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EVALUATION OF MANAGEMENT OPTIONS FOR BUS MAINTENANCE

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16. Abstract

A practical framework for understanding, reviewing, and evaluating a transit agency's maintenance program is described. The maintenance department's mission is viewed as a set of management activities that are associated with the functional tasks that comprise the entire bus maintenance process. Different environmental features and organizational characteristics are shown to influence the complexity and structure of a transit organization's maintenance program; the major influence being the size of the fleet. The framework simplifies the case study process with a format that enhances consistency and transferability of results among different cases. It encourages comparative analyses. A case study of the maintenance operation of the Tidewater Transportation District Commission demonstrates the practical utility of the methods. The resulting method is recommended for use by the industry.

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I. INTRODUCTION

A. PURPOSE

The purpose of this report is to present an organized method for defining and reviewing bus transit maintenance operations for small and medium size transit agencies.[1] This report describes the study results which are: development of a practical maintenance management guide for understanding, reviewing, and evaluating a transit organization's maintenance program; and demonstration of a useful method for documenting a bus maintenance program.

This report focuses on the organization of maintenance activities at the management level. An overview of the transit maintenance process is developed to provide a guide that can be used by management to evaluate methods and procedures. A case study of the maintenance operations of the Tidewater Transportation District Commission of Norfolk, Virginia is presented which places the maintenance management procedures in a practical context.

B. TRANSIT MAINTENANCE FUNCTIONS

Transit bus maintenance is by nature a highly complicated and irregular activity which often is scheduled around, and determined by, the needs of the entire transit organization. Because of the basic, fundamental dependence on the maintenance department by other divisions within the transit agency--(i.e., operations, marketing and administration)--the maintenance function often must be responsive to immediate needs.

Although the role of transit maintenance has always been vital, recently this role has grown in importance. Certain factors account for the growing emphasis on maintenance:

- Maintenance activities have been shown to absorb more than 20% of annual transit operating expenses, and the proportion seems to be growing.[2]
- Federal operating subsidies are diminishing, thereby intensifying the need to control maintenance expenses.
- Recent complex bus designs have placed a growing burden on the task of maintenance.

Growing awareness and interest in these problems has spurred some recent research, but many needs remain to be addressed. Often maintenance research has taken the viewpoint of maintenance labor--the enumeration of tasks and the description of their proper execution. This approach is exemplified by the many procedural manuals that are available within the industry.

In this report, the maintenance department is first differentiated from other units within a transit agency, and then the key activities of maintenance management are illustrated, with alternative strategies that may be selected for each. Finally, a general model for the analysis of bus maintenance management is presented and illustrated in a case study format.

C. THE ORGANIZATIONAL ROLE OF MAINTENANCE

Because they are a support function, bus maintenance operations must be viewed as serving more than the objectives of the maintenance department; they must be viewed as activities aimed at achieving the maximum good for the collective transit organization.

Figure 1 illustrates the sequence of basic factors that affect the delivery of bus transit service. In a small- to medium-sized agency as this figure indicates, three primary departments share responsibility for executing transit

policy. These three departments are operations, marketing, and maintenance.[3]

Beginning at the far left of Figure 1, special attention should be given to the community and external constraints that surround any transit organization.[4] These circumstances set the priorities for the entire agency and are outside the maintenance manager's control.

Community and external conditions are listed on Figure 1. The size of the community that the system serves is the first impacting circumstance. The size and density of the community influence the decisions for types and levels of passenger service. The values of the community (transit use, local support) exert a similar influence.

A maintenance department in a large transit agency will find itself better situated to consider high overhead alternatives (such as capital or staffing decisions), since cost can be spread over the higher volume of operations. A small transit operation may be compelled to utilize more labor-intensive, low-overhead alternatives because its low service volumes cannot generate enough savings from these investments in capital or staff improvements.[5]

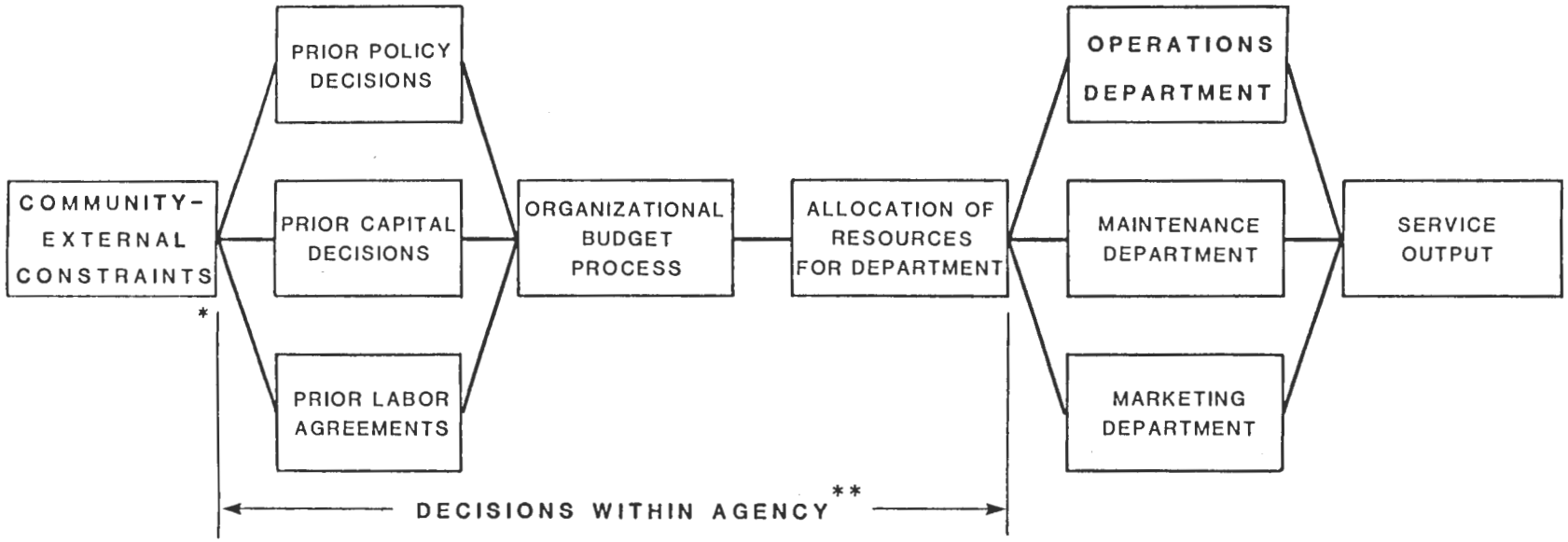
Other conditions that affect a maintenance organization are, terrain, climate, street conditions, and local labor markets. For example, a hilly terrain will cause greater stress on the maintenance of brakes and transmissions; winter conditions will contribute to body corrosion, radiators, and tires; severely deteriorated street surfaces will require greater maintenance of vehicle suspension and tires; and local labor markets will determine the cost trade-off that an agency must incorporate in its evaluation of labor-saving alternatives.

