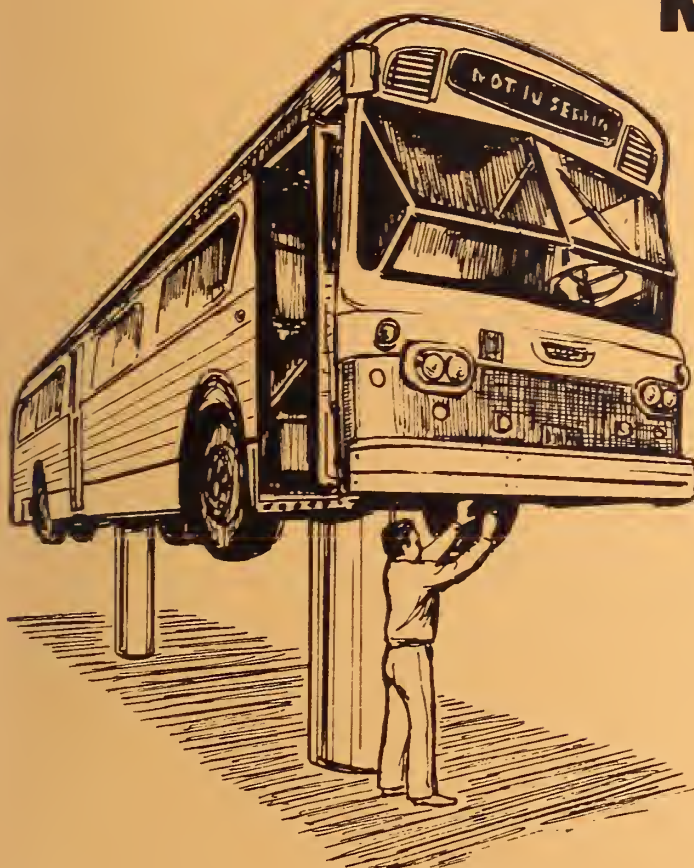
UMTA-VA-06-004-75-5

BUS MAINTENANCE FACILITIES



A Transit Management Handbook

U.S. Department of Transportation
Urban Mass Transportation Administration
Office of Transit Management
Washington, D.C. 20590

NOVEMBER 1975

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BUS MAINTENANCE FACILITIES

A Transit Management Handbook

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NOVEMBER 1975

THE MITRE CORPORATION

MTR-7080

NOTICE

ABSTRACT

An understanding of current urban transit bus maintenance facility capabilities is needed for use in planning new facilities and for the evaluation of requests for aid. Industry guidelines, based on a survey of 55 properties with fleets of 11 to 4300 buses, were developed for garages, shops, service lanes, and capital equipment. Facility ages varied from new to 100 years; 61 percent were older than 21 years. Building costs varied from a low of $12 to $28 a square foot for indoor bus storage space, to a high of $55 to $82 a square foot for equipment intensive servicing facilities (1975 dollars). Cost multiplier curves for bid forecast years from 1975 to 1985 were developed, including inflation rates varying from 6 to 12 percent per year. Small, single facility properties (less than 100 buses) were found to have greater unit space needs for repairs than large properties.

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1.0 INTRODUCTION

As transit properties provide increased passenger service, the demands on bus maintenance departments and their resources increase. In addition, many maintenance facilities have been converted from trolley car to bus operations, and their site and shop layouts do not necessarily provide for efficient maintenance operations. In response to critical needs and with the assistance of Federal capital funds, transit properties are replacing, adding to, or modernizing their maintenance facilities. These new facilities not only provide safe, convenient work space but also offer a unique opportunity to improve bus maintenance and daily service procedures.

To determine facility needs, The American Public Transit Association (APTA), Mechanical Division, distributed a questionnaire on maintenance facilities to APTA operating property members. With the questionnaire responses, augmented by visits to several properties, a preliminary report was prepared by MITRE for the May 1975 Mid-Year Meeting of The American Public Transit Association. The preliminary report has been expanded into the present document, which primarily addresses bus maintenance facility capacities necessary to support particular fleet sizes.

MITRE analysed the nationwide survey of bus maintenance facilities to assist the Urban Mass Transportation Administration (UMTA) in aiding operating properties in their planning, and in evaluating capital grant applications. The primary objective of the project has been to determine composite standards and guidelines for buildings, service facilities, garages, plant layouts, and support equipment.

The compendium of ideas in garage layouts and equipment use obtained from the surveyed properties serves as a guide for planning purposes and for judging standard practices in the industry. The report also includes measures of efficiency in facility use by which properties may reorganize space, change traffic patterns, or otherwise modernize their plants.

Guidelines are given for the development of a Planning Estimate by transit management for new maintenance facility construction. A background of recent new construction costs is provided, including cost parameters (in dollars per square foot) for maintenance functions of bus storage, shops, and servicing. Building sizes (in square feet) are combined with floor area costs to establish an initial estimate of construction costs for new maintenance facilities.

Subjects related to bus maintenance facilities and considered apart from the main theme in the text are combined in the final section. For example, an overview is presented of the Federal Occupational Safety and Health Standards and its implications.

Additional copies of this report may be obtained from:

Program Manager
Operations and Maintenance
Office of Transit Management
Urban Mass Transportation Administration
2100 Second Street, SW
Washington, D.C. 20590

Phone: 202-426-9274

or from

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161

Phone: 703-321-8500

2.0 SURVEY OVERVIEW

A total of 54 urban transit properties provided data for this study by returning questionnaires on their inspection garages and main maintenance facilities. The 54 properties collectively operate 25,000 motor buses, which represent about one-half of the estimated national urban bus fleet of 50,000 buses.

Individual participating properties are listed by state in the Appendix. Exhibit 2-1 groups the properties by fleet size. The number of properties, buses, and maintenance facilities are shown for each group. The number of properties and fleet sizes appears to be sufficient for a representative sample of the nation's transit fleets. Fleets of 200 buses or less represent six percent of the buses and 46 percent of the properties surveyed. Fleets between 200 buses and 500 buses have 18 percent of the buses and are operated by 26 percent of the properties. Fleets between 500 buses and 900 buses have 16 percent of the buses operated by 11 percent of the properties. Sixty percent of the buses and 17 percent of the properties are associated with fleet sizes or 900 or more buses.

EXHIBIT 2-1

FLEET DISTRIBUTION

Fleet Size	Number Of Properties	Active Buses	Maintenance Facilities
0 - 100	21	942	21
101 - 200	4	584	7
201 - 300	6	1437	12
301 - 400	4	1360	4
401 - 500	4	1820	10
501 - 600	3	1573	7
701 - 800	1	715	4
801 - 900	2	1678	11
901 - 1000	3	2805	12
1001 - 1100	1	1002	4
1101 - 1200	1	1198	--
1401 - 1500	1	1492	10
1801 - 1900	1	1852	NR
2401 - 2500	1	2417	12
4501 - 4600	1	4540	21
TOTAL	54	25,415	135

Geographical distribution of questionnaire responses is shown in Exhibit 2-2. Several of the larger properties furnished partial responses, and a few properties not included responded only to a few specific questions. About 76 percent of the respondents are located in the northeastern United States and Canada. About 61 percent of the facilities had inside bus storage and are predominantly located in the U.S. northeast.

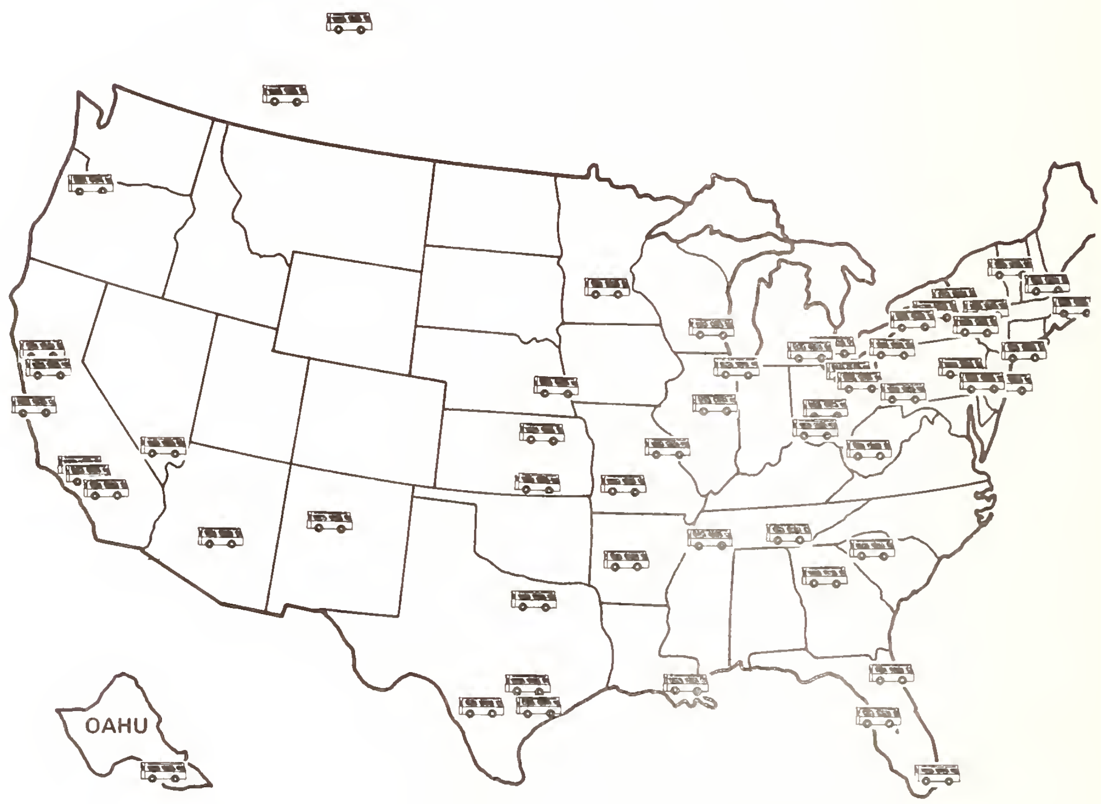


EXHIBIT 2-2
PROPERTY LOCATIONS

2.1 Fleet Data

The composite bus fleet of the respondents reflects recent modernization programs in that 62 percent of the buses are less than 10 years old; 32 percent are between 10 and 20 years old; and 6 percent are over 20 years old. Diesel is the predominant fuel (used by 98.5 percent of the fleet). Gasoline buses comprise 0.4 percent of the fleet and are used primarily in Dial-A-Ride and CBD circulation applications. Propane (0.7 percent) and electricity (0.4 percent) were minor sources of power.

GMC was the manufacturer of 75.6 percent of the fleet, followed by Flxible (21.1 percent) and AM General (0.6 percent). The remaining 2.7 percent of the fleet was supplied by other manufacturers. These percentages will change in the future as other suppliers, such as AM General, attain manufacturing production.

Passenger capacities of the fleet are predominantly in the range of 41 to 55 passengers (96.4 percent). Twenty- to 40-passenger buses comprise 2.7 percent of the fleet, and small buses (less than 20 passengers) 0.7 percent of the total. Large capacity buses seating over 55 passengers are in the minority with 0.2 percent. Most buses are the standard 40-foot urban coaches. Facility space requirements assume 40-foot coaches, which is reasonable in that smaller coaches may be repaired in the same facilities. However, higher parking and storage densities may be realized with smaller coaches.

Charter mileage is not a large contributer to bus utilization. Among all respondents, charter mileage accounted for only 1.8 percent of the total annual mileage. Some properties reported no charter work, many reported 2 percent to 4 percent, and one reported a high of 19 percent charter mileage.

Transit properties use automobiles and service vehicles to support their operations. The average non-revenue service fleet has a vehicle population of about 8 percent of the size of the revenue fleet.

The active fleet averages about 32,000 annual miles per bus, as shown in Exhibit 2-3. The reserve fleet is composed of buses in excess of those required for peak service demands. The average reserve fleet is 22 percent of the peak service requirement (Exhibit 2-4). Reserve fleets of 10 percent or less require careful planning for effective maintenance programs. Many buses are available midday for maintenance as they return from peak tripper service (Exhibit 2-5). A reduction of the peak/base ratio through the increase of base service would imply the need for an increase in the reserve fleet, as would an increase in annual mileage.

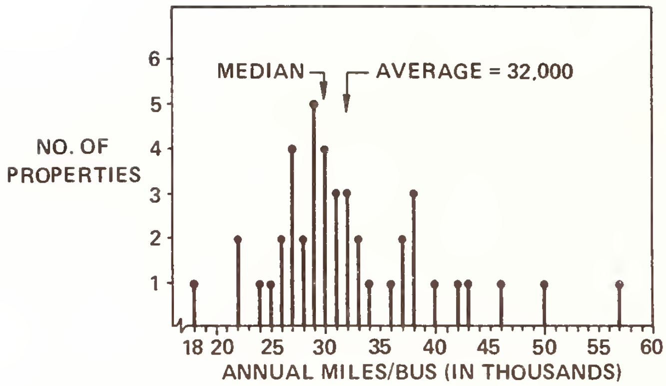


EXHIBIT 2-3
ANNUAL MILES

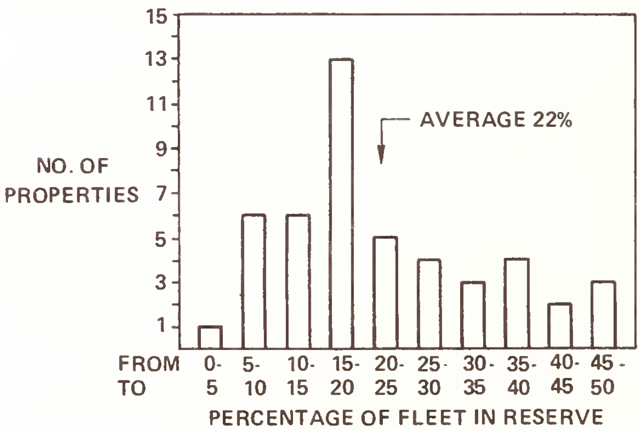


EXHIBIT 2-4
RESERVE BUSES

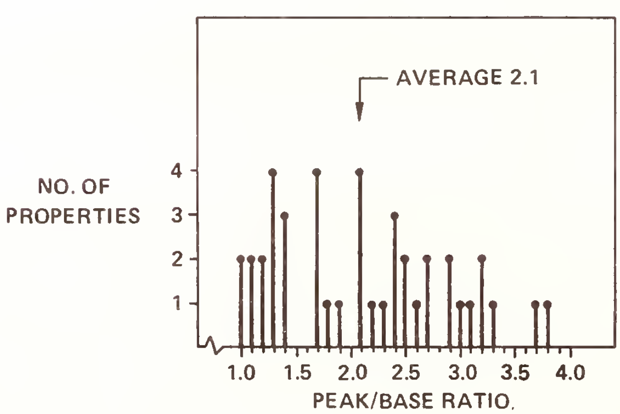


EXHIBIT 2-5
PEAK/BASE

2.2 Employee Data

Questionnaire data provided numerical information on transit property employees, maintenance employees, and bus operators.

The ratio of operators to buses was calculated for both active buses and peak service buses. These two ratios are shown in the histogram of Exhibit 2-6. The average ratio of operators to active buses is 1.45. The ratio of operators to peak service buses is the more meaningful ratio, and its average is 1.78. There was no meaningful correlation between operator-to-bus ratios and property size.

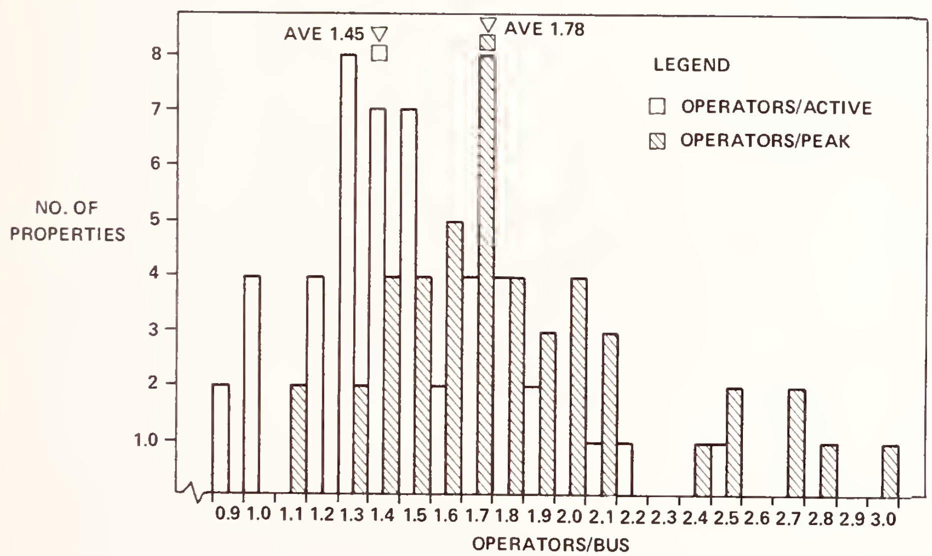


EXHIBIT 2-6
OPERATORS/BUS

Maintenance employee data obtained included all personnel of the department: supervisors, mechanics, service attendants, and clerks. The average in the sample was 2.7 buses per maintenance employee, as shown in Exhibit 2-7. This ratio may reflect maintenance department efficiency even though there is no means to provide such a relationship with present data. An existing ratio for an individual transit property may be used for facilities planning, particularly if an expansion is forecast.

A maintenance department requires between 11 percent and 33 percent of all employees of the transit property (Exhibit 2-8). The average of the survey is 20 percent. Since no meaningful relationships could be found between size of maintenance departments and fleet sizes, it appears that local practices determine the maintenance department requirements.

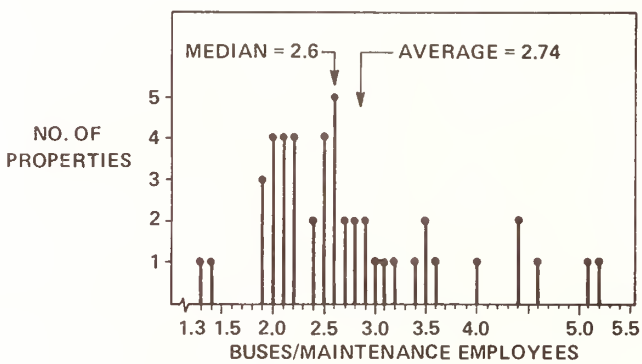


EXHIBIT 2-7
BUSES/EMPLOYEES

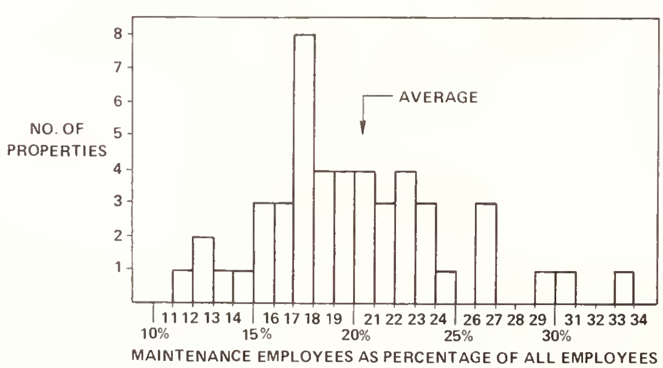


EXHIBIT 2-8
MAINTENANCE EMPLOYEES

2.3 Facility Ages

The age of existing maintenance facilities is shown in the histogram of Exhibit 2-9. Some transit properties have added buildings to their sites over a long period. In these cases the age of the primary structure has been used. If the site contains several buildings constructed over a short (two or three years) interval, the average age of the buildings was used.

The average age of facilities in this sample (Exhibit 2-9) is about 36 years. New facilities of less than 10 years of age account for 29 percent of the total and were probably constructed with Federal funding assistance. Facilities that are 21 years of age or older account for 61 percent of the total. The Internal Revenue Service considers 30 years to be an acceptable building life for depreciation purposes for many types of construction. Facilities 30 years of age or older account for 49 percent of the total.

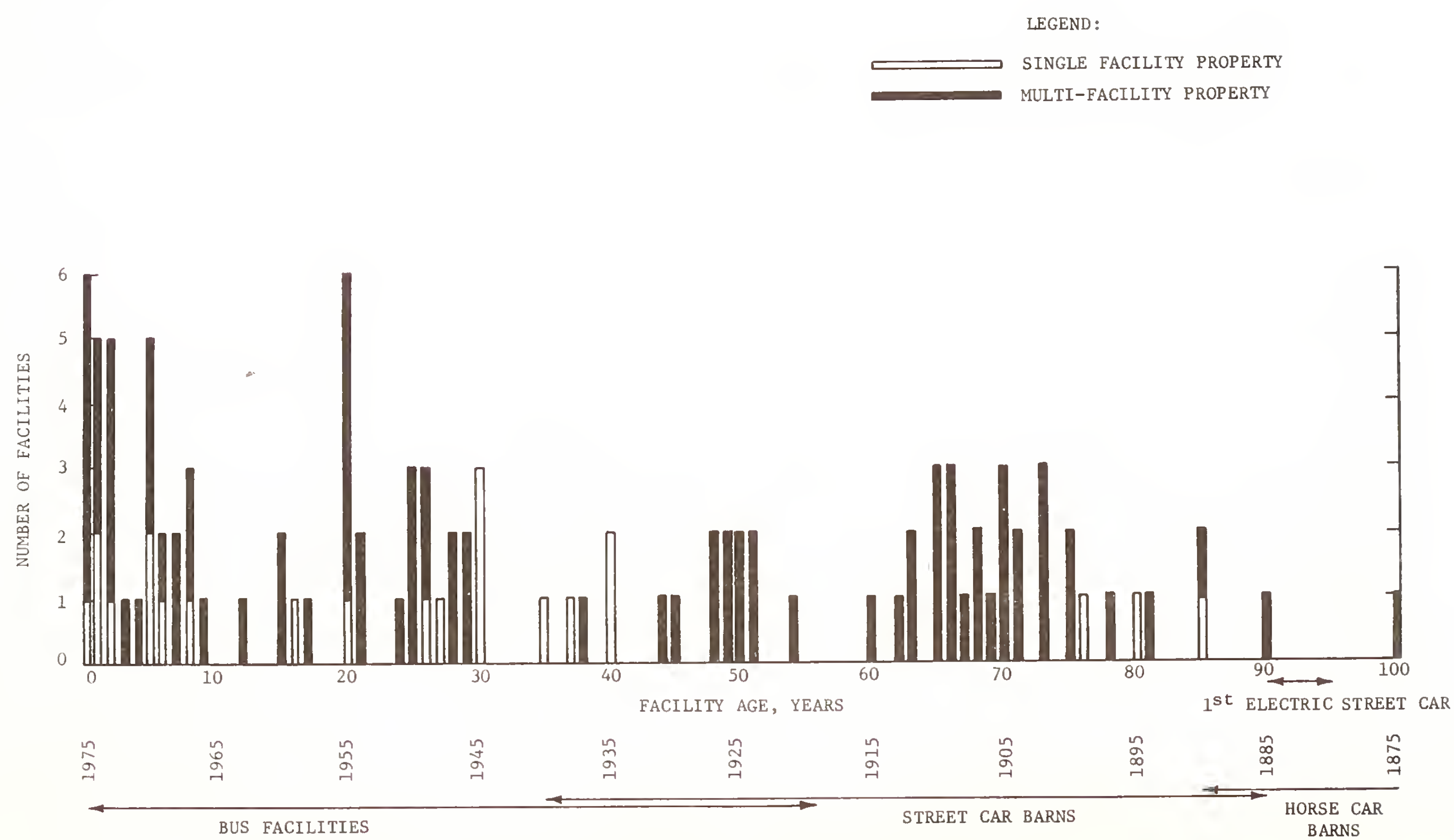


EXHIBIT 2-9
FACILITY AGES
(ALL REPORTING PROPERTIES)

3.0 INSPECTION GARAGES

An inspection garage, often called a division garage, provides daily servicing for transit buses and is thus the heart of the preventive maintenance program (periodic inspections and repairs). Most inspection garages do brake adjustments and engine degreasing in conjunction with inspections. Some properties include tire work, minor body repairs, minor painting, and engine dynamometer testing. Unit rebuild, engine overhaul, significant body repairs, and other major repairs may be performed at a main maintenance facility.

An inspection garage is usually an integrated facility. Provisions for bus operators and transportation department functions are included in the building structure, and overnight storage of buses is provided in either enclosed garages or open parking lots. Employee parking space is provided for both maintenance and transportation personnel.

By the nature of the facility, communications between operators and the maintenance staff are encouraged. However, some care should be taken to separate the various traffic patterns for safety and efficiency. Traffic patterns include employee parking, bus departures and returns, bus movements for service and maintenance, and pedestrian traffic.

Occasionally, a combined facility may be found wherein one of the main maintenance facilities is located on the same site as the inspection garage. Some properties only have one facility for transportation, main maintenance, inspection, and servicing (discussed in the section on Single Facilities). The following discussions are limited to capabilities required for inspections and inspection repairs. To function effectively, an inspection garage needs bus stalls with underside access capability (hoists or pits) and only a minor complement of special equipment.

3.1 Location

Maintenance managers were asked about their preference of inspection garage locations. Selection factors, along with the number of responses to each factor, are shown below:

a.	City Center	16
b.	Reduction of Deadhead Miles	35
c.	Accessibility to Interstate	21
d.	Accessibility of Main Thoroughfare	24
e.	Periphery of City	12
f.	Center of Assigned Route Structure	36
g.	Boundary of Assigned Route Structure	15
h.	Other	11

A garage location close to the assigned route structure that minimizes non-revenue mileage is clearly preferred.

The magnitude of deadhead mileage is not specifically reported. However, informal sources suggest that deadhead mileage may range from a low of about 10 percent of all miles to as much as 50 percent of all miles. The lower figure is related to base service runs and the higher figure to peak service, both local and express. Proper location and sizing of inspection (operating) garages may reduce deadhead miles.

A calculation of savings in deadhead mileage should be based on direct mileage costs rather than on total mileage costs. To calibrate this direct mileage cost, data from the ATA 1973 Transit Operating Report was analysed. The direct mileage operating* costs averaged 67.3¢/mile for 30 large motor-bus-only properties. For the same properties, the average total operating costs were $1.19 per mile. The direct costs relate to incremental changes in system mileage in that management, supervision, and support will not be materially affected. A reduction of one percent in annual system miles (all deadhead) could mean a savings of 320 miles per bus year or $214 per bus year. The savings in the future could even be higher with wage and fuel price increases that have occurred since 1973.

3.2 Capacity

Maintenance managers were asked what the maximum bus capacity of an inspection garage should be. Their responses are tabulated:

Bus Capacity	Responses
180	5
200	18
250	27
280	1
300	3
350	2

*Repair to revenue vehicles, tires, drivers' wages, and fuel.

Most responses (89 percent) specified 250 buses or less. The capacity extremes probably reflect current local conditions. No specific rationale was obtained from the questionnaire for the choices specified. However, conversations with managers brought out four possible reasons for restriction to 250 buses or less. These reasons are:

a. effective span of management control;

b. unnecessary deadhead miles for the larger route structure;

c. the inefficiency of a larger traffic pattern for storage and servicing; and

d. the corollary management problems of the transportation division.

Present use of inspection garages is shown in Exhibit 3-1. One property with 2400 buses and 10 garages (average of 240 buses/garage) is not shown because of scale. It must be remembered that most facilities date to earlier days of transit and that the capacity of a particular facility may be constrained by the size and/or shape of the real estate. Small properties have only one maintenance facility serving the inspection garage and main maintenance functions.

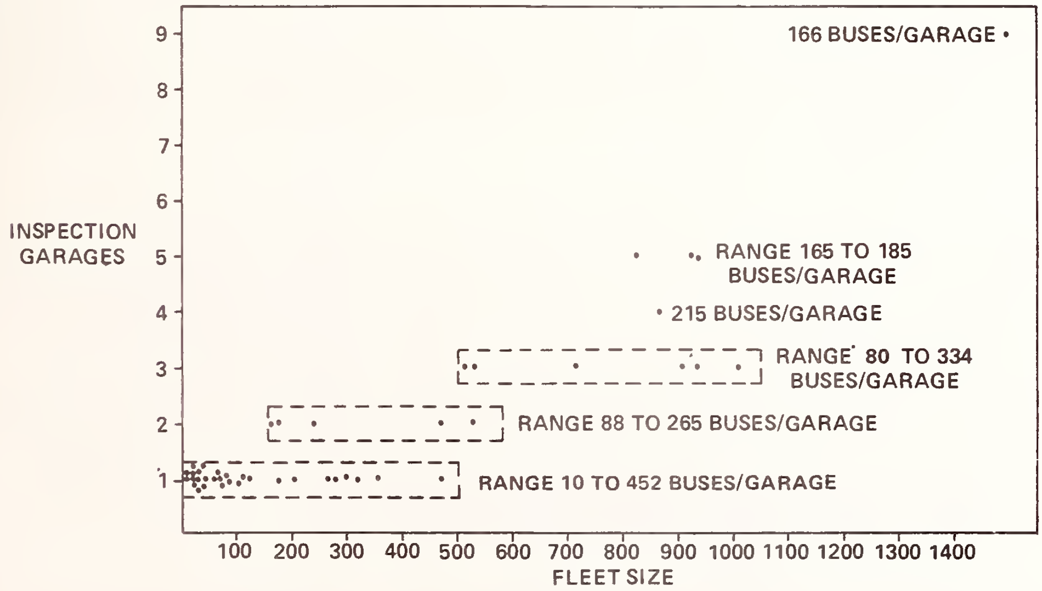


EXHIBIT 3-1
INSPECTION GARAGES

A study entitled "Optimum Garage Size Analysis" dated June 1975, prepared for the Twin Cities Area Metropolitan Transit Commission, recommends a garage size of 300 buses for the Twin Cities. This recommendation is based on an analysis of annual costs per bus for garages of various size that house from 100 to 400 buses.

Seven cost elements (annualized capital, service, maintenance labor, transportation labor, building maintenance, storeroom, and farebox labor) were used in the analysis. Each of the cost elements behaved differently over the range of garage sizes. The overall effect was a decrease in costs per bus as the garage increased in size up to 300 buses. Costs per bus increased for garage sizes larger than 300 buses.

Capital costs and transportation costs (costs of personnel necessary to monitor and dispense work assignments) decreased with increasing size of garage. Maintenance and storeroom labor costs per bus decreased with increasing garage sizes to a 300-bus facility and then increased. Building maintenance and farebox labor costs (the exchanging of empty fareboxes for full ones) fluctuated insignificantly with garage size, depending on the size of the staff necessary to fulfill the function. Servicing costs increased significantly with the size of the facility and the rate of increase accelerated for larger garages.

The Twin Cities study illustrates that economies of scale can be realized with larger facilities, up to a point. Beyond that point increased size becomes counter productive, particularly in operating costs. The study apparently did not consider the trade-off which may occur by adding one facility to reduce the total system deadhead miles and associated costs.

The Twin Cities study shows a $65 per bus annual garage expense reduction (from $7,297 to $7,232) when moving from a 250-bus facility to a 300-bus facility. If by adding one garage and retaining the 250-bus facility, the total system miles could be reduced by one percent; the annual savings of $215 per bus would more than offset the $65 savings of the larger facility. The economy-of-scale benefit drops from $65 per bus-year to $7 per bus-year when annualized capital costs are removed from the total. This is an important relation because the annualized capital cost will remain unchanged as labor and material costs inflate in future years. Deadhead mileage considerations could become very important with future labor costs.

