in final form, a decision was made to accelerate the delivery schedule of the light rail cars. That, in turn, required an earlier completion date for the facility so that the first cars could be delivered to the site. An analysis of the initial schedule was made to determine if the construction period could be started sooner or shortened, or both, so that the facility would be complete by early 1986. It was found that the schedule could not be shortened appreciably. However, the work could be started 3 months sooner by phasing it into a number of contracts. That way construction would start on the initial phases while contract documents for later phases were put in final form.

Other advantages that resulted from advancing the start of construction included the completion of more work, particularly site preparation, before the winter rainy season began and the saving of 3 months escalation costs due to earlier advertisement of the projects. This lessened the potential for construction delays and higher costs.

The project was broken into three major construction contracts:

- Site work preparation included demolition, rough grading, and underground utilities;
- Structural steel procurement included fabrication and erection of structural steel for the buildings; and
- General facility contract included building construction and final site work, such as final grading, paving, and landscaping.

The site work and structural steel contracts were advertised simultaneously. Both projects started construction in April 1984. The general contract started in July 1984 as the initial site work was being completed and the structural steel was being fabricated. The first work of the general contractor included construction of the building grade beam foundations, the maintenance pits, and building utilities. As these items were completed, the structural steel was delivered to the site and erected on the foundations. The general contractor then continued with completion of the buildings.

Trackwork and traction electrification projects for the maintenance facility were done under system-wide contracts. That approach establishes one contractor, with responsibility for this specialty work, for all trackwork and one for all traction power.

The equipment needed for the facility was also phased into a number of contracts. In general, bolted-down equipment was included in the general facility contract. The remaining equipment was

broken into four procurement contracts. This was done because of varying types of equipment and delivery schedules. The four contracts were

- Wheel truing machine,
- Portable LRV lifts,
- Small tools and equipment, and
- Furniture and furnishings.

The wheel truing machine was awarded before the general facility contract so that the pit details for the machine were known before the building was started. Project schedules that detail the interrelationships of the contracts mentioned are shown in Figure 7.

The advantages of phasing the maintenance facility project into a total of nine contracts were mentioned at the beginning of this section. A number of disadvantages also resulted. They include

1. Additional control and coordination of the prime contractors is needed by the agency's contract administrators;
2. There is a greater chance of errors, duplications, and omissions in the contract documents for projects with interrelated work;
3. The contract documents are more costly to develop for the additional projects; and
4. There is a greater likelihood of claims by the prime contractors resulting from the interrelated work.

In determining whether construction phasing should be pursued, an analysis of the advantages versus the disadvantages must be done for the total impact on the project.

CONCLUSION

The budget established for this project presented a challenge to the design team. That challenge required careful attention to cost control and reduction opportunities throughout the design process. That process identified several key areas and procedures to control costs and to assure a facility that meets program requirements. Significant issues include

- Site selection. When options are available, a careful analysis against a set of selection criteria tailored to the specific system and local conditions can produce both initial cost reductions and future operating cost savings.
- Peer group reviews. A selected panel of experienced system operators and maintenance specialists can lead to more cost-effective and efficient facilities, particularly for agencies not experienced in rail transit operations. The reviews should be held after concept plans are developed and again at about the 30 percent level in detailed design.
- Deferred items and future expansion. Any deferred items and expansion requirements should be defined early through an operations analysis, and provisions for such items should be designed into the facility so that future additions can be made with minimal interference with existing operations and without major reworking of the existing facility or equipment.
- Cost reduction and operations trade-off. Any proposed cost reduction item should be analyzed for its impact on operations to assure cost-effectiveness in operating efficiency and that no serious operating deficiencies result from the initial savings.