Organizational objectives, hours of revenue service, fleet size, fleet composition (type of vehicle selected for revenue service, age of vehicles, and the degree of homogeneity of vehicle fleet), physical layout of facilities, existing labor agreements, and annual budget allocation are decisions that are made within the transit agency but outside the maintenance department. Decisions concerning many of these items summarized in Figure 1 may require input from the maintenance department.

The last consideration in Figure 1 is the relationship among the three primary departments. Although they are structurally separate, they are highly interrelated. Figure 1 separates these departments because they each must compete for limited resources, although each serves common organizational goals. The success of one department will often impact another, so that sometimes one department actually benefits by yielding a share of resources to another. For instance, the marketing department's campaign for visually appealing buses would benefit from sufficient funding levels for the maintenance department, which must administer cleaning operations.

Ultimately, following the path of Figure 1 from left to right, all of the listed influences result in service output. This output must be evaluated in terms of the overall system or in terms of the objectives for the three primary departments of operations, maintenance, and marketing.

Figure 2 expands a section of Figure 1: it follows the maintenance process from the point of budget allocation to the ultimate production of output. In this figure, the internal activities of maintenance can be examined in far greater detail.



*Community-external Conditions (Outside the Agency)
- Community Size
- Community Density
- Community Values (transit use, local funding)
- Terrain (flat or hilly)
- Climate (cold or hot, moderate or variable)
- Street Conditions (potholes, narrow streets)
- Local Labor Market (union climate, high or low wage rates)

**Decisions within the Agency (Outside the Maintenance Department)
- Organizational Objectives
- Hours of Revenue Service
- Fleet Size
- Fleet Composition (type of vehicle, homogeneity of fleet)
- Physical Layout of Facilities
- Labor Agreements (vague Levels, work rules, promotion system, shift restrictions)
- Budgeting Allocations