The Twin Cities study clearly supports the opinions of maintenance managers. That is, an optimum garage size exists and is somewhere in the range of 250 to 300 buses. Furthermore, present practices are not far different from these data.

Geographical configurations of a route structure may best be handled without direct consideration of this "optimum" size. A long narrow route structure along a coastal region might best be served from two garages of 125 buses each rather than one facility of 250 buses.

3.3 Capability

A capability is required for ready access to the underside of buses and is provided by either hydraulic hoists or pits. The number of hoists and pits currently provided in inspection garages is shown in Exhibit 3-2. Constant ratio lines are provided on the chart for identification purposes. Capabilities range from one hoist (and/or pit) per 100 buses up to six hoists per 100 buses. The inspection function was isolated from other functions for this chart (Exhibit 3-2) for those cases where small properties use one facility for heavy repairs and inspections. In other cases, several inspection garages of a large property were combined to provide a single point on the graph. Hoists may be installed at strategic locations to facilitate special work. For example, a hoist in a degreasing area can be used for underside cleaning and a short-rise hoist can be used effectively in a tire shop or brake work area.

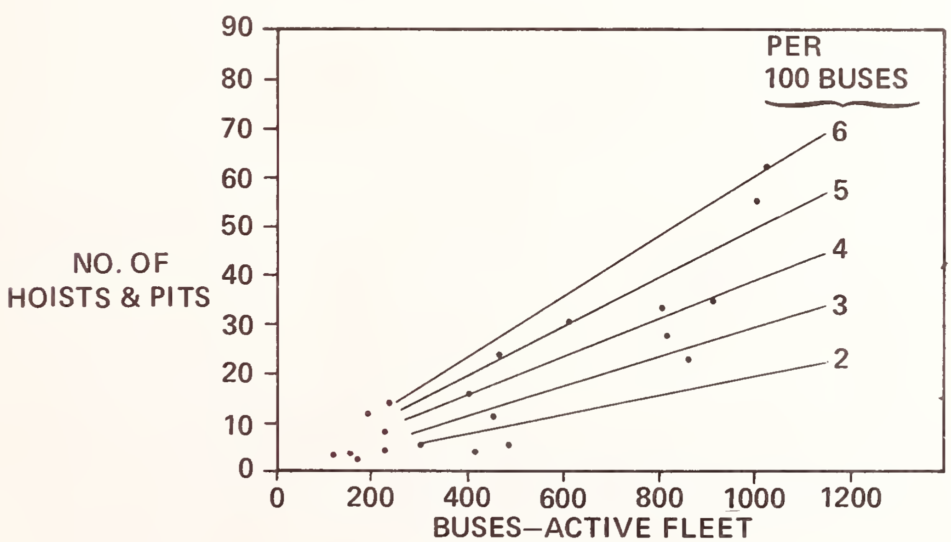


EXHIBIT 3-2
HOISTS AND PITS

Exhibit 3-3 illustrates similar provisions for bus stalls or bus bays where a stall may have either pit or hoist capability. These capabilities range from one stall per 100 buses to more than seven stalls per 100 buses. A small number of stalls does not have hoists or pits.

The size of individual bus stalls ranges from under 1000 square feet to about 1600 square feet (Exhibit 3-4). Larger stall spaces in old facilities do not necessarily mean more effective working space around a bus; some are long and narrow. Twelve-foot widths are often found in converted trolley facilities.

Stall widths of 12 feet provide four feet of clearance between adjacent buses, which is awkward for wheel removal, etc. Widths of 16 feet to 18 feet provide good access clearance, and in some cases, room for a workbench. A totally enclosed bus stall used as a tire room, engine degreasing room, or dynamometer room is typically 20 feet to 23 feet wide, which provides necessary clearance between the bus and wall.

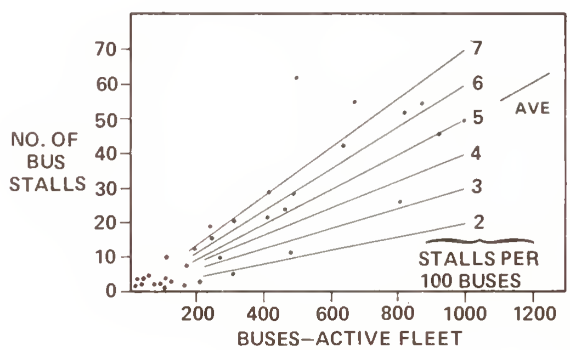


EXHIBIT 3-3
BUS STALLS

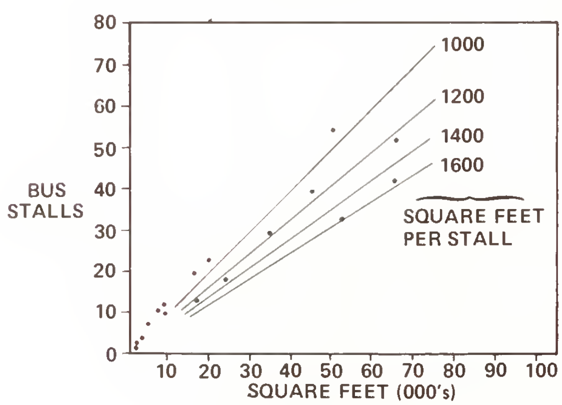


EXHIBIT 3-4
STALL SPACE

Length of stalls varies from 55 feet to 80 feet. The longer dimensions may at first seem overly generous for 40-foot buses. However, respondents tended to relate all space in a garage not used for separate rooms or enclosures to bus stall space. Extra length is therefore used for passageways, engine work areas, and for the movement of bulky parts around the facility. In some cases, this space has been used for storage of engines or transmissions when specific provisions cannot be found elsewhere. Modern facilities have both comfortably long bay or stall areas and separate provisions for shops and storage. In any event, proper allocation of space for bus access repair areas and materials storage promotes efficiency.

Support space is needed in each inspection garage for stockroom, component storage, special lubricant storage, restrooms, and office space. Support space is configured so that a bus may not occupy the space. Support space varies from about 10 square feet per bus to 17 square feet per bus, as shown in the graph (Exhibit 3-5). A facility designed for 250 buses therefore has between 2500 square feet and 4250 square feet of support space.

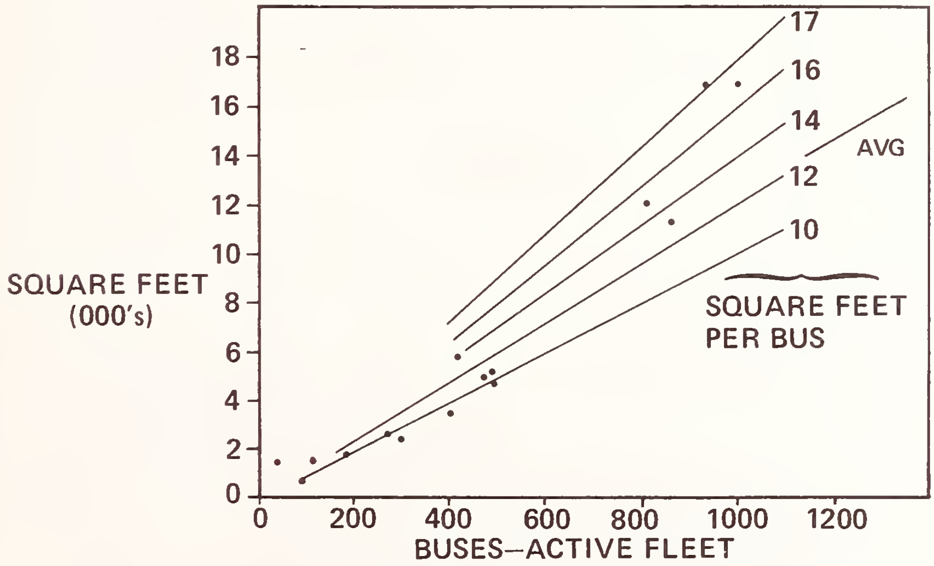


EXHIBIT 3-5
SUPPORT SPACE

3.4 Garage Layouts

The four simplified inspection garage floor plans shown are illustrative of those facilities examined during the study. The in-line floor plan is narrow and very long (Exhibit 3-6). This illustration shows bus access only from one end, although some garages have doors at both ends. The pits are long and will accommodate more than one bus. Clearance between adjacent buses will be no more than three or four feet. The limited door area in this plan limits exposure in cold climates. This floor plan is also a natural conversion from trolley car repair facilities. Bus movement is often inconvenient.

The back in/pull out facility illustrates newer facilities found in both cold and temperate climates (Exhibit 3-7). There is maximum flexibility in the movement of buses into stalls. Office, stockroom, storage facility, and locker room areas are located along one side of the building. Bus bays may exit directly onto a parking apron or into an enclosed storage garage.

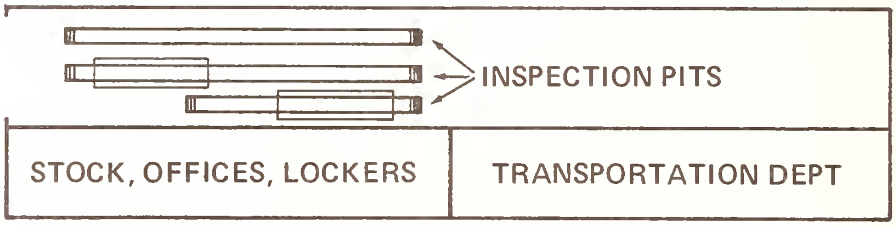


EXHIBIT 3-6
IN-LINE

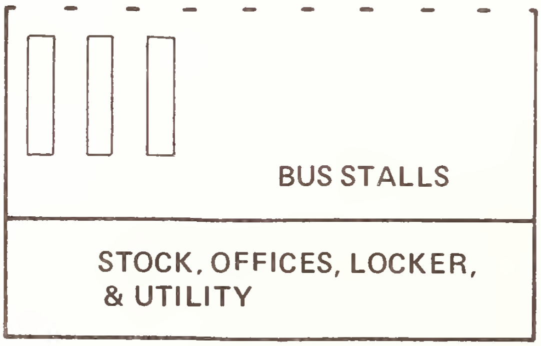


EXHIBIT 3-7
BACK IN/PULL OUT

An example was found of a truly drive-through facility (Exhibit 3-8). There are entry doors on one side and exit doors on the other so that a bus need not be backed at any time. This facility is located in a moderate climate so that larger total door area does not burden the heating system. This particular facility serves both as a inspection garage and a heavy repair facility.

The double drive-through facility may be entered from either side (Exhibit 3-9). Frequently, backing is necessary if either bus stall is occupied. These facilities make reasonable use of floor space even though they are often adaptations of trolley car repair facilities. They are normally found in temperate climates, as cold draughts can develop with doors open on either side.

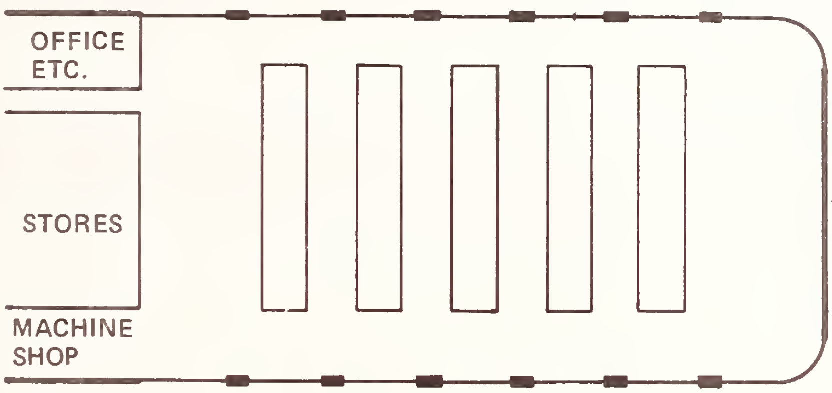


EXHIBIT 3-8
DRIVE-THROUGH

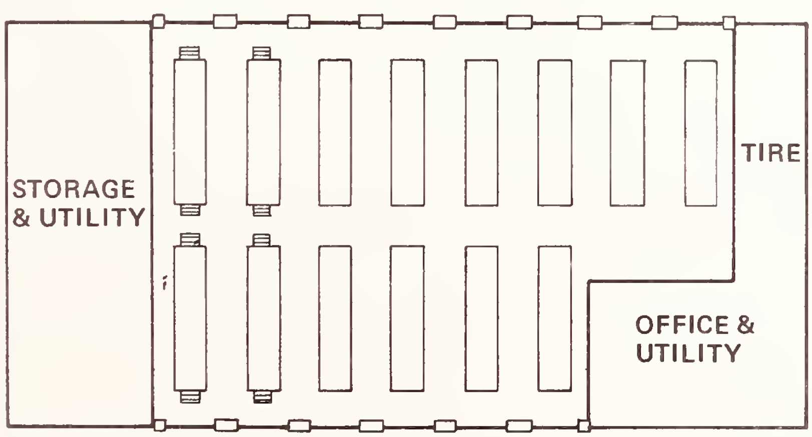


EXHIBIT 3-9
DOUBLE DRIVE-THROUGH

Even more restricted door space may be required in severe climates. Exhibit 3-10 is an illustration of an angle drive-through facility with limited door area. Actually, this plan may be extended in length or may be made with angled bus bays on either side of the passageways.

The drive-through, back in/pull out, and angled drive-through facilities are desirable configurations for facilities requiring only a nominal number of bus stalls or bays. As the requirement for stalls increases, other configurations should be considered, such as the double drive-through or a double-sided angled drive-through. As facilities become long and narrow, the convenience of support facilities is reduced.

These layouts are by no means the only choices available. A back in/pull out design may be combined with a double drive-through design. The size and shape of the facility site will influence the design selection.

An early step in the design of a facility is the specification of capabilities needed to support the required functions. The composite inspection garage layout was developed to assist in identifying possible capabilities.

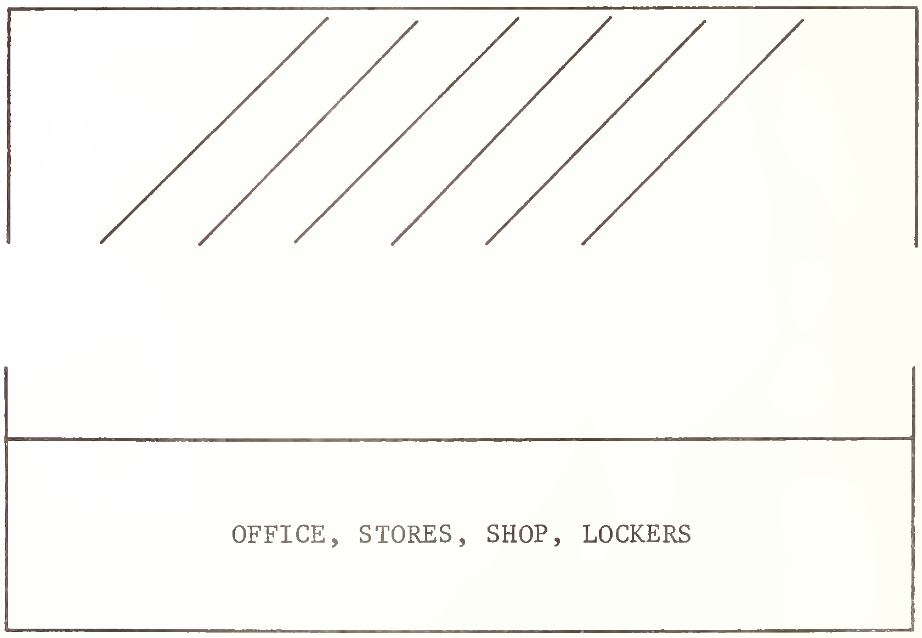


EXHIBIT 3-10
ANGLED DRIVE-THROUGH

3.5 Composite Inspection Garage

The floor layout in Exhibit 3-11 does not directly represent any existing facility. It is, however, a composite of ideas obtained from several facilities with capabilities for the future.

A separate enclosed degreasing (steam or high-pressure water) bay with a hoist provides for inspection preparation. An enclosed tire bay is equipped with a hoist and tire storage facility. An overhead hoist allows retrieval of tires and wheels from a multilevel rack. There is ample room for tire changing equipment and regrooving gear.

The main bus shop consists of two primary areas: air conditioning repair and inspections. The air conditioning area has stalls equipped with permanent overhead catwalks. Catwalks provide a stable platform for inspection and repair of the condenser and condenser fan motor.

The inspection and repair bays are used for routine maintenance functions. Each bay may be equipped with a hoist or pit for under-bus access. Individually accessible bays allow independent bus movement and ease maintenance scheduling. Storage, office, and stockroom areas are centrally located for convenience to major work areas.

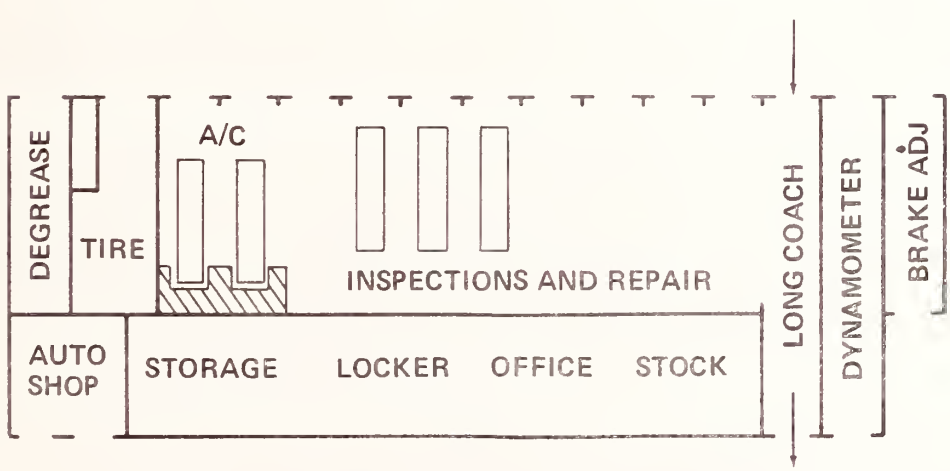


EXHIBIT 3-11
COMPOSITE INSPECTION GARAGE

A very long drive-through bus bay is provided at one end of the inspection area specifically for work on articulated coaches. An equally long repair bay is designed for dynamometer testing. Wheel traction rollers are located in the center of the dynamometer bay to allow testing of the steered wheels (braking and alignment testing), as well as the powered wheels (timing, power, acceleration, and exhaust testing). The drive-through design will accommodate the long articulated coach as well.

Heights of bus stalls must be considered if double-deck buses are anticipated. This will also affect bus washers, entrance doors, and all other drive-through passageways.

Brake adjustments are provided for separately. The brake adjustment bay has a pit for rapid bus positioning. The drive-through capability allows rapid sequential scheduling of numerous buses requiring brake adjustments.

The auto shop is separate from bus repair facilities. It is specifically designed for vehicles with spark-ignition systems. Some small buses and property-owned trucks and automobiles fall into this category.

This concept may be extended further if the inspection garage is to have significant responsibilities for body repair or painting.

Support space is situated to minimize walking distances from the most used repair areas to the stockroom. Direct access to the maintenance offices is also provided. Transportation facilities can be provided in an area adjacent to the support areas. In severe climates the floor plan may be enlarged to include a bus passageway and a reduced number of exterior doors.

The layout of an inspection facility should be simple to allow convenient movement of buses for inspection and repair work. Office areas should bring supervisors in touch with maintenance personnel. Stores and shop areas should be directly accessible from the stall areas for efficiency. Planning for the needed number of bus stalls can be done from examination of the inspection policies.

3.6 Capacity Planning

The number of stalls, hoists, and pits required is a function of work levels and frequency of use. Current inspection interval practices are shown in Exhibit 3-12. The most popular interval is 6000 miles. Inspection intervals less than 2000 miles may be needed for brake adjustments rather than for a complete preventive maintenance checklist. Inspection intervals of 6000 miles and higher are probably recent changes to maintenance practices brought about through development of modern lubricants and oil analysis techniques.

The inspection planning formula (Exhibit 3-13) may be used to arrive at the first estimate of stalls, hoists, and/or pits needed for mechanical inspections. It provides the number of inspections to be done each day for a specific inspection interval policy. The equation should be used to examine alternatives. Possible future extensions of route structure, reduced headways, or fleet-size growth will increase the annual mileage resulting in more inspections. A change in the interval will also affect the number of inspections. (A reduction of the interval will increase the number of inspections.)

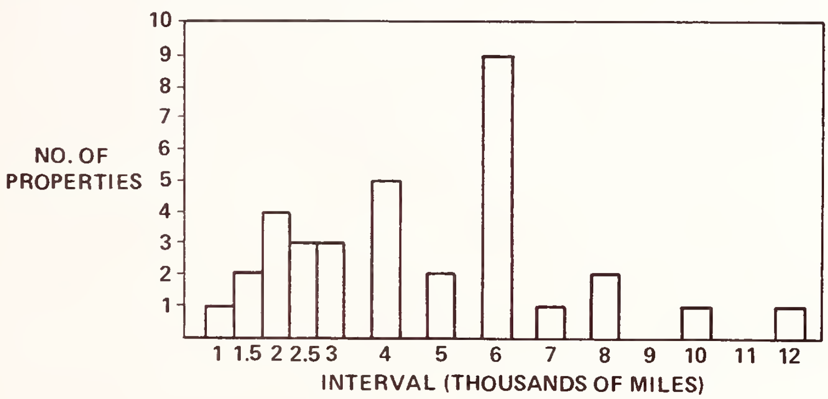


EXHIBIT 3-12
INSPECTION INTERVALS

$$\text{DAILY INSPECTIONS} = \frac{M}{I \times 250}$$

M = TOTAL ANNUAL MILEAGE OF ASSIGNED BUSES
I = INSPECTION INTERVAL IN MILES
250 = NUMBER OF ANNUAL WORK DAYS

EXHIBIT 3-13
INSPECTION PLANNING FORMULA

The daily inspections chart illustrates the sensitivity of inspections to average annual mileage per bus and to the inspection interval (Exhibit 3-14). The chart was developed for a typical inspection garage with an assigned fleet of 250 buses. Short intervals will increase the number of inspections dramatically. Inspection work loads do not increase significantly with normal changes in annual mileage. If a 10,000- or 12,000-mile inspection interval is now being used, a more conservative planning number may be used, such as 6000 or 8000 miles.

An oil change interval of 4000 or 6000 miles should be used for capacity planning, rather than a 1000- or 2000-mile brake adjustment interval. The brake adjustment pit can handle many jobs in a single day.

A pit or hoist may be used for more than one inspection per day, depending on the average time for an inspection and inspection repairs. A pit or hoist may also be used for more than one work shift, depending on the local practices and labor resources. The number of required pits or hoists then becomes the number of daily inspections divided by the number of inspections which can be done over a pit in one day.

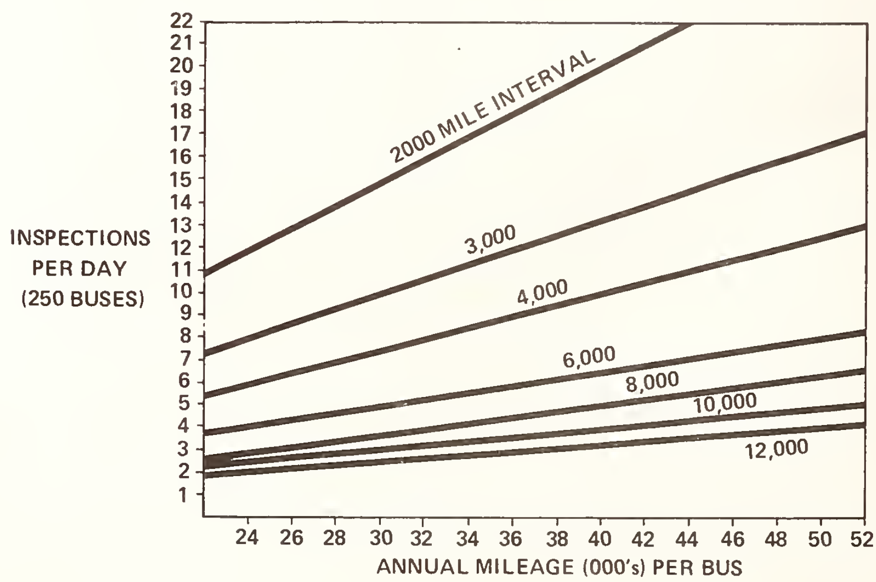


EXHIBIT 3-14
DAILY INSPECTIONS

Planning for repair stalls should also include functions other than the mechanical inspections. Examples are:

a. a wheel change area with associated tire equipment and storage;

b. stalls with overhead catwalks for air conditioner condenser access;

c. engine degreasing area;

d. a dynamometer stall; and

e. a special drive-through brake adjustment pit.

Additional stall areas will be required for body and paint work if local policy includes them in the inspection garage responsibilities.

A tally of bus stalls needed for inspections, inspection repairs, brake adjustments, air conditioning inspections, and other functions is the first step in capacity determination. The number of stalls multiplied by the desired area of an individual stall gives a total estimate of space needed for stalls. To this stall area must be added support space based on the maximum number of buses to be maintained at the facility. Provision for recording this planning information is provided in Section 8.0.

4.0 BUS SERVICING

Bus servicing is a daily routine in which vehicles are prepared for revenue operation. It includes refueling, interior cleaning, exterior washing, and some minor maintenance checks. Servicing requires almost 50 percent of the labor hours used by the maintenance department and therefore service facilities deserve careful design for efficiency. It is usually included in inspection garage functions.

4.1 Servicing Description

The complete service cycle begins with the retrieval of a bus from a parking space where it was left by an operator. This parking space may be an overnight storage or a staging or preservice area. Preservice areas are generally off-street driveways used to store buses temporarily.

Revenue removal may be done as a bus enters the garage site or as a first step of the service cycle. The bus is then moved to the service island for refueling. When large interior vacuum cleaners are used, interior cleaning is done at this time. From the service island the bus is driven through a washer to a designated overnight storage spot.

The complete service cycle is portrayed in Exhibit 4-1. Time periods of each function vary with local policies and equipment availability. Buses may be moved to a "bad order" parking area if either the operator or service attendant has noted a defect. If the bus interior is cleaned manually, the service cycle will be shorter than illustrated since cleaners work on buses at overnight storage locations.

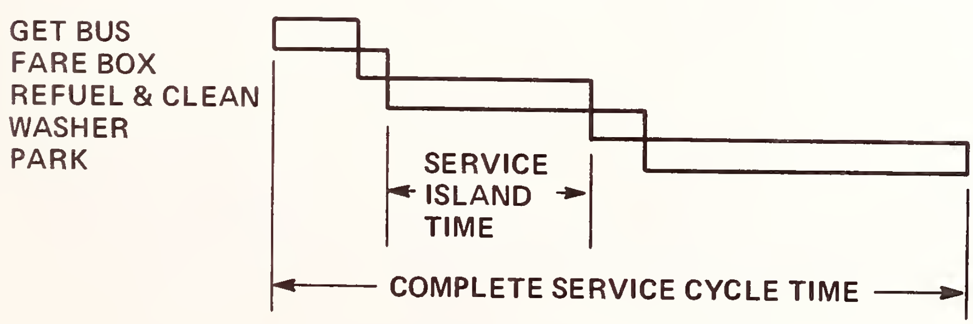


EXHIBIT 4-1
SERVICE CYCLE

4.2 Service Island Functions

Questionnaires were designed to provide an overview of service island practices and functions. Exhibit 4-2 is a list of functions and the number of respondents performing those functions at the service island. A service attendant inserts the fuel nozzle into the bus fuel tank and performs most of the mechanical checks while the tank is filling. Cleaning personnel use air hoses to dislodge dust and debris inside the bus for removal by the large vacuum. This is done during the time that the service attendant is performing his functions. Revenue removal is usually done by an employee of the treasury department immediately prior to the servicing.

EXHIBIT 4-2

SERVICE ISLAND FUNCTIONS

Function	Number of Respondents
Fuel refill	61
Oil check and refill	61
Recording of fuel and oil	58
Tire check	54
Coolant level check	54
Cleaning, interior	51
Lights check	44
Torque fluid check	38
Farebox removal	37
Maintenance check, minor	34
Brake check	24

4.3 Service Island Requirements

Servicing requires time and manpower. Exhibit 4-3 is a histogram relating responses with time required at service islands and time required for a complete service cycle. Time at the service island averages about six minutes, as shown in the lower histogram. A 50-gallon refill requires 2½ minutes at a 20-gallon per minute (gpm) pumping rate. This allows the time necessary for oil and other maintenance checks. Pumping rates much in excess of 20 gpm are not practical, as foaming, surging, and early shutoff may be encountered.

The complete cycle averages about 10 minutes, although some properties require 15 minutes. Longer times are required in large lots to move and park buses. If manual washing is involved, the cycle time may be as long as 90 minutes.

If refueling can be accomplished in an average of 3 minutes, 20 buses can be processed per hour and a total of 5 hours is required for 100 buses. An average fueling time of 5 minutes lengthens the time to about 8 hours for 100 buses.

Most refueling is done between the hours of 5 p.m. and 10 p.m. However, considerable refueling is done after 10 p.m., and the activity may extend into the early morning hours as owl runs return.

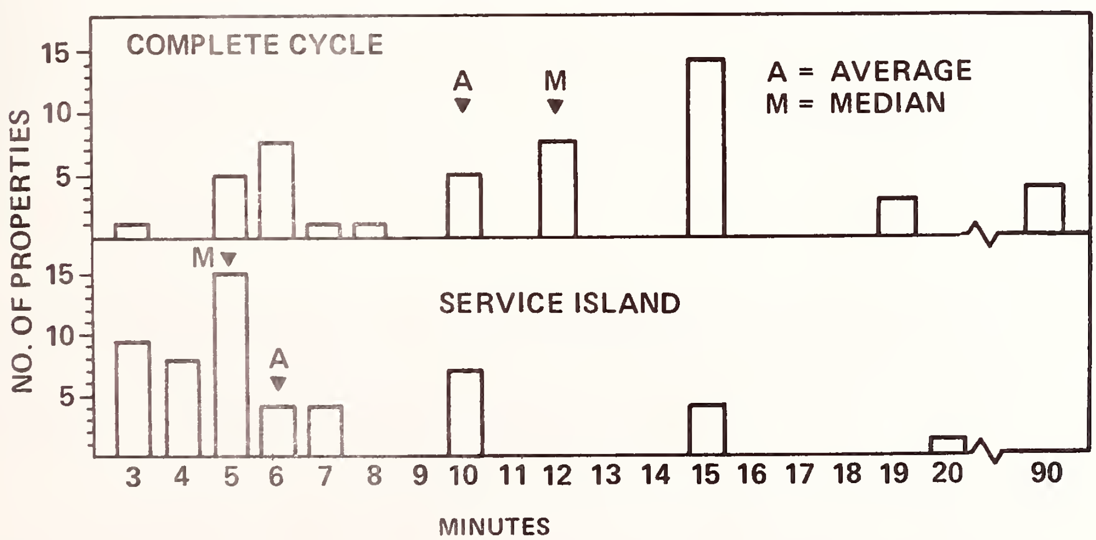


EXHIBIT 4-3
SERVICE CYCLE TIME

The number of service islands needed at an inspection/service facility depends on the number of buses that can be processed through one lane per hour and the length of time available for servicing. The number of attendants required to fully use a service lane depends on the length of the total cycle and the number of buses per lane.

