Vehicle Maintenance: Cost Relationship and Estimating Methodology

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An investigation into maintenance costs and programs at transit properties throughout California is summarized. The objectives of the research were to study and report on maintenance cost information, and on the need for maintenance management support. The materials presented in this paper are intended to aid maintenance managers in planning, managing, and controlling maintenance costs and effectiveness. Cost relationships are presented for the estimation of maintenance costs by element and maintenance function area. Graphs are presented for estimating total maintenance cost dependent on fleet size and annual vehicle miles. Cost element contributions to total maintenance cost are identified for repair, inspection and servicing labor, fringe benefits, and overhead; maintenance administration, material, and supply cost rates are also provided.

Providers of public transportation are being challenged by high costs, dwindling sources of support funds, and pressures to improve services. To meet these challenges, managers must balance the need to take cost reduction measures against the need to provide adequate budgets for maintaining and extending revenue equipment life.

The direct impact of inadequate maintenance on vehicle life is well documented and well known to professionals. The importance of maintenance planning and cost control is not as well documented, but is equally critical to transportation managers. In the transit industry, maintenance costs

- Can account for more than 30 percent of total costs, if fully identified;
- Have increased 33 percent faster than vehicle operations costs in recent years;
- Have increased four times faster than general/administrative costs in the same period.

The industry has responded by concentrating management resources on maintenance costs and systems.

MAINTENANCE: A CRITICAL MANAGEMENT ISSUE

Managing Maintenance as a Cost Center

Many transportation providers focus on critical maintenance issues by managing the maintenance function as a cost center. This philosophy can be (and is) applied successfully by providers over the entire spectrum of operation sizes and service offerings. Small and large properties almost invariably treat maintenance as a cost center for the following reasons:

- The magnitude of maintenance costs demands direct control and scrutiny;
- The human, material, and facility resources applied to maintenance are usually unique to this function;
- Costs can be separately collected and tracked; and
- Performance measures that reflect maintenance effectiveness and efficiency can be established.

The share of maintenance costs as part of total costs is often more than managers realize or for which they can account. Some of the maintenance resources applied to small and medium-sized transit fleets may be shared or provided by other local government organizations. Because costs picked up by other entities are not always figured into the overall maintenance costs, the real cost of maintenance is often masked. Subcontracting some functions can also mask real costs, depending on the accounting methods used.

Maintenance resources and capabilities in small organizations are as specialized and unique as in large ones. In small properties, practicality often dictates that staff and management perform more functions than just maintenance. This requirement may place a larger number of training and learning requirements on the staff, but it should not prevent allocating time and cost to the proper cost center.

Critical to establishing and effectively managing a cost center is having the capability to measure and attribute performance to the center. Vehicle and equipment maintenance lends itself well to performance indicator monitoring that enables managers to monitor performance in particular areas by evaluating specific indicators in those areas.

By breaking down areas into indicators and calculating the effects of those indicators, the manager can make reliable cost estimates and develop effective budget guidelines. This cost center strategy facilitates managing maintenance processes and functions.

Structuring Maintenance Processes and Functions

In revenue vehicle maintenance, the processes and functions that must be performed are universal. The challenges in managing these functions involve properly balancing resources among the functions and avoiding the temptation and penalties of short-range thinking. The overall relationship between effective maintenance programs and successful delivery of transportation services is clear and strong, but the long-term effects of specific maintenance management deficiencies are not always obvious or immediate.

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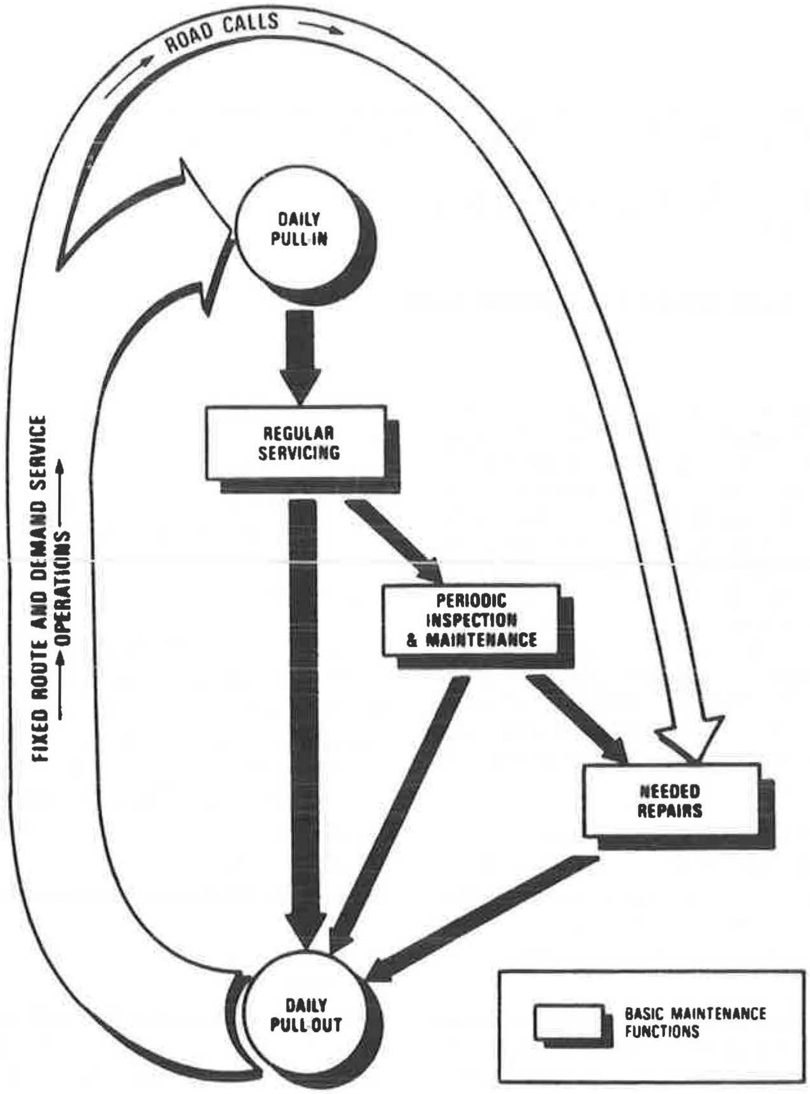


FIGURE 1 Relationship of basic maintenance functions.

Figure 1 shows the relationship of the three basic maintenance functions to overall transportation operations. Servicing, inspection and maintenance (I/M), and repair are functions that are indispensable to operations on a daily or periodic basis. How frequently repairs are needed is related largely to the effectiveness of the servicing and I/M programs. Failure to apply appropriate resources to any of the three basic functions has certain and predictable negative impacts on transportation services, or requires continuous, large investments in new equipment. For properties large or small,

- Too little service capacity limits daily vehicle availabilities—an immediate effect;
- Neglecting periodic I/M cuts vehicle life and availability and increases road calls—deferring but increasing expenditures; and
- Poor-quality or slow repair work increases road calls and can steadily reduce availability, slowing transit services.

Problems with vehicle life and availability rates directly translate into the need to expend scarce capital to replace or increase the size of the transit fleet. Road calls are, of course, a major transportation service quality issue.

Revenue for vehicle maintenance is either a cornerstone or a bottleneck. When managed well, it is important but is not noticed. Problems with maintenance are highly visible and have a deep impact on the transportation provider. Properly allocating resources to the basic maintenance functions is a matter of defining clearly the overall requirements and balancing the resources well. Put another way, there is little benefit to be derived from too much capability in any one functional area, but shortfalls can be punishing and can drive up costs.

Typical flow of work and of information in transit maintenance is shown in Figure 2. In this simplified diagram, the basic functional areas are shown as rectangles with flows of equipment, materials, and information indicated by appropriate arrows. Key, minute-to-minute decision points and management actions are shown as circles. In some way, all these actions and functions occur in even the smallest transit organizations. The features that tend to vary with the scope of transit operations are

- The degree to which responsibilities for more than one function are consolidated in individual managers; and
- The extent to which some or all of the functions are