Figure 1. Determining Factors for Transit Service Output

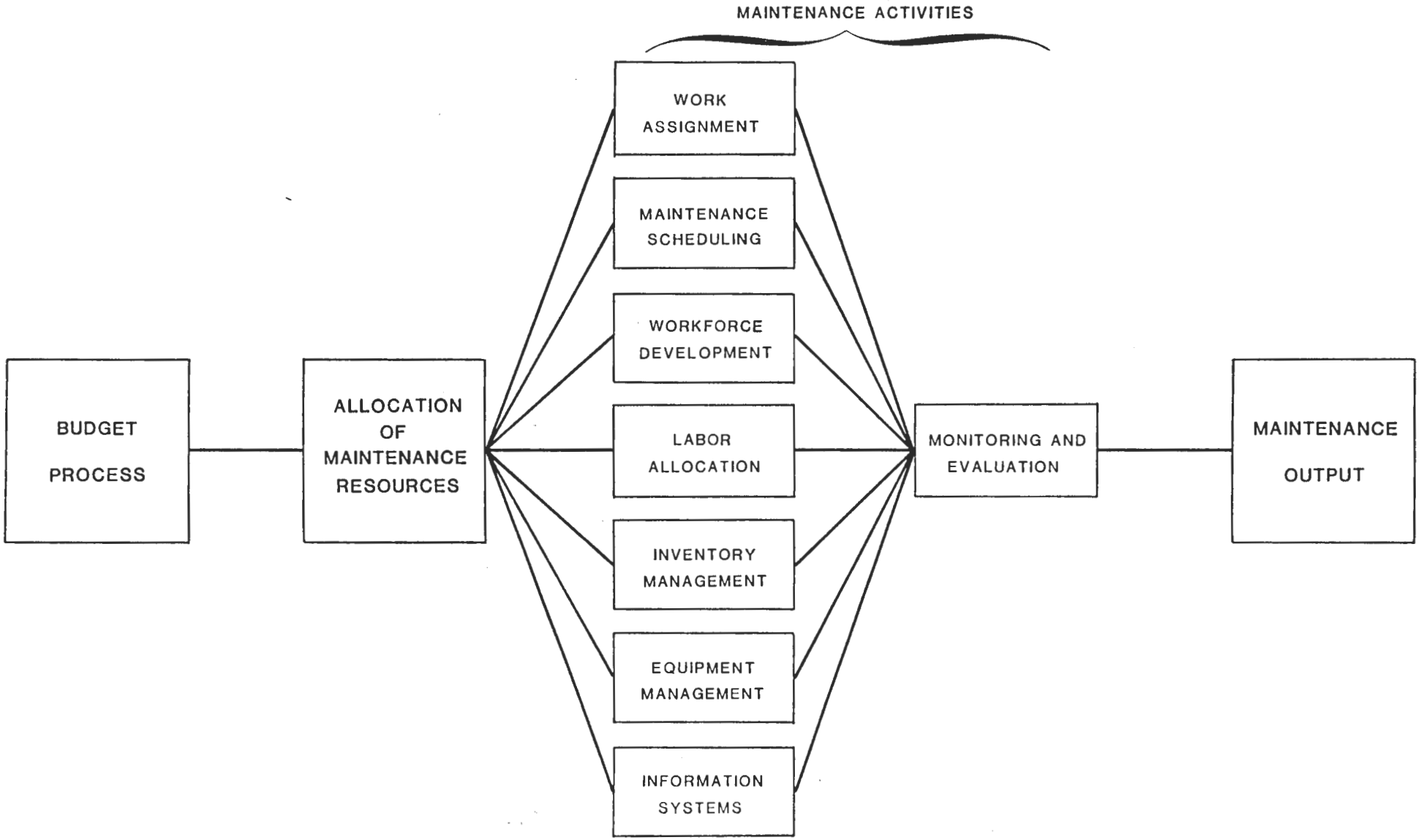


Figure 2. Operating Activities of the Maintenance Department

These activities represent a classification of the maintenance program into areas of maintenance management. They are:

- Work Assignment
- Maintenance Scheduling
- Workforce Development
- Labor Allocation
- Inventory Management
- Equipment Management
- Information Systems
- Monitoring and Evaluation

The above activities are under the direct control of maintenance management, and represent the highest level for maintenance management analysis. Each of these activities is discussed in greater detail in the following sections.

II. EVALUATION OF MAINTENANCE ACTIVITIES

A. FUNCTIONAL ACTIVITIES VS MANAGEMENT ACTIVITIES

The management of maintenance activities is vastly different from the actual execution of maintenance activities. For this reason, this report classifies maintenance into management activities, rather than the conventional functional activities. A statement of maintenance activities along the lines of the conventional functional classification is given to show compatibility between the approaches.

A typical functional classification separates the maintenance department into four major functional activities: daily servicing; inspection; minor repair; and major repair and rehabilitation.[6] In turn, these headings contain assorted subactivities. Daily servicing typically entails replenishment of fuel, lubricants, and fluids; vehicle cleaning; tire pressure monitoring; and the recording of mileage and other readings. Inspection includes daily driver inspection (pre-run and post-run); scheduled periodic maintenance; and fluids analysis. Minor repair encompasses component repairs required as a result of scheduled inspections and other repairs necessitated by in-service breakdowns. Major repair and rehabilitation takes in assorted major component repairs resulting from scheduled inspections; assorted major component repairs resulting from in-service breakdowns; and rebuild work that follows special rehabilitation campaigns. This itemization is shown in Figure 3.

Upon identifying the various responsibilities within each functional activity, the pattern of management areas that are associated with each of the functional activities can be obtained. Following Figure 3 downwards, it can be seen that similar management areas are brought to bear on each functional activity.[7]

If maintenance is approached from a functional viewpoint, management analysis is repeated with each function addressed. By contrast, if maintenance is approached directly through management areas, each subject of maintenance management can be treated in a more orderly fashion.

Figure 3 demonstrates how similarities in management areas develop into the eight management activities. By following the table down and then across, the functional activities are identified, elaborated, and then translated into management activities. Having confirmed the translation of functional activities into management activities, this analysis proceeds with a review of the details of maintenance. The next eight sections describe these management activities individually.

B. MANAGEMENT ACTIVITIES

1. Work Assignment

The work assignment task seeks to match the random arrivals of workload with the resources at hand. It takes workload as it arises and assigns priority and responsibility for the work.

Many critical subactivities reside within work assignment, and each can be manipulated to suit a manager's particular strategy. Work assignment includes the following critical subactivities:

- In-house repair vs. contracting out
- Vehicle inspection
- Queue discipline

In-House Repair vs. Contracting Out. There are two major reasons to contract repair work to commercial vendors: certain heavy repair operations require specialized personnel and/or equipment;[8] and contractors can perform

Daily Servicing	Inspection	Minor Repair	Major Repair and Rehabilitation	
DESCRIPTION OF FUNCTIONAL ACTIVITIES				
Fuel, lubricants, and fluids Farebox collection Cleaning interior Cleaning exterior Tire pressure Recording mileage and other readings	Daily driver pre-run inspection Daily driver post-run inspection Scheduled periodic maintenance Fluids analysis	Minor repair from inspection-generated work orders (scheduled) Minor repair from breakdown (unscheduled)	Major repair from inspection-generated work orders (scheduled) Major repair from breakdown (unscheduled) Special rehabilitation campaigns	
MANAGEMENT AREAS FOR EACH FUNCTION				MANAGEMENT ACTIVITIES
Setting daily agenda	Setting daily agenda	Setting daily agenda	Setting daily agenda	WORK ASSIGNMENT
--	Scheduling of inspections	Repairs generated from inspection schedule	Repairs generated from inspection schedule	INTERVAL SCHEDULING
Labor supervision	Labor supervision	Labor supervision	Labor supervision	WORKFORCE DEVELOPMENT
Labor deployment	Labor deployment	Labor deployment	Labor deployment	LABOR ALLOCATION
Use of fuel and cleaning materials	Use of parts and supplies	Use of parts and supplies	Use of parts and supplies	INVENTORY MANAGEMENT
Provision of mechanical equipment	Tools and mechanical equipment	Tools and mechanical equipment	Tools and mechanical equipment	EQUIPMENT MANAGEMENT
Ingestion of recorded information	Recording information, generation of inspection orders	Recording information, generation of repair orders	Recording information, generation of repair orders	INFORMATION SYSTEMS
Analysis of fuel, lubricant, and fluid use	Reviews of: recurring component problems; attainment of scheduled workload	Reviews of: quality assurance; attainment of scheduled workload	Reviews of: quality assurance; attainment of scheduled workload	MONITORING AND EVALUATION

Figure 3. Translation of Functional Activities into Management Activities

some work at a lower cost.[9] Smaller transit agencies tend to favor contracting more than large agencies, because they cannot afford the investment in equipment or skilled specialists. As organizations become larger, they are better situated to absorb the overhead of such investments.