A reasonable planning factor would be one service lane per 100 buses or a fraction thereof. Current capabilities are shown in Exhibit 4-4. Although there is considerable scatter in the data, the suggested rule of one service lane (or fuel pump) per 100 buses is generally upheld. However, it would be prudent to install an extra pump for emergencies.

Fuel is usually stored in underground tanks in the vicinity of service islands. Tanks are available in discrete sizes. Correlations between fuel storage capacity and other factors, such as the number of buses at a garage or annual mileage, were only remote. However, the most popular storage capacity was between 150 and 200 gallons per bus. This would be equivalent to four to six days of normal operation for buses averaging 150 to 200 miles per day and realizing 5 miles per gallon. Fuel storage planning must consider the projected daily use and an expected frequency of deliveries.

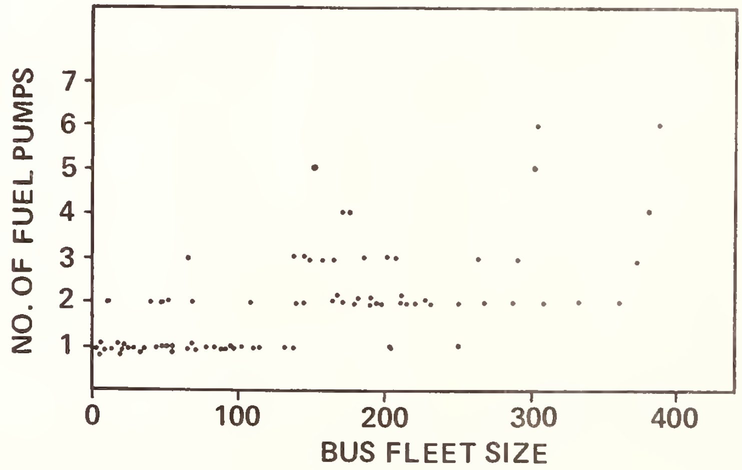


EXHIBIT 4-4
FUEL PUMPS

4.4 Internal Cleaning

Internal bus cleaning is performed with the aid of large vacuum cleaners by many properties (38 out of 63). Bellows extend from the device and enclose the front door of the bus. Rear windows are opened and a high-velocity air stream passes through the bus, removing airborne dust and debris. Air hoses are used to dislodge dirt, papers, and other debris. A bus can be cleaned during the few minutes that it is positioned at the service island. Debris finally comes to rest in a trash house which may be located on the roof or at ground level.

Facility design must provide for a trash house and the removal of debris from it. Roof-mounted trash houses are cleaned through trap doors which open to allow trash to drop into a truck at the service lane. Ground-level trash houses are cleaned with scoops and shovels.

Large vacuum cleaners are not as universally popular as automatic bus washers. Airborne dust settles on seats, dashboards, and ledges and must be removed manually. Large vacuum cleaners are not particularly effective in cleaning luxury buses with carpeted floors and woven upholstery. Some properties are testing the use of portable industrial vacuum cleaners that do not stir up dust and may be used on carpet and upholstery as well.

Most properties schedule a complete "internal housecleaning" program to augment the daily routine. Buses without carpeted floors are washed with soap, water, and running water below the window line. Windows, ceilings, and seats are washed manually. Water hoses are not used above window lines to avoid the accumulation of water in the air conditioning/heating duct; while this eliminates a breeding haven for roaches and other insects, periodic fumigation may be necessary.

4.5 Bus Washing

Bus washing is the final element of the service cycle prior to parking. Automatic bus washers are extensively used (35 properties) and provide improvements in service cycle time and labor over manual washing (6 properties). Manual washing may require 75 minutes, whereas automatic washing can be done in a minute or so. Variations in automatic bus washers are shown in Exhibit 4-5.

All automatic washers have a rotating brush and water spray side-washing capability. Some washers have an additional front and rear capability with rotating brushes that move across the front and rear as the bus progresses through the device. The most common roof washer is a wet mop. However, a rotating brush is also possible. Wheel washers are not widely used.

EXHIBIT 4-5

AUTOMATIC BUS WASHER CAPABILITIES
(39 Properties Reporting)

Basic Capability	Percentage
Side Only	100
Additional Capabilities	
Front and Rear	61.6
Roof	63.2
Wheel Washers	31.9

4.6 Service Lane Configurations

Service lanes have a fuel hose, crankcase oil dispenser, and coolant refill hose available for normal servicing. When large internal vacuum cleaners are used, they are located at the front door position of the bus when parked for service. Revenue removal facilities may be very simple (locked vault storage) or elaborate (coin vacuum system). The driveway is concrete, bordered by curbings to guide buses properly through the lane. A bus washer may be located beyond the servicing position.

Typical service lane configurations are shown in Exhibit 4-6. The outside configuration has one or more bus washers at some distance from the service islands to allow bus manuevering room from service lanes through or around washers. One washer is usually sufficient for three service lanes. A single bus washer does not provide redundancy in the event of a mechanical failure.

The outside configuration is used primarily in moderate climates. Service lanes will be covered to protect against rain. Walls along the sides may also be used to protect against wind and driving rain.

The bus washer is integrated into the service lane for the inside configuration. This conserves building space for more severe climates. Doors may be located at both ends to further isolate the servicing operation from the elements. Bus maneuvering space is lost in the configuration which requires a bus washer in each lane, and the malfunction of one washer cannot be smoothly accommodated.

The location of servicing facilities varies considerably depending upon the site, other buildings, traffic patterns, and local codes. The three primary types of locations are separate, attached, and integrated. A separate facility is not attached to any other structure. In fact, the washer may be some distance from the service lanes in outdoor situations. A separate service facility may be enclosed or open depending upon local climatic conditions. Servicing facilities may be attached to one end or along one side of the regular maintenance building. Or finally, the servicing facility may be integrated into shop and indoor storage areas.

Diesel fuel handling is not as hazardous as gasoline handling. Even so, some local fire and building codes may be sufficiently restrictive so that separate fueling facilities may be required.

A primary consideration for the location of the servicing facility should be the traffic patterns of bus movement necessary for routine servicing. One-half of the service cycle time may be consumed in bus movement--a candidate area for possible improvements in efficiency (discussed in subsequent Section 5.5).

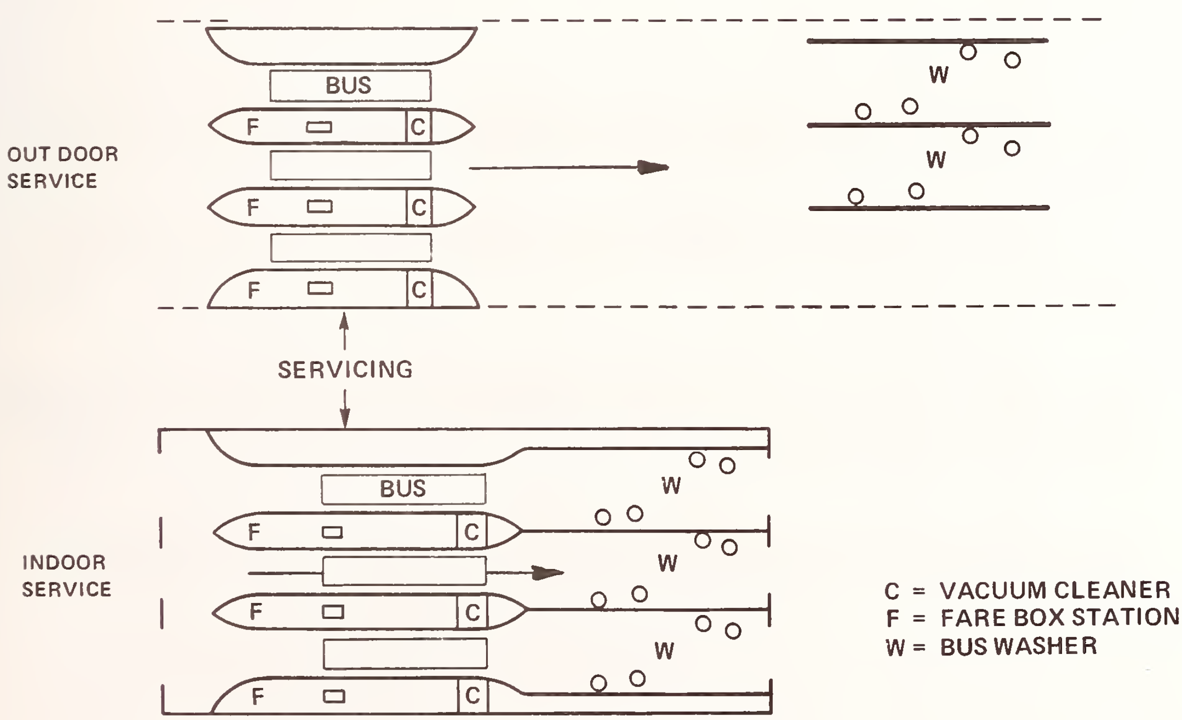


EXHIBIT 4-6
SERVICE LANE CONFIGURATIONS

In cold climates, servicing and washing facilities are completely enclosed and heated. Washing presents special problems because water can freeze on the exterior, and the exit apron can become slick from dripping water which forms ice. If not enclosed, an exit apron can be heated with an underground system to prevent ice formation. The exit apron should also have a traction-producing surface to prevent wheel slipping on a thin layer of water in any climate.

Occasionally a servicing facility has special provisions for internal bus washing. This is usually another bus lane adjacent to servicing lanes but without fueling capabilities. The lane surface is slanted and tilted in a fashion that encourages water to drain out of the front door of the bus. Washing hoses will be provided at convenient locations.

Water recycling may also be provided from the floor drains of both the bus washer and internal bus washing areas. Standards are being imposed by communities to either conserve in the use of water or to reduce the volume of effluent through the sewage system. Six properties are either recycling bus wash-water or have plans to do so. Recycling equipment is generally provided in the service/washer building.

4.7 <u>Planning Factors</u>

One fuel and service lane is required per 100 buses stationed at a facility. This factor should be modified for specific requirements, such as long service cycles or the time available for servicing.

Fuel storage of at least 150 to 200 gallons per bus is common practice. However, daily use rates and local delivery schedules may alter these values.

One washer may handle buses from three service lanes. However, the configuration of the service lanes may dictate one washer per lane. Water recycling should be evaluated as a means of reducing operating costs for the new facility.

Service/washer facilities may be separate from, adjacent to, or integral with other maintenance facilities. They should be located in a position that will permit servicing efficiency.

5.0 BUS STORAGE AND MOVEMENT

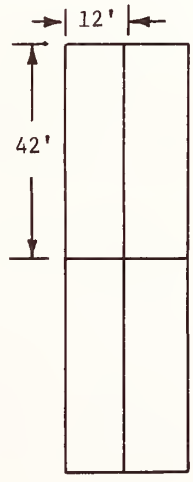
Overnight bus storage is commonly provided at the inspection garage facility or at a small property's integrated facility. An overnight storage area is the largest single requirement for space and real estate for a motor bus operation. Space requirements vary with the parking pattern used. It is the purpose of this section to describe the common parking configurations, provide comparisons, and relate the storage patterns to the routine service cycle.

Separate parking-only facilities are rarely used. Problems of efficient staffing, personnel movements, convenience, control, and security deter separate facilities. We have noted two examples of effective use of remote parking, but these are used for daytime storage between the morning and evening rush hours. Both AC Transit and Golden Gate Transit leave buses at the downtown San Francisco Transbay Terminal during midday. This avoids deadhead runs back to regular facilities. Operators are transferred by shuttle runs to other assignments, while security is maintained by station personnel. Bus deadhead mileage is minimized even though some operator travel time expense remains.

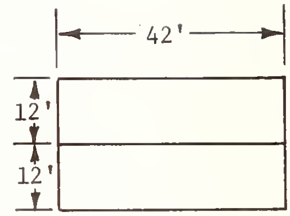
5.1 Parking Configurations

Six basic parking configurations are used by transit. These are in-line, row, double-row, angled, double-angled, and herringbone. Each of these configurations will be described and a method will be given for computing the dimensions of a row of buses. For this purpose, a basic stall space of 12 feet by 42 feet (504 square feet) was used assuming a fleet of 40-foot buses. Measurements can, of course, be altered to fit other size buses or to provide different clearance between buses.

In-Line Parking: Buses are parked end-to-end in rows. Rows are adjacent. No aisles are provided but, in actual practice, exterior aisles are needed. This configuration consumes the least space and is commonly used for inside parking. The first bus to be parked must be at the head of the line, and the first bus removed must be at the head of the line. At least three extra rows should be provided: one row for service cycling and two rows for bad order parking to minimize conflicts of bus movement.



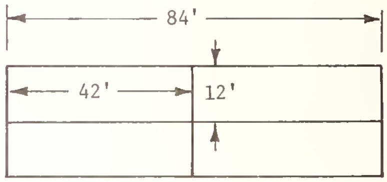
Row Parking: This configuration provides maximum flexibility (as each stall can be accessed independently) but does require more space. Wide aisles are provided to negotiate a turn from the aisles into the stall. Buses may be pulled in and pulled out; no backing is required unless there is a fence or other obstacle at one end.



ROW LENGTH = 12N

N = NUMBER OF BUSES PER ROW

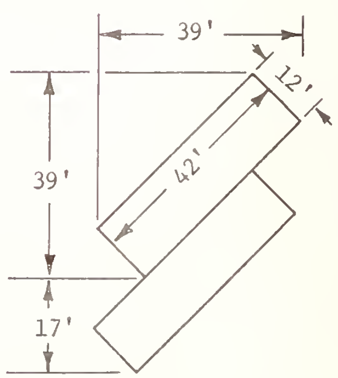
Double-Row Parking: Space required is reduced from multiple-row parking in that total space needed for aisles is reduced by having two buses end-to-end in each row. Aisles are wide to allow turning into the stall. For complete flexibility, some bus backing may be required.



ROW LENGTH = $\frac{N}{2}$ X 12

N = NUMBER OF BUSES IN ROW, MUST BE AN EVEN NUMBER

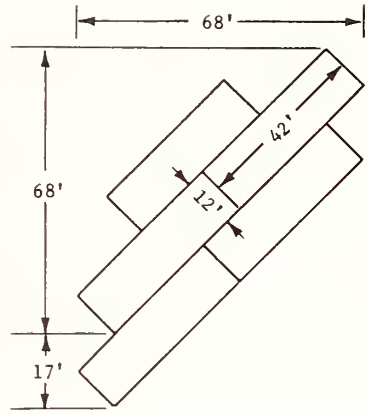
Angled Parking: Rows one bus wide are provided. Buses are parked at 45 degrees from the aisle to improve maneuverability. No backing is required as buses may be pulled in and pulled out of parking stalls. Other angles, such as 60 degrees, may be used.



ROW LENGTH = 39 + (N-1)(17)

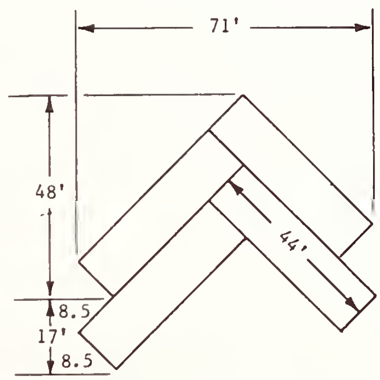
WHERE N IS NUMBER OF BUSES IN ROW.

Double-Angled Row Parking: This configuration offers good maneuverability because 45 degree parking reduces the total need for aisle space, as compared with single-row angled parking. The configuration is such that a single stall is available at each end of the row. Some backing may be required to achieve maximum flexibility.



$$\text{LENGTH} = 68 + \left(\frac{N-2}{2}\right)\left(17\right)$$

Herringbone Parking: This 45-degree configuration has basically the same features as double-angled row parking. Great care must be used when parking, as bumpers do not meet bumpers. For this reason, the stall space has been enlarged to 12 feet by 44 feet. Some backing is required.



$$\text{ROW LENGTH} = 48 + \left(\frac{N-2}{2}\right)\left(17\right)$$

N IS NUMBER OF BUSES IN ROW AND MUST BE EVEN

Parking stalls can be assigned for individual buses in most every configuration except in-line parking. Many properties are using reserved bus stalls. Oil and water leak spots on paving can be related directly to the faulty bus. A particular bus may be retrieved by the operator or by maintenance personnel without an extensive search because the storage pattern is quickly learned. Some properties have improved fault detection by using assigned stalls.

5.2 Parking Comparisons

Each of the six parking configurations have been used to formulate dimensions of sample lot sizes for 250 bus storage facilities. These are shown in Exhibit 5-1 for comparison of lot sizes required for storage. Stall sizes were defined in the preceding section. With the exception of in-line parking, aisles or trafficways are provided on both sides of each row. Each configuration will accommodate at least 250 buses.

Configuration	In-Line		Double Row	Angled	Double Angled (b)	(c)	Herringbone (d)	(e)
Specifications								
Buses Per Row	12	50	84	42	84	64	84	84
Number of Rows	24	5	3	6	3	4	3	3
Length of Row (ft.)	504	600	504	736	748	578	745	745
Width of Row (ft.)	12	42	84	39	68	68	71	71
Number of Aisles	-0-	6	4	7	4	5	4	4
Width of Aisles (ft.)	-0-	55	55	45	45	45	45	20
Total Width (ft.)	288	540	472	549	384	497	393	293
Area[a] (Square Feet)	145,152	324,000	237,888	404,064	287,232	287,266	292,785	218,285
(Acres)	3.33	7.43	5.46	9.28	6.59	6.59	6.72	5.01
Bus Capacity (Buses)	252	250	252	252	252	256	252	252
Area Per Bus (Sq. Ft.)	576	1,296	944	1,603	1,140	1,122	1,162	866
Flexibility	Poor	Excellent	Good	Excellent	Good	Good	Good	Fair/Poor
Maneuverability	Good	Fair	Fair	Good	Good	Good	Fair	Fair

(a) Area = (Total Width) x (Length of Row)
(b) Double Angled - Long and Narrow Area
(c) Double Angled - Rectangular Area
(d) Herringbone - Wide Aisles
(e) Herringbone - Narrow Aisles

EXHIBIT 5-1
EXAMPLES OF PARKING CONFIGURATIONS

Alternate configurations are shown for both double-angled and herringbone patterns. Double-angled (b) is long and narrow with three rows and four aisles. Double-angled (c) has four rows and five aisles, which almost forms a square. Area required is almost identical in both cases. Herringbone pattern (e) has a reduced aisle width, which can be used with a sequential pull-in (and pull-out) pattern similar to in-line parking.

Ratings of two subjective qualities (flexibility and maneuverabilty) of each configuration are also given in Exhibit 5-1. Flexibility pertains to the ability to retrieve any bus at any time from its parking stall. Maneuverability pertains to the ease with which a bus may be driven into or out of a parking stall. Ratings used are excellent, good, fair, and poor. Policies and experience at specific properties may provide ratings other than those offered.

In practice, these lot dimensions would have to be enlarged to provide end zones. End zones are needed as trafficways providing turning space into the aisles. In-line parking would also require passageways at the side so that buses may be moved from one end of the configuration to another.

Space usage comparisons are given in Exhibit 5-2. In-line parking needs only about one-third the space of angled-row parking. In-line parking is commonly used for inside parking to minimize building space requirements. Double-row parking requires 64 percent more space than in-line parking.

A practical application of any parking configuration may be somewhat different than these examples. Lot shape, size, and capacity requirements may dictate variations. Angled parking need not be at 45 degrees. Property boundaries may be used with a row of buses in either parallel or nose-in patterns. Innovative planning is needed to effectively use irregularly shaped lots.

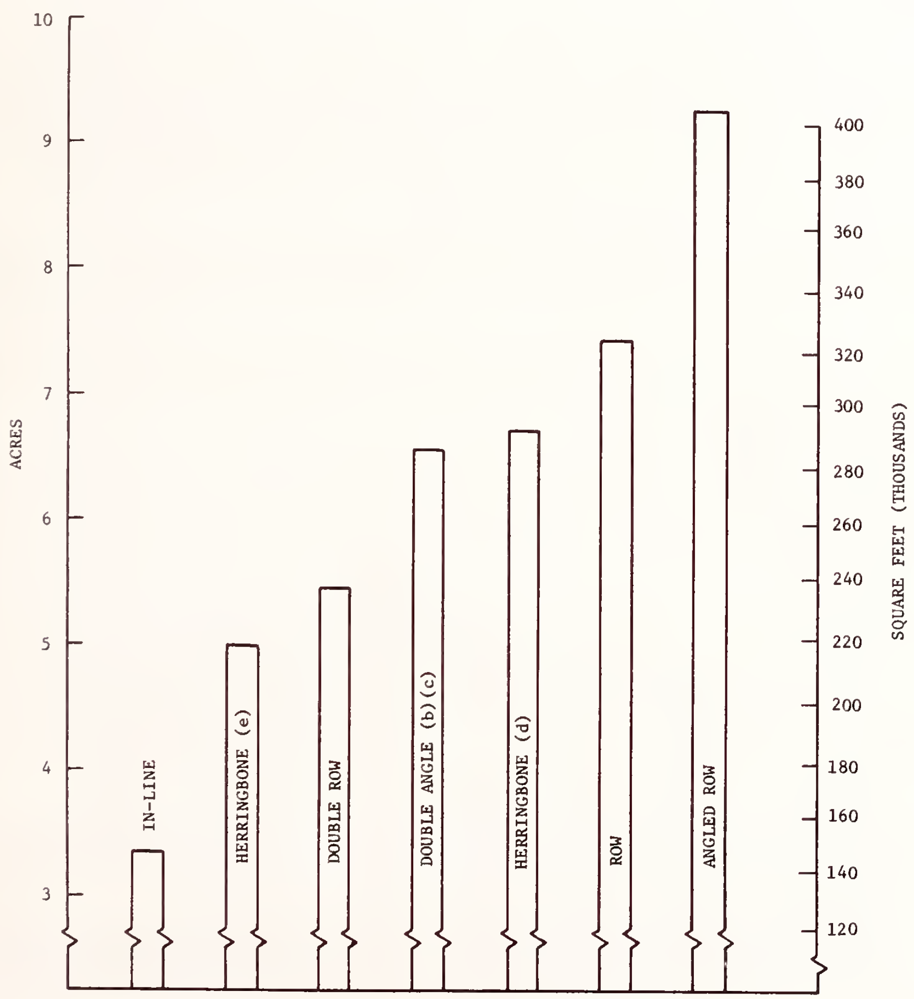


EXHIBIT 5-2
PARKING CONFIGURATIONS
COMPARATIVE SPACE (250 BUSES)

The overnight storage configuration has an impact upon several aspects of the operation for both the maintenance and transportation departments. For example, buses at the heads of the lines (in-line parking) must be suitable for the first pull-out assignments. Lack of flexibility in the pull-out sequence may constrain the choice of buses to routes. Maintenance operations need a smooth flow for routine servicing and inspections. Parking configurations that provide good bus accessibility are therefore highly desirable.

A bad-order parking area is needed when in-line parking is used because of flexibility constraints. A bad-order area may also be needed for other configurations to provide temporary storage for maintenance.

5.3 Storage Practices

Questionnaire responses provided information about current practices of storage configurations. These are shown in the histogram, Exhibit 5-3. In-line storage is used at about 64 percent of the facilities. Sixty percent of the facilities provide inside storage. In-line storage is used to conserve outside bus storage space at four percent of the properties.

Flexibility is one attribute that maintenance managers consider important, but space limitations often prohibit the use of alternatives.

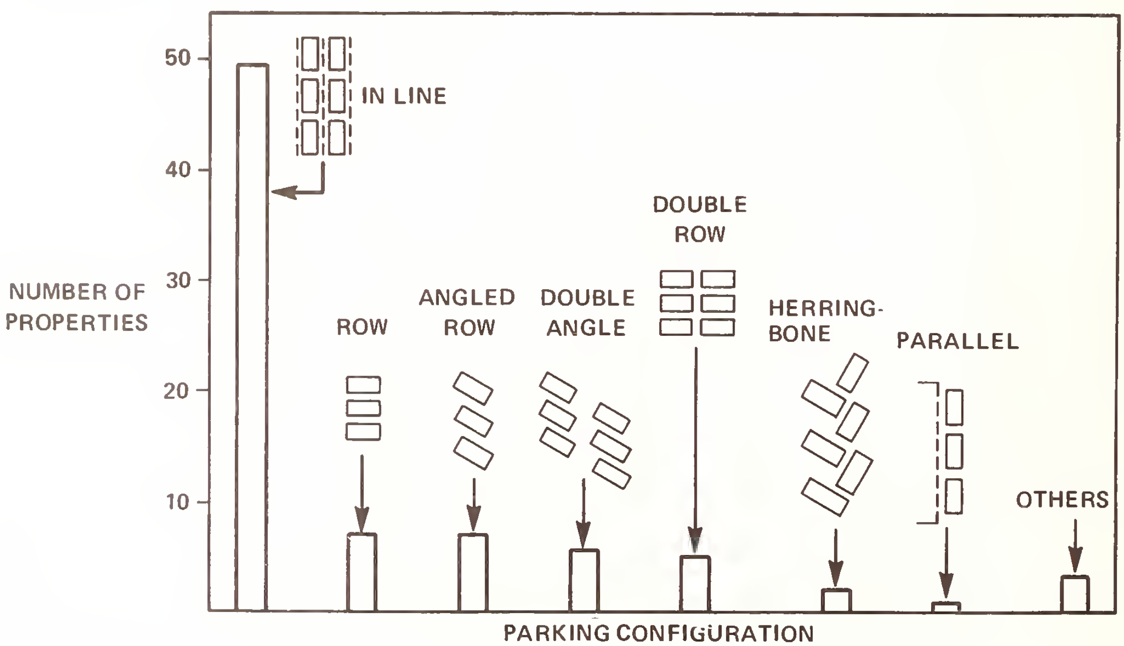


EXHIBIT 5-3
BUS STORAGE CONFIGURATIONS

5.4 Inside Bus Storage

Inside storage is used at many properties, particularly in colder climates. Storage structures, including heating where necessary, are expensive to build and operate. The cost is offset, to varying degrees, by the many advantages of inside parking. These advantages are intrinsically understood and are included as a reference for facility planning.

Indoor heated parking facilities have the following advantages in colder climates:

a. Snow and ice, which melts and drips from the undercarriage of buses, might otherwise be a source of corrosion, or prevent proper operation of suspension systems and steering.

b. The formation of ice on bus exteriors after washing is prevented. Window fogging and interference with door operation are minimized.

c. Winter starting is eased and component wear (batteries and starters) and repairs are reduced.

d. Bus interiors are warm for early passengers.

e. Antifreeze requirements are reduced.

Additional advantages of indoor parking throughout the year and in moderate climates include:

a. Reduction in vandalism damage to exposed buses.

b. Containment of starting noise, particularly in residential neighborhoods.

c. Cool bus interiors for summer afternoon trippers, since air conditioner pull down may require an extended period.

d. Elimination of evening mist and airborne dirt deposits, leaving clean windows and exterior surfaces.

Some properties are evaluating the costs and operational benefits of inside parking. This may indicate a favorable trade-off of initial capital expenditures with continuing operating expenditures.

5.5 Bus Servicing Movement

Daily servicing accounts for a major expenditure of the maintenance department. Almost one-half of maintenance man-hours are used for daily servicing. About one-half of the time needed for a complete service cycle is used in bus movement. Improvement in bus movement patterns has a high potential for long-term savings and efficiencies.

Variations in service-cycle bus movement procedures are common. At the completion of the revenue run, the operator may leave the bus at one of several places. Twenty-seven respondents have operators leave the bus in the service lane (staging area); twenty-one have operators move the bus directly to overnight parking; and ten have other polices. Bus movement through the servicing cycle is done primarily by maintenance department employees, as shown in the tabulation from the questionnaires (Exhibit 5-4).

Buses deposited in overnight storage by an operator must be subsequently driven to the service building and returned to an overnight spot. The complete route may take the bus the entire length of the parking lot (follow the aisle traffic pattern to far end, then via an arterial lane to service area, and return) and possibly the width of the parking lot as well. End zone and service area distances must be added to the service loop.

EXHIBIT 5-4
BUS MOVEMENT PERSONNEL

	Hostler	Service Attendant	Operator
To Service Island	22	25	16
From Service Island	25	31	7
Through Washer	27	23	8
To Overnight Park	25	28	7

As an example of bus movement time, the dimensions of three parking configurations are used (Exhibit 5-5). Average lot speed is assumed to be 5 miles per hour. Times do not include parking stall maneuvering time. There is more than a one-minute time difference between the largest lot (angled) and the smallest lot (in-line). For 250 buses, that totals to a little over four man-hours--a plus for in-line parking.

Buses left by operators in a staging area must be retrieved by a service attendant on foot and eventually left in an overnight parking spot. The attendant must return to the staging area by foot, which may be a distance of 800 or 1000 feet. The walking part of the service loop would require several minutes, far outweighing the driving time. A not unusual five-minute difference between a full cycle drive and a park and walk cycle translates to 21 man-hours for 250 buses.

Parking Type	Lot Dimensions (feet)				Service Cycle Travel Time at 5 mph (minutes)
	Length	Width	End Zones & Service*	Total	
Angled	736	549	400	1,685	3.8
Double Angled	578	497	400	1,475	3.4
In-Line	504	288	400	1,192	2.7

EXHIBIT 5-5
SERVICE TRAVEL TIMES

* Allowance for typical end zone

These examples illustrate a method of calculating transit times in the service cycle. The same method can be applied with more precision from specific lot plans, traffic patterns, and building locations. In any case, an emphasis on traffic movement at the facility design stage can result in long-term economies.

A garage design for the Twin Cities in which traffic and circulation patterns were carefully considered is shown in Exhibit 5-6. It is an inspection garage with light repair, tire repair, degreasing, servicing, and washing capabilities.

The service island is a one-stop station (including vacuuming). Ample room is provided to maneuver through the bus washers and move directly to overnight parking. The defect (bad order) area is convenient to repair areas.