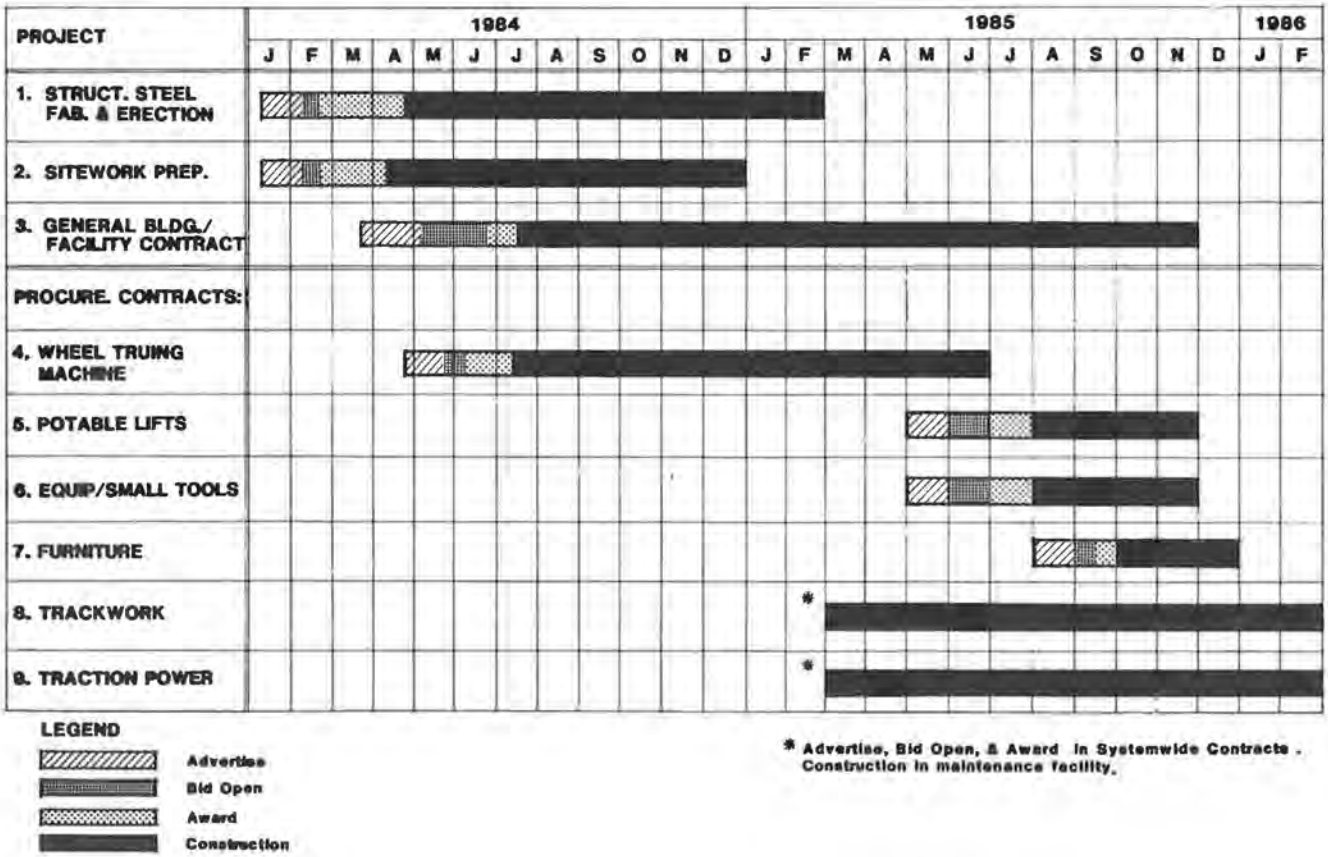

FIGURE 7 Construction packaging and schedules.

• "Design-to" budget. After completing design development (about 30 percent working drawings), a firm budget should be established as a "design-to" limit. Subsequent design reviews should include cost estimates in increasing detail, and any variation should be analyzed and explained as a basis for appropriate design or budget adjustments.

• Phasing or "fast tracking." Fast tracking can reduce escalation costs and take advantage of seasonal weather conditions. However, multiple phases or contracts can complicate construction coordination and administration. Therefore a fast track decision should be based on an analysis of overall cost-effectiveness, schedule requirements, and construction administration problems.

• Consultant-client relations. A design team that involves the client operations and maintenance personnel in every phase of the project will achieve better schedule adherence and overall cost control because they are aware of all issues as they develop. This facilities both review and decision making and also assures satisfaction with facility operations.

Applying these concepts to the design process for the Guadalupe Corridor Maintenance Facility Project produced a high-quality product and assured that the Santa Clara County Transit District did "get the most on a modest budget."