Vehicle Inspection. The practice of contracting is not as prevalent for inspection as it is for repair. However, one form of contracted inspection that has become increasingly accepted is fluid analysis, typically in the form of spectroanalysis.[10]

Queue Discipline. In the course of work assignment, two problem situations can arise: simultaneous arrival of work, or backlog of work. In such situations, the maintenance department should have some established policy for which type of item should be attended first.[11] Typical options for queue management are as follows:

- First come, first serve
- Quickest tasks to be attended first
- Scheduled work attended before breakdowns

The selection of a specific criteria will significantly impact the output of the department. "First come, first serve" is simplest to administer, and therefore, may be suitable to the smaller operations. "Quickest tasks first," is a more difficult criteria to administer, but may better serve the objective of vehicle availability. "Scheduled work first" may best serve the objective of schedule adherence.

From this discussion of subactivities, work assignment can now be simplified into four basic sets of strategies. These strategies are presented in Figure 4 as points along a spectrum. Note that in general the very basic arrangements of A represent a package that may be more appropriate for smaller transit systems. As one moves toward D, more elaborate means of work assignment become more appropriate for the larger, more complicated operations.

2. Maintenance Scheduling

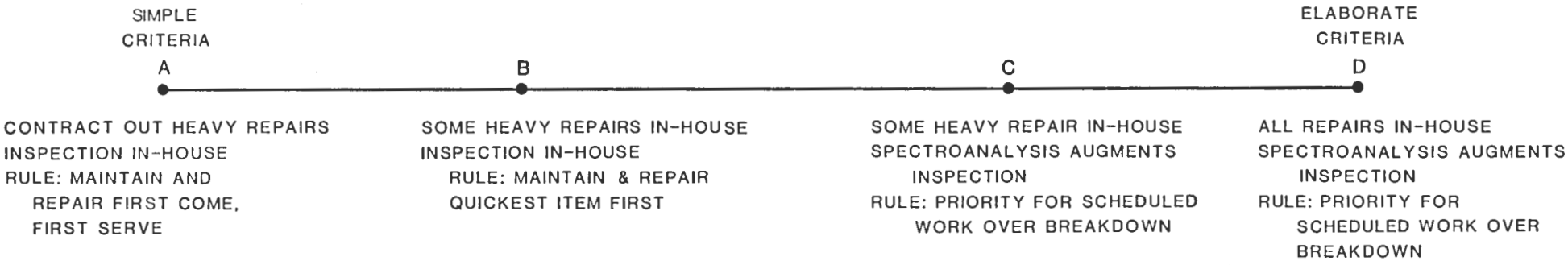
Maintenance scheduling is that activity which assigns periodic intervals to maintenance tasks, and provides an organized structure for this activity. Maintenance intervals are expressed in terms of vehicle miles (or hours), and these may vary for different components. The planning and scheduling of inspection intervals provide structure for both minor repair and major repair functions.

Maintenance scheduling strategies relate to the following subactivities which are also summarized in Figure 5:

breakdown-oriented, reactive maintenance,
manufacturer guidelines for inspection, mileage-based intervals,
custom-tailored inspection intervals, and
scheduled replacement of components,

Breakdown-Oriented Maintenance. An agency may select a strategy of maintaining vehicle components only upon breakdown.[12] Work remains essentially unstructured, and high breakdown incidence may be experienced.

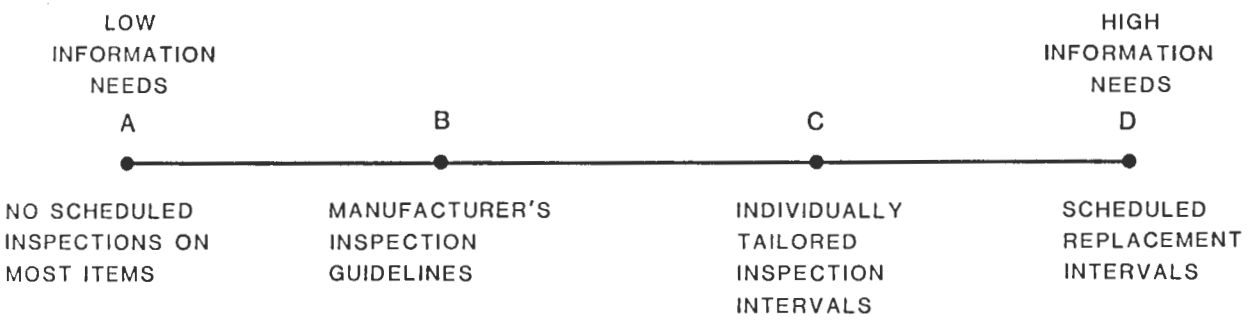
Manufacture Guidelines. The use of manufacturers' suggested intervals is commonplace for maintenance scheduling. Strict adherence to manufacturer guidelines requires little information capability, but their inspection frequencies may be too expensive for some agencies to enforce.[13]



SUBACTIVITIES ADDRESSED IN THIS SUMMARY :

In-house repair vs contracting out
Spectroanalysis: in-house inspection vs contracting out
Queue disciplines

Figure 4. Strategic Alternatives for Work Assignment



SUBACTIVITIES ADDRESSED IN THIS SUMMARY:

Breakdown-oriented maintenance
Manufacturer guidelines
Custom-tailored inspection intervals
Scheduled replacement of components

Figure 5. Strategic Alternatives for Maintenance Scheduling

Custom-Tailored Intervals. Individually tailored inspection intervals are also common in the industry. In their most common form, they accept most of the manufacturer guidelines, with only a few adjustments to reflect a particular circumstance. These adjustments may be based only on judgement,[14] or may be grounded in a rigorous statistical research.[15] As more intervals are tailored, a greater reliance is placed on information capabilities.