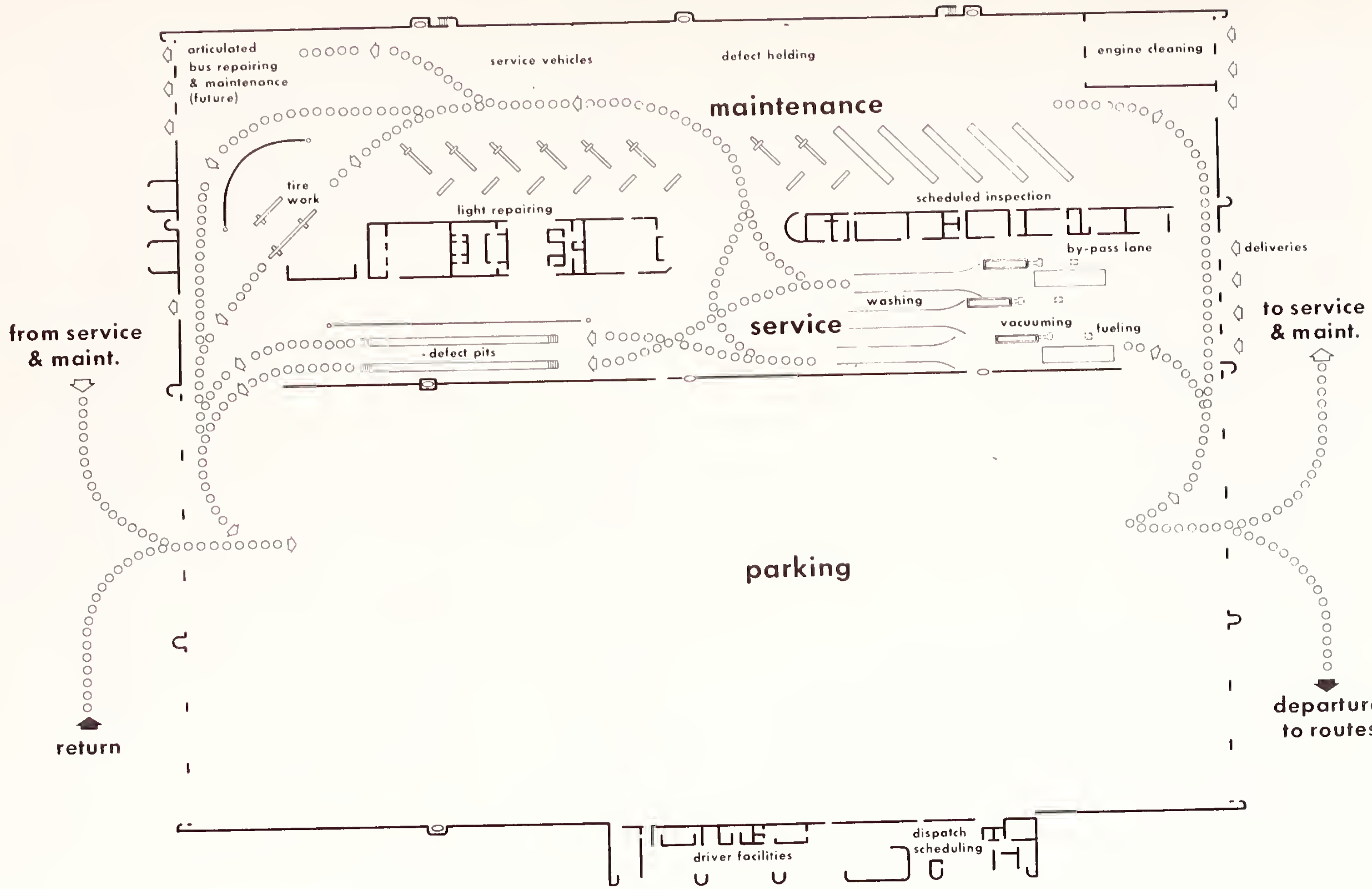


EXHIBIT 5-6
GARAGE FLOOR PLAN
Courtesy of Twin Cities Area Metropolitan Transit Commission and Smiley, Glotter Associates, Inc.

6.0 MAIN MAINTENANCE FACILITIES

Multi-facility properties take advantage of their size and establish a main maintenance facility to complement the inspection garages. Infrequent and major repair functions are done at main maintenance facilities. These functions often require specialized equipment and skills. The basic preventive maintenance program remains with the inspection garage and only the major work or specialty items are referred to the main facility.

Common functions done at main maintenance facilities include:

a. heavy repairs,
b. engine overhauls,
c. unit rebuilds,
d. major body repairs,
e. painting,
f. upholstery,
g. route sign preparation,
h. bus stop signs,
i. brake relining,
j. brake drum turning, and
k. radiator repairs.

The main maintenance facility may be located at a unique site or may be collocated on a site with an inspection garage. At single facility properties, main maintenance functions are integrated with other maintenance functions.

6.1 Capacity

Main maintenance facility capacities are described in terms of bus occupancy space and support space. Buses undergoing repairs are placed in stalls (bus occupancy) within a building. Support space includes:

a. machine shop,
b. component rebuild,
c. sheet metal shop,
d. stockrooms,
e. offices,
f. vat rooms,
g. welding shop, and
h. all other space not designed to hold buses.

A sufficient number of bus stalls are needed to support the entire fleet of the transit property. Exhibit 6-1 shows the stall capacities of responding properties for both heavy repair and body shops. Heavy repair stalls average between two and three per 100 buses in the fleet. Body repair stalls, including paint booths, average two per 100 buses in the fleet. Together, heavy repair and body repair stalls are sufficient to house about five percent of the total fleet. Individual maintenance policies and local conditions may alter specific requirements.

Most heavy repair stalls are equipped with hoists (or pits). If pits are used, it is advantageous to have at least some of the body repair stalls equipped with hoists as well.

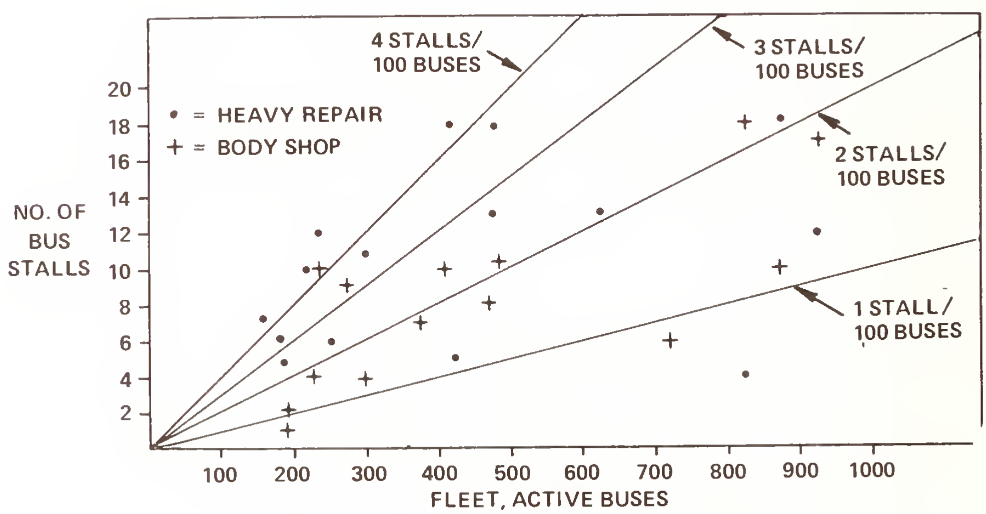


EXHIBIT 6-1
BUS STALLS

Floor space used for bus stalls is shown in Exhibit 6-2. This space as plotted includes the stall and bus trafficways. Enclosed space for trafficways is used in cold climates to limit the number of exterior doors and provide space to maneuver buses into repair stalls. On a total fleet basis, the average allocation of space for repair stalls is about 60 square feet per bus. Larger space allocations are needed where inside trafficways are provided.

Data from Exhibit 6-1 and 6-2 can be combined to provide nominal sizes of bus stalls. A stall space allocation of 60 square feet per bus results in 6000 square feet for 100 buses. A total of four or five stalls would be provided and each would be between 1200 and 1500 square feet. The resulting stalls would be about 18 by 67 feet or 18 by 80 feet, respectively. These dimensions may seem generous. However, this allocation includes clearance and passageways for equipment movement, work benches, and in some cases bus trafficways.

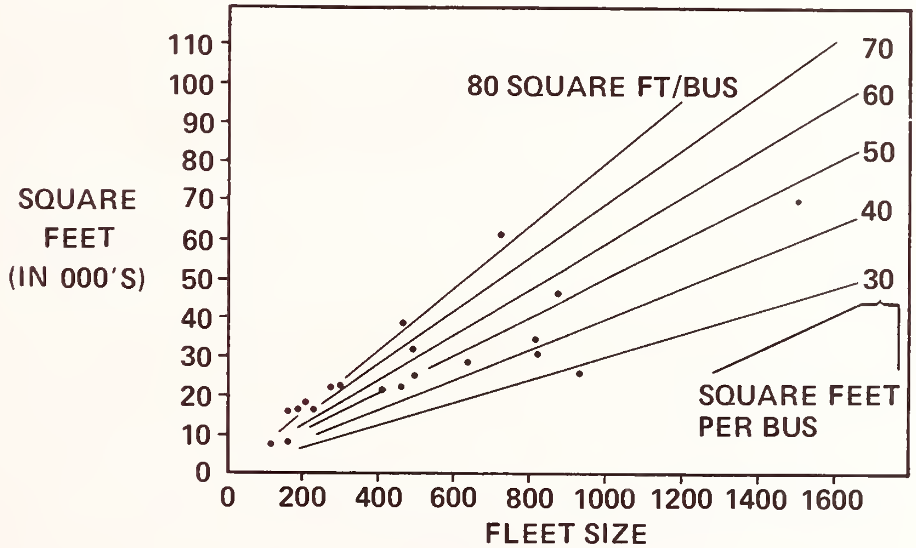


EXHIBIT 6-2
FLOOR SPACE FOR BUS STALLS & LANES

6.2 Support Space

Area devoted to shop work is shown in Exhibit 6-3. The average allocation of floor space is 20 square feet per bus in the total fleet for the machine shop and component rebuild areas.

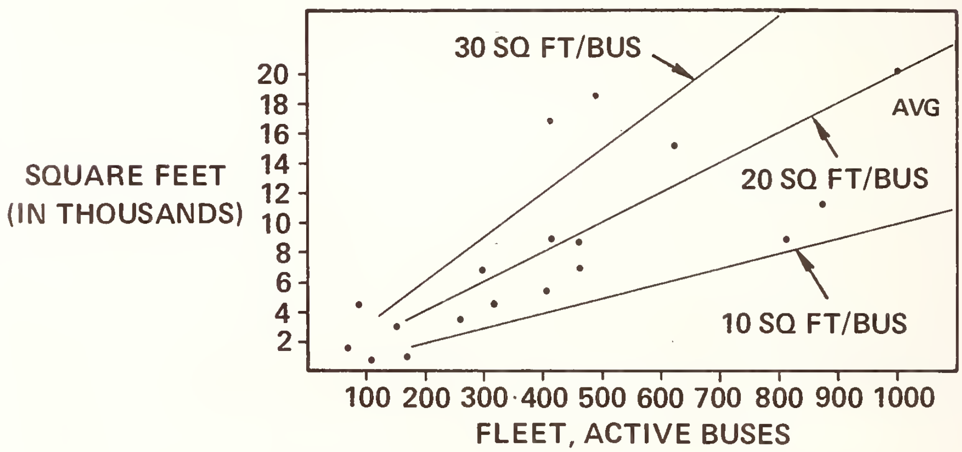


EXHIBIT 6-3
COMPONENT REBUILD AND MACHINE SHOP

The average allocation of main stockroom space (Exhibit 6-4) is about 25 square feet per bus. Large stockrooms use counter displays for storage of replacement parts. Small stockrooms tend to have multilevel bins for storage.

Shop areas (20 square feet/bus) and stockrooms (25 square feet/bus) together require 45 square feet/bus. Other activities require about 35 square feet per bus and include:

a. cleaning vats,
b. battery storage,
c. offices,
d. locker rooms,
e. lubricant storage,
f. air compressors, and
g. miscellaneous functions.

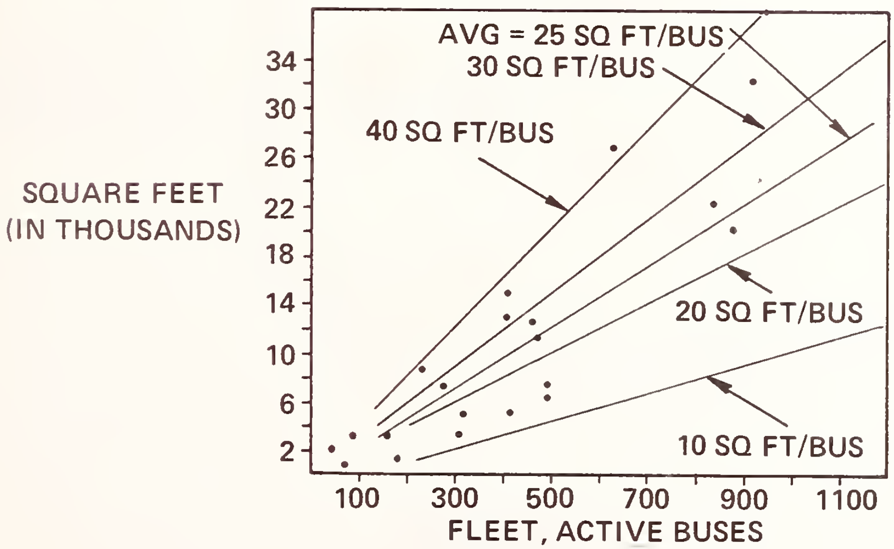


EXHIBIT 6-4
MAIN STOCK ROOM

6.3 Total Facility Space

Space allocation for the average main maintenance facility is shown in the pie chart (Exhibit 6-5). This allocation is the average of the survey data. It is not necessarily an optimum. Many surveyed facilities are old and were originally designed for other purposes. Properities planning on replacing older buses in lieu of conducting extensive overhauls may have smaller shop and support areas. Inside bus manuevering room in colder climates will require larger bus stall areas. Body shop areas may be larger in those urban areas having higher accident rates. Planned growth or fleet enlargement may dictate facilities which are oversized with respect to existing requirements.

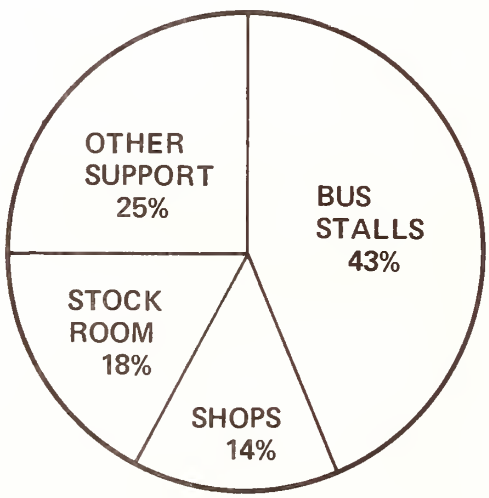


EXHIBIT 6-5
SPACE ALLOCATION

Floor space provided in the total main maintenance facility is shown in Exhibit 6-6. This includes both stall space and support space. The average space allocation for main maintenance garages is 140 square feet per bus (14,000 square feet per 100 buses). Of this figure, the bus stall allocation is 60 square feet per bus and the allocation for shops, storage and other support areas is 80 square feet per bus. These average figures for stalls and lanes are lower for facilities located in moderate climates where enclosed bus turning lanes are not necessary.

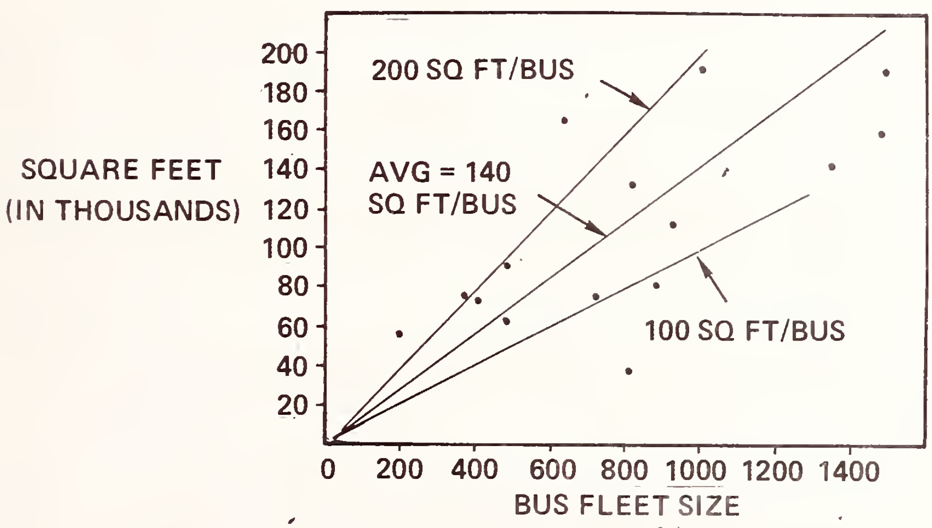


EXHIBIT 6-6
BUILDING SPACE

6.4 Facility Layouts

Three floor plan layouts of actual main maintenance facilities are shown below and on the following pages for illustration and comparative purposes. Main Maintenance Facility: Floor Plan A, is a facility in a moderate climate designed to support a fleet of about 1200 buses (Exhibit 6-7).

Bus stall space including areas for heavy repair, body repairs, and paint shop accounts for about 32 percent of the total building area. Bus stall space will accommodate only about 3 percent of the fleet to be supported, due to support provided by inspection garages. Hoists are used in lieu of pits and the body repair area can accommodate heavy mechanical repairs during periods of workload variances. The stockroom is readily accessible to shop and lift areas. Shop space is provided for a rather extensive rebuild and maintenance program.

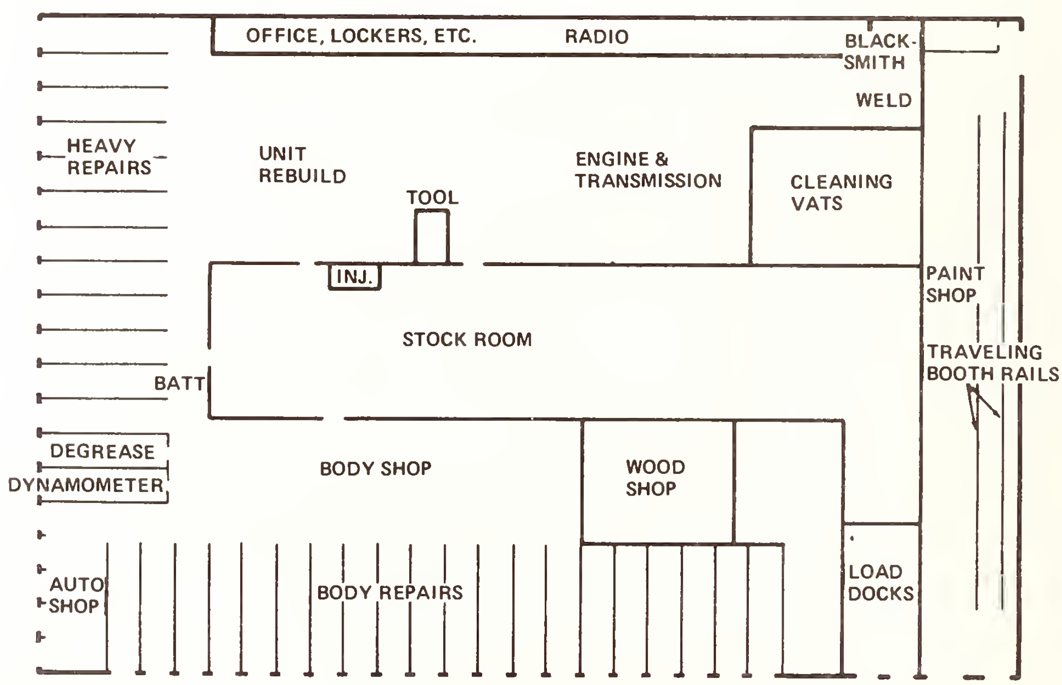


EXHIBIT 6-7
MAIN MAINTENANCE: FLOOR PLAN A

Floor Plan B is a new facility located in a moderate climate (Exhibit 6-8). Stall space accounts for nearly 50 percent of the total floor space as shown. Not shown is a limited second story that provides additional office space, locker rooms, and some storage. Stall space will accommodate about five percent of the fleet for which it was designed. Shop areas are somewhat smaller than other similar facilities, due in part to effective use of floor space and to an emphasis on bus replacement rather than extensive repairs. The proportionately large paint area reflects a local policy of repainting each bus periodically. The stockroom is accessible from all shop and stall areas. Hoists are provided for most heavy repair and body repair areas.

There are bus stalls on two sides of the building. A common variation of this basic plan is to lengthen the building and limit the stall area to one side. Such a variation could be useful for certain real estate configurations.

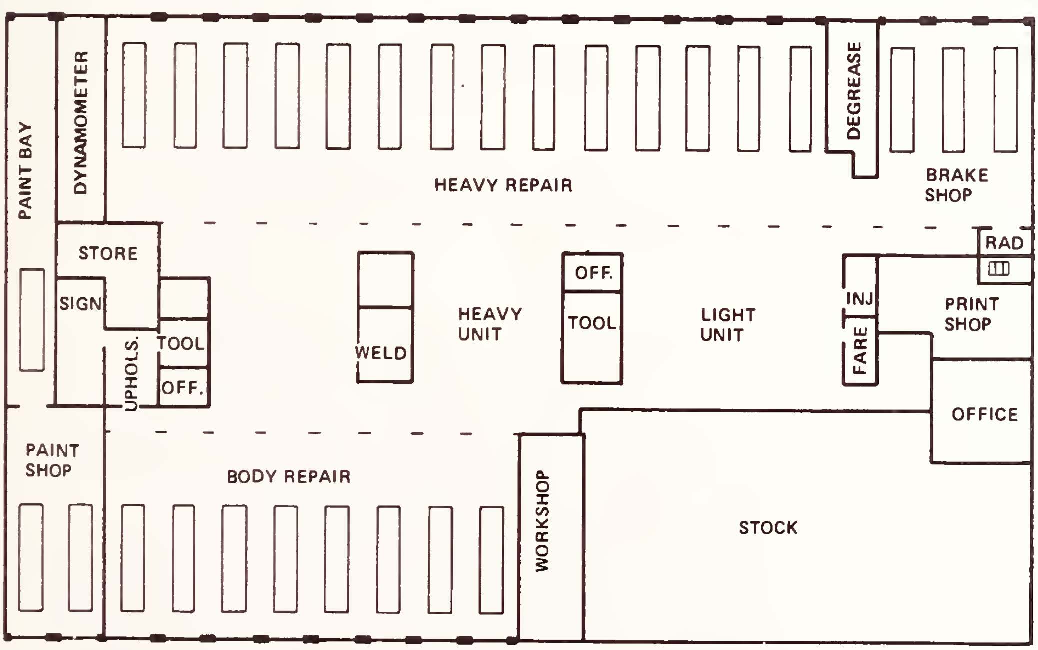


EXHIBIT 6-8
MAIN MAINTENANCE: FLOOR PLAN B

Floor Plan C is also a new facility, but located in a colder climate (Exhibit 6-9). Stall space includes traffic lanes, as outside door areas are minimized for heat conservation. Stall space will accommodate between three percent and four percent of the total fleet, and each stall is equipped with a hoist. Painting is done with a traveling paint booth. Stall space accounts for almost 50 percent of the floor space shown. Shops were designed for a complete program of component and engine rebuilding. The stockroom is readily accessible from the stall area and shops.

Stockrooms in all three layouts include provision for loading areas or docks. This allows easy access for deliveries of materials and the distribution of replacement parts to maintenance facilities at other locations.

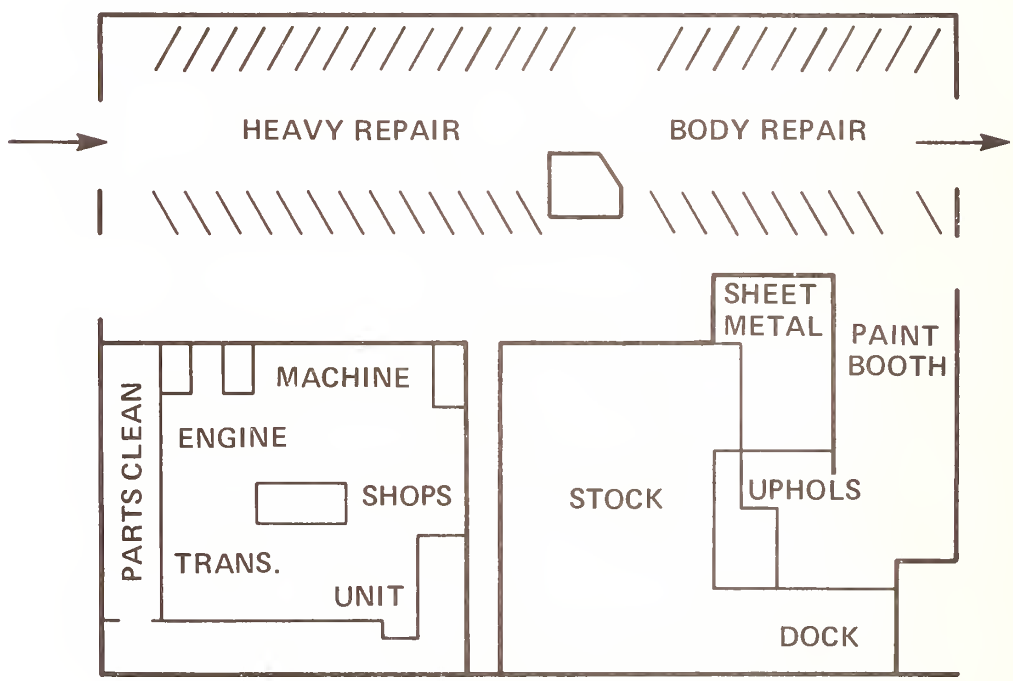


EXHIBIT 6-9
MAIN MAINTENANCE: FLOOR PLAN C

7.0 SINGLE FACILITY PROPERTY

Data appearing in other sections of this report are not accurate when applied to small single facility properties. A single facility property is one that centralizes operations; all of the building space, and people essential to operate, house, support, and manage a bus fleet are at one location.

The single facility property is generally a small property--that is, one with 100 or fewer buses. For the purposes of this report, a property with from 31 to 100 buses is defined as a small property, and one with 30 or fewer buses is defined as a very small property. The procedures for operating a small property vary considerably from those in a large property, and are most noticeable when comparing facilities with 30 or less buses with those having more than 100. Facilities, capabilities, traffic flow, and maintenance scheduling grow in complexity with fleet size. Operating from a single facility tends to become cumbersome as fleet size grows beyond about 250 buses (Section 3.2). The customary practice of the larger properties is to divide the fleet into operating divisions, with each division located within or near its assigned route structure.

The majority of transit properties surveyed are single facility properties (51.8 percent), and slightly more than one-fourth of these have very small fleets (fewer than 30 buses). The proportion of single facility respondents is shown in Exhibit 7-1; the distribution of fleet sizes for these facilities is shown in Exhibit 7-2. About 41 percent of the single facility respondents had fleets with more than 100 buses (the largest had 452), but only 13 percent of bus population sampled was operated by single facility properties (Exhibit 7-3).

7.1 Capabilities

Small properties were found to have a wide range of capabilities. The minimum capability was that of conducting inspections, tuning engines, and making light repairs. The highest level of capability was found at properties equipped to overhaul nearly any part of a bus, if not the whole vehicle. Only 24 percent of the small fleets (100 or less buses) reported being able to function with limited overhaul capability. Operation is possible by using vendors to make major body repairs or to rebuild engines, transmissions, or other units. Properties operating in this mode had from 11 to 39 buses and the largest had 60; they comprised about one-quarter of the small properties.

EXHIBIT 7-1
DIVISION OF RESPONDENTS

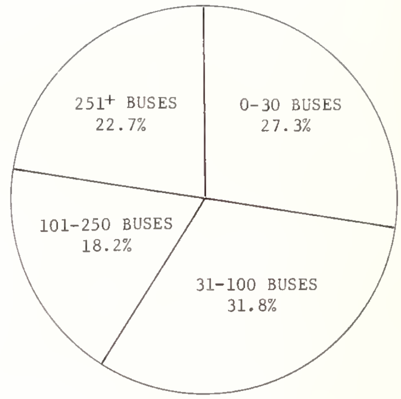


EXHIBIT 7-2
SINGLE FACILITY FLEET SIZES

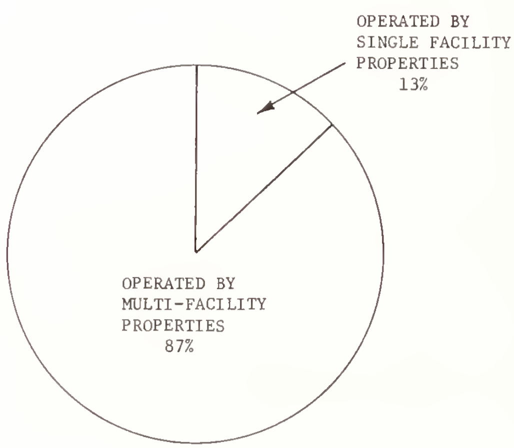


EXHIBIT 7-3
BUS POPULATION

No fleet with more than 60 buses reported being able to operate without the benefit of some degree of in-house overhaul capability. Seven properties with less than 50 buses reported a limited overhaul capability. (A limited capability is generally interpreted in terms of the extent to which engine overhauls are carried out; in-frame overhauls are often less complete in terms of engine tear-down than those where the engine is removed from the bus.)

7.2 Capacity

A small property's capacity to house and support its fleet is easily measured in terms of square feet of floor area for its operations center building. The properties surveyed reported from 200 to 500 square feet per bus to house the major functions of administration, transportation, and maintenance (Exhibit 7-4). If the property is located in a climate that necessitates indoor overnight bus parking, the building size varies from 500 to 700 square feet per bus.

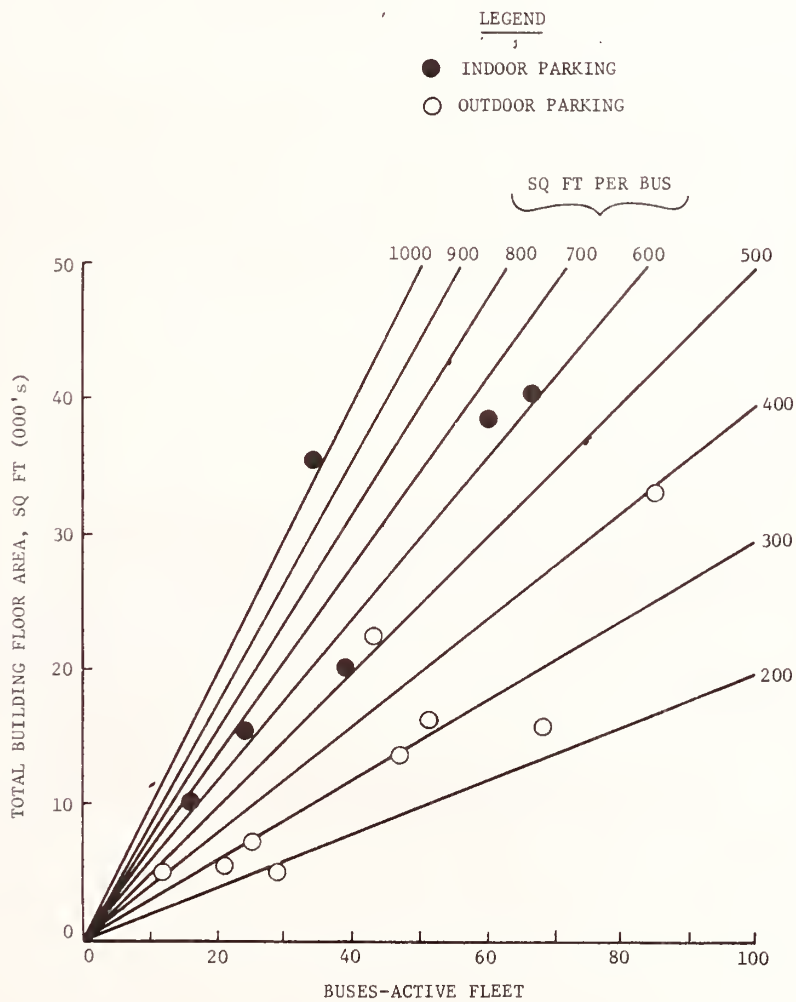


EXHIBIT 7-4
AREA REQUIREMENTS (ADMINISTRATION, TRANSPORTATION, AND MAINTENANCE)

A key measure of a property's maintenance capacity is the number of hoists and/or pits that are available to provide under-coach access. The results of the survey are shown in Exhibit 7-5. A minimum of one hoist or pit is required to properly inspect, lubricate, and repair buses in the very small fleets. In the range from 15 to 40 buses, the concensus is that 2 hoists or pits are required (one of each might suffice). For fleets in the range from about 40 to 80 buses, the data suggest that at least 4 pits or hoists will be necessary, and from 80 to 100 buses at least 6 are needed. For larger fleets, it appears that the range of values for fleets with 100 or more buses should be used (Section 3.3). These values were obtained for the survey as a whole and vary between 2 hoists and/or pits per hundred buses to 6 per hundred.