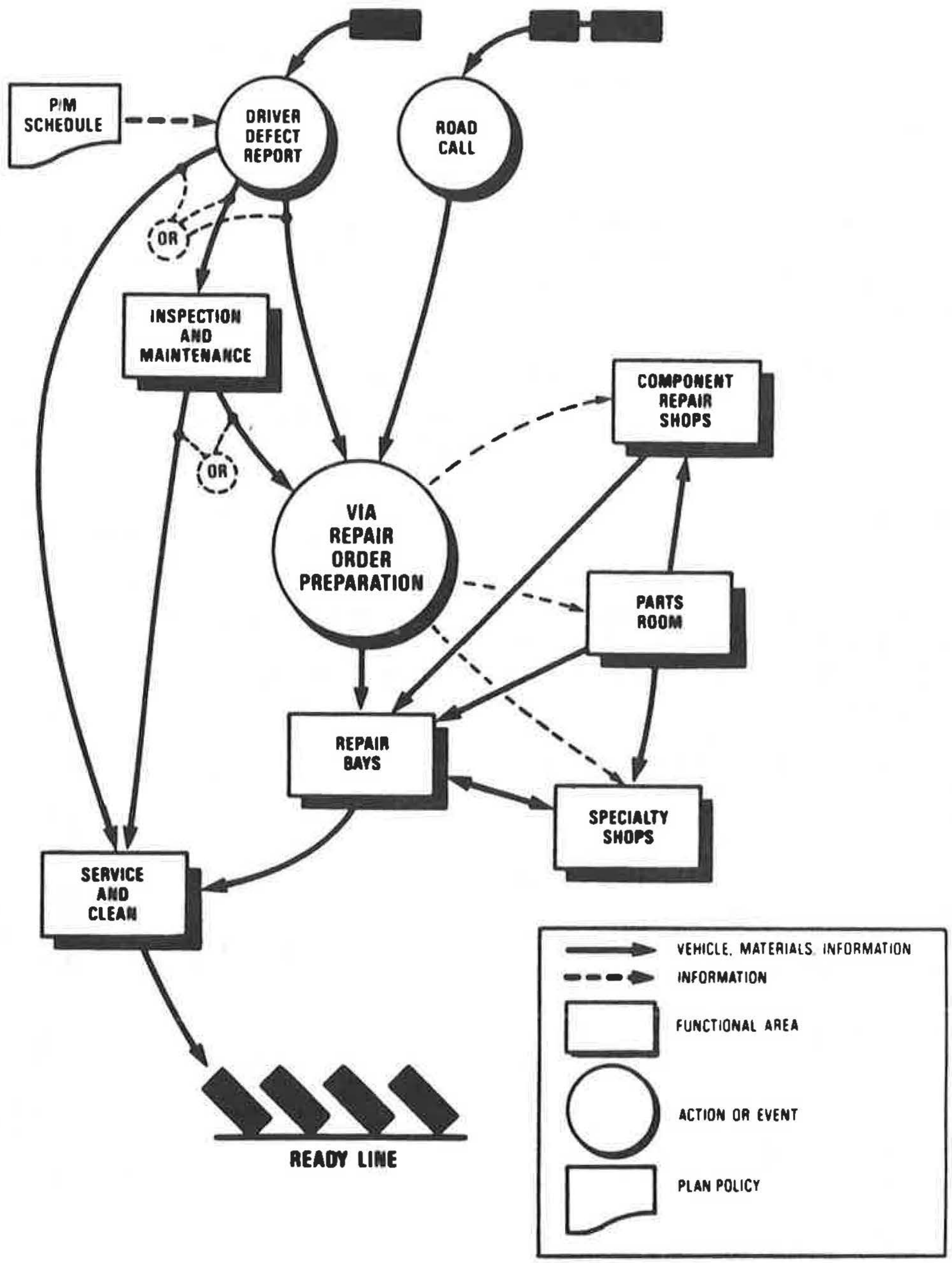


FIGURE 2 Typical work flow for maintenance functions.

contracted or performed outside the direct supervision of the transit provider.

As buses pull in after completing operations, one of three directions can be taken in the work flow, as follows:

- If a driver reports a defect needing immediate repair, the vehicle queues for repair by the preparation of a repair order;
- If the preventive maintenance plan or policy calls for I/M at the time, the vehicles is routed to the I/M function queue; and
- If neither of the preceding conditions holds, the vehicle is routed through the service-and-clean function.

Driver's defect reports, I/M, and road calls can all result in identification of a needed repair. In this case, a repair order is the key authorization and control document. Preparation of the repair order authorizes activity and provides planning information in the repair bays, the parts supply function, and the component and specialty shops (body and paint, upholstery, etc.), if necessary.

The repair order, driver's defect reports, preventive maintenance schedule, I/M reports, and road call reports form the basis of most production control and performance measurement systems in transit. Most other information on parts inventory, vehicle histories, fleet condition, and trends are keyed or reconciled to these reports.

The typical work flow is presented as a guide and reminder to transit managers that each of the basic functions and processes shown should be evaluated, allocated proper resources, and monitored, whether or not these functions have separate organizational entities.

RESEARCH APPROACH

The purposes of the research effort presented in this paper were to assess the maintenance information problem, to provide materials, and to aid transit maintenance managers. Its objectives were to

- Study and report on maintenance cost information collected and monitored by transit operators in California;
- Inform managers of and sensitize them to the significance of maintenance costs; and
- Develop rules of thumb that managers can utilize in developing and structuring an effective maintenance program.

The study was conducted in two phases during the fall of 1985 and early 1986.

STUDY PERFORMANCE

Phase 1 of the study included several activities focused on obtaining the participation of California transit organizations that provide motor buses and demand responsive transit. At the onset of the study, 501 organizations were canvassed for basic budget data and fleet composition. From the returned questionnaires, 68 transit properties were selected for comprehensive cost element and maintenance function expense identification based on availability of cost data and minimal use of maintenance contract service.

A further screening conducted through a telephone interview produced 28 transit properties for participation in the final on-site data collection effort. The purpose of the final effort was to develop cost element and maintenance function expense distributions and patterns. Data from some transit properties were not included in the distributions due to the following factors: inadequate cost accounting, unavailability of staff to assist project team members, and difficulties in meeting project schedule requirements.

Products of the Phase 1 effort were focused on quantifying cost element relationships and functional area cost distributions. The products included

- Total cost distribution by fleet size into operating budgets, maintenance budgets, and general administration budgets;
- Maintenance cost distribution by fleet size into cost elements that included direct labor, fringe benefits, overhead, maintenance administration, and material and supply expense; and
- Maintenance cost distribution by fleet size into function areas that included servicing, I/M, running repair, corrective maintenance, wheelchair system repair, and road call expense.

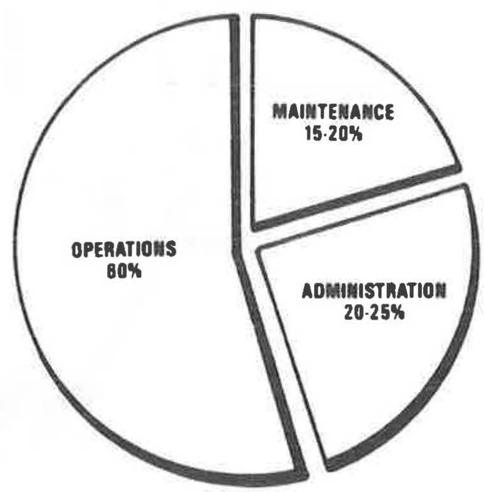
Phase 2 of the study synthesized maintenance cost and program guidelines to assist managers in program development. Maintenance cost guidelines were developed following basic transit cost allocation techniques and cost building methodologies based on cost elements. The cost allocation and estimating methodologies were calibrated for use by California properties based on cost trends and patterns identified in Phase 1. Maintenance planning and management guidelines were developed to focus and aid managers in establishing and evaluating the programs. The materials, though intended for use in California, are easily used by transit managers anywhere in the country, because cost relationships and proportional distributions are identified.

MAINTENANCE SHARE OF TOTAL OPERATING EXPENSE

Maintenance costs are well worth careful attention in budgeting transportation services. In fleets of fewer than 25 vehicles, maintenance costs are almost always in the hundreds of thousands of dollars; in larger fleets, costs are usually in the millions of dollars. Maintenance also makes up a large slice of total costs and is a good target for cost improvement efforts. The general distribution of costs found among transit providers in California is shown in Figure 3 for two broad categories. In both cases, the operating budgets (including drivers dispatchers, running costs, etc.) fall in a narrow band at about 60 percent. The remaining budgets are divided between

- Costs clearly identified by the organizations as maintenance—service, I/M, and repair; and

UNDER 100 VEHICLES



100 VEHICLES OR MORE

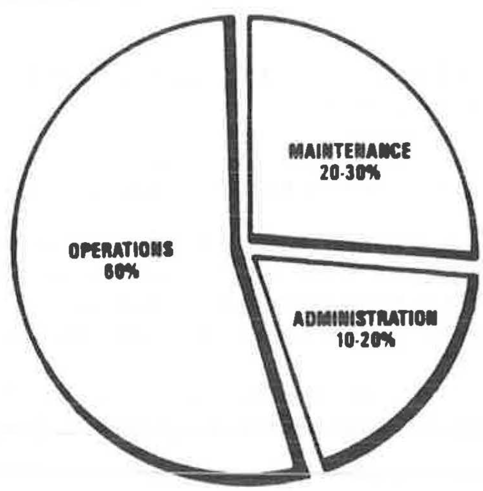


FIGURE 3 Typical budget distributions.

- Costs for administrative functions including general management, legal, marketing, and planning.

For properties operating fewer than 100 vehicles, costs accounted for (and specifically identified) as maintenance costs typically amounted to between 15 and 20 percent. The remaining nonoperations costs are identified as administrative and as other. For properties with 100 or more vehicles, operating costs average about 60 percent of the total, but a large proportion of budget (20 to 30 percent) can be specifically attributed to maintenance. Many factors dramatically influence maintenance costs; those factors must be considered on a case-by-case basis as specific transit properties are addressed.