Scheduled Replacement of Components. At set intervals, designated components are replaced--at which point the removed component may be either discarded or rebuilt. The scheduled change-out of components reduces the expense of inspection, placing more emphasis on routinized repair instead of routinized inspection. Despite the apparent benefits of this approach, designing the appropriate intervals requires considerable analysis of component lives.[16]

Figure 5 shows a spectrum of alternatives for maintenance scheduling. As the agency moves from A to D, the sophistication and cost increase.

3. Workforce Development

Workforce development can be thought of as the personnel activities of the maintenance department. It includes: training programs, criteria for promotion, motivation: incentives, work standards.

Training Programs. Training becomes more urgent as recruitment of qualified, experienced labor becomes more difficult. Four essential options are outlined for training: (1) developing in-house training (classroom environment, manuals); (2) sending employees to outside institutions for instruction (local technical schools, other transit systems, or participating manufacturers); (3) on-the-job training through formal apprenticeship; (4) on-the-job training with essentially no formal structure. These four options are listed in order of desirability, but also in order of resource requirements. While the last option is clearly undesirable, it recognizes that some transit agencies, especially the smaller ones, do not have the capacity to invest in the overhead of training programs.[17]

Criteria for Promotion. A promotion policy must address its criteria for evaluation: whether it be seniority, testing, or records of performance. Seniority provides a very straightforward criteria for evaluation, and it discourages turnover. However, excessive reliance on seniority ignores substantive qualifications, such as skill and ability. Therefore, some formalized testing of skills and abilities at each stage of promotion may be desirable.[18] An even more precise evaluation is available through employee performance records, for performance items such as absenteeism and completion times of maintenance tasks.

Motivation. Transit industry base salaries usually offer little differentiation for achievement, and so the subject of incentives becomes quite important.[19] Incentives may be defined as special rewards in an attempt to enhance performance. Incentives come in two primary categories: monetary and nonmonetary. Monetary incentives, while important, are not necessarily the greatest incentive in the workplace. In cases where pay incentives are restricted (as in many public organizations), nonmonetary incentives (status and recognition) may provide the needed motivation factor.[20]

Work Standards. Work methods and standards are typically established through clinical observation of the routine tasks that comprise work activities. When time standards are established for tasks, promotion and incentive evaluations are assisted. Furthermore, planning (crew sizing, equipment planning, and annual budgeting) are assisted by work standards. Standards present one of the frontiers of maintenance management,[21] but their institution often requires good management-labor relations. In addition, the supervision of work standards often requires automated information systems.[22]

Using the elements of subactivities discussed above, Figure 6 summarizes workforce development into strategic alternatives on a scale that relates increasing complexity of investment in this management elements.

4. Labor Allocation

Labor allocation is distinguished from workforce development. The latter represents activity toward personnel policies, whereas the former represents the allocation of manpower as a resource. In this sense, labor allocation may actually be more comparable to equipment management and inventory management, rather than to workforce development.

The subactivities to be discussed under labor allocation are

number of shifts: 1, 2 or 3,
specialized vs. generalized orientation of mechanics,
inspection vs. repair crews, and
specialized teams.

Number of Shifts. The number of shifts can vary from 1, 2, or 3. If 2 or 3 shifts are deployed, vehicle availability is promoted, because maintenance activity occurs during off-hour shifts when revenue service is reduced or nonexistent. If only one shift is deployed, a higher spare vehicle level is required to ensure availability for transportation operations. However, other considerations might favor deployment of only 1 shift. For example, labor requires a wage premium for working the undesirable hours of a second or third shift, which is a requirement that public transit generally has difficulty accommodating.[23] In general, larger agencies prefer 2 or 3 shifts, while smaller ones might be more inclined to one shift.

Specialized vs. General Orientation of Mechanics. Certain functions of repair require greater skill than others. Examples are major repair items such as engine rebuilds, transmission repair, and air conditioning repair. For such special items, it is appropriate to develop specialized personnel for their tasks. Smaller organizations may avoid the designation of specialists due to the need for small crews to be available for all duties, and limitations in special repair equipment, which limits the department's opportunity to address the major repair items. As agency size grows, both of these constraints are removed, and it becomes orthodox to designate specialists.

Inspection vs. Repair Crews. One of the most fundamental strategies facing the manager is whether or not to differentiate the maintenance department into an inspection crew and a repair crew. There are many arguments for the separation of inspectors from mechanics--one being that specialization leads to proficiency, another being that an unseparated workforce may under-inspect. An inspector may be less likely to generate a repair work order that he may also be responsible to execute.[24] Nonetheless, smaller transit organizations may prefer across-the-board duties so as to preserve flexibility in attending the peaks that occur in either function of inspection or repair.