Stall space is another effective measure of a repair shop's capacity. The ratio of the number of stalls per bus for small properties is higher than the range of values reported by all properties (including those with more than 2000 buses). The range of values for all reporting properties is from 2 to 7 stalls per hundred buses. The median value for small properties is about 10 stalls per hundred buses (10 buses per stall).

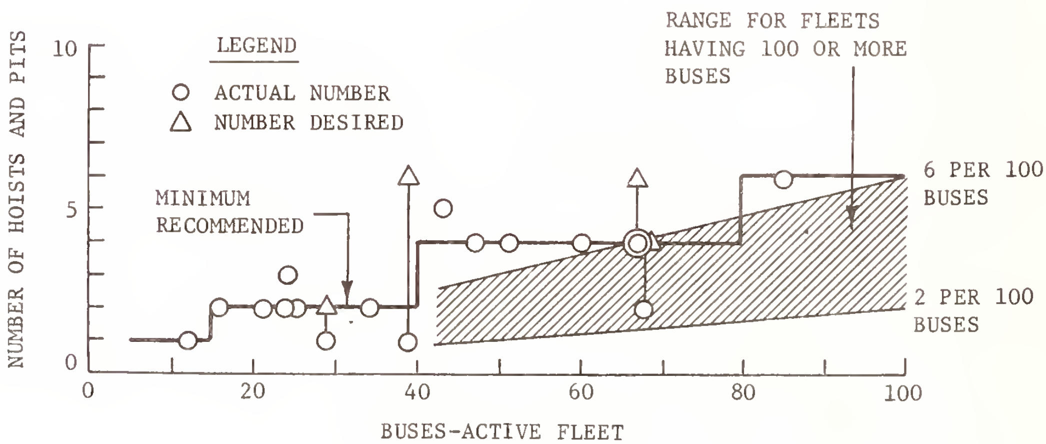


EXHIBIT 7-5
HOIST AND PIT REQUIREMENTS

The ratios shown in Exhibit 7-6 can be misleading for very small properties in that a minimum number of stalls is needed to conduct inspections, tune engines, and to make light repairs. The data indicate at least 3 stalls as the minimum number for very small properties with 30 or less buses; at least 4 stalls for those with between 30 and 60; and at least 7 stalls for properties with 60 to 100 buses. Small properties should have at least one stall with a hoist or pit for bus inspections and repairs.

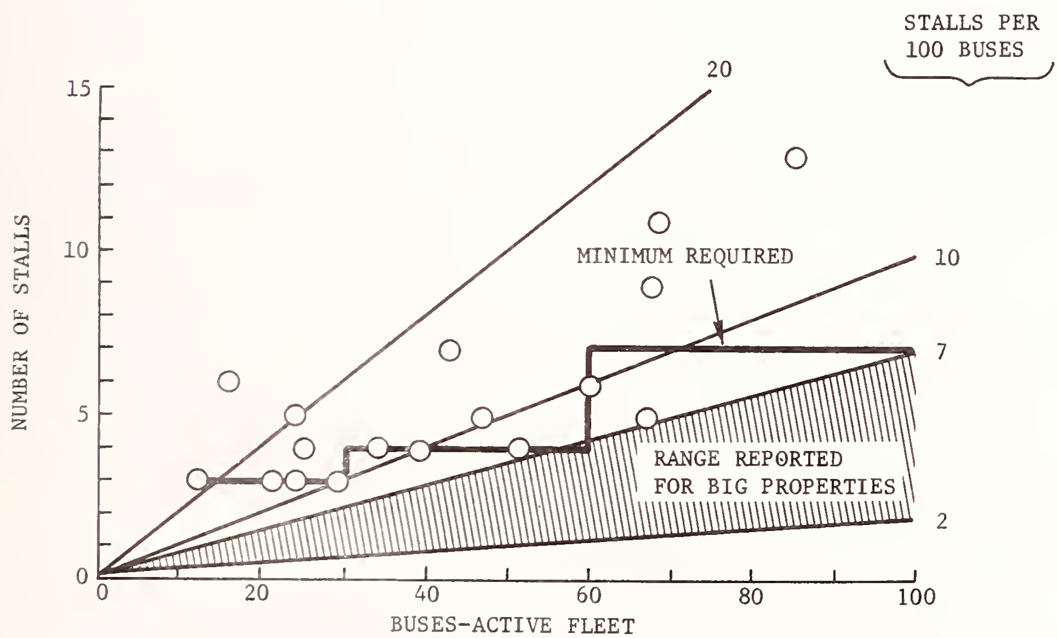


EXHIBIT 7-6
BUS STALL REQUIREMENTS

The number of stalls associated with the total stall area in use at small properties is shown in Exhibit 7-7. Constant ratio lines have been superimposed on the plot to show average stall areas. Average stall areas varied from 525 square feet per stall to 1350 square feet per stall. In general, the stalls in use at small properties tend to be smaller than those reported by the larger properties, although about one-fourth of the small properties had stalls in the size range of 1000 square feet or more.

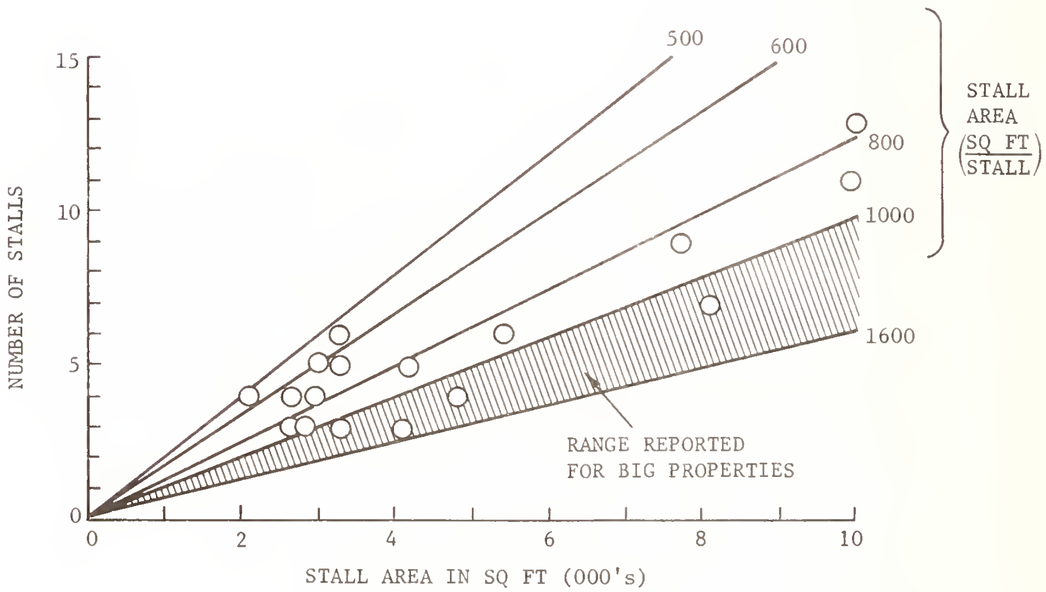


EXHIBIT 7-7
BUS STALL SIZE REQUIREMENTS

A 525 square foot stall provides barely adequate working space around a 35-foot coach (about 4½ feet between adjacent buses with only 3½ feet at each end). The median stall size for small properties is 835 square feet (about 6½ feet between adjacent buses with 8 feet) at each end of a 102-inch wide, 40-foot coach.

There is a poor correlation, in the data obtained, between support space and fleet size for small properties. Support space may be defined as that used for the storage of components and special lubricants as well as for office space. Support space includes the stockroom, speciality shops, the foreman or maintenance manager's office, and restrooms. Small properties do not always provide enclosed spaces for all of these functions, nor was all such space reported by small properties. Many small properties conduct maintenance operations in an open shop area without the benefit of speciality shops. However, all have stockrooms; some have machine shops, body and paint shops; and the maintenance manager usually has a cubicle.

Stockroom sizes range from 6½ to 130 square feet per bus. The median value for very small properties is 18 square feet per bus; the median value for properties with between 30 and 100 coaches is 18.6 square feet per bus.

Only 3 of the 7 properties with less than 30 buses reported having a machine shop. Of those with a machine shop, the median value was 19.2 square feet per bus. Properties with between 30 and 100 buses reported a median value of 16 square feet per bus for the machine shop; 70 percent of the properties in this size range have machine shops.

Only about half of the small properties reported body and paint shops; of those that did, the range of values is wide (400 to 6900 square feet). The size of a body and paint shop is influenced to a large extent by the need for a room in which paint can be applied and then dried. The minimum size for such a booth is roughly 14 by 50 feet (700 square feet), or enough room for a 40-foot coach. Body work can be done in the general repair area; however, three small properties with more than 60 buses reported areas that were designated exclusively for body work. The median value of the areas involved (including paint and body work) is 37.6 square feet per bus. Although the area allotments for body and paint shops are included in the count of bus stalls, they are reported as separate items because paint shops may require special consideration.

7.3 Equipment

Maintenance capability is often a function of the availability of various types of shop equipment. The single facility properties surveyed reflect this quality clearly. The distribution of various types of shop equipment among single facility properties with less than 100 buses is shown in Exhibit 7-8.

Certain pieces of equipment are basic to any garage operation regardless of the property's size. An example is a portable jack to lift a bus to change wheels or make a quick inspection without moving the bus to a hoist or pit; nearly all properties have portable jacks. The chain hoist is another valuable piece of equipment: it provides the means to support heavy units being removed from or replaced on a bus. Again, nearly all properties have one or more chain hoists of various types.

The variety, quality, and capability of machine shop tools provides a good example of the type of work that may be done by the small properties. Nearly all properties in each size class have a drill press, but few have a shaper or a milling machine to refinish cylinder heads or other parts.

The equipment list covering very small properties provides an indication of the basic needs in tools (Exhibit 7-8). The most important items of maintenance equipment include: portable jacks, chain hoists, drill presses, air compressors, arc welders, and wheel dollies. Properties in the size range from 31 to 100 buses are generally better equipped than very small properties, and single facility properties with more than 100 buses are usually equipped as well as multi-facility properties of comparable size.

7.4 Traffic Flow

Traffic flow on the facility lot or through the service cycle is not much of a problem with the very small property. As the size of the fleet grows, the importance of efficient facility layout increases rapidly. Service and maintenance operations for fleets with between 60 and 100 buses require well disciplined procedures if efficiency is to be realized.

The problems with fleets larger than 100 buses are inherently more demanding in terms of achieving efficient bus movement. The movement of buses around the shop and grounds of the typical older, large single facility property is often a more complex arrangement than it is at a comparable size division facility. This is particularly true if engine, transmission, and body overhauls are performed at the facility.

EXHIBIT 7-8

SMALL PROPERTYS' SHOP EQUIPMENT

ITEM	NUMBER REPORTED (TOTAL)	NO. PROPERTIES WITH ITEM	PERCENT WITH ITEM (BY PROPERTY SIZE) 0-30 Buses	31-100 Buses
JACKS				
Portable	54	16	86	100
Hydraulic, manual	9	8	43	50
CHAIN HOISTS				
Manual	30	15	71	100
Power	17	14	57	100
Movable	13	9	43	60
MACHINE SHOP TOOLS				
Drill press	25	15	71	100
Metal lathe	18	12	36	100
Heavy duty press	14	12	57	80
Valve facer	14	13	57	90
Valve seater	11	11	57	70
Band saw	4	3	0	30
Shaper	3	3	0	30
Mill	2	2	0	20
GENERAL				
Air compressor	34	15	71	100
Arc welder	26	15	71	100
Chemical cleaning tanks	17	10	57	60
Jib crane	8	3	0	30
Fork lift truck	4	4	14	30
Electrical generator	2	2	14	10
WHEEL, TIRE, AND BRAKE WORK				
Wheel dolly	25	16	86	100
Inflation cage	13	8	43	50
Brake lathe	12	12	57	80
Tire groover	9	9	28	70
Wheel alignment rig	4	4	14	30
BODY SHOP EQUIPMENT				
Sheet metal shear	4	4	14	30
Sheet metal break	4	3	0	30
TEST EQUIPMENT				
Injector tester	11	10	28	80
Ignition tester	5	4	14	30

Note: Ten small and seven very small properties responded to this set of questions.

On-property traffic congestion at older facilities often results from the general arrangement of the site. If it is one in which the property grew as it made the transition from street rail operation, and the various types of work changed, work space was made available wherever it could be found. In many cases this necessitated the construction of additional buildings, the acquisition and conversion of nearby commercial property, or expansion of existing buildings.

A facility built to support the maintenance of trolley cars is seldom an efficient plant for bus maintenance. Streetcars, cumbersome to hoist frequently, were repaired over long pits that usually ran the length of the shop. Present day use of long pits for bus repairs is possible, and three or four buses can be accommodated over one such pit. However, scheduling is required to avoid unnecessary delays for buses positioned near the middle of the pit and to avoid constant shuffling of buses on and off the pits.

The maintenance of electric traction equipment is quite different than the maintenance of internal combustion engines, transmissions, and air conditioning systems. Thus, the evolutionary changes in a property to accommodate buses may impair efficient operations as a result of building alternations, changes in traffic flow through the shops, and loss of storage or holding areas. MITRE found some large single facility bus properties operating in streetcar barns that are over 75 years old. These properties have poor lighting, inadequate work space, and deteriorating structures.

Age and conversion problems are not unique to single facility properties. However, many multi-facility properties may have found the evolutionary conversion easier because of the availability of space for light repairs at division facilities.

A representative sample of the ages of single facility properties in the United States and Canada indicated that many of the smaller properties have relatively new facilities, while some of the larger ones are still operating from old facilities. The properties are divided into appropriate size groups (Exhibit 7-9). The smallest properties (less than 30 buses) tend to have the newest facilities; six properties fell into this size category. Of all respondents with fewer than 100 buses, nearly 40 percent have buildings that are approaching potential replacement age (about 40 years). Over half of the properties with more than 100 buses are operating with facilities 35 or more years old. Bus movement at properties of this size and age can become cumbersome if the maintenance and servicing work has to be performed at several buildings scattered around a cramped property.

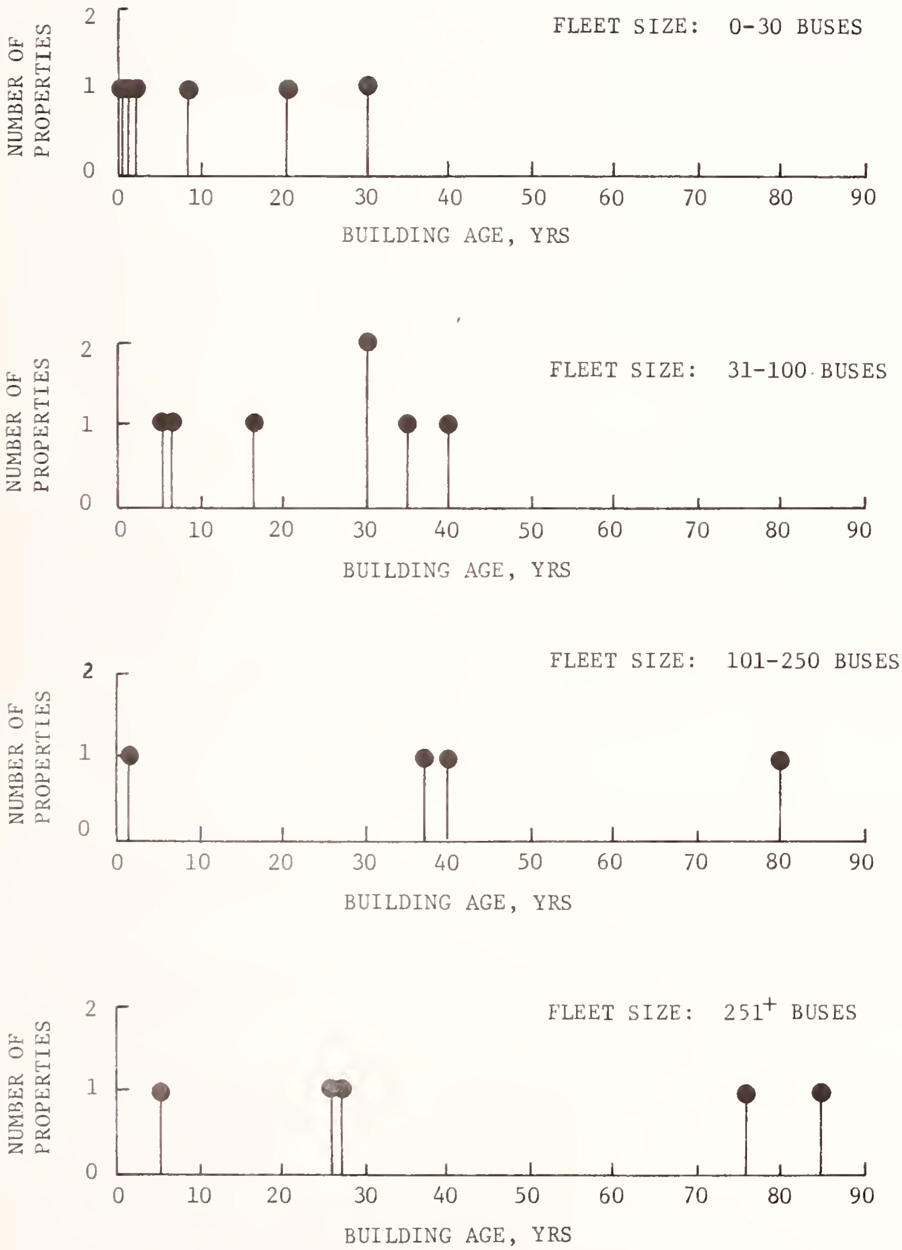


EXHIBIT 7-9
AGE SPREAD OF SINGLE FACILITY PROPERTIES

8.0 DEVELOPING A PLANNING ESTIMATE

Planning a new facility means that many items must be considered; most important are facility size and the kinds of equipment needed. In addition, a new facility's impact on the surrounding community must be taken into account. Planning a new facility involves at least five steps before construction begins:

a. List the functional requirements for the new building.
b. Develop the Planning Estimate.
c. Review the Planning Estimate with an architectural engineering consultant for design and cost purposes.
d. Obtain detailed design and specifications.
e. Obtain construction costs from contractors through a bidding process.

This section provides guidance in the development of a Planning Estimate that will cover the basic needs of the property. A Planning Estimate may be a memorandum or report that summarizes the objectives of a new facility, the requirements (equipment, service, and space) and a preliminary cost estimate. In addition, the Planning Estimate should anticipate the short-term needs (five years) of the property in terms of fleet growth or changes in equipment. The Planning Estimate is the first output of the maintenance manager or the "new garage" committee; it is to be used to guide their subsequent work with architectural engineering consultants.

8.1 Requirements

Functional requirements include the physical ingredients necessary to conduct bus maintenance operations.

Requirement lists are useful for the appraisal of each of the major functions involved. The lists provide means to appraise the following:

a. buses in use and to be acquired,
b. shop and support areas (including equipment),
c. OSHA standards, and
d. environmental impact factors.

The first step in the formulation of the Planning Estimate is to record the current and projected bus inventories. The second step is to evaluate current shop and storage capabilities and to determine the requirements for the new facility (Exhibit 8-1).

Examples of vehicle checklists for the functional requirements are shown in Exhibits 8-2 and 8-3; more detailed requirements for the building are in Section 8.2.

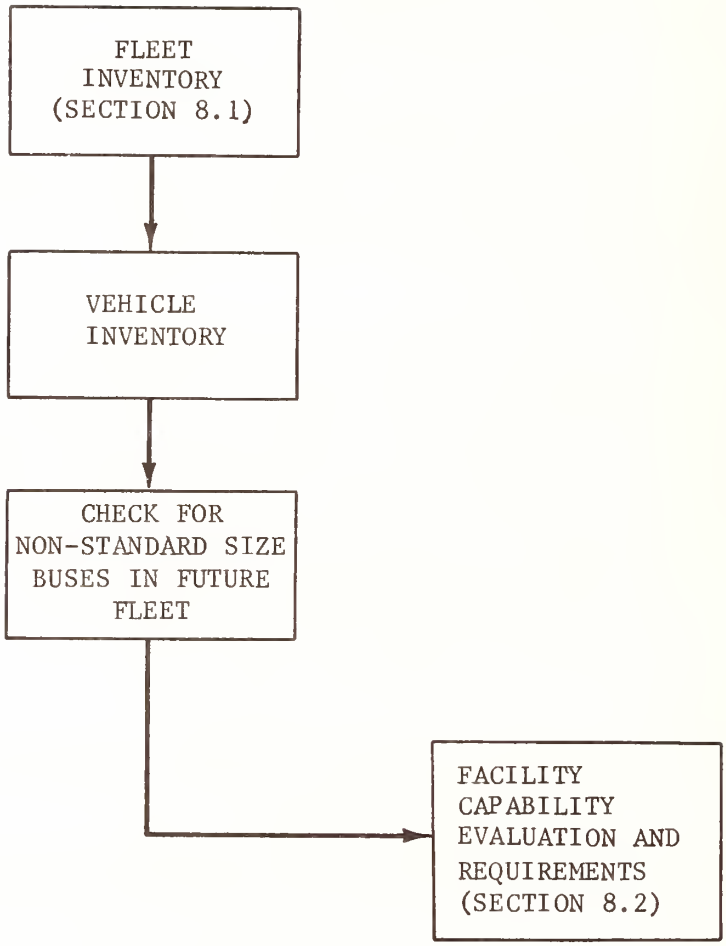


EXHIBIT 8-1
DEVELOPMENT OF A PLANNING ESTIMATE

EXHIBIT 8-2
VEHICLE INVENTORY PLANNING CHECKLIST

CATEGORY	CURRENT INVENTORY	ANTICIPATED INVENTORY FIVE YEARS HENCE
Active buses		
Peak service		
Base service		
Charter		
School trippers		
TOTAL BUSES		
Service vehicles		
Automobiles*		

Completion of the Vehicle Inventory Planning Checklist (Exhibit 8-2) provides an opportunity to estimate future changes in fleet size. A five-year time span is suggested as an interval for this purpose for two reasons: First, it is a reasonable interval between the time of initial planning and the time of the new facility's operation. Second, a five-year interval tends to smooth out variations in the bus inventory; it assumes that older models have been replaced, new units added, and that obsolete and/or inactive buses are no longer in the fleet.

An estimate of area to be occupied by buses and other vehicles is important because the bulk of the new facility's size will be determined by service and repair area needs. In places where climatic conditions warrant indoor storage of the fleet, the building size requirements will be significantly greater. A checklist is provided in Exhibit 8-3 for the purpose of itemizing bus sizes. The range and variety of bus sizes is large, and there has been a proliferation of small buses on the market in recent years. (The small bus specification endorsed by APTA calls for an 8-foot wide bus no longer than 31 feet.) Other nonstandard buses being procured by the transit industry are so-called Superbuses (double-decked buses, and articulated buses with 54 to 60-foot long bodies). In addition, many smaller van-sized coaches are being used for "Dial-A-Bus."

Exhibit 8-3 provides space to enter the number of buses of each size. Vehicle size has been calculated for each type of coach; the size listed in Exhibit 8-3 represents the floor area needed by an individual coach with a surrounding one-foot clearance strip to account for mirrors or other appendages. These areas represent the

*Owned and maintained by the property.

relative sizes of various types of coaches; they are not to be used as the basis of stall size or parking space size unless suitable factors are applied to account for access. Bus access requirements will be presented in subsequent paragraphs.

EXHIBIT 8-3
BUS SIZE CHECKLIST

TYPE OF COACH	SIZE AREA sq. ft.	SIZE LENGTH ft.	NUMBER IN FLEET CURRENT	NUMBER IN FLEET FIVE YEARS HENCE
40-ft standard bus*	441	40		
35-ft standard bus*	388	35		
APTA small bus	330	31		
Articulated bus*	588	54		
Double-deck bus*	441	40		
Transbus type coach*	441	40		
Transit vans	192	22		

Some properties will be operating fleets of mixed sizes of buses. Small coaches used for "Dial-A-Bus" and downtown circulation service require special hoists because of short wheelbases, although most pits will accommodate this type vehicle. Articulated coaches require hoists with at least three lift posts, or long pits and stalls. Double-decked buses require special consideration in terms of garage door heights, automatic bus washer roof clearance, and the availability of space above hoist areas. The overall height of a typical double-decked bus is 14 feet.

Functional requirements for shop and support areas will vary depending on the basic policies and size of the property. Very small properties (less than 30 buses) often operate without an overhaul capability. Maintenance operations are limited to servicing, washing, cleaning, periodic inspections, tune ups, and light repairs. This capability is comparable to an inspection garage. Small-to-moderate size properties operate from a single facility and may be described as having combined inspection and overhaul capabilities. Properties with several hundred buses generally operate with geographically separate division garages. Usually one or more divisions will have a combined capability. Very large properties generally maintain one facility for overhaul work (the main maintenance facility) in addition to several division (inspection garage) facilities.

*Assumes 102-inch width

The initial planning process should also include a review of pertinent standards prescribed by the Occupational Safety and Health Administration (OSHA). These standards are discussed in Section 10.0.

An assessment of environmental impact factors should be started at an early stage in the planning process. UMTA grant application procedures require public hearings on proposed transit facility construction. At the hearings, transit management must present transit plans to the public and obtain citizen's views on the proposals.

Public acceptance of the site plan may vary considerably depending on the extent to which potential objections are anticipated. People residing near the proposed facility may react adversely to the plans. Examples of typical complaints are traffic congestion, start-up noise and exhaust smoke, and loud work-shift claxons. These potential problems can be avoided by providing effective ventilation, effective use of shop space, innovative architectural features, and adequate land area and landscaping to buffer or suppress the potential adverse aspects. If public objections are not anticipated, the results of the hearings may alter the proposed site plan significantly. (Anticipation of public reaction to a new facility is a sound policy even if the transit property plans construction with its own funds.)

A checklist is suggested for consideration before starting work on the Planning Estimate. The checklist is based on design features suggested by respondent maintenance managers.

<u>Repair facilities should have</u>:

a. individual bus stalls wherever possible;
b. adequate number of hoists and/or pits;
c. good pit access;
d. adequate working space between buses in stalls;
e. tool storage in pits;
f. overhead dispensing systems for lube, air, and coolant;
g. dispensing system for lube, air, and coolant in pit;
h. oil drain and disposal system for pits/hoists that is integral with building;
i. a maintenance area separate from bus storage area;
j. water curtain in paint booth;
k. adjustable or elevated work stands for air conditioner condenser unit access;
l. tire shop large enough for two buses (where property size warrants);
m. adequate machine shop equipment and work space;

n. diagnostic equipment;
o. portable lifts; and
p. an electronic shop (or space for one).

Service facilities should have:

a. an indoor (protected) service island,
b. fueling bay exit into the garage (or storage area),
c. automatic bus washers,
d. water recycling for washers, and
e. automatic bus cleaning.

Parking facilities should feature:

a. indoor parking for all coaches in areas of extreme temperatures,
b. individual or reserved bus spots,
c. no turning or backing by buses in garage,
d. water lines for small wash jobs, and
e. adequate separate space for employees.

General architectural considerations should include:

a. efficient traffic patterns,
b. low building maintenance,
c. secure revenue collection provisions,
d. central stockroom location,
e. good floor drains,
f. efficient heating and ventilation,
g. separate maintenance and transportation work areas,
h. quiet ventilation system,
i. an exhaust vent system,
j. adequate levels and locations for illumination,
k. air curtains,
l. air conditioning where appropriate,
m. adequate locker facilities for shift changes, and
n. a single level (one floor) facility.

8.2 Planning Estimate Report

Site selection may depend on the area requirements of the new facility. Therefore, it is advisable to make a preliminary planning estimate which may be revised. The Planning Estimate Report as described here will cover all aspects of the maintenance department's space requirements. The space requirements of the transportation department and general administration office requirements are not covered, nor are the spatial requirements for buildings and grounds.

The maintenance department Planning Estimate Report includes the following topics:

a. inspection and light repair area,
b. service station area,
c. bus storage and traffic lanes,
d. overhaul and unit rebuild areas, and
e. preliminary cost estimates.

It is recognized that not all maintenance facilities are alike; they vary in size and function. For example, the requirements for an inspection garage (servicing, inspection, light repairs, and storage) are different than those for a main maintenance facility that is dedicated to major or heavy repair work and unit overhauls only. The requirements for a combined facility will include provision for servicing, light repairs, overhauls, and bus storage at one location. Finally, the requirements of the small property with only 30 buses or so may conspicuously differ from those of the large properties.

Planning charts (Exhibits 8-4 through 8-7) and checklists (Exhibit 8-8 through 8-13) follow. Their purpose is to provide guidance for the functional and detailed planning of a new facility. The planning charts refer to the appropriate sections of this manual for information needed to plan a new facility. The checklists provide space to record current and planned capabilities. The next step is to review shop requirements and the Planning Estimate with an architect (Section 8.3).