The tendency for larger organizations to identify a larger portion of costs as maintenance may well be due to the scale and specialization of activities.

- Larger organizations are more likely to assign and fully dedicate management personnel to purely maintenance functions.
- Costs of all kinds tend to be accounted for in greater detail and specificity in larger organizations, permitting clearer definition by function.
- Systematic preventive maintenance programs are more common and elaborate in the larger properties because the fleets are too large for a diagnostic response approach in which knowing when maintenance is needed is based on observation and judgment.
- Information systems, work order control, and other monitoring and records needs tend to increase with scale of operations.

Notwithstanding the variation in budget proportions that can be expected over a spectrum of transit system sizes, the most powerful factors that influence costs are as follows (in order of impact):

- Total operating miles per year,
- Number of units operated, and
- Prevailing wage and cost structure in a locality.

As will be shown in the next section, these factors (in the order shown) far outweigh other maintenance planning considerations. Any one of the factors can, by itself, change the order of magnitude of a maintenance budget estimate if all other factors remain constant.

DEVELOPING BUDGET COST ESTIMATES: BASIC ASSUMPTIONS

Estimation of a total maintenance budget and costs depends on a host of variables that are fleet and property specific. Managers should examine the assumptions and generalizations underlying the development of the guidelines in order to interpret and apply the guidelines in specific operating and maintenance environments. When significant discrepancies occur between the actual costs and those identified by the guidelines, the cause of the discrepancy should be investigated. The investigation should explore the assumptions underlying the guidelines and examine areas where productivity and efficiencies can be achieved.

In this section the factors and trends are discussed and specific assumptions for developing the material for estimating total maintenance cost are presented.

In general, cost rates (e.g., cost per vehicle) are expected to increase as fleet size becomes larger. As fleet size increases, transit properties tend to use standard (40-ft) transit buses for the bulk of their fleet, whereas small properties use a mix of small (30-ft) buses, modified vans, and other specialty vehicles to provide transportation service. Larger vehicles typically have greater maintenance requirements due to their heavier weight and the manner in which they are deployed.

Geographic location also influences cost rates in California because the major urban centers (e.g., San Diego, San Francisco, and Los Angeles) have some of the highest cost-of-living rates in the country. Larger properties in California tend to be located in regions with higher cost-of-living rates (i.e., for salaries, wages, and rents), causing fringe benefit and overhead expenses to escalate as competition for skilled labor is encountered and adequately sized facility sites compete with other potential land use.

For the same reason, salaries and wage rates increase as the property's size increases. However, numerous small transit properties are also located in areas with high cost (in wage rates) relative to small properties operating in more rural environments. For these reasons, typical wage rates for various property sizes and locations were developed for estimating total maintenance costs. Typical wage rates such as the following were used to determine direct labor costs.

	Typical Wage Rates ($/hr)			
Property Size	*Mechanics*		*Servicers*	
(no. of vehicles)	*Low*	*High*	*Low*	*High*
1–9	9.00	12.00	5.50	8.50
10–24	7.00	12.00	5.50	8.00
25–99	11.00	13.00	7.50	8.50
100+	11.30	15.80	8.50	12.50

Small transit properties, with 1 to 9 vehicles, tend to have higher wage rates than properties with 10 to 25 vehicles. Small transit properties operating in low-cost rural areas and in small-employment markets often must offer higher wages for skilled diesel mechanics because these regions tend not to need skilled diesel mechanics beyond the transit property itself. In high-cost areas, small operations must compete with several organizations such as other transit properties and alternative businesses to attract relatively unskilled bus servicers and washers. The competition tends to increase wages most significantly for this category.

In the following table, representative fringe benefit and overhead factors are presented as percentages of direct labor expense.

	Fleet Size (no. of vehicles)			
Cost Element	*1–9*	*10–24*	*25–99*	*100+*
Fringe benefit factor	0.30	0.30	0.30	0.45
Overhead factor	0.15	0.15	0.15	0.20
Maintenance administration ($/veh)	2,000	5,000	5,000	5,000

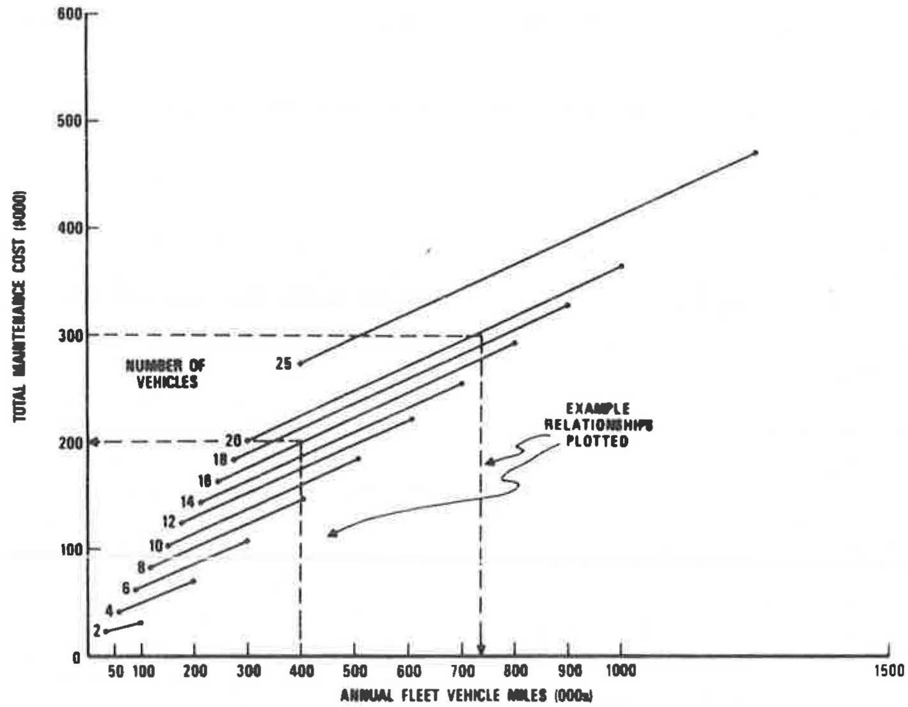


FIGURE 4 Total maintenance costs for fleets of 1 to 25 vehicles in high-cost area.

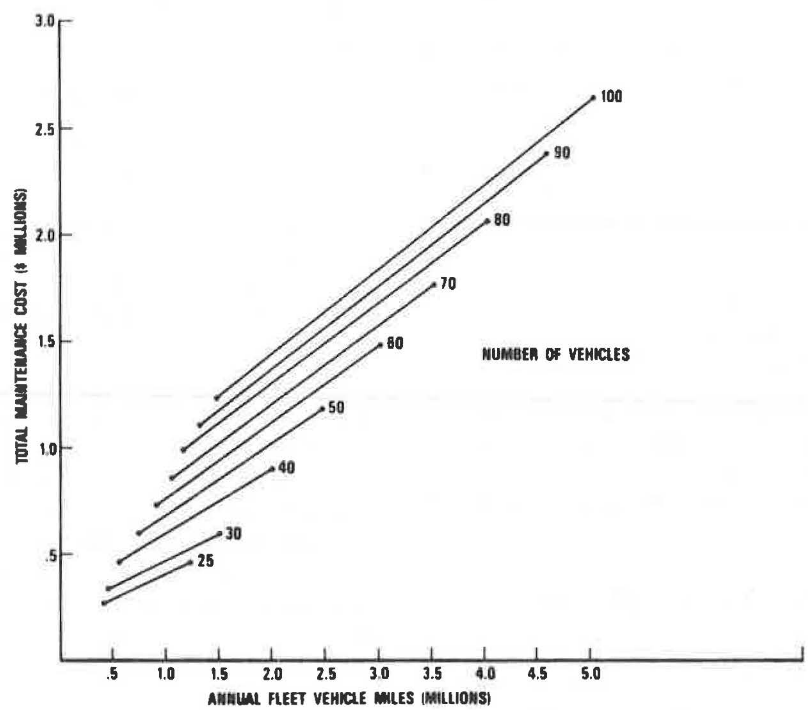


FIGURE 5 Total maintenance costs for fleets of 25 to 100 vehicles in high-cost area.

The table also presents estimates of approximate maintenance and administrative costs per vehicle. Generally, the cost factors provided in the exhibit are shown to escalate as fleet sizes increase. The forces behind the escalation include geographic location and fleet characteristic differences between small and large properties.