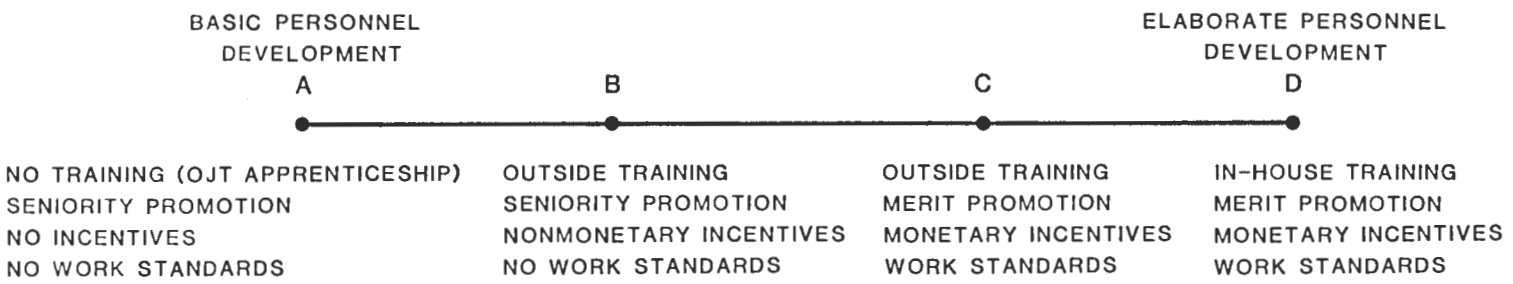


Figure 6. Strategic Alternatives for Workforce Development

A separate structure for inspection and repair tends to occur as size of operations increases beyond about 150 buses.[25]

Specialized Teams. Lastly, specialization can be taken furthest by providing permanent specialty teams--for such items as air conditioning, body work, or brakes.[26] Specialized teams represent the greatest commitment to specialization; they act as independent subdepartments. Whereas a specialized individual may be assigned to non-specialty tasks with relative dispatch, the disassembly of a specialized squad is far less practical. In view of the inflexible commitment of workteams, a large, steady volume of repair tasks--as might be experienced with air conditioning or brakes--is necessary to support a fully specialized team.

The subactivities of labor allocation have been introduced and discussed. Labor allocation is summarized as a set of strategic alternatives in Figure 7.

5. Inventory Management

Inventory management controls the fundamental resources of materials and supplies. Effective inventory management provides inventory in a timely fashion, and maintains low stock levels. These two goals compete, as the surest way to provide dependable response is to stock enormous quantities. Therefore, inventory management policy seeks to achieve an optimum balance between these two goals.

The critical subactivities of inventory management include

- management of inventory quantities,
- concept of safety stock,
- concept of service levels, and
- manual vs. automated control and supervision.

Management Methods. Different methods of inventory management are available to the maintenance department. The minimal method simply establishes certain low levels for inventory items. When stock quantities sink to these levels, then stock is reordered, in any quantity that is expedient at the time. With irregular demands, this method risks a high probability of stockout, and at the same time it risks higher-than-necessary inventory levels. As size of operations grows, the problems of stockouts and inventory levels become more difficult to control, and thus more careful administration of inventory is warranted. More analysis is applied to the order timing and the order quantities. Two common analytic methods are the periodic order system, and the economic order quantity/reorder point (EOQ/ROP System).[27] The periodic system fixes regular order times but employs irregular order quantities, whereas the EOQ/ROP system does the opposite. It employs irregular order times but fixes regular order quantities. Whichever method is selected, the increased analysis and supervision interests of these systems brings more control to inventory operations.

Concept of Safety Stock. The above management methods try to pattern inventory levels after some perceived forecast of demand. However, uncertainty accompanies all forecasts, no matter how perceptive the forecasts may be. Therefore, a margin of safety stock is usually added to the quantities prescribed in management methods, as extra insurance against stockouts. The particular degree of safety stock may be determined by very informal judgement, or may be determined through an analysis of service levels.

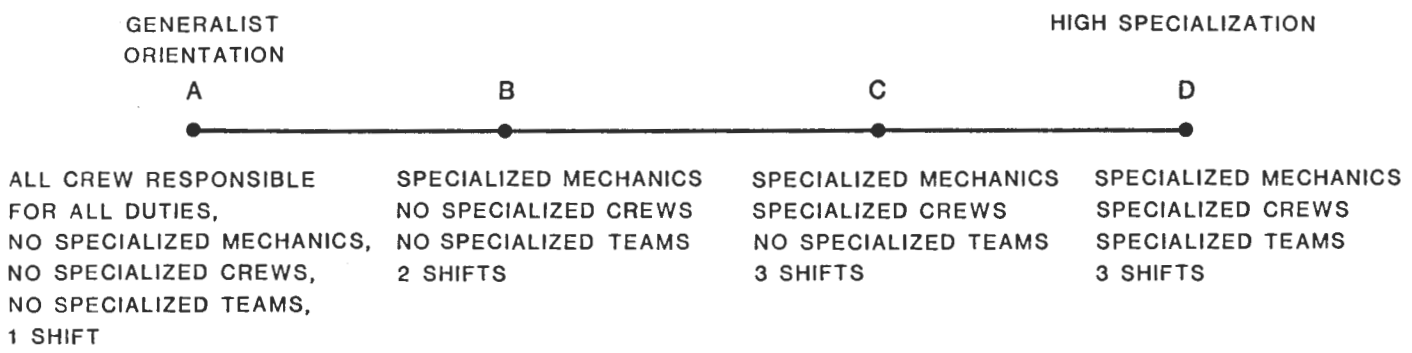


Figure 7. Strategic Alternatives for Labor Allocation

Concept of Service Levels. Inventory service levels are explicitly analyzed in the more developed inventory systems. Sophisticated forecasts of parts use are developed from historical records, and the forecasts include measures of variations in parts usage. From these forecasts, safety stock levels can be determined to deliver a definable probability of stockout, e.g., 1%, 5%, 10%, etc. Through service level analysis, a department can articulate the probability of stockout that it finds acceptable, and then achieve that level of service.[28]

Manual vs. Automated Control and Supervision. Throughout the discussion of inventory management, it should be evident that information systems are vital to a strong inventory system. Inventory management requires an attention to tedious detail, and it requires quick retrieval of records. As operations grow, the inventory area becomes a prime candidate for automated information. At the most sophisticated level of information management, the program of one activity can be coordinated with the program of another. For instance, events occurring in the maintenance scheduling program might automatically trigger events in the inventory management program; notification could thus occur well in advance of part need.