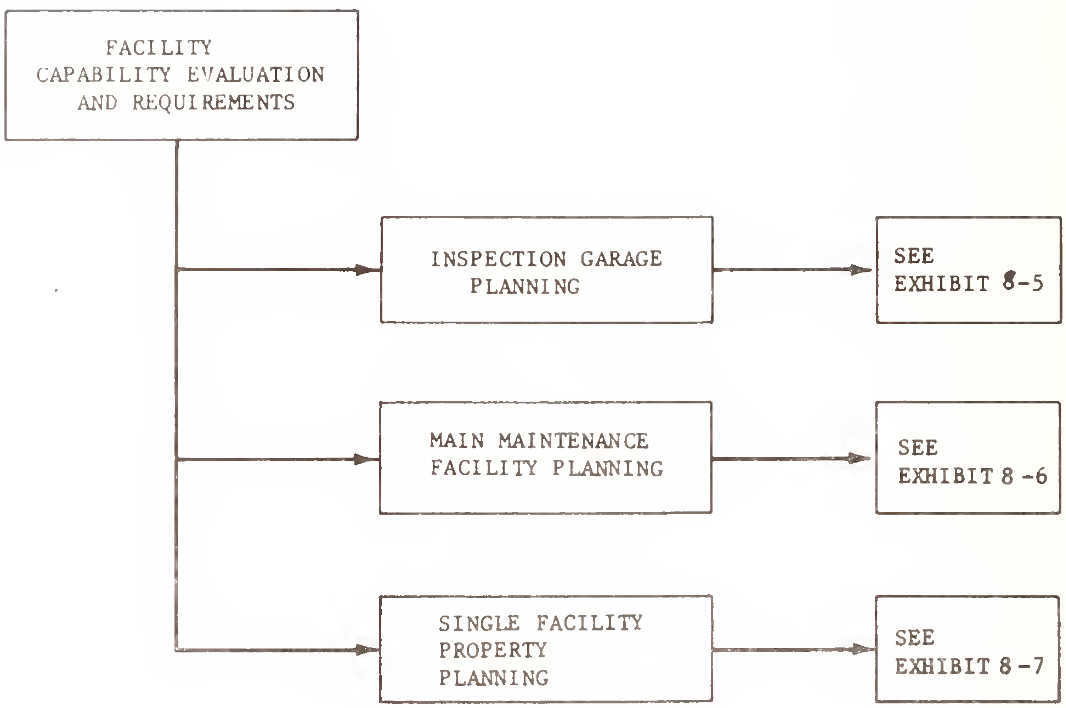


EXHIBIT 8-4
GUIDE TO PLANNING CHARTS

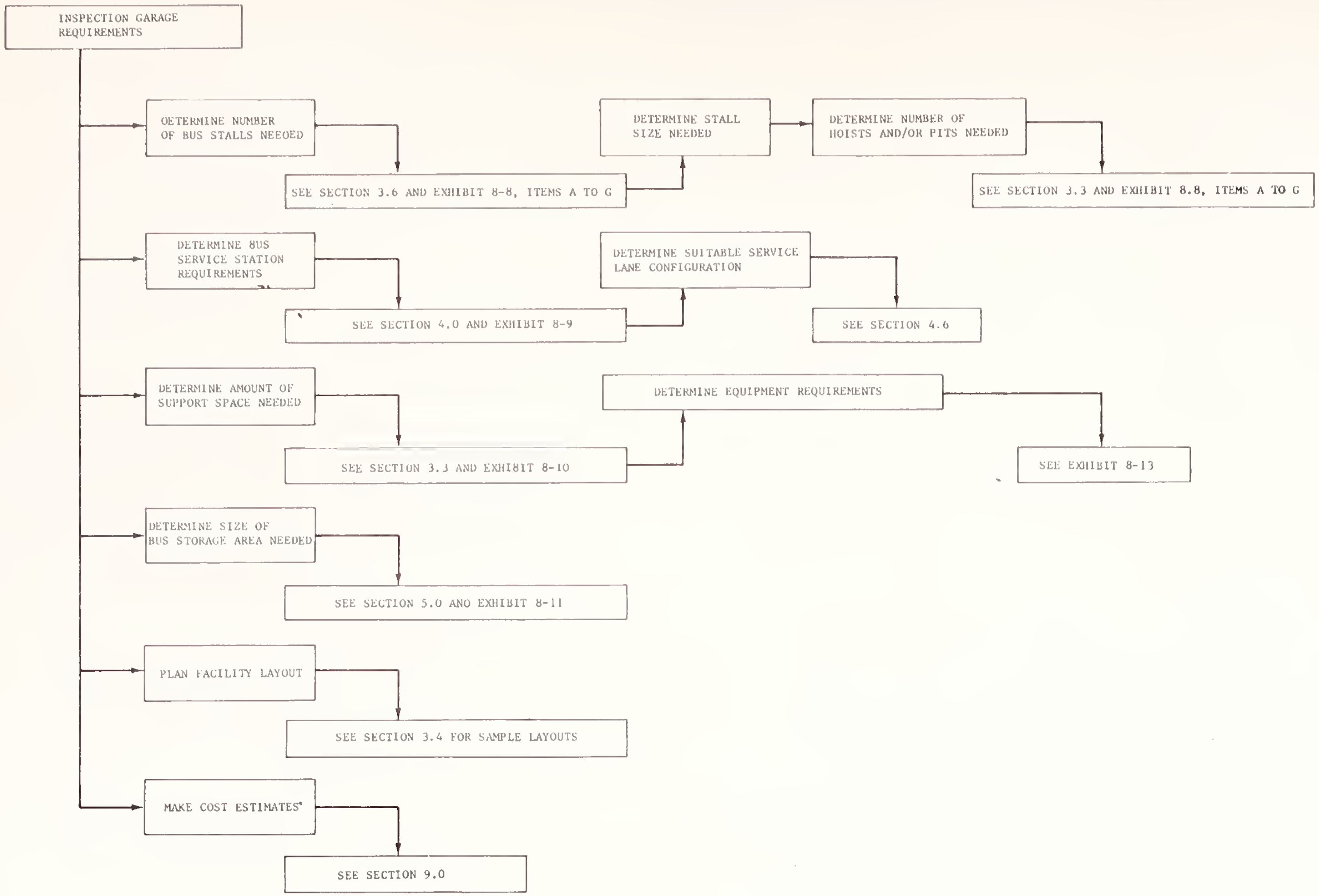


EXHIBIT 8-5
INSPECTION GARAGE PLANNING CHART

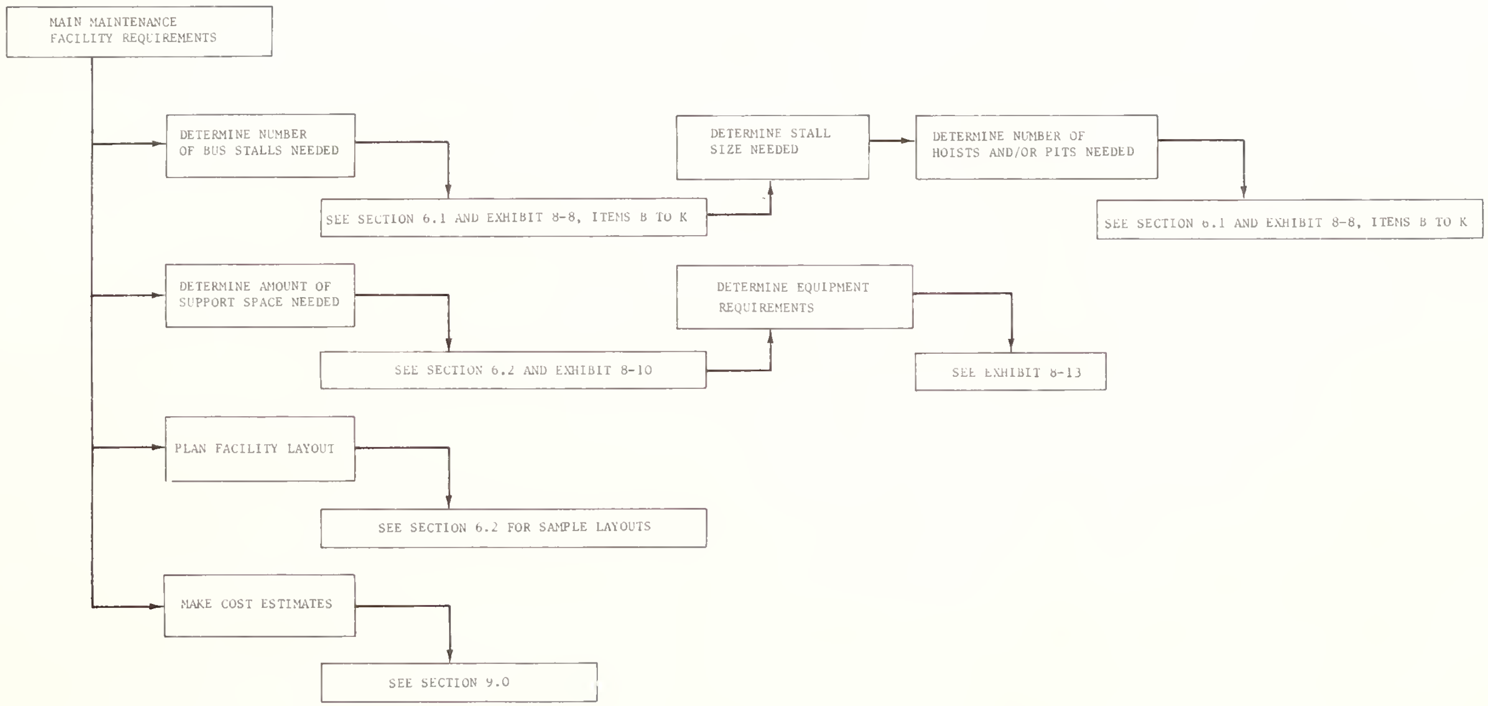


EXHIBIT 8-6
MAIN MAINTENANCE FACILITY PLANNING CHART

EXHIBIT 8-7
SINGLE FACILITY PROPERTY PLANNING CHART

ITEM	NUMBER CURRENTLY IN USE	SIZE OF EACH	NUMBER REQUIRED	SIZE REQUIRED	HOIST (H) OR PIT (P) REQUIRED
A. Inspection and lube					
B. Light repair area					
C. Tune-up area					
D. Steam clean bay					
E. Brake lane					
F. Air conditioner shop					
G. Tire/wheel shop					
H. Paint shop					
I. Body shop					
J. Dynamometer room					
K. Heavy repair area					

EXHIBIT 8-8
BUS STALL CHECKLIST

ITEM	NUMBER CURRENTLY IN USE	SIZE OF EACH	NUMBER REQUIRED	AREA REQUIRED
Farebox collection station				
Refueling lanes				
Fuel pumps		XXXXX		
Oil, air, coolant dispensers		XXXXX		
Internal cleaning stations				
External washing stations				
Internal washing station				
Brake adjustment station				

EXHIBIT 8-9
SERVICE AREA CHECKLIST

ITEM	AREA NOW IN USE (SQ. FT.)	CHECK IF NEEDED FOR NEW FACILITY	AREA REQUIRED
Stock room			
Unit storage (open area)			
Unit storage (closed area)			
Battery room			
Cleaning vats			
Radiator vats			
Restrooms (M&F)			
Locker rooms (M&F)			
Offices			
Machinery room (compressors, HVAC, boilers, generators)			
Storage room: paint and special lubricants			
Automotive repair			

EXHIBIT 8-10
SUPPORT AREA CHECKLIST

ITEM	AREA NOW IN USE (SQ. FT.)	CHECK IF NEEDED FOR NEW FACILITY	AREA REQUIRED
Indoor parking area			
Indoor bad order area			
Overnight storage in repair bays (stalls)			
Outdoor bad order area			
Outdoor staging area			
Outdoor parking area			

EXHIBIT 8-11
BUS STORAGE AREA CHECKLIST

ITEM	AREA NOW IN USE (SQ. FT.)	CHECK IF NEEDED FOR NEW FACILITY	AREA REQUIRED
Engine overhaul			
Transmission overhaul			
Small unit overhaul			
Electric unit overhaul			
Radio repair			
Injector room			
Fare box repair			
Sheet metal shop			
Carpentry shop			
Radiator shop			
A/C compressor shop			
Upholstery shop			
Sign shop			
Building maintenance shop			

EXHIBIT 8-12
SHOP AREA CHECKLIST

	NUMBER CURRENTLY IN USE	SIZE OR CAPACITY	NUMBER REQUIRED	REMARKS
LIFTING DEVICES Portable jack posts Manual hydraulic jacks Heavy duty jacks Overhead monorail beams Manual chain hoists Power chain hoists Movable chain hoists Fork lift truck Jib crane				
MACHINE SHOP TOOLS Drill press Metal lathe Heavy duty press Band saw Shaper Mill Small brake Valve seater Engine stand Other unit stands				
WHEEL, TIRE & BRAKE WORK Wheel dolly Inflation cage Brake lathe Tire groover Wheel alignment rig				
BODY SHOP EQUIPMENT Sheet metal shear Sheet metal brake Arc welder				
TEST EQUIPMENT Injector tester Ignition tester Chassis dynamometer				
GENERAL Air compressor Vacuum pump Cleaning tanks Radiator vats Overhead lube, air, and coolant supply				

EXHIBIT 8-13
SHOP EQUIPMENT CHECK LIST

8.3 Working with the Architect

A new facility project requires the assistance of an architect, either an individual or a consulting firm. He should join the project early and remain with it through to completion. The architect brings building design and engineering expertise to the project and relieves transit management of burdens and details which they are not equipped to handle.

Maintenance management should initially set down its requirements for a new facility, that is, establish capacity requirements and maintenance functions to be provided for. With the assistance of this report, an initial gross cost estimate can be prepared. With this assessment of the magnitude of the project, the architect can profitably begin to contribute.

The architect will provide valuable assistance in the preparation of the bid specifications for general contractor competition. However, transit should participate with the architect in the determination of the scope of the specification regarding non-construction items. It may be advantageous to procure some equipment separately, outside of the scope of the construction contract. Equipment such as bus washers, internal vacuum systems, paint booth equipment, and possibly hoists should be considered for separate procurement and installation. Heavy equipment provided by the contractor, in some recent cases, has proven to be inadequate for transit requirements.

General contractors have, in isolated instances, substituted other equipment after receiving a contract award. This practice can result in inferior equipment at the same price as originally negotiated. To preclude such substitutions the contract should specify the qualified suppliers and sub-contractors and the acceptable models where appropriate.

The architect can assist in the coordination of these separate procurements and their installation, as appropriate with the construction schedule. By this process, architect fees are substituted for general contractor markup. However, long-term satisfaction is the primary benefit.

The support that can be expected of an architect includes the following:

a. Assist transit in the selection of trade-offs with respect to costs, capabilities, and construction methods.
b. Translate maintenance objectives and requirements into detailed construction drawings.
c. Interpret and include OSHA and local building code requirements into the design.
d. Prepare a plan for site preparation and construction.
e. Develop a refined cost estimate that reflects the final details of design.
f. Assist in the preparation of a funding plan.
g. Prepare construction bid specifications.
h. Assist in the technical evaluation of bids.
i. Provide continuing service as a transit consultant and perform quality control functions on the work of the general contractor.

This list of support functions is impressive. The architect brings expertise to the project that is generally not available in the transit organization and relieves transit personnel of time consuming functions. However, transit cannot and should not abdicate its responsibilities. Eventually, the architect will complete his assignment, but transit personnel will continue operations in the new facility for years to come.

The architect's expertise is associated with construction, building codes, structural integrity, etc. The maintenance manager is qualified in the intricacy of maintenance operations. These two areas of expertise must be melded together to achieve a successful and rewarding development project. The maintenance manager must set aside time to communicate his requirements and objectives to the architect and to review the resulting design solutions.

Regardless of the time spent and detail devoted to planning and design, the final result will include some surprises that must eventually be corrected. A contingency allowance is commonly included in the project budget for this reason.

9.0 CONSTRUCTION COSTS

Determination of the cost of a proposed maintenance facility is a detailed and intricate process requiring special skills, experience, and source information. Data presented in this section will enable a maintenance manager to develop a gross estimate for initial planning purposes. The approach is simple and is based upon floor area and floor area costs for various types of areas (service, parking, main shop). Ranges of floor area costs are provided for each type of bus maintenance area.

9.1 Construction Cost Data

Cost data are rarely available in a form suitable for the quick establishment of simple and reliable detailed cost estimating relationships (CERs). In the absence of reliable CERs, it is necessary to use project cost data from recent bus facility construction projects. Variations in size, structural system, and configuration of the various facilities preclude their use on a precise basis. It is possible to place upper and lower limits on costs and establish a range of values; a practice followed in this report.

Data were obtained on the construction costs of urban transit bus maintenance facilities from periodicals, publications, transit properties, and an APTA listing of transit grants. These data relate to facilities completed or planned in recent years. Compilations have been prepared for bus storage facilities, inspection garages, main maintenance facilities, and servicing facilities.

Exhibit 9-1 is the compilation of bus storage facilities. Each facility is described in terms of location, garage name, number of buses stored, type of construction, and bid or construction date if known. The data include project cost as incurred, floor area, unit area costs, and costs per bus. Project costs include not only the structure and internal fixtures but site preparation and outside paving.

Floor area costs result from the division of project cost by floor area. Floor area costs are therefore not absolutely comparable, as they reflect differences of site preparation and other factors unique to each project. Floor area costs are adjusted to March 1975 costs, (actual costs were adjusted to a common time period for comparative purposes). Cost per bus reflects the adjusted cost data in 1975 dollars.

EXHIBIT 9-1

BUS STORAGE FACILITIES

DESCRIPTION	COST IN MILLIONS	AREA (Sq. Ft.)	UNIT AREA COST ($/Sq. Ft.) AS BUILT	UNIT AREA COST ($/Sq. Ft.) MAR 75	MAR 75 COST/BUS
AKRON, OH Steel, Insulated 70 Buses Date 4/72 (Started)	0.42	33,000	13	16	5,250
ROCHESTER, NY					
Garage B 88 Buses Block and Brick Date 8/72 (Bid)	0.94	44,233	21	22	10,680
Garage C 88 Buses Block and Brick Date 8/72 (Bid)	1.01	44,482	23	24	11,490
KANSAS CITY, MO Prestressed 302 Buses Under Construction Date 2/75 (Bid)	3.58	163,000	22		11,790
MPLS/ST. PAUL, MN South Garage 300 Buses Brick and Block Proposed	4.56	160,000		28	15,000
MILWAUKEE, WI Fiebrantz 84 Buses Date 11/68	0.6	35,608	17	27	11,440

Most storage facilities are in the range of \$22/sq. ft. to \$28/sq. ft. for construction of conventional block with brick facing. However, an Akron facility is an outstanding example of the economy of a prefabricated metal building (nearly 27 percent less than block and brick on a floor area cost basis). It is an attractive facility which is insulated and heated for winter storage use. Akron plans to construct maintenance shops and administrative quarters in the more conventional block and brick construction.

Actual and adjusted costs of a limited number of inspection garages are shown in Exhibit 9-2. The data are dominated by five Pittsburgh facilities, but each Pittsburgh garage houses a different number of buses. There is some variance in the normalized (March 1975) unit area costs, which illustrates the type of variance to be expected. These variances occur because of different site preparations, contractors, and prevailing conditions.

All facilities in this sample have inside bus storage as well as inspection and servicing capabilities. Therefore, unit area costs for an inspection facility without inside storage may be expected to be higher than these samples. At least two-thirds of the total floor area will be allocated to bus storage. Unit area costs for an inspection garage without inside storage should be from 25 to 30 percent higher.

Main maintenance (main shop) facilities data are tabulated in Exhibit 9-3. The number of buses provided in this table, and used for the cost per bus value, is the total planned bus population of the property being served by the main shop. This basis for estimating costs is different than that used for an inspection garage since the number of buses is different. In the latter case, only those buses housed at the garage are used as the base number.

These data can also be used for estimating construction cost as a function of property size or division size in lieu of floor space calculations and as a very gross estimate. Main shops appear to cost about \$7,000 for each bus on the property. Inspection garages with inside storage appear to cost about \$21,000 per bus serviced by the division. Inspection garages with outside storage appear to cost about \$10,000 per bus serviced by the division.

By comparison, air conditioned buses are currently being purchased for about \$65,000 each. Capital outlays for maintenance facilities can then be expressed in terms of the replacement value of buses

EXHIBIT 9-2

INSPECTION GARAGES

DESCRIPTION	COST IN MILLIONS	AREA (Sq. Ft.)	UNIT AREA COST ($/Sq. Ft.)		MAR 75 COST/BUS
			AS BUILT	MAR 75	
PITTSBURGH, PA					
Ross 203 Buses Brick Date (3/68 (Completed)	1.58	115,190	14	23	13,050
Harman 104 Buses Brick and Block Date 12/70 (Completed)	1.67	81,680	20	29	22,780
West Mifflin 191 Buses Concrete with Brick Date 11/69 (Completed)	2.47	138,000	18	27	19,510
Collier 172 Buses Concrete with Brick Date 7/69 (Completed)	2.31	115,170	20	31	20,560
East Liberty 250 Buses Precast Concrete, Brick and Block Date 7/72 (Completed)	4.0	170,320	24	29	19.760
ROCHESTER, NY	1.26	47,712	26.5	27	14,300
Garage 88 Buses Brick and Block (Under Construction) Date 8/74					
MPLS/ST. PAUL, MN	8.33	253,000		33	27,800
South Garage 300 Buses Brick and Block (Proposed)					

EXHIBIT 9-3

MAIN MAINTENANCE FACILITIES

DESCRIPTION	COST IN MILLIONS	AREA (Sq. Ft.)	UNIT AREA COST ($/Sq. Ft.) AS BUILT	UNIT AREA COST ($/Sq. Ft.) MAR 75	MAR 75 COST/BUS
DALLAS, TX	3.0	83,000	36	48	8,500
East Dallas 469 Buses Brick and Block Date 3/72 (Began Const.)					
ROCHESTER, NY	1.86	43,800	42	44	7,000
Main Shop 276 Buses Brick and Block (Under Construction) Date 8/74 (Bid)					
PITTSBURGH, PA*	4.7	135,000	35	39	5,700
Manchester 927 Buses Precast Concrete, Brick Date 9/73 (Completed)					
KANSAS CITY, MO	1.6	50,600	32	32	5,400
Main Shop 302 Buses Prestressed Under Construction Date 2/75 (Bid)					

*Estimated

as shown below:

Facility	Cost per bus	Percent of Bus Cost
Main Shop	$ 7,000*	11
Inspection Garage (inside storage)	21,000	32
Inspection Garage (outside storage)	10,000	15
All new facilities (inside storage)	28,000	43
All new facilities (outside storage)	17,000	26

This table can be used to compute very gross estimates. For example, a main shop for a property of 500 buses can be expected to cost about $3,500,000 ($7,000 x 500). An inspection garage with inside storage for 250 buses may cost about $5,250,000 ($21,000 x 250).

In general, it appears worthwhile to invest in the building of a facility that provides more than the minimum level of service. The current (1975) cost of an air conditioned 40-foot coach is about $65,000, and labor rates in the maintenance categories are also high and likely to remain high. Therefore, facility investments that contribute to lower bus operating and maintenance costs appear justifiable. Examples of facility investments of this nature are:

a. Sufficient aisle width so that bus maneuvering is facilitated.

b. Long span roof beams to minimize the number of roof supporting columns in areas where buses must be driven.

c. Indoor parking to provide bus security, reduce neighborhood environmental impacts, and reduce bus air conditioner pull-down loads for afternoon trippers that are otherwise stored in the sun.

d. Diagnostic equipment, including chassis dynamometers.

A single facility property with outside storage should use floor area costs comparable to the main facilities.

Usually new maintenance facilities are constructed as a joint project with transportation or administration department facilities. In two cases, a main shop and the transit administration facilities were combined into a single project (Exhibit 9-4).

*Does not involve service facilities.

EXHIBIT 9-4

MAIN SHOP AND ADMINISTRATION FACILITY

DESCRIPTION	COST IN MILLIONS	AREA (Sq. Ft.)	UNIT AREA COST ($/Sq. Ft.)		MAR 75 COST/BUS
			AS BUILT	MAR 75	
PITTSBURGH, PA Manchester 927 Buses Precast Concrete, Brick and Block Date 9/73	8.87	203,370	44	51	11,200
DETROIT, MI Warren Avenue 1500 Buses (Built for) Brick and Block Date 12/72 (Occupied)	14.5	225,000	64	100	15,000

Servicing facilities may be considered separate from inspection garages. Exhibit 9-5 is a tabulation of service facilities. There are many variables in these costs per service lane. Usually the costs of underground fuel and oil storage tanks are included. Other variables relate to heavy equipment selection such as internal vacuum cleaners and external washers.

9.2 Construction Cost Variables

Due to several factors, a single rule will not apply to estimating construction costs. These factors, discussed in this section, are building function, type of construction, locality, and inflation.

Building Function. Unit area costs vary with the function of the building. some structures are simple shells whereas others may contain equipment, inner rooms, and special equipment provisions.

Inside bus storage facilities are basically shells or warehouses with minimal needs for plumbing, electrical, storage rooms, and equipment. Floor area costs tend to be smaller for inside bus storage facilities than other maintenance structures.

Inspection garages (division garages) are somewhat higher in floor area costs than storage facilities. Bus bays, lubrication systems, storage rooms, offices, restrooms, shops, hoists, pits, and locker rooms add to the complexity and to the average costs.

Main shops (main maintenance facilities) have higher unit area costs than other regular maintenance structures (except for service areas). This is due to the added complexities of special shop provisions necessary for unit rebuild, body repair, and painting capabilities. Administrative office and transportation department space is often as expensive or more expensive (unit area cost) than main shop space.

Servicing facilities have the highest floor area costs (dollars/sq. ft.) of any type of maintenance facility. This is primarily because in a relatively small area a great deal of special equipment must be provided. Equipment costs in servicing facilities include fuel pumps; fuel meters; oil dispensers; fare removal equipment and provisions; underground fuel, oil, and coolant storage tanks; bus washers; and large internal vacuum cleaning systems. These high equipment costs inflate the floor area costs.

EXHIBIT 9-5

SERVICING FACILITIES

DESCRIPTION	COST IN MILLIONS	AREA (Sq. Ft.)	UNIT AREA COST ($/Sq. Ft.)		MAR 75 COST/LANE
			AS BUILT	MAR 75	
BALTIMORE, MD	1.75	22,000		80	440,000
Bush Facility 300 Buses 4 Lanes Brick and Block Under Construction					
ROCHESTER, NY	0.79	11,300	70	73	274,000
Main Shop 276 Buses 3 Lanes (1 Washer) Brick and Block Date 8/74 (Bid)					
MPLS/ST. PAUL, MN	0.92	16,700		52	459,000
South 300 Buses 2 Lanes Brick and Block Date Proposed 3/75					

Floor area cost ranges for the various parts of a total facility are displayed in Exhibit 9-6. All cost data are for recently constructed facilities and have been converted to a 1975 base for uniformity. These ranges are representative of the functions and costs, even though it has not been possible to distinctly identify all related aspects of the available data.

A selection of a planning value within a particular range will be influenced by factors described later. The inspection garage range, as presented, overlaps with inside storage. Each example of inspection garage data includes inside bus storage. An inspection garage construction project which does not include inside storage can be expected to have a higher unit area cost than is shown in the range of Exhibit 9-6. When planning an inspection garage without provision for inside bus storage, a unit area cost near or at the low end of the main shop scale should be used to eliminate the bias contained in these data.

Service center costs should be considered in terms of cost per service lane as well as floor area costs. Costs of enclosed service lanes range between $260,000 per lane to $460,000 per lane, where included equipment costs may range between $75,000 and $130,000 per lane. Equipment costs will vary due to desired capabilities such as bus washers and internal vacuum systems. Equipment costs can range widely depending on capability and vendor. For example, a bus washer (4 brush) may be procured for as low as $25,000 or as much as $55,000 depending upon features and vendor.

Many properties have only a single facility containing all maintenance functions. In this case, it would be prudent to use unit area costs for segments of the planned structure. Repair facility area costs should be estimated from the low end of the main shop range; service lane costs can be estimated by cost per lane and checked against unit area costs; and inside bus storage estimated as needed.

Type of Construction. Type of construction also will influence the project cost. Examples of this are shown in Exhibit 9-7. Wall materials are considered in terms of wall area rather than floor area. Wall area costs are the least for metal buildings and the highest for prestressed concrete sections. Wall area costs are sensitive to both materials and labor costs. Metal buildings are essentially prefabricated and erected rapidly on site. Block and brick buildings require a high level of masonry labor. Cast-in-place concrete may be more expensive than other methods of concrete construction because of the cost of building and removing casting forms. However, cast-at-the-site tilt-up concrete panels are less expensive because casting forms are simple, and the process has elements of mass production repetitiveness which keep costs down.