APPENDIX

I. Operations plan
- A. Maintenance of equipment
  - 1. All vehicle-related maintenance and repair
    - a. Preventive maintenance/periodic inspection
    - b. Running repair
    - c. Scheduled overhaul
    - d. Program changes
    - e. Wreck repair
    - f. Daily inspection
  - 2. Yard operations
    - a. Make and break train for revenue service consist
    - b. Moves to shop track
    - c. Moves to clean track
  - 3. Daily car cleaning
  - 4. E (extraordinary) cleaning
  - 5. Car washing
  - 6. Car sanding
  - 7. Vehicle work records and maintenance schedule
  - 8. Vehicle moves to/from shop
  - 9. Shop housekeeping
  - 10. Component shops to support vehicle maintenance
    - a. Truck shop
    - b. Electric shop
    - c. Machine shop
    - d. Brake shop
    - e. Electronic shop
    - f. A/C shop and pantograph shop
- B. Revenue service operations
  - 1. Dispatch
  - 2. Quality control--daily vehicle inspections for damage and operating malfunctions reporting
- C. Parts/stores
  - 1. Maintain secured storage
  - 2. Coordinate shipping/receiving of materials
  - 3. Maintain records of material consumption
  - 4. Place orders for required materials
  - 5. Maintain adequate level of materials for day-to-day operations
- D. Maintenance of way
  - 1. Main-line and yard trackwork
  - 2. Main-line and yard substations and electrification
  - 3. Station maintenance
  - 4. Right-of-way maintenance
  - 5. Yard and main-line electrical systems maintenance
  - 6. Signals and communications systems
  - 7. Facility building and grounds maintenance

II. Maintenance and operations department operations associated with yard-related activities
- A. Pull-out (yard to revenue service)
  - 1. Operator reports to dispatcher before pull-out, receives car number/numbers and location of consist in yard
  - 2. Operator locates consist in yard and performs pre-pull-out inspection, noting deficiencies on defects card
  - 3. Operator gives copy of defects list to yardman assigned to yard by operations during pull-out period
  - 4. Yardman determines if defect is serious enough to retain vehicle in yard or if quick fix can be made; maintenance performs quick fix if consist can leave on schedule; if not, operator is assigned new consist by dispatcher
  - 5. Operator moves consist out of yard into revenue service
- B. Pull-in (revenue service to yard)
  - 1. Shopperson assigned to daily inspection track meets consist at entrance to daily inspection building and obtains observations on malfunctions during service run
  - 2. Shopperson climbs inspection platform and observes pantograph as operator moves consist into the building
  - 3. Shopperson walks the pit under the consist noting any defects on under-car equipment
  - 4. Simultaneously, operator walks the interior of the car, closing windows, picking up lost items, and noting interior defects
  - 5. Operator returns to front of consist and meets shopperson, noting additional defects on defects card
  - 6. Shopperson releases operator
  - 7. Shopperson takes consist through car wash and to yard storage location
  - 8. Operator returns to dispatch for signout
  - 9. Shopperson relays car defects and consist locations to shop foreman at end of pull-ins
  - 10. Shop admi istration relays consist locations and cars on hold to dispatcher before pull-outs
- C. Daily car cleaning
  - 1. Exterior car wash performed once daily at end of pull-in inspection by shopperson
  - 2. Interior cleaning performed once daily at pull-in by maintenance department in car storage area; consists of picking up loose items, sweeping floor, cleaning windows, and so forth
- D. E (extraordinary) cleaning performed after monthly inspection by maintenance department
  - 1. Window cleaning
  - 2. Scrubbing/waxing flooring

3. Scrubbing/cleaning wainscot and ceiling lines

4. Cleaning fixtures

E. Sanding to be performed on an as-needed basis after pull-ins in the car storage area by mechanical department

III. Vehicle-related activities provided in shop building

A. Vehicle functions

1. Preventive maintenance/periodic inspection done monthly, quarterly, semi-annually and annually

2. Running repair of items needing repair on an as-needed basis

3. Major repair

a. Retrofitting vehicles with new components

b. Wreck repair

4. Overhaul to be performed at 5-year intervals

5. Major component change-out of truck, air conditioner/compressor and pantograph

6. Body repair

7. Preparation and repainting necessitated by damage and to replace worn finish

8. Blowdown before preventive maintenance and major repair to remove carbon buildup, dirt, and the like

B. Component support shops

1. Truck shop--removal and replacement of axle sets, traction motors, truck hardware, treads on resilient wheels, and so forth

2. Electric shop--repair of electrical components

3. Machine shop--repair of mechanical components and modification items

4. Pneumatic repair shop--rebuild brake units and systems

5. Electronic shop--vehicle electronic component repair, wayside signal electronics, fare collection equipment, and so forth

6. Air conditioning shop--repairs to compressors, condensors, and other elements

7. Items to be repaired elsewhere

a. Seats and frames

b. Overhaul of motors

c. Axle and wheel work other than wheel truing and tread replacement

d. Batteries

e. Windows

f. Overhaul of compressors and pumps

g. Rebuild of condensors and evaporators

C. Vehicle maintenance scheduling

1. Shop superintendent maintains vehicle schedules for preventive maintenance

2. Yard foreman schedules consists such that cars designated for preventive maintenance can be moved to shop waiting track areas

3. Shop superintendent maintains running repair reports and schedules running repair work when required