The set of strategic alternatives for inventory management are exhibited in Figure 8.

6. Equipment Management

Equipment is regarded as a capital item, which hinders its comparability to other resources. However, equipment management can be made compatible with operational analysis by expressing capital costs as annualized sums.

Equipment management contains these subactivities:

analysis of operational savings vs. annualized costs,
review of types of functional equipment, and
information systems hardware.

Operational Savings vs. Annualized Costs. In bus maintenance, specialized equipment captures two important benefits. Equipment can serve as a labor-saving device or equipment can enable departments to perform some tasks that otherwise could not be performed--an example being a milling machine, without which a department cannot perform cylinder resurfacing.

In general, equipment investment represents increased savings in labor, and increased costs in capital. Therefore, benefits are received per unit worked, but costs are assessed per day. For this reason, those agencies with a higher unit volume per day have an advantage in equipment decisions.

Review Types of Functional Equipment. The number and types of items that can be considered maintenance equipment are quite extensive. Some reports have listed at length the typical equipment associated with bus maintenance operations.[29] To these basic lists certain specialized equipment, such as dynamometer testing equipment, could also be added. A transit system can compare its capabilities against such lists and determine whether it might be classified a "low capital intensity" or "high capital intensity" department.

Information Systems Hardware. Although information hardware clearly overlaps into the activity of information systems, it remains an equipment management decision. Like any other equipment, information hardware should be evaluated for its costs and benefits relative to alternatives. Information

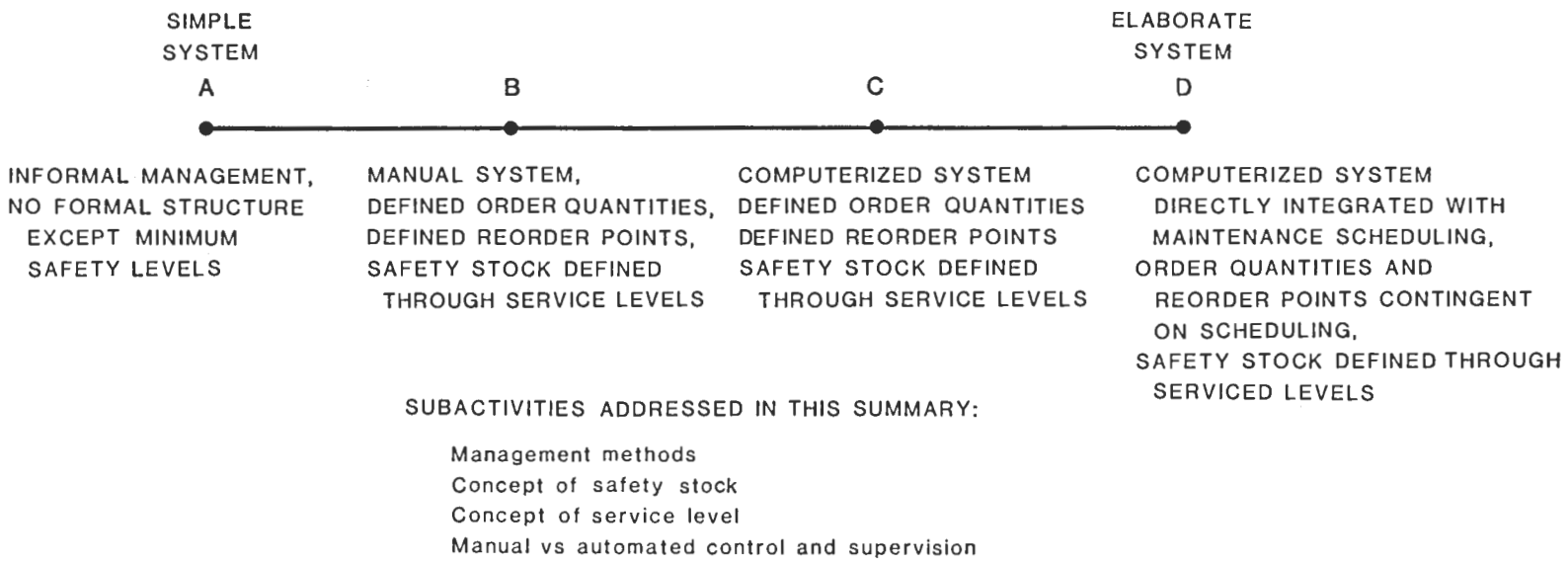


Figure 8. Strategic Alternatives for Inventory Management

hardware falls into three basic families of capabilities: microcomputer, minicomputer, and mainframe computer. The families are listed in ascending order of capabilities, as well as size of investment. The larger hardware may not necessarily be more appropriate for larger operations, especially with the enhanced capabilities of newer personal computers. Clearly, the hardware chosen (if any) will greatly impact the opportunities in the information systems activity.

Equipment management is summarized in Figure 9, as a set of capital intensity strategies.

7. Information Systems

Mention of information systems has recurred throughout the discussion of other activities, since information pervades all department operations. There are many options available for the design of information systems, and it is imperative that all options be considered. Some of the critical considerations include

level of information detail,
manual systems,
automated systems,
direct vs. indirect systems, and
integrated vs. non-integrated programs.

Level of Information Detail. One can typify information systems as aggregated information or disaggregated information. All systems engage in considerable detail, as even the simpler systems support individual parts records for inventory and individual work histories of vehicles. However, typical benchmarks in system complexity occur when a department achieves these levels of disaggregation:

1. Convenient storage, retrieval, and analysis of worker tasks times (see work standards).
2. Convenient storage, retrieval, and analysis of component failure records (see scheduled replacement of components).