TOTAL MAINTENANCE COST ESTIMATE

Total maintenance cost curves were developed as a function of the annual fleet vehicle miles and total fleet size. Traditional transit cost allocation models typically use these two variables as well as vehicle operating hours. However, vehicle operating

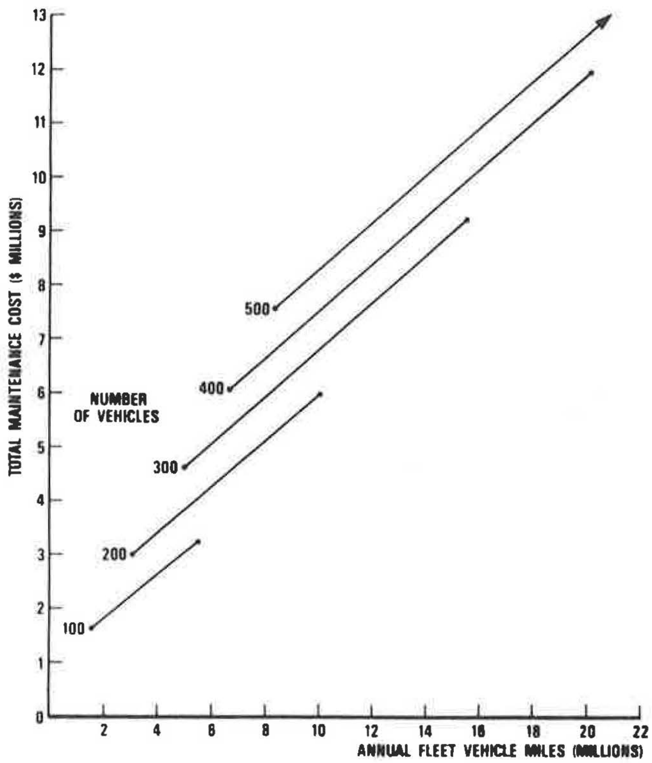


FIGURE 6 Total maintenance costs for fleets of 100 or more vehicles in high-cost area.

hours are primarily the driving factors behind operating costs, whereas vehicle miles and fleet size are primarily drivers of maintenance cost and fixed costs (e.g., general and administrative costs).

Total maintenance cost curves in Figures 4–6 reflect estimation of costs based on an assumed typical high-wage cost area. The exhibits correspond to fleet size groupings of 1 to 25 vehicles, 25 to 100 vehicles, and 100 or more vehicles. Cost curves for low-wage cost areas are provided in Figures 7–9 for the same fleet size groupings. The cost of fuel is not included in total maintenance cost for any set of curves.

On these charts as fleet size becomes larger, the annual fleet mileage appears more important in determining maintenance cost. That is, the range of total maintenance cost for a given fleet size becomes larger as annual fleet mileage increases. This trend is explained by a tendency toward increased vehicle utilization rates; therefore, maintenance requirements increase as more inspections are performed, and components reach maximum service lives more quickly.

For small fleets (1 to 25 vehicles), the number of vehicles tends to be the predominant factor in determining maintenance cost. For these fleets, the maintenance labor requirements are generated primarily by fueling and other routine service activities that are controlled by the number of vehicles used in a day.

Managers of transit properties approaching a fleet size of 100 vehicles should use the charts with caution because there are some discontinuities at the 100-vehicle fleet size. For fleets of about 100 vehicles that operate in a major urbanized area, managers should use the charts for 100 or more vehicles. These charts reflect higher cost-of-living rates and other economic factors associated with the major urbanized regions of California.

Examples of the use of these charts can be shown in Figure 4.

1. A motor bus operator with a fleet of 16 buses operating about 400,000 veh-mi/year in a high-cost area checks for an appropriate budget order of magnitude. The operator locates 400,000 mi on the lower axis of Figure 9 and plots vertically to

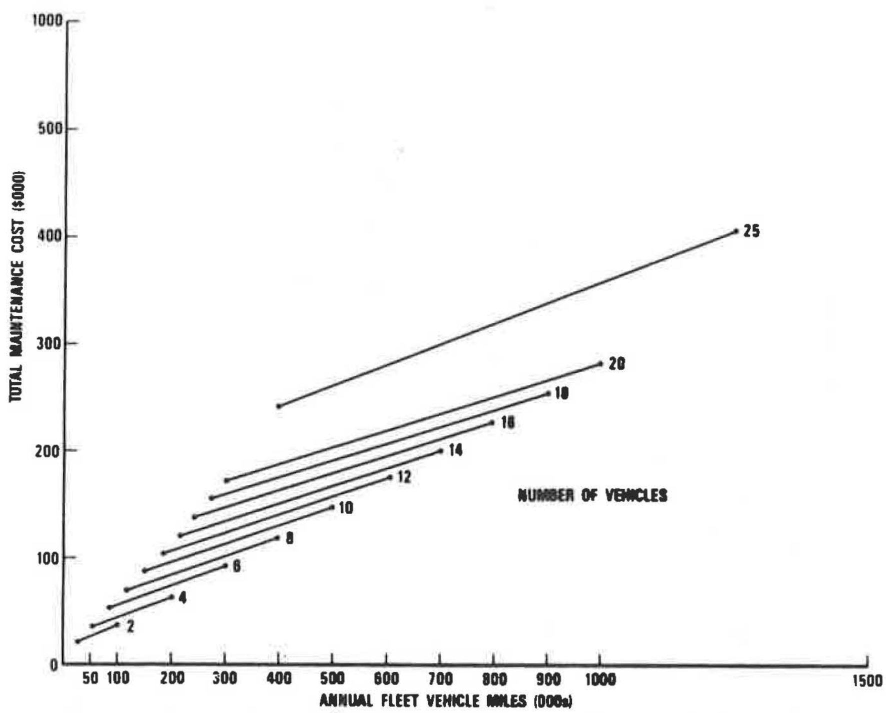


FIGURE 7 Total maintenance costs for fleets of 1 to 25 vehicles in low-cost area.

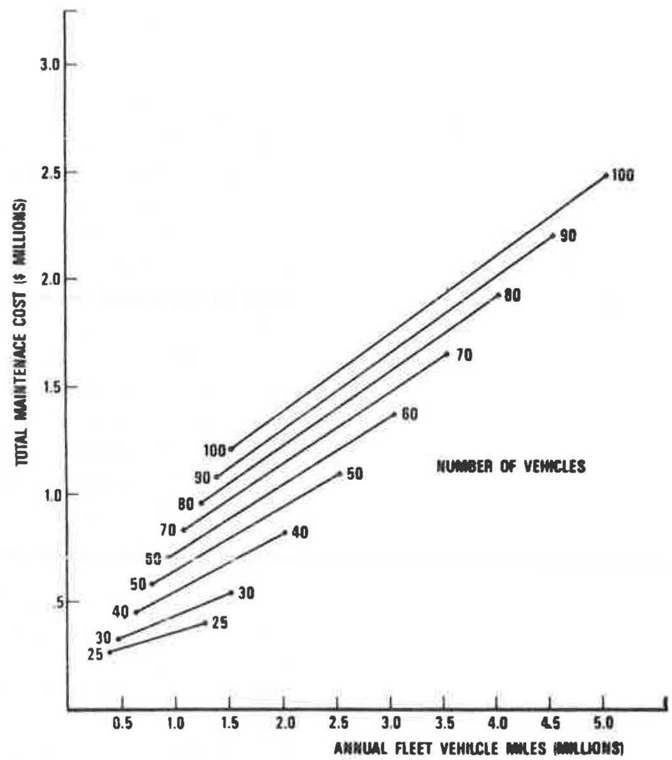


FIGURE 8 Total maintenance costs for fleets of 25 to 100 vehicles in low-cost area.

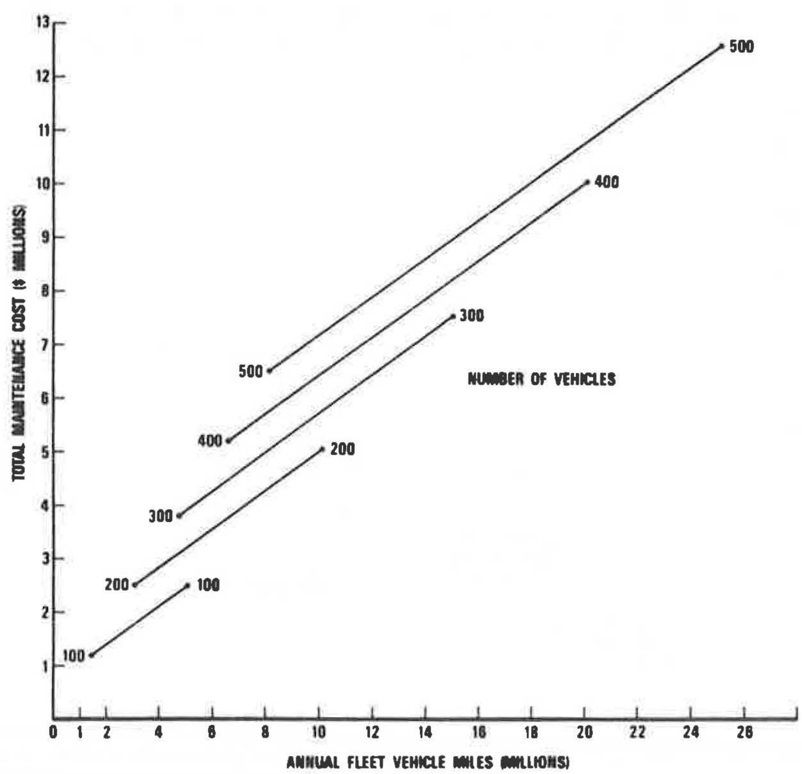


FIGURE 9 Total maintenance costs for fleets of 100 or more vehicles in low-cost area.

a point on the 18-vehicle line. The overall $200,000 cost estimate is read on the left axis level with the point plotted.