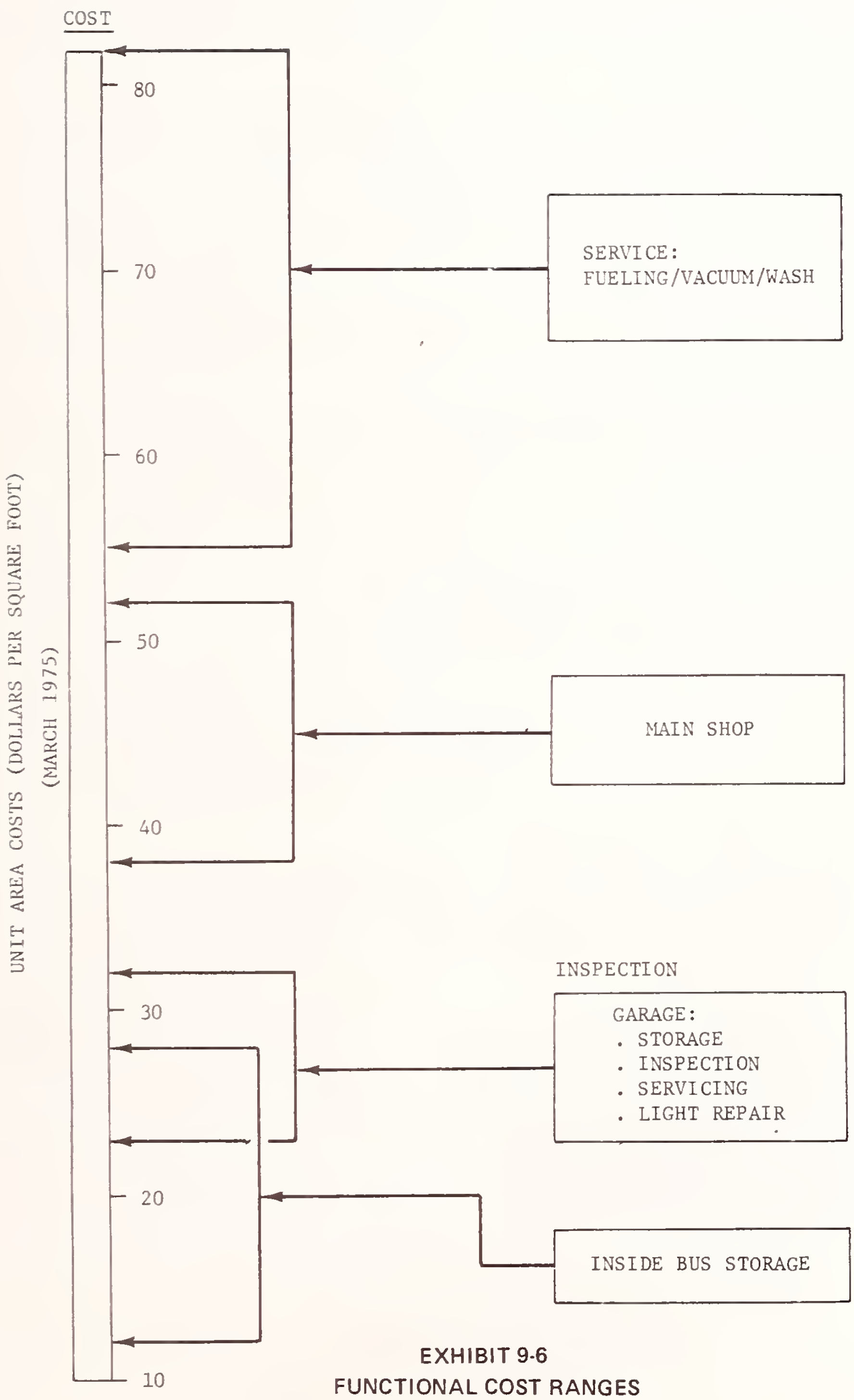


EXHIBIT 9-6
FUNCTIONAL COST RANGES

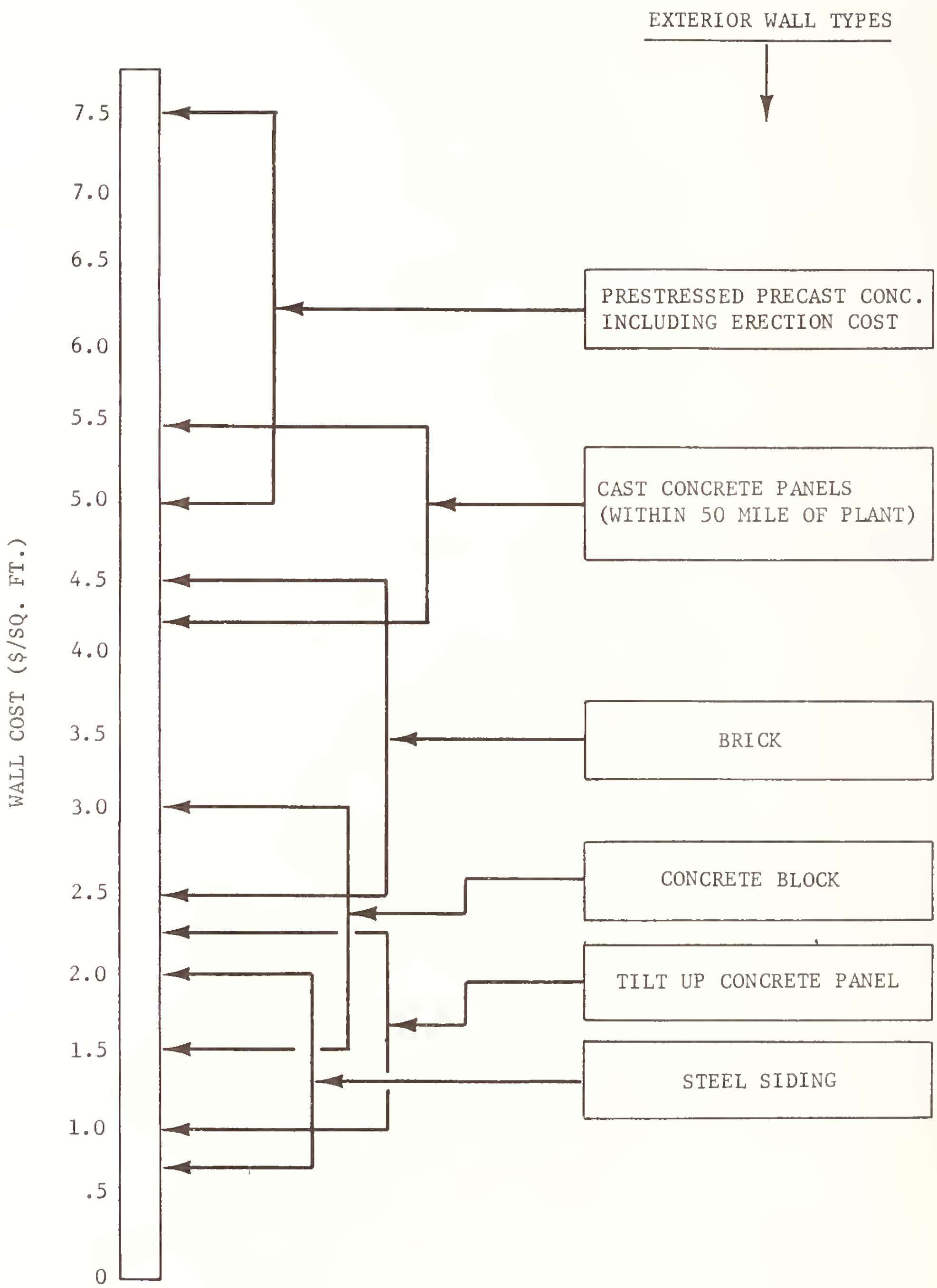


EXHIBIT 9-7
MATERIALS COMPARISONS

Exterior appearance may add to wall costs. Concrete block may be used as the basic wall, for example, but the addition of brick facing will increase that cost.

Building structure is another cost item. For maintenance facilities, the roof and ceiling supports may make a significant cost influence. Short roof spans, although apparently economical, may require supporting columns at inconvenient locations. Costs of longer roof spans and fewer supporting columns may be offset by improved bus maneuverability and a reduction of collisions with posts.

When developing the initial estimate, it is suggested that wall materials and structures be considered indirectly. For example, select a unit area cost factor for floor area from the low, middle, or high end of range, depending on objectives for overall exterior appearances. The project architect may assist in other trade-offs during detailed design.

Locality. Local conditions in the geographic area may influence the selection of construction type and will influence the end cost of the construction. All building materials are not uniformly available at economic prices in all areas. Sand aggregate concrete block may vary from 28¢ per block in Atlanta to 51¢ per block in Seattle. A metal building prefabricator may be convenient or some distance away. Labor rates for building trade skills vary. In general, construction costs are high in major metropolitan areas and high in coastal and northern regions.

Other local factors include climate and building codes. Climate may influence the selection of structure and materials. Building code requirements must be considered for the detailed estimate. Fire codes, for example, may dictate separate structures for bus storage and servicing facilities.

Inflation. Inflation may be the most important factor to include in the initial planning estimate. The true cost of a construction project will not be known until general contractor bids are reviewed. That data may be three or more years after an initial estimate is developed. The builder may experience cost increases that may be passed to the property for contracts having escallator clauses. The project may then exceed the planned budget, and a compensating cutback in capability could result.

A reasonable initial estimate can be developed for 1975 from floor space estimates and unit costs shown in this report. The inflationary factor can be introduced into the estimate as the final step.

Exhibit 9-8 illustrates the actual growth of the U.S. Department of Commerce composite cost index from 1967 through 1974. This growth increased from an annual rate of 6.4 percent to 13.6 percent over that period. Curves are plotted to assist in determining the effect of inflation in future time periods. Three different annual rates are plotted in terms of both the cost index and a cost multiplier.

The use of Exhibit 9-8 can best be made through a simplified numerical example. Assume that an initial estimate for a new facility is $2.2 million (1975 dollars). Additional planning must be done, an architect must produce a detailed design, and funding sources must be identified. Perhaps the earliest predictable date for general contractor bidding is mid-1978. The transit financial officer may suggest using an annualized cost index growth rate of 9 percent. From Exhibit 9-8, the cost multiplier of about 1.35 is determined for the 9 percent rate in mid-1978. The planning estimate becomes $2.97 million ($2.2 million x 1.35).

It is best to maintain the initial planning estimate in 1975 dollars separately from the effects of inflation. The initial estimate will require revision as the project progresses and if the anticipated bid date is changed.

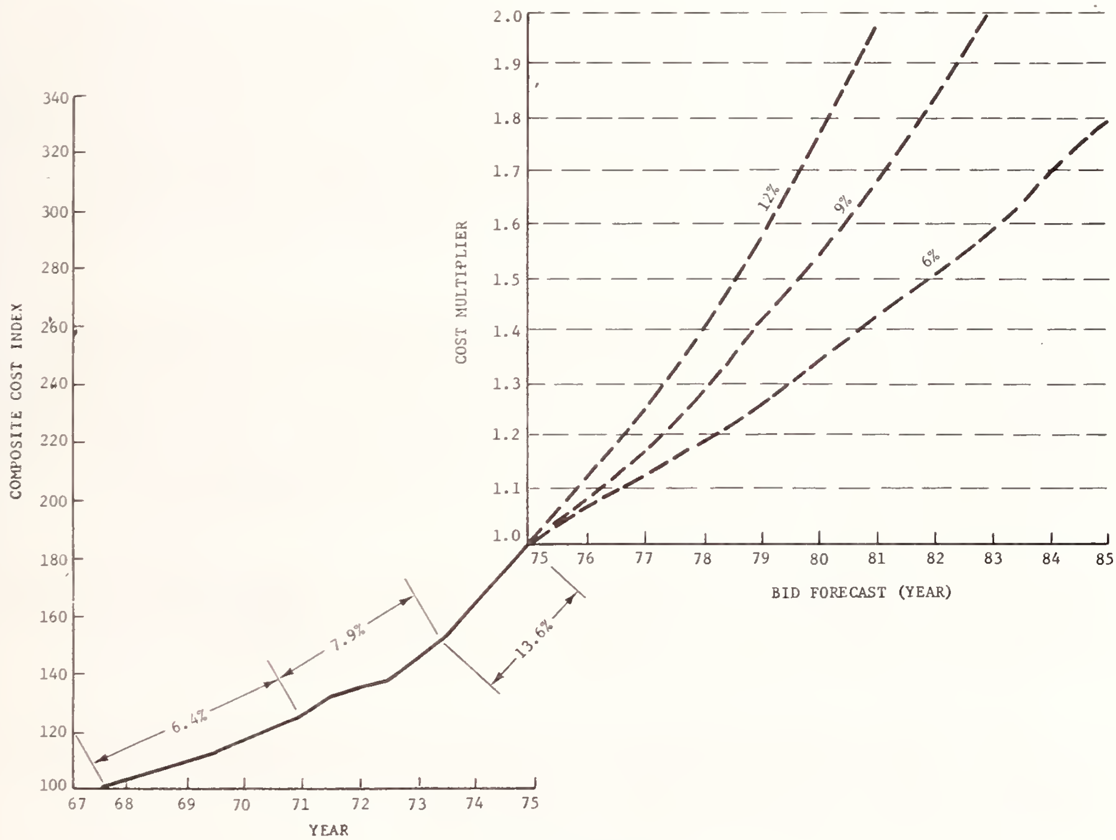


EXHIBIT 9-8
INFLATION PLANNING

9.3 Equipment Costs

The cost of equipping a new facility can be a substantial share of the facility cost, and the proportion depends on the type of facility being considered. Equipment may be considered in one of two categories: built-in or movable (not necessarily portable). If equipment must be built into the facility, the cost of the equipment is generally included with the building cost.

Service facilities generally have the highest cost per square foot because of the cost to procure and install much equipment that must be built into the facility at the time of construction. Examples of this equipment are: fuel pumps, fuel meters, fuel and oil storage tanks, bus washers, large vacuum cleaning systems, and heating and ventilation systems (if the climate requires them). Procuring and installing these items is usually the responsibility of the general contractor.

Main maintenance and inspection facilities have, respectively, lower costs per square foot because the requirements for built-in equipment are lower. Both main shops and inspection garages require hoists and/or pits, heating and ventilating equipment, and dispensing systems for lubricants, coolant, and compressed air. All of the foregoing must be built into the facility at the time of construction and are usually the responsibility of the general contractor.

Movable equipment is used in main maintenance and inspection facilities. Equipment in this category includes lathes, drill presses, presses, jack stands, and sheet metal tools. In many cases, equipment of this nature may be salvaged from old facilities.

There are a multitude of vendors for most every equipment item used in bus maintenance facilities, as well as a multitude of potential equipment items. A wide variety of prices may be expected for most items depending upon vendors and competition.

Exhibit 9-9 gives an example of some major items as of August 1975. Wherever possible, price ranges are given. (In some cases only a single price example was found.) Specific equipment requirements may produce prices somewhat removed from these examples.

EXHIBIT 9-9

EQUIPMENT COSTS

	LOW	SINGLE	HIGH
SERVICE LANE EQUIPMENT			
Bus Washer (2-brush)	$18,000		$30,000
Bus Washer (4-brush)	25,000		55,000
Roof Brush		$ 6,500	
Interior Vacuum System	15,000		30,000
Wheel Washer (4-brush)	13,000		17,000
Air Dryer/Water Stripper		18,000	
Fuel Tanks (12,000 gal.)	3,000		5,000
SHOP EQUIPMENT			
Air Compressor			13,000
Lift (twin post)	3,000		9,000
Lift (Paint Platform)	25,000		59,000
Portable Lifts (4 with controls)		16,000	
Jib Crane	600		1,000
Press (50-Ton)		2,000	
Brake Drum Lathe	2,000		6,000
Paint Booth (Drive-through)	6,000		14,000

SOURCE: Vendor budgetary estimates, August 1975.

9.4 Summary

An initial estimate may be prepared for budget and management review from data presented in this section. Floor space is multiplied by a unit area cost related to the building function. Allowances for the time lapse between planning and bid can be made by the inclusion of the cost multiplier to integrate inflationary effects.

A refined estimate will be prepared with the assistance of an architect during and at the conclusion of the detailed design. The refined estimate will include effects of construction type, variances in local construction costs, local building codes, and, of course, equipment. The final cost will be determined at the opening of construction bids, unless the contract includes escalator clauses.

10.0 ADDITIONAL CONSIDERATIONS

Most of the subjects in this section apply to main maintenance, inspection garages, and single facilities. These and other subjects of general interest did not meld into previous discussions naturally and are thus grouped together here to avoid redundancy. Of particular importance is the discussion of occupational safety and health.

10.1 Shop Environment

Heating. A popular shop heating arrangement has the heat source located at a sufficient elevation to provide bus clearance. Several types of local space heaters can be found; they include gas fired radiant, electrical radiant, and individual gas furnaces with blade fan air circulators. Gas fired radiant heaters appear to be effective but may not be acceptable under certain local codes, since they are not vented. Local heaters have the advantage of simple installation, particularly where storage, maintenance, or service areas are detached from other buildings.

Central heating systems are also used. Some forced air systems are combined with the shop ventilation system to heat make-up air. Central boilers are used with local and regional heat exchangers of either the forced air or convection type. Central heating plants have the advantage of providing heating capabilities for maintenance, transportation, and administrative space in an integrated facility.

Air Conditioning. Air conditioning of offices and restrooms is quite common in warm climates. Air conditioning of maintenance shops is found only infrequently. One reason for this is the added burden of cooling large areas with a relatively low human occupancy rate. Another factor is the air circulation requirements necessary in shops and the resultant air conditioning load for make-up air. One shop was found which was air conditioned. In this shop, an evaporative cooler was integral with a high-volume fresh-air ventilation system. Evaporative coolers work well in arid climates and are inexpensive to operate; however, they are not effective in humid climates.

Insulation. Specific provisions for insulation of maintenance and storage facilities, other than in all metal buildings, are not commonly made. During these energy-conscious days, consideration of insulation during facility planning is prudent and may reduce future operating costs.

A measure of a building's insulating properties is a "U" factor, which can be associated with different construction methods. The National Forest Products Association suggests that a residence should have a U factor of 0.07 for all weather comfort. By comparison, 12-inch cinder block walls (a common garage wall material) has a U factor rating of 0.35, or is five times less effective than the all-weather standard. Filling the cinder block cores with insulating material reduces the U factor to 0.20, or about three times less effective than the all-weather standard.

The project architect should be required to investigate methods of insulation for new maintenance facilities. Slight additional investment costs can be returned in only a few years of reduced heating bills. Insulated buildings will also improve summertime comfort, even without refrigerative air conditioning.

Air Movement. An adequate ventilation system is needed for comfort and to reduce concentrations of fumes, toxic chemicals, and nuisance dust. Proper ventilation includes an exchange of air from the outside, and internal air motion within the shop. Generally, stale air near ceilings is mechanically exhausted to the outside. The climate conditioning of make-up air must be considered along with the induced circulation patterns.

Air should be exhausted to the outside from particular areas where there may be concentrations of toxic materials. Examples of candidate areas are chemical cleaning vats, paint booths, and engine run areas.

A wise practice is to provide exhaust air sleeves which fit over bus engine exhaust pipes during periods of engine operation. Exhaust air sleeves may be installed in compartments in the shop floor or may be dropped from an overhead system. Overhead systems have the advantage of being easily connected to exhaust pipes near the roof line of EIP equipped vehicles, as well as to street level exhaust systems.

Floor Drains. All shops should have an adequate floor drain system for direct removal of water and liquids from the shop. A good floor drain system eases floor cleaning and slick floor problems. Buses may bring in large quantities of dripping water from washers or rainstorms. Snow and ice can become packed on the underside of a bus and can cause minor flooding as it melts in the heated garage. This seemingly trivial subject was mentioned as being a deficiency of present facilities (even new ones) by several maintenance managers. Local codes may require oil and grease traps in the garage drainage system.

Emergency Power. Certain operations must continue even during periods of power failures. Dispatching and servicing are two such operations. Urban transit is expected to continue operation under all conditions. For these reasons, many properties install an emergency power generation capability.

Emergency plants may be either gasoline, gas, or diesel powered. Natural gas and diesel are preferred for reliability reasons and even they should be operated periodically to retain reliable starting.

At a minimun, the emergency power should have the capacity to power bus servicing, storage illumination, and dispatching for the transportation department. Some properties go further and provide a capability to retain full power to the facility in the event of commercial power failure.

Automatic controls are available which will start a motor generator and switch the supply lines when commercial power does fail.

Personnel Facilities. Personnel facilities planning should not be overlooked in new design projects. These include lockers, restrooms, and lunchrooms. Lunchrooms are often provided, since short lunch periods and garage location often prevent the employees from eating at commercial establishments. A separate lunchroom should provide a pleasant atmosphere, vending machines for drinks and candy, and a clean and sanitary environment.

Employment of women in maintenance departments is becoming common. Women trainees are working at some larger properties in main shops and inspection garages. This practice can be expected to become more prevalent in the future and possibly extend to servicing operations. It is much simpler and less expensive to include separate locker and restroom facilities in the initial design of a new building rather than to install them later.

Locker facilities for clothes changing and storage of lunch boxes should be adequate. It is the space around the lockers used for changing of clothes that is critical: it should be spacious enough to accommodate all workers of a shift at the same time.

10.2 Outside Support

Maintenance facilities do not necessarily have to be designed to provide capabilities for all aspects of bus repair. Contract shops or vendors may be used for some types of repair work. Requirements for special equipment and skills may thereby be reduced. In many cases, vendor support may be obtained at a cheaper cost than in-house repairs

The survey suggests that contract shops are used very little in bus maintenance work. However, smaller properties appear more dependent on vendor support than do large properties. The major manpower expenditure of both large and small properties is devoted to the preventive maintenance program, fault correction, servicing, and cleaning. Component rebuild work is the prime candidate area for vendor support, as the component may be removed from the bus and sent out for repair. Special skills or equipment may be required for component rebuild.

Examples of component rebuild work available from vendors include: cylinder reboring, armature rewinding, radio repair, crankshaft turning, engine rebuilding, bumper replating, radiator repair, fuel injector rebuild, battery rebuilding, and X-ray fault location.

Small properties use vendors to avoid the capital expense of providing space and equipment. Even if the equipment were available, a small property would be required to retain highly skilled technicians for occasional tasks. Larger properties have sufficiently large volumes of rebuilds to justify the retention of the capability.

Maintenance contracts are often obtained for "new technology" equipment such as two-way radios. After a period of time, the property may obtain the necessary skills and provide in-house maintenance even on these items.

Medium and large properties often are inclined toward in-house repairs wherever possible. This is due to desires for effective management control, perhaps influenced by past experience with unresponsive vendors.

There are very few examples available where in-house component rebuild programs have been replaced by vendor services. Work agreements often discourage pursuit of vendor services, even when cost effectiveness can be demonstrated. The trend toward vendor services may increase in the future. Experienced mechanics reach retirement and are difficult to replace. In some cases it may not be possible to obtain and retain a staff level sufficient to support both the preventive maintenance and component rebuild programs.

As maintenance costs continue to escalate, there may be more interest in obtaining component rebuild support through vendors. Canadian operators are studying maintenance budget reductions through vendor use or by the establishment of cooperative facilities.

One property visited during the study has found a vendor with an injector trade-in program. Used injectors are traded for new or rebuilt ones at less cost than repair by an in-house program. As a result, the injector repair room is unused even though the facility is new.

About 85 percent of the surveyed properties lease their tires. If the volume of work is sufficiently high, tire company employees work at the transit property to fulfill the tire maintenance leasing agreement. This illustrates the necessity to provide facilities for a maintenance function irrespective of whether the work is to be done by transit employees or outside vendors. It is possible that this principle might be extended to other components, that is, provide the facilities to be used by outside vendors and thereby eliminate the need to transport materials.

10.3 Shop Facilities

10.3.1 Pits and Hoists

One decision that must be reached in planning for new facilities is the selection of types and numbers of pits, hoists, or combinations. Pits or hoists provide bus underside access needed for inspections, inspection repairs, and many heavy maintenance functions. The number of bus stalls (many with pits or hoists) needed for particular fleet sizes is discussed in Sections 3.0, 6.0, and 7.0. The following discussion describes the merits and limitations of pits and hoists, to assist in selecting one over the other.

Pit Designs. Trolley cars were heavy and cumbersome to lift for inspections. Underside access was provided by excavation of an area between the rails, which allowed the repairman to work under a car in a standing position. As buses replaced trolleys, these same facilities were used for buses. Some pit facilities have been constructed specifically for bus maintenance and many variations can be found in design, layout, and capabilities.

Several pit designs are shown in Exhibit 10-1. These are illustrative of capabilities that can be provided but are not inclusive. Illustrations (a), (b), and (c) of Exhibit 10-1 show variations of vertical profiles that may be found. Pits are generally about 54 inches in depth. A simple pit, Exhibit 10-1(a), is of a uniform width throughout its depth and is useful for certain functions such as brake adjustments. A wide pit, Exhibit 10-1(b), has expanded working area below the garage floor to provide additional clearance for lights, tools, etc. Another variation, a raised garage floor, can be constructed above the pit floor level to provide a wider working area and passageways between adjacent pits.

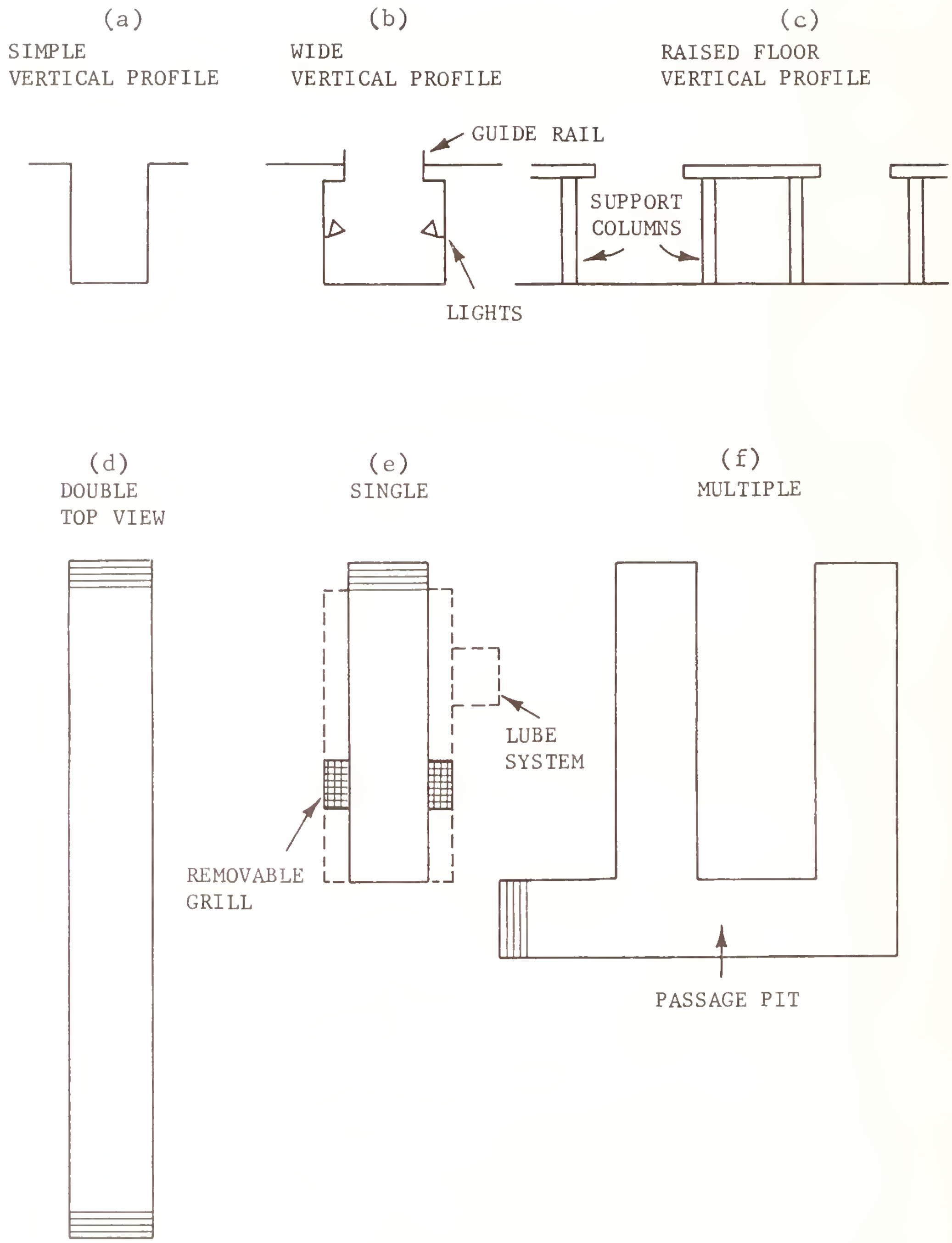


EXHIBIT 10-1
PIT DESIGNS

Illustrations (d), (e), and (f) of Exhibit 10-1 show top view variations of pit designs. The double length pit, Exhibit 10-1(d), has stairwells at both ends and will accommodate two buses at one time. A removable or permanent cover may be used between the buses to provide a garage level walking surface. The single pit, Exhibit 10-1(e), illustrates the wide pit and other useful features. In one area the pit is unusually wide to provide for air, water, coolant, and pressure lubrication reels. The garage floor may have grills which are removable after the bus is in position to provide access to pancake engines or the heater boxes. The ultimate in flexibility is a wide pit having a series of removable grills for the entire length of the pit. Adjacent pits may be constructed with connecting passage pits so that a mechanic may move from one pit to another without the use of stairways, as shown in Exhibit 10-1(f). The passage pit area may also provide space for convenient storage of tools and workbenches.

All pits should have good illumination and ventilation systems. Stairways are needed for access. Pits should be designed with the safety features required under the Occupational Safety and Health Standards.

Lift (Hoist) Types. Hydraulic technology has provided another method of underside bus access. Posts rise out of the garage floor under hydraulic pressure to engage wheels or axles and lift or hoist a bus to an appropriate height. Most lifts use two posts, one to raise the front axle and one to raise the rear axle.

Exhibit 10-2 shows a typical two-post hoist. One post is permanently positioned for the rear axle. Tire detents are often built into the floor to correctly align the rear axle over the rear post. The front post is positioned in a floor cavity in a manner that allows adjustment to bus wheelbase for either 35 or 40 foot bus models. These posts will raise to maximum heights of 60 or 70 inches above the floor level. A bus may be positioned to any desired working height, which can be beneficial for tire, brake, or engine work. Hoists may be obtained with maximum vertical travel of 24 inches or so for tire and brake work only.

Another type of hoist features wheel ramps and raises the bus by lifting the wheel rather than the undercarriage. Exhibit 10-3 is a two-view illustration of such a hoist. The rear wheels of the bus are positioned in the rear wheel detent, which prevents any tendency to roll forward. Wheel ramps on the front post are sufficiently long to accommodate different wheelbase lengths, eliminating the need to reposition the posts.

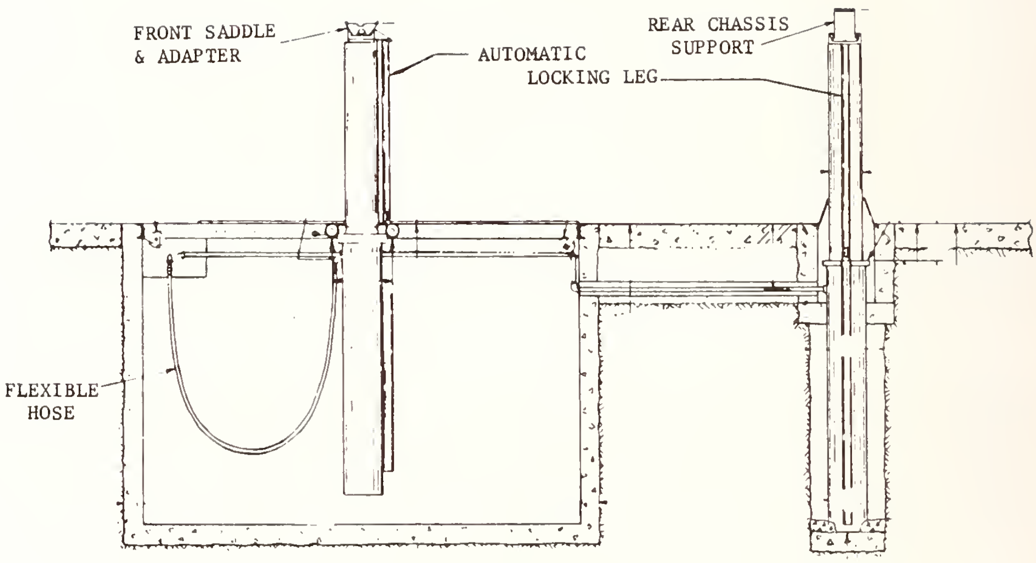


EXHIBIT 10-2
TWO POST HOIST

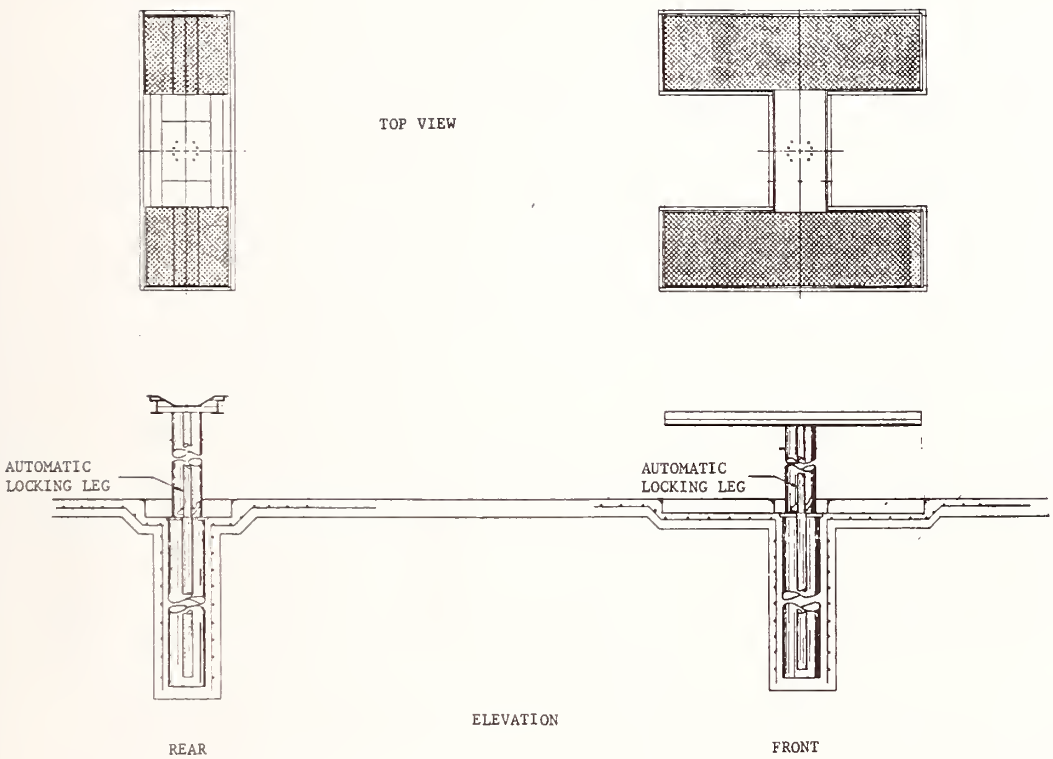


EXHIBIT 10-3
TWO POST WHEEL RAMP HOIST

An innovative but expensive lift uses both wheel ramps and a platform, as shown in Exhibit 10-4. The wheel ramps are full length for a bus and will handle various wheelbases. Each wheel ramp is raised with a short travel screw jack. The center area is a hydraulically operated platform which lowers into a pit to provide the necessary working height under a bus.