2. An operator of 20 buses in a high-cost area with an annual maintenance cost of $300,000 wants to compare his program with typical expectations. The operator locates $300,000 on the left axis and plots horizontally to the 20-bus fleet line. The operator reads about 725,000 veh-mi/year on the lower axis directly below the point. If the operator is operating significantly less total mileage, yet sustaining $300,000 in maintenance costs annually, he should examine his program to find the reason for the departure, highlighting either a problem or a logical explanation of the difference.

BUDGETING THE COST ELEMENTS

The development of maintenance budget estimates relies on the identification and allocation of expenses to five basic cost elements as shown in Figure 10. Each cost element can be further segmented to provide increasing levels of detail. However, for general budget guideline purposes, it is appropriate to segment the direct labor cost element into three basic functional areas, and to divide material and supply costs into consumable and nonconsumable categories. As the exhibit shows, some organizations may further disaggregate repair labor into four additional categories—running repair, corrective maintenance, wheelchair equipment repair, and road calls. However, even in larger organizations, the necessary distinctions are too fine or data quality is too low to correctly allocate and monitor to this level. In fact, a good example of this problem is in wheelchair equipment repair; many organizations report wheelchair-related road calls are so frequent that most repair of this equipment is performed in connection with the road calls.

Total Direct Labor Proportion of Maintenance Cost

Estimates of the percentage of direct labor to maintenance costs are provided in Figures 11–13. Again, the charts correspond to fleet sizes of 1 to 25 vehicles, 25 to 100 vehicles, and 100 vehicles or more. The charts show that direct labor costs tend to be more volatile for small transit properties as the number of vehicle-miles increases than they are for large transit properties. As fleet size increases, direct labor costs represent a smaller percentage of total cost and the percentage range decreases, reflecting less sensitivity to incremental maintenance needs.

Direct Labor Budget by Functional Area

Managers are advised to budget direct labor costs by functional area to account for differential wage rates and staff specialization. Disaggregation between repair activities and I/M activities should be made because mechanics performing preventive maintenance activities are typically paid less than mechanics responsible for component overhauls and rebuilds. Servicing labor cost should also be separated because personnel responsible for fueling, washing, and cleaning vehicles are typically the lowest paid of the maintenance labor force.

Figures 14–16 show charts for estimating the direct labor percentage of total maintenance costs for repair activities according to different fleet size groups. Figures 17–19 show charts for estimating inspection labor costs.

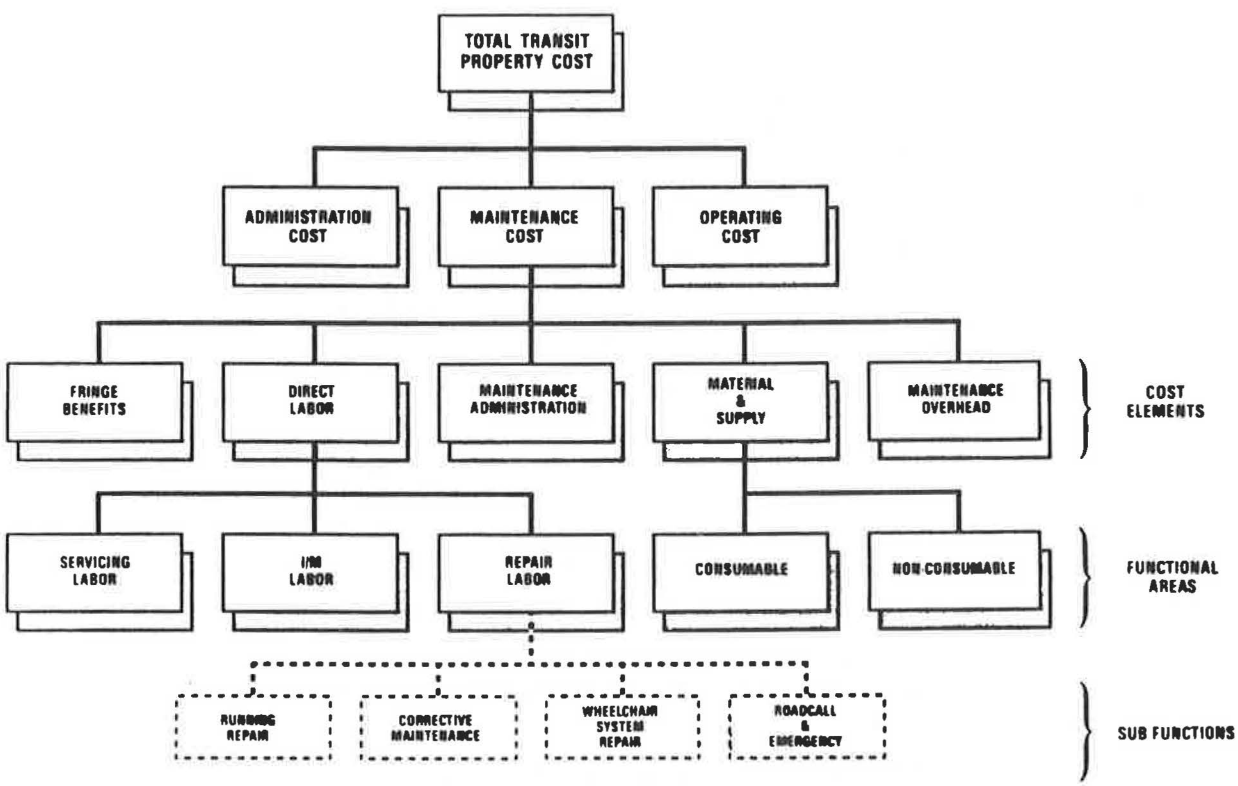


FIGURE 10 Maintenance cost disaggregation.

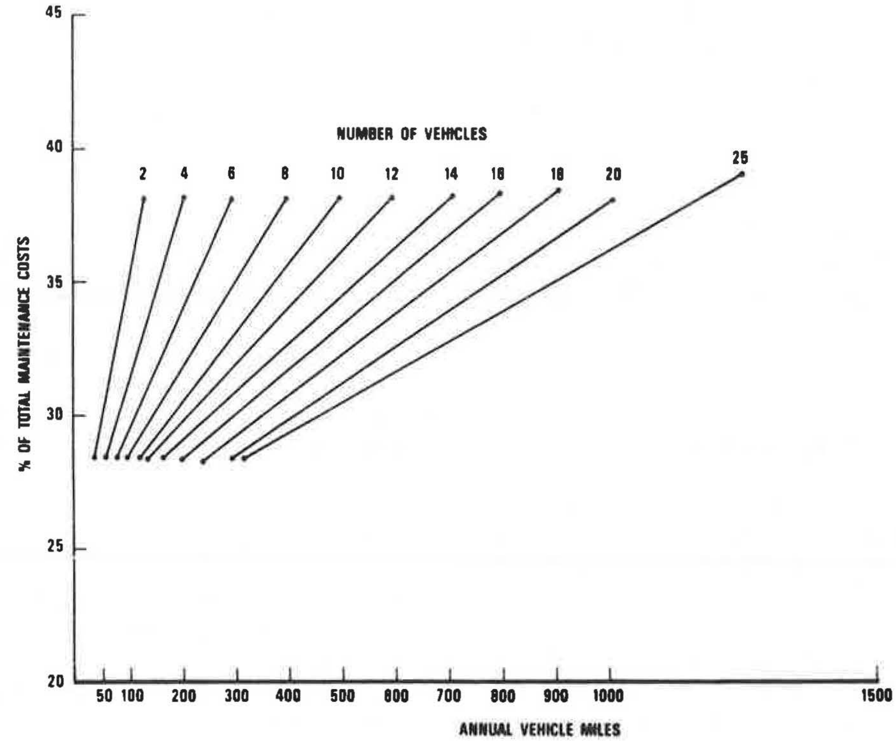


FIGURE 11 Total direct labor cost percentage of total maintenance costs for fleets of 1 to 25 vehicles.

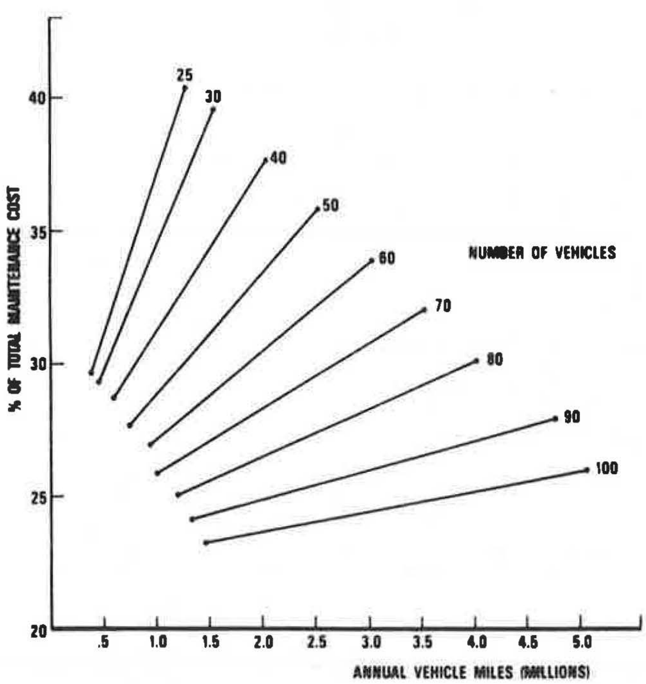


FIGURE 12 Total direct labor cost percentage of total maintenance costs for fleets of 25 to 100 vehicles.

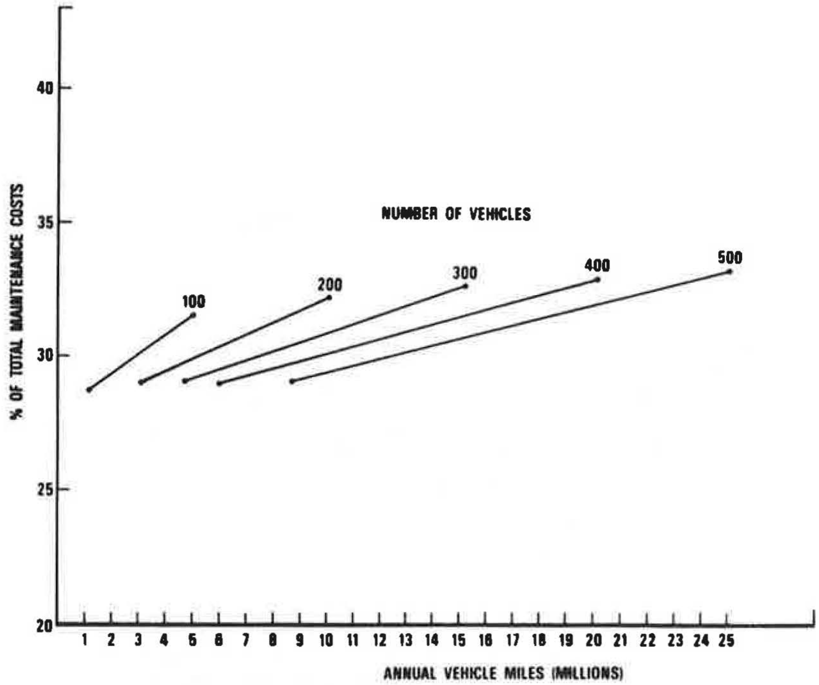


FIGURE 13 Total direct labor cost percentage of total maintenance costs for fleets of 100 or more vehicles.

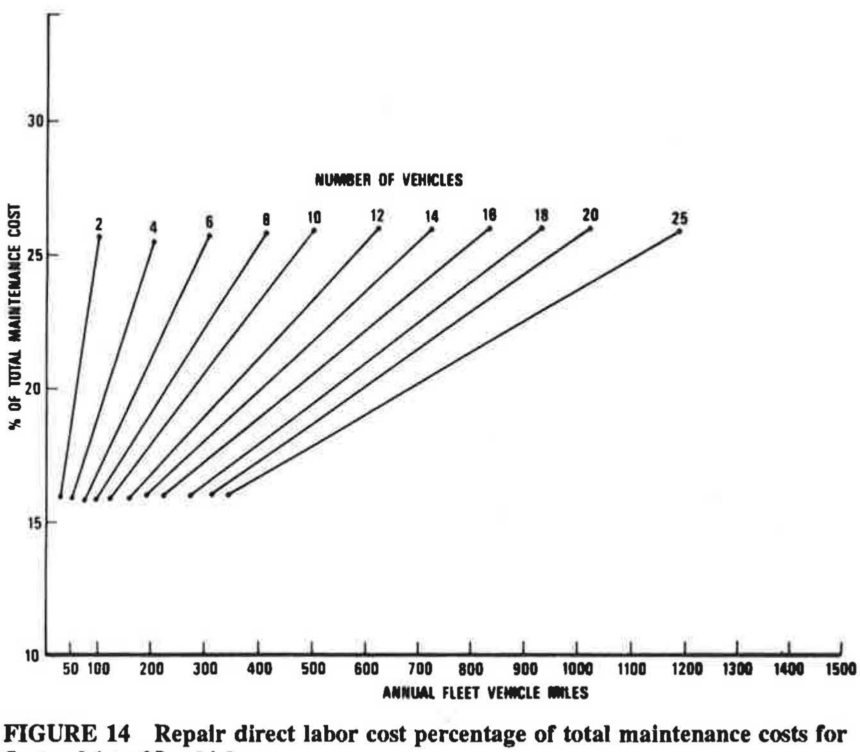


FIGURE 14 Repair direct labor cost percentage of total maintenance costs for fleets of 1 to 25 vehicles.

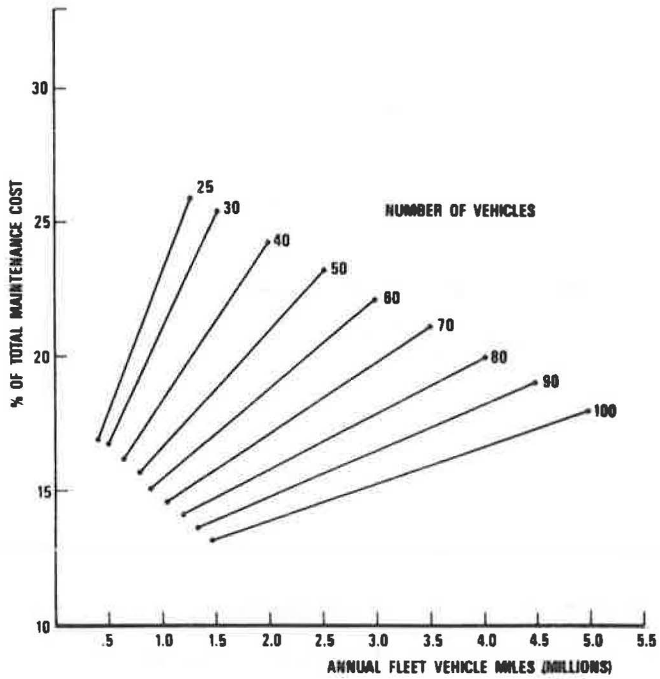


FIGURE 15 Repair direct labor cost percentage of total maintenance costs for fleets of total maintenance costs for fleets of 25 to 100 vehicles.

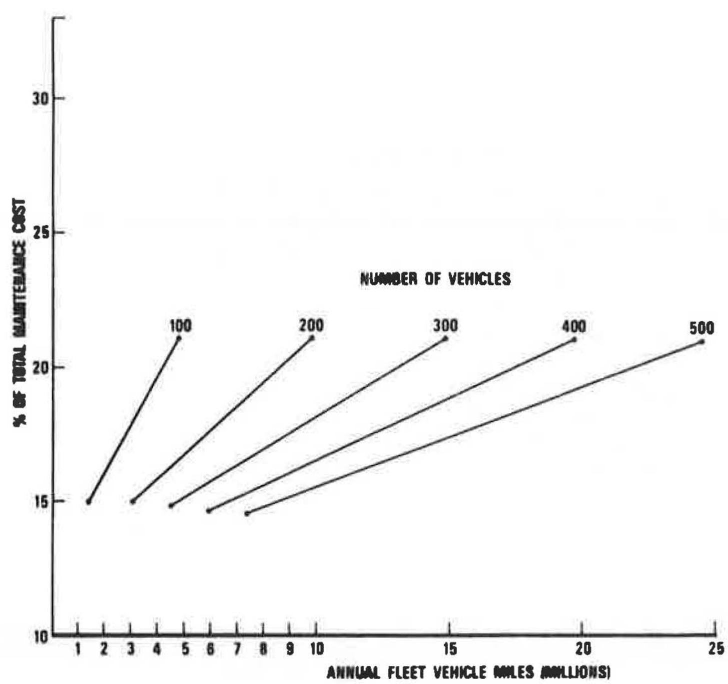


FIGURE 16 Repair direct labor cost percentage of total maintenance costs for fleets of 100 or more vehicles.