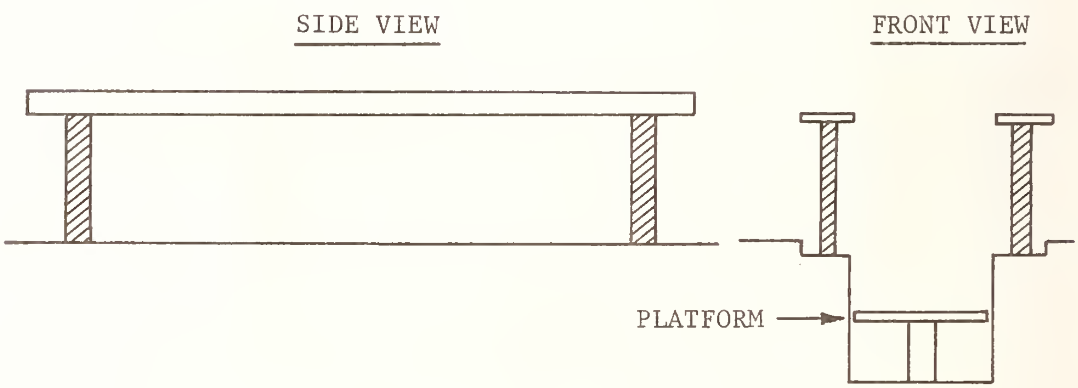


EXHIBIT 10-4
WHEEL RAMP LIFT AND PLATFORM

Comparisons. Maintenance managers often have positive preferences for either pits or hoists. These strong preferences usually stem from either favorable or unfavorable past work experiences. A consensus is not possible. Therefore, this discussion presents the merits and limitations of both alternatives as gathered during the study and survey.

Hoists expose most of the bus undercarriage so that special provisions for heater boxes and pancake engines are unnecessary. A hoist may be elevated to the most convenient height for the work being performed. A partial elevation provides for easy wheel or brake work and may eliminate awkward positions for engine work. A continuous floor level without pits facilitiates cleaning and the movement of heavy components. Access to work benches, tools, and replacement parts may be obtained without climbing in and out of pits. Supervision is improved. Workers are exposed to visual surveillance, and it is convenient for supervisors to offer helpful tips and maintain quality control.

Hoists do have some limitations. A hoist extended to full height puts the interior and side panels out of reach. Positioning a bus over the hoist, raising the bus, and lowering the bus extends job time on short duration jobs. The lift mechanism requires some maintenance. Electrolytic action of some soils may cause hydraulic leaks unless protected during installation. Some supplementary illumination may be required (such as drop lamps). Ceiling clearance is often a limitation in hoisting double-deck buses.

Merits of pits are readily apparent and easily stated. A bus can be positioned over a pit quite rapidly, improving the efficiency of operation for short repair tasks. There are no moving parts to keep in repair. Normal pit lighting fixtures provide good underside illumination. Side panels and bus interiors are accessable along with the undercarriage so that several repairs may be made while the bus is in the garage and in one location.

Pits are more difficult to clean and keep orderly than hoists. Lube systems, oil drains, and tool storage are more difficult to provide. Repeated step climbing is time-consuming and tiring for personnel. Removable grills may be needed to allow for the maintenance of components that overhang the garage floor. Wheel and brake work require some sort of jack to raise the bus. The most serious limitation of pits may involve safety considerations imposed by the Federal Occupational and Safety Standards. Briefly, when pits are not in use they must be covered or protected by guard railings. Pit preparation may then require as much or more time than bus positioning on hoists.

Some sources feel that hoists have a cost advantage over pits. With the new Occupational Safety and Health Administration (OSHA) standards, hoists may actually be cost competitive with pits at the time of installation. Working conditions and supervisory aspects of a shop equipped with hoists may offer long-term efficiencies that can favorably affect the operational budget. Many of these aspects are difficult to quantify, but a qualified architectural firm can assist in this evaluation during the detailed planning for new maintenance facilities.

Inherent in the survey responses and discussions with maintenance managers are suggestions that the best decision could be a mixture of pits and hoists for a new facility. For articulated coaches, a long pit has advantages in view of the difficulty of positioning the bus correctly over a three-post hoist. Pits are also useful when working on double-deck buses in areas with ceiling restrictions. Pits can be effective for short repetitive jobs such as brake adjustments, particularly for those properties who schedule brake adjustments at specific times once or twice weekly. Elsewhere, a hoist may be the best selection for the majority of inspection and repair functions.

10.3.2 Materials Storage

Parts and supplies must be conveniently available for an effective maintenance operation, and provisions for their storage should be carefully integrated into a facility design. Questionnaire data on current stockroom sizes are provided in Section 6. Materials storage requirements encompass much more than the stockroom, and these broader aspects are presented here. Three types of materials storage areas are discussed: the stockroom, the shop area storage, and the hazardous materials storage.

The stockroom is where controlled inventory items are kept. It is generally a restricted area staffed by stores personnel. Control of stockroom materials is exercised so that the issues may be correctly charged to appropriate accounts. Resupply may be done in an orderly manner, and pilferage is discouraged. A central location for the stockroom minimizes the time it takes repairmen to obtain replacement parts. The amount of stock maintained is dependent on the number of buses and possibly the number of different bus models owned.

Reported stockroom sizes did not correlate with the number of bus models at the various properties. In fact, correlations of stockroom sizes with property sizes were only remote. There are many reasons for this.

Maintenance facilities, for the most part, were designed many years ago for situations and budgets prevailing at the time. The current fleet size and mix is handled, one way or another, in existing facilities. Existing floor space is used more effectively in some stockrooms than others. Six-foot high shelving allows more storage per square foot than benches and may be necessary in limited quarters, even though stock functions may be better served with bench or countertop storage.

Intuitively, stockroom requirements should be greater for a mixed fleet than for a uniform fleet. However, it may not be as great a variance as one might think. Small parts and components are the normal bill of fare of the stockroom, and many diesel bus models have numerous common components. Bulky items (usually body parts) are not as common between models and are often stored outside of the stockroom. As transit begins to use small Dial-A-Ride buses, European articulated coaches, and double-deck coaches, the need for enlarged stockroom facilities may become pressing. Unfortunately, the survey data do not provide a basis for offering mixed fleet guidelines.

Stockroom size data as reported do not relate well to the total requirement for materials storage. This was evident as MITRE visited a number of properties. Materials are stored all around shop areas by necessity and on a space-available basis. Bulky items used for body repair may be found in body shop areas. Components awaiting rebuild, or those recently rebuilt, are stored on shop floors, under benches, or in shop cabinets. Tires are stored in or around the tire shop. Spare engines may be tucked into a corner or an unused bus bay. Brake drums may be stacked on the floor in the brake shop. Glass may be stored in cartons in or around the glass shop. Bulk vinyl may be held in a roller rack in the upholstery shop.

Shop area storage of bulky items is effective. Materials are where they are needed and the small parts stockroom retains organization for efficiency. Nonetheless, facility design should include adequate, organized, planned space for shop storage. Without planning and proper allowances, components and bulky items will be stored in rather surprising places. Random storage may clutter passageways (frowned upon in OSHA standards) and may inhibit efficient repair operations.

Small, frequently used items such as screws and bolts are often considered as free stores items. Free stores may be located in small bin racks at several convenient places throughout the shop to improve operations.

Hazardous materials, including paints, solvents, and chemicals, should be stored separately. Local fire codes often require special storage conditions for hazardous and toxic materials. Local building codes should be investigated and their requirements should be incorporated into facility design.

Adequate, well-planned storage should be provided in new facilities. Materials should be controllable, convenient to those who use them, and out of the way of normal movement and traffic patterns. A central stockroom with multiple windows can be used effectively to reduce time required for repairmen to obtain needed materials.

10.3.3 Painting Facilities

There are several options available to provide painting capabilities. Open air spray painting can produce undesirable results because dust may settle on fresh paint; paint spray may be deposited on nearby equipment; and paint spray may contaminate the air. An enclosed facility which can provide a controlled environment is frequently used for exterior bus painting. Three examples are the paint booth, the paint booth with variable floor, and the traveling paint booth.

Paint Booth. A controlled atmosphere is provided for painting buses. Air entering the paint booth is filtered to eliminate dust particles, and paint-laden air is filtered (via a waterfall) for paint removal in the power exhaust process. The paint booth may also have a catwalk on both sides of the bus to provide a stable platform when painting the roof and top side (Exhibit 10-5). Painting is done with a manual spray gun.

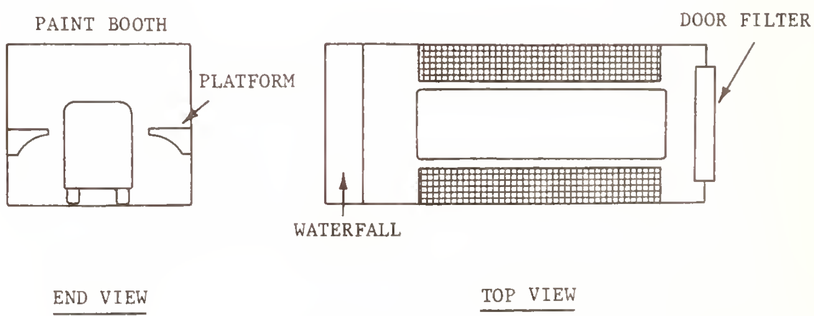


EXHIBIT 10-5
PAINT BOOTH

Paint Booth with Variable Floor. Access to the roof and the top side of a bus is obtained by a recessing elevator floor which allows lowering the entire bus for an effective work area. Hydraulic hoist mechanisms are used for elevator floor movement, as shown in Exhibit 10-6.

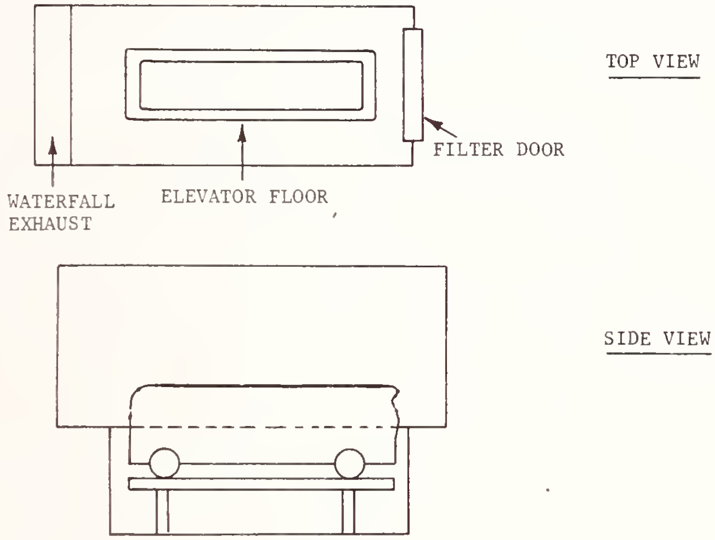


EXHIBIT 10-6
VARIABLE FLOOR PAINT BOOTH

Traveling Paint Booth. This is a device that can travel the length of a bus on rails. Paint spray nozzles are positioned so that a uniform paint thickness is obtained at all levels of painting. Air exhaust ducts are located, as shown in Exhibit 10-7, at the top of the device to evacuate paint fumes and paint-laden air. This is a particularly useful device in those cases where the same paint color is to cover large areas of the bus; however, exhaust filtering is

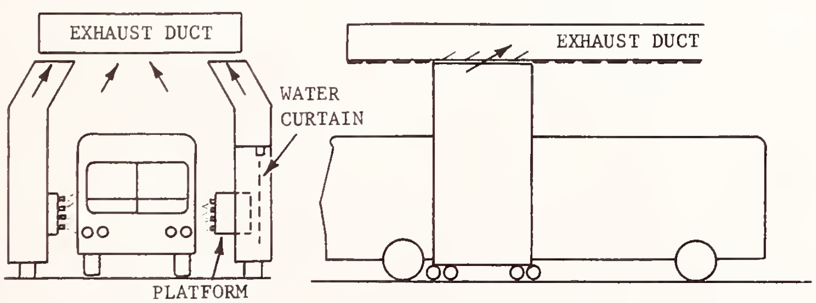


EXHIBIT 10-7
TRAVELING PAINT BOOTH

inferior to the more conventional paint booth, unless it is equipped with an internal recirculating water curtain to catch extraneous paint spray. Most of the models available today are equipped with a painter's platform that may be elevated or lowered as the booth moves. Three or four spray nozzles are usually mounted on each side of the painter's platform.

10.3.4 Air Conditioning Repair

The air conditioning compressor and evaporator coils are located on lower portions of the bus. The condenser coil and fan (blower) are located on the rear bus roof. Repair access to the condenser unit is awkward. Several transit properties have installed a special platform that provides a stable platform at a convenient working height. The platform floor is constructed of metal grillwork with protective railings. Some areas are provided with removable railings to expose the rear bus roofline. Either a fixed ladder or stairway is also provided. This air conditioning catwalk platform is installed at the rear of a back-in bus bay, as illustrated in Exhibit 10-8.

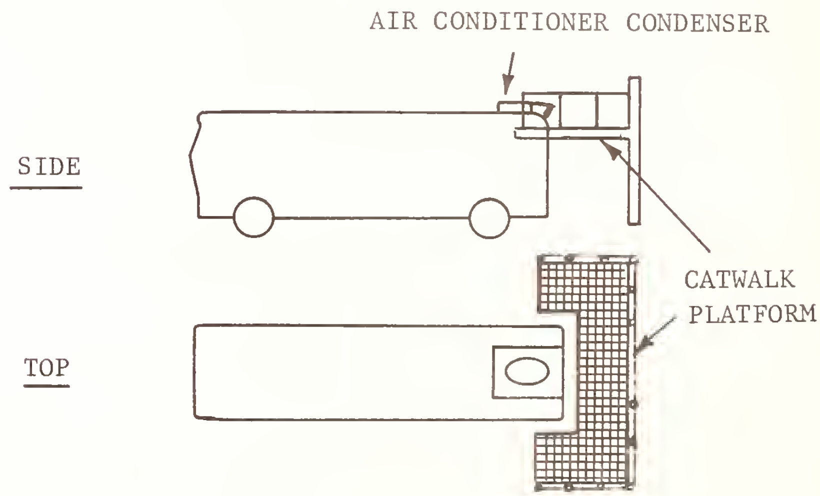


EXHIBIT 10-8
AIR CONDITIONER ACCESS PLATFORM

10.3.5 Dynamometers

These devices allow dynamic testing of vehicles in the shop. Few dynamometers are currently in use by urban transit. Some properties are planning to install them only at the main facility. One property is installing dynamometers at each inspection garage and is including a complete dynamometer test in their regular preventive maintenance program (at 25,000-mile intervals).

Twenty-three respondents indicated plans to obtain a dynamometer. Reasons offered for not considering dynamometers include: do not have the need, too costly, not necessary for diesels, and unreliable as diagnostic equipment.

Regardless of these opinions, however, it may be worthwhile to consider a dynamometer because the device can augment the skills of a limited number of highly trained mechanics.

10.3.6 Lubrication Systems

Lubricant dispensing systems are used throughout maintenance facilities. They improve efficiency and cleanliness around garage areas. Lubricant dispensing systems consist of pressure hoses which are retractable on enclosed reels. A reel unit contains several reels for several different lubricants.

Lubricants are piped to the reel units from supply tanks which may be either underground or above ground. Crankcase oil, chassis grease, differential grease, and torque fluid are the most common lubricants provided. The reel unit will often have a compressed air capability for tire inflation or pneumatic tools and a coolant or water hose.

One reel unit is often suspended above and between two bus stalls in main maintenance facilities or inspection garages equipped with hoists. Garages equipped with pits will have a few of the pits enlarged to house a reel unit, thereby providing lubricants at the most convenient location. Not all bus stalls are so equipped. Stalls used for inspection work and a select number of other stalls are equipped with these systems.

Similar systems will be installed in the service lanes, but configured differently. Crankcase oil and, optionally, torque fluid will be available at the rear of the bus when the bus is stopped at the fuel station. Water or a coolant mixture hose will be available at the left rear. Retractable hose reels are particularly important in service lanes to keep hoses out of the wheel paths.

10.4 Occupational Safety

The Williams-Steiger Occupational Safety and Health Act of 1970 provides for the establishment of safety standards which have implications for maintenance facility design. The Act established the Occupational Safety and Health Administration (OSHA) within the Department of Labor as the agent for establishment and enforcement of standards. The purpose of the law and the establismhment of OSHA is "... to assure so far as possible every working man and woman in the nation safe and healthful working conditions and to preserve our human resources."

General information about the Act, OSHA, and procedures is presented in this section. The Act does pertain directly to everyday working conditions and procedures. Therefore, a general description is provided here prior to discussion of relevant standards which may affect garage designs.

Roles of OSHA. The roles of OSHA are twofold: the establishment and publication of standards, and the enforcement of standards. All published standards are now in effect. Standards will be modified, revised, and increased in scope as situations and events warrant. The OSHA inspection and enforcement program provides a source of data that will be used for future revisions of standards. Another source of data will be provided by the National Institute for Occupational Safety and Health, Department of Health, Education and Welfare (HEW), which will conduct research and develop recommendations for occupational safety and health standards.

The OSHA enforcement program relies on inspections of work areas. Inspections are initiated by events such as accidents, complaints, and at random. Any work-related accident resulting in a catastrophe or fatality will be investigated. An investigation will be made as a result of an employee complaint. Random investigations are spread over different industries and in some cases are concentrated in troublesome target industries such as asbestos, construction, and excavation.

The Act assures OSHA investigators free access into places of employment and work. A violation found during an investigation may result in monetary penalties or criminal penalties including imprisonment. Employers who have been cited for violations may contest the proposed penalties.

OSHA does not approve places of employment, equipment, or work patterns. OSHA assists employers in the interpretation of standards. This assistance will be provided at a regional OSHA office, and copies of the Act and the Federal Register and other material are available through regional OSHA offices. If OSHA representatives are invited to an establishment, they will conduct an investigation--which suggests that assistance in standards interpretation should be obtained through a visit bv the employer to an OSHA office.

The Act encourages states to assume the fullest responsibility for the administration and enforcement of state safety and health programs. State agencies and courts may assert jurisdiction under state law over any issue for which no Federal standard is in effect.

If assistance is needed in properly formulating safety and health considerations in facility design, it is recommended that consultants be employed. Consultants may be found who are specialists in industrial hygiene and safety. Some organizations may have laboratories and testing facilities useful in determining air quality problems. The office at a state Department of Safety and Health may also be able to assist in an advisory capacity.

Role of Employer. The Williams-Steiger Occupational Safety and Health Act requires that the employer be responsible for the safety of his employees as follows:

> "SEC. 5. (a) Each employer--
>
> (1) shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or likely to cause death or serious physical harm to his employees;
>
> (2) shall comply with occupational safety and health standards promulgated under this Act.
>
> (b) Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his own actions and conduct."

The primary responsibility for providing safe and healthful working conditions resides with the employer. It would therefore be wise to study and consider existing standards in the design of new facilities. By doing so, costly and frustrating construction modifications may be avoided. The regional OSHA office may also be able to provide, for planning purposes, information on new or revised standards that can be expected in the near term.

The employer must also maintain accurate records (and periodic reports) of work-related deaths, injuries, and illnesses and make these records available to the Labor Secretary and to the HEW Secretary. Minor injuries requiring only first aid treatment need not be recorded. A record must be made if an injury or illness involves medical aid or transfer to another job. These recorded requirements should be fully understood by the employer. For example, first aid treatment performed by a doctor must be recorded. When in doubt, the event should be recorded, since the log entry may be lined out if the event is determined later to be irrelevant.

Standards. In many cases, the standards published in the Federal Register represent existing and accepted safe working practices. While it is the purpose of this section to identify certain procedures that are either not now generally practiced or should be specifically considered in the design of new facilities, this review is by no means fully comprehensive. It is therefore recommended that transit properties review the Federal Register, with respect to their practices or designs for new facilities.

General Shop Conditions. Part 1910.22 of the Occupational Safety and Health Standards codifies general working conditions which are quoted in part as follows:

> "Housekeeping. All places of employment, passageways, storerooms, and service rooms shall be kept clean and orderly and in a sanitary condition. The floor of every workroom shall be maintained in a clean and, so far as possible, a dry condition.
>
> Aisles and Passageways. Aisles and passageways shall be kept clear and in good repairs, with no obstructions across or in aisles that could create a hazard. Permanent aisles and passageways shall be appropriately marked.
>
> Covers and guardrails. Covers and/or guardrails shall be provided to protect personnel from the hazards of open pits, tanks, vats, ditches, etc."

Parts 1910.144 and 1910.145 provide specifications and colors for accident prevention signs and tags. These include fire protection, traffic ways, danger, toxic substances, radiation substances, and caution situations.

Air Quality. Part 1910.93 of the standards specifies maximum allowable air contamination levels for approximately 300 different toxic materials. These materials include solvents, cleaners, insecticides, metals, chemicals, and mineral dusts. For the most part, bus maintenance work involves little use of these toxic materials. Even when toxic materials are used, the large areas and ventilation systems of maintenance facilities would limit exposure and chemical concentrations in air samples.

However, adequate ventilation should be provided in any garage area where chemicals or solvents are used regularly. Machine shop cleaning vats are one such candidate. Another might be regular use of solvents and adhesives used in plastic work such as upholstry.

Part 1910.94 contains specific requirements for exhaust ventilation of grinding equipment of all sizes. These requirements specify ventilation hoods for all grinders, which includes occasional-use bench grinders found in most maintenance facilities. The OSHA staff advises that these standards are to be revised in the near future to accommodate occasional-use bench grinders in a more realistic manner. OSHA does advise that the air quality standards for inert or nuisance dust in and around grinders will apply (as given in Table 6-3, Part 1910.93 of the standards). These same nuisance dust standards would be applicable to the air quality in any areas where sanding or grinding was being done, such as body preparation for painting, etc.

Painting facilities are also discussed in the standards. Of concern is air quality surrounding painters, proper cleaning of exhausted air, and explosion proof electrical fixtures in a paint booth. Painting facilities will also be covered by local building and safety codes.

Asbestos is currently of particular concern to OSHA as a long-term health hazard. It remains as one of the primary materials in brake linings used in motor vehicles. Brake linings are commonly turned to size in bus maintenance facilities. As long as that process is a cutting operation no particular hazard is expected. However, if the treatment of brake lining material involves grinding, the production of dust may be a hazard. Part 1910.93a specifically defines asbestos, fiber lengths, permissible air quality, exhaust ventilation, clothing, and laundering requirements in conditions where there is an asbestos hazard. As brake linings wear, a dust of lining material and drum material is formed. This dust is commonly removed from brake assemblies inside a garage. OSHA advises that contemporary theories are that the asbestos in lining material changes its composition in the braking and wearing process to a less hazardous substance. However, chemical processes are imperfect, and some residual harmful asbestos may be expected to remain as dust. Therefore, this dust should be removed and cleaned with a vacuum system rather than by blowing the dust out of brake assemblies with an air hose.

Stairwells and Ladders

Maintenance facilities will include stairways, ladders, and platforms of various types. These may be permanent installations or movable. Parts 1910.24 through 1910.28 of the Standards cover most possible situations and should be reviewed with respect to new construction or existing facilities.

Floor Openings

Part 1910.23 specifically delineates protection that must be provided for floor openings. This is of particular concern in the case of maintenance facilities in which pits are used to provide underside access for bus repairs and preventive maintenance. The open pit presents a hazard. For the most part, the pit is covered and protected when occupied by a bus. There are many periods when this is not the case and pits are exposed.

Under all other situations the Standards require protection of an exposed pit. Two methods are recognized in the Standards. One is covering the pit when not in use. Pit covers may be heavy, large, and awkward to handle and may present hazards such as back strains, etc. while handling. The second method is to provide railings and toe boards capable of supporting 200 pounds. The following partial quotation delineates the requirements:

> "A standard railing shall consist of top rail, intermediate rail, posts, and shall have a vertical height of 42 inches nominal from upper surface of top rail to floor... The top rail shall be smooth-surfaced... The intermediate rail should be approximately halfway between the top rail and the floor...
>
> For wood railings the posts shall be of at least 2-inch by 4-inch stock spaced not to exceed 6 feet; the top and intermediate rails shall be of at least 2-inch by 4-inch stock. If the top rail is made of two right-angle pieces of 1-inch by 4-inch stock, posts may be spaced on 8-foot centers, with 2-inch by 4-inch intermediate rail.
>
> For pipe railings, posts and top and intermediate railings shall be at least 1½ inches nominal diameter with posts spaced not more than 8 feet on centers.

For structural steel railings; posts, top and intermediate rails shall be of 2-inch by 2-inch by 3/8 inch angles... with posts spaced not more than 8 feet on centers."

Service pits have stairwells or ladders to provide access. A separate stairwell is probably referred to in the Standard as a floor hole. Partial quotations from the Standard are:

"Every floor hole into which persons can accidently walk shall be guarded by either:

A standard railing..., or

A floor hole cover of standard strength and construction that should be hinged in place. While the cover is not in place, the floor hole shall be constantly attended by someone or shall be protected by a removable standard railing."

OSHA is undertaking a revision to these aspects of the Standard to accommodate service pits. This revision will allow the use of a chain to serve as a top rail and an intermediate rail. This revision will allow a chain to be considered as a smooth surface and provide for the catenary sag with relation to the 42-inch height. Even so, the requirement for posts at 8-foot intervals will probably remain. For a pit accommodating a 40-foot bus, this will require six or seven posts along one side.

As stated, these standards appear to impose obstacles to the effective use of pits for service functions. A challenge is certainly presented to the transit industry for the innovative design of pits and protective railings.

Summary

The Occupational Safety and Health Act establishes a program for the safety and protection of employees. The Occupational Safety and Health Administration has been established within the Department of Labor to set standards and enforce compliance. The National Institute of Occupational Safety and Health (NIOSH) has been established in the Department of Health, Education, and Welfare to conduct research and demonstrations related to development of standards recommendations. States have been encouraged to develop their own safety programs with Federal assistance.

The responsibility for providing a safe and healthful working environment resides with the employers. Even though there are many specifics set forth in the Standards, the employer must work out his own program which will be suitable for his unique operation. The general requirement of safe and healthy working conditions may demand as much ingenuity as meeting the documented specifications of the current Standard.

Transit managers would be well advised to visit a regional OSHA office and obtain copies of the Standards and reporting requirements, etc., and study the implications for his own operation. Two pamphlets are available from NIOSH which may be helpful.

The current standard will affect bus maintenance facilities most directly in providing service pit protection as described herein.

10.5 Occupational Safety References

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APPENDIX

PARTICIPATING PROPERTIES

State	Fleet Size
Arizona	
Phoenix Transit Corporation	110
Arkansas	
Central Arkansas Transit (Little Rock)	68
California	
Culver City Municipal Lines	24
Monterey Peninsula Transit	11
Golden Gate Transit	230
South Coast Area Transit (Ventura)	28
AC Transit (Oakland)	778
Long Beach Public Transportation Co.	122
Florida	
Central Pinellas Transit Authority (Clearwater)	21
Jacksonville Transportation Authority	205
Metropolitan Dade County Transit Agency (Miami)	452
Georgia	
MARTA (Atlanta)	715
Hawaii	
City & County of Honolulu Mass Transit Division	324
Illinois	
Champaign-Urbana Mass Transit District	25
Chicago Transit Authority	2417
Kansas	
Topeka Metropolitan Transit Authority	26
Wichita Metropolitan Transit Authority	46
Louisiana	
New Orleans Public Service, Inc.	465

PARTICIPATING PROPERTIES

State	Fleet Size
Massachusetts	
Massachusetts Bay Transportation Authority (Boston)	1198
Michigan	
City of Detroit, Department of Transportation	1002
Minnesota	
Metropolitan Transit Commission (Minneapolis-St. Paul)	864
Missouri	
City Utilities of Springfield, Mo.	67
Bi-State Transit System (St. Louis)	823
Nebraska	
Metro Area Transit (Omaha)	160
Nevada	
Las Vegas Transit System, Inc.	24
New Hampshire	
New Hampshire Transportation Authority	
New Mexico	
Albuquerque Transit System	67
New Jersey	
Transport of New Jersey	1852
New York	
Capital District Transportation Authority (Albany)	190
Regional Transit Service, Inc. (Rochester)	236
Broome County Transit (Binghamton)	31
NYCTA/MABSOA (New York)	4315
Niagara Frontier Transit Metro System Inc.	483
CNY Centro, Inc. (Syracuse)	170

PARTICIPATING PROPERTIES

State	Fleet Size
Ohio	
Queen City Metro (Cincinnati)	420
Cleveland Transit System	634
Central Ohio Transit Authority (COTA) (Columbus)	243
Maple Heights Transit	39
Oregon	
Tri-County Metropolitan Transportation District (Portland)	422
Pennsylvania	
Erie Metropolitan Transit Authority	60
Port Authority Transit (Pittsburgh)	918
Lehigh & Northampton Transportation Authority (Allentown)	66
Southeastern Pennsylvania Transportation Authority (Philadelphia)	1492
South Carolina	
Greenville City Coach Lines	41
Tennessee	
Chattanooga Area Regional Transportation Authority (Chattanooga)	85
Memphis Transit Authority	300
Texas	
Dallas Transit System	469
San Antonio Transit System	263
Texas Bus Lines (Galveston)	43
Rapid Transit Lines, Inc. (Houston)	376
Vermont	
Chittenden County Transit Authority (Burlington)	15
West Virginia	
Tri-State Transit Authority (Huntington)	34
Wisconsin	
Milwaukee & Suburban Transport Corporation	480

PARTICIPATING PROPERTIES

	Fleet Size
Canada	
Edmonton Transit System	402
Sandwich, Windsor & Amherstburg Railway Co. (Windsor)	95
Calgary Transit	360

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