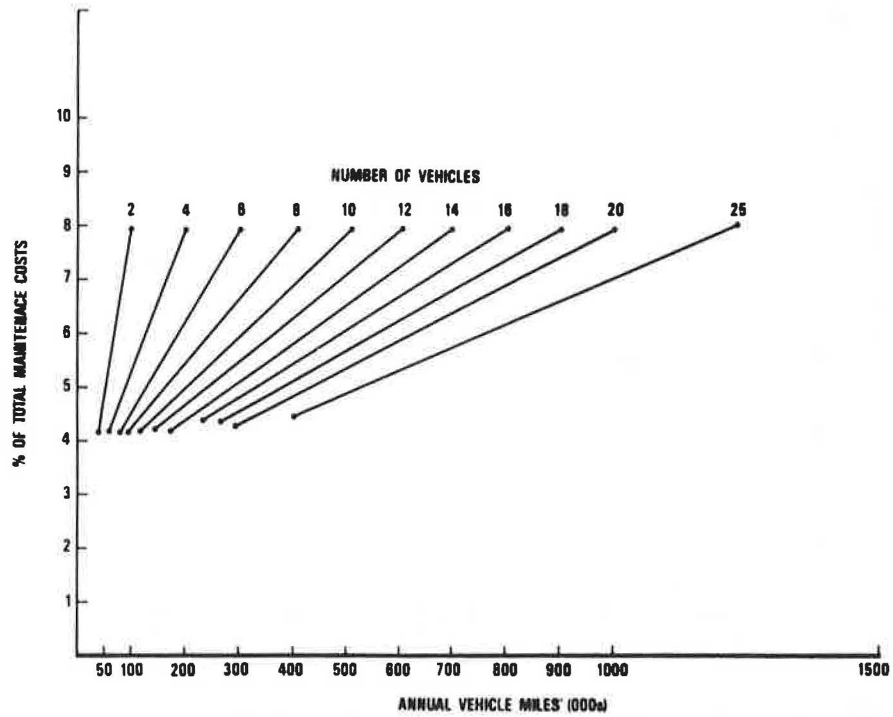


FIGURE 17 Inspection direct labor cost percentage of total maintenance costs for fleets of 1 to 25 vehicles.

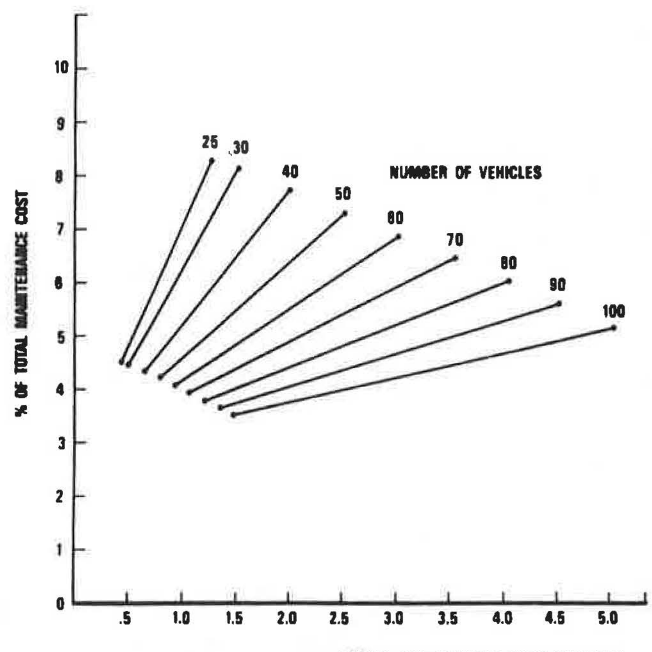


FIGURE 18 Inspection direct labor cost percentage of total maintenance costs for fleets of 25 to 100 vehicles.

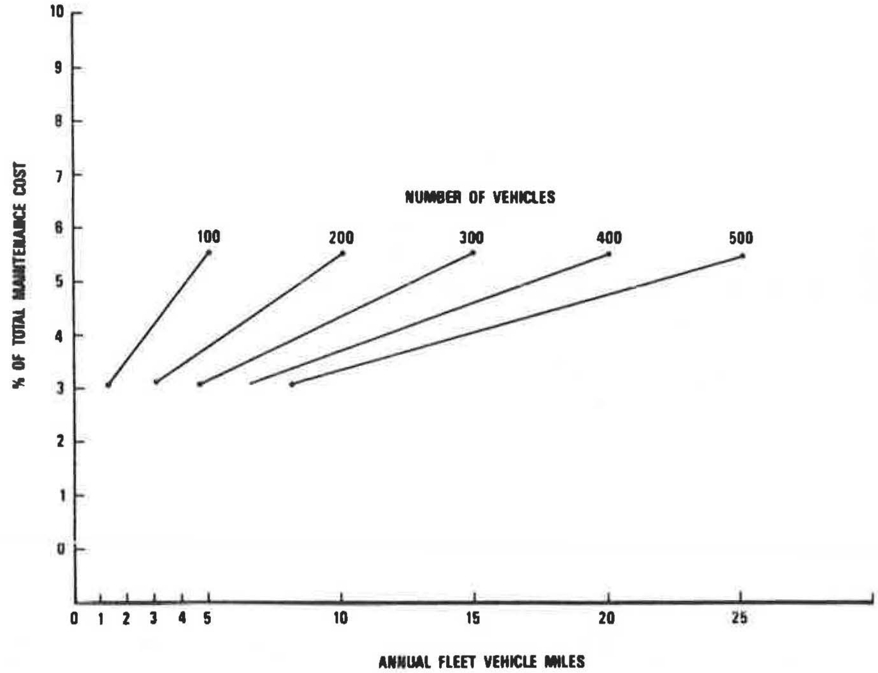


FIGURE 19 Inspection direct labor cost percentage of total maintenance costs for fleets of 100 or more vehicles.

Finally, Figures 20–22 show charts for estimating servicing labor costs as a percentage of total maintenance costs by fleet size group.

Some general trends and principles can be observed in the charts. Servicing labor cost is driven more strongly by the number of vehicles than by the number of vehicle-miles, explaining the decreasing contribution of service labor to total direct labor cost. As more vehicles are put into service, more labor is needed for servicing when vehicle mileage remains constant. This trend shows that the incremental time necessary

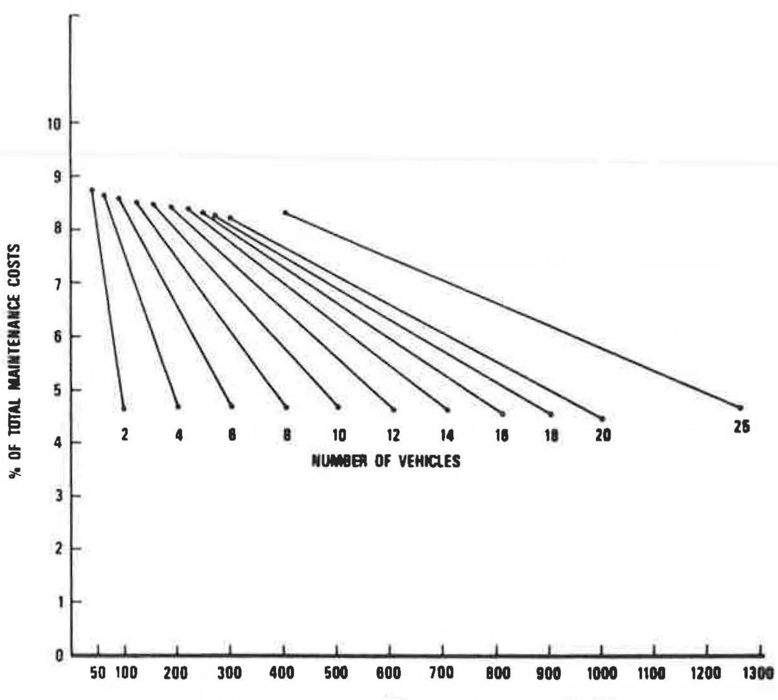


FIGURE 20 Servicing direct labor cost percentage of total maintenance costs for fleets of 1 to 25 vehicles.

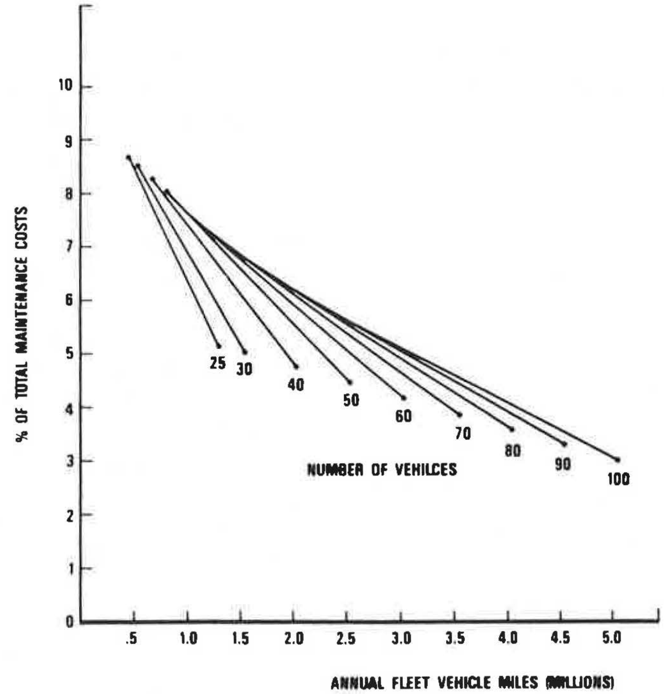


FIGURE 21 Servicing direct labor cost percentage of total maintenance costs for fleets of 25 to 100 vehicles.

to service buses with high daily mileage versus buses with low daily mileage is considerably less than the time required to retrieve buses from service queues, fuel and service the buses, and park the buses on the ready line. Inspection and repair labor follows an opposite trend. As vehicle mileage rises, direct labor for these functional areas increases, contributing to the decreasing percentage of service labor for total costs.

Fringe Benefit Expense

Fringe benefit expenses, as a percentage of direct labor, generally increase with property size starting from a typical low of approximately 13 percent of total direct labor cost for properties with fleet size of under 10 vehicles to a high of approximately 59 percent of direct labor cost for fleets of 100 vehicles

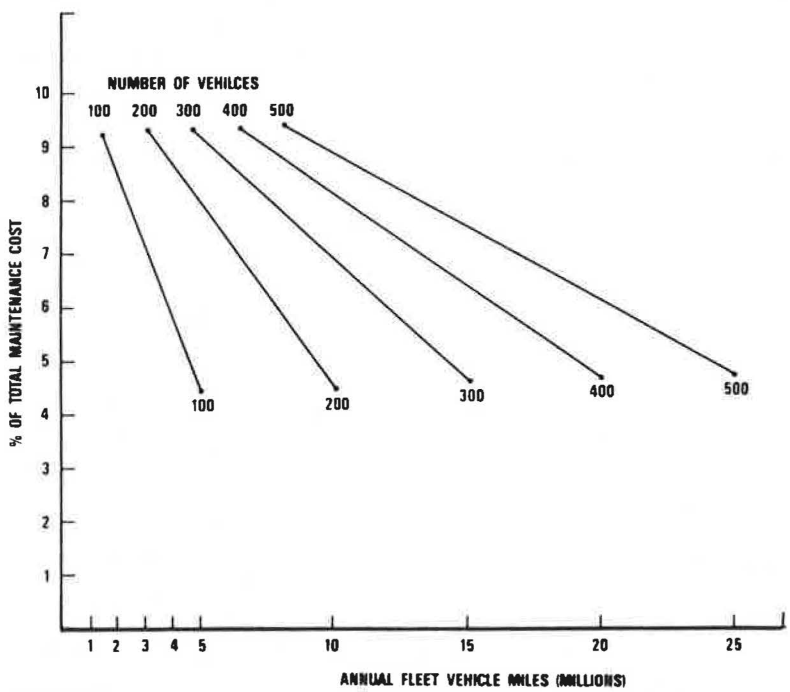


FIGURE 22 Servicing direct labor cost percentage of total maintenance costs for fleets of 100 or more vehicles.

or more. Study findings by fleet size and high- versus low-cost areas in California are shown in the following table. Obviously, the fringe benefit expense for an individual property is highly variable and subject to many local considerations.

	Expense (% of labor) by Fleet Size			
Level	*1–9*	*10–24*	*25–99*	*100+*
Low	0.13	0.34	0.26	0.45
Average	0.25	0.37	0.34	0.52
High	0.38	0.40	0.43	0.59

The trend of increasing fringe benefit expenses with increasing fleet size probably reflects increased competition for skilled personnel in competitive employment market areas. As a mechanic's skill level increases, compensation (including fringe benefits) must be competitive with other organizations requiring skilled diesel mechanics. Competitors for skilled mechanics include municipal organizations, trucking companies, construction companies, and some energy-related companies that rely on diesel equipment to operate pumps and remote power-generating facilities.

Maintenance Overhead Expense

Overhead expense incurred as a function of maintenance activities is frequently not allocated to the maintenance department. However, to reflect true costs, managers should include overhead expense.

Overhead is conventionally allocated as a percentage of total direct labor. Overhead varies significantly among properties of similar size. Overhead factors as a percentage of direct labor for California properties appear to increase as fleets become larger, as shown in the following table.

	Expense (% of labor) by Fleet Size			
Level	*1–9*	*10–24*	*25–99*	*100+*
Low	0.14	—	0.06	0.13
Average	0.39	0.17	0.14	0.22
High	0.64	—	0.22	0.31

More important, the research indicated that overhead expense data were typically not available or not allocated to transit maintenance activities. Maintenance facilities were frequently owned by municipalities and serviced both the transit fleet and other municipal vehicles. This shared-facility use made overhead expense identification difficult at even the best-managed small transit authorities.

The apparent higher overhead factor for large properties of 100 or more vehicles can be attributed to several factors. Facilities for these operations typically are dedicated to transit. Furthermore, larger properties carry specialized equipment and facilities, which translates into higher overhead expense.

Maintenance Administration Expense

Maintenance administration activities performed at a transit property are difficult to allocate to specific functional areas because an administrator's time is spent on a variety of activities spanning several functional areas. Maintenance personnel accounted for in this expense category usually include the maintenance director, manager, engineer, superintendents, supervisors, nonworking foreman, secretaries, clerks, and other staff who do not directly maintain the fleet.

Maintenance administration expense is particularly difficult to identify at small properties where one person may perform the duties of director of operations, director of maintenance, and director of personnel. In larger organizations, particular administrative personnel are more often dedicated to supporting and managing the maintenance functions. Not only does property size influence administrative costs, but the maintenance philosophy also influences administrative costs. Transit properties sometimes experience increased administrative expense and reduced direct labor expense by relying on contract maintenance service.

Maintenance administration and support expense found for California operators is shown in the following table. The data indicate that a significant difference occurs between fleets of less than 10 buses and fleets with more than 10 buses.

	Expense ($/veh) by Fleet Size			
Level	*1–9*	*10–24*	*25–99*	*100+*
Low	600	1,600	2,300	900
Average	1,900	5,100	5,100	5,100
High	6,100	6,600	7,800	7,800

The relatively constant average administrative expense per vehicle reflects the increased productivity and utilization of maintenance administrative staff as fleet size exceeds 10 buses. Intuitively, maintenance administration expenses should decrease on a per-vehicle basis as fleet size increases. However, each vehicle generates a constant flow of maintenance-related information regardless of service levels and fleet deployment. Even though more streamlined systems are often used, additional administrative activities tend to be needed as the overall operation becomes more complex. The two trends appear to be offsetting.

Material-and-Supply Expense

Material-and-supply expense can be allocated to two categories, consumable and nonconsumable expense. Consumable expense includes fuel cost, oil cost, and the cost of other liquids used to maintain and operate vehicles. Frequently, fuel costs are not assigned to the maintenance department because the fuel costs are driven primarily by service levels (i.e., the number of vehicle-miles). Maintenance managers should be aware of fuel costs and general trends in fuel costs because overall vehicle condition, frequency of tune-ups, and other factors can increase fuel mileage.

Nonconsumable expense is associated with the cost of parts, components, and other items used primarily in repair activities, although some nonconsumable expense is attributed to I/M activities (e.g., belts and hoses). Nonconsumable expense is driven by the amount of repair activity. Repair activity is primarily influenced by the number of vehicle-miles, type of vehicle, age of vehicle, and the operating environment (e.g., the terrain, passenger levels, and temperature).

In California the following consumable (including fuel) and nonconsumable cost rates were found:

- For fleet size between 1 and 25 vehicles, a typical consumable cost was $0.20/veh-mi; nonconsumable cost was $0.065/veh-mi.
- For fleet size of 25 vehicles or more, consumable cost was typically $0.27/veh-mi; nonconsumable cost was $0.180/veh-mi.

These cost rates will fluctuate from property to property. Therefore, managers should strive to develop their own consumable and nonconsumable cost rates. The cost rates are significantly influenced by the type of vehicles operated, vehicle age, terrain, and other factors.

IMPLICATIONS FOR MAINTENANCE MANAGERS

To plan and control maintenance costs, managers must know what cost components can be influenced, and they must use appropriate tools, approaches, and strategies. The cost relationships discussed in this paper provide managers a starting point for the assessment of their maintenance cost structure.

Maintenance costs are influenced by factors internal and external to a maintenance manager's span of control and often outside the overall transit organization.

Economic conditions such as employment levels and inflation rate are examples of external factors that affect the amount of servicing and cleaning vehicles require as well as the amount of repair activity needed to replace worn seats, and so forth. Inflation rates influence wage rates and the cost of materials and supplies.

There are several factors within a manager's span of control that influence maintenance costs, especially in relation to operating costs and overall administrative costs.

The cost relationships presented in this paper are applicable to transit operations located across the country. Though total maintenance costs in other areas may differ from those found in California, their contributions to total operating expense are not expected to vary significantly. Likewise, because no deviation between low- and high-cost areas in California was identified, the contributions of repair, inspection, and servicing labor to total maintenance costs are not anticipated to vary significantly.

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