Manual Systems. Manual, or paperwork, systems can accommodate all of the functions that simpler automated systems can (note strategies A and B in Figure 10).[30] The difference in systems tends to be one of ease and rapidity of processing. Naturally as operations increase in size, the benefits of automation become more pronounced.

Automated Systems. Different gradations accompany the automation of information systems, depending upon the level of system which is desired. As stated in the equipment management section, these options represent different capabilities as well as different investments. It should also be kept in mind that some portion of an information system can be converted to automation, while other portions remain manual. For instance, inventory is often the first program to be automated in maintenance, while work histories and scheduling often follow later.[31]

Direct vs. Indirect Data Entry. Information can be entered directly or indirectly. Indirect entry occurs when information is recorded first at the work station, only later to be organized or translated into the information system. Paperwork systems typically require indirect entry, where clerks process and file forms that are first filled at work sites. Automated systems frequently require a similar indirect procedure, where forms are filled out at

SUBACTIVITIES ADDRESSED IN THIS SUMMARY:

Analysis of operational savings vs annualized costs
Review of types of functional equipment
Information systems hardware

Figure 9. Strategic Alternatives for Equipment Management

work stations and later translated by clerks to automated storage. Direct data entry occurs when information is entered directly at the work station, through on-site terminals or portable recorders. Direct entry tends to streamline information procedures and frequently reduces interference in procedures; but it requires additional investment in automated equipment.[32]

Integrated vs. Non-integrated Programs. As a last consideration, automated information can be designed in a coordinated fashion, where events in one program directly trigger another program (see inventory management). Such sophistication in programs is not of immediate necessity to maintenance departments, and thus this alternative is appropriate for only the very largest transit organizations.

The above discussion is summarized as a set of strategic alternatives, ranging from simple to elaborate as presented in Figure 10.

8. Monitoring and Evaluation

Monitoring and evaluation reflects upon each of the preceding management activities. As outlined earlier, a strategy must be chosen for each of the activities, but, additionally, the success of that choice must be assessed. The monitoring and evaluation task selects those qualities that are to be measured, and then it evaluates those measurements. Performance measurements might address one specific activity, some combinations of activities, or the aggregate maintenance department. For example, a high value for absenteeism may suggest failings in a department's motivational programs.

Other measurements, such as spare-to-peak vehicle ratio, may reflect a combination of activities. A high share of spare vehicles usually indicates a capacity constraint in one or more of the following resources: labor, equipment, or facilities.

Still other measures reflect the aggregate of all maintenance department activities. "Miles per roadcall" or "maintenance cost per vehicle mile" tend to describe the collective department's output. Typical aggregate output performance measures for the maintenance department include

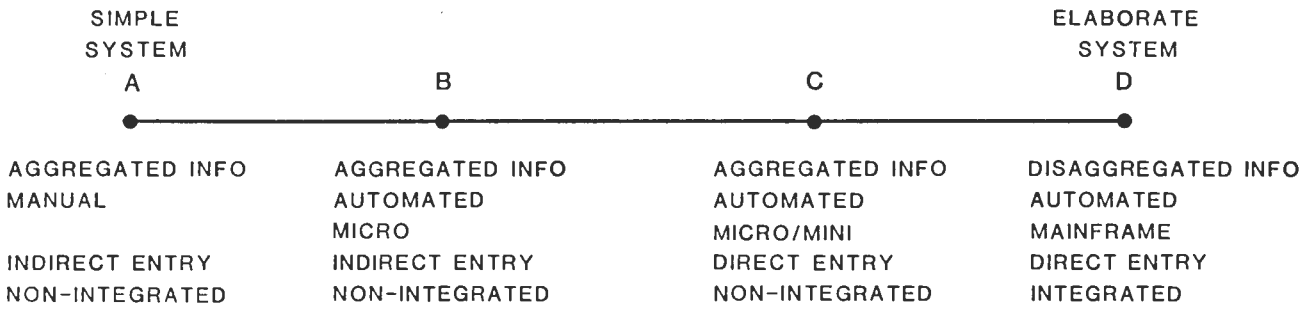
roadcalls,
missed runs,
late outs,
inactive buses,
life mileage,
fuel and lubricant use,
accidents due to mechanical failure, and
cost of maintenance per mile.

For the purpose of this analysis, output can be used to compare the performance of a maintenance department against

past performance of the department,
an established ideal of performance, and
the performance of departments in other agencies.

All of the output measures are worthy, but the latter comparison must be confined to those measures that are most common in the industry.

UMTA Section 15 data provide an excellent source of comparative data, but comparison is limited by those measures that it records. Roadcalls, accidents, and maintenance cost are recorded.[33] Accidents, however, are not identified for mechanical failure. For simplicity's sake, then, the two measures, roadcalls and maintenance cost, provide a basic aggregate picture



SUBACTIVITIES ADDRESSED IN THIS SUMMARY:

- Level of information detail
- Manual systems
- Automated systems
- Direct vs indirect data entry
- Integrated vs non-integrated programs

Figure 10. Strategic Alternatives for Information Systems

of the maintenance department. Roadcall data must be carefully examined, however, to assure that definitions are consistent.

The subject of bus maintenance has now been classified into eight management activities. These activities have been further broken down into pertinent subactivities, and the subactivities have been discussed in brief. After some discussion, each activity has been summarized as a collection of management strategies. [34]

C. COMPOSITE PROFILE OF A MAINTENANCE DEPARTMENT

Figure 11 presents a synthesis of organizational structure and managerial alternatives that have been developed. Community and external factors appear as descriptors on the left hand column of the table. Given a description of an agency's situation, the appropriate activity designations can be made across a row. A maintenance department can thus be rendered as A-A-A-B-A-C-A or D-C-C-B-C-C-D or B-B-A-B-B-C-C, etc.

Figure 11 suggests visually that some strategies for an activity are consistent with circumstances and other strategies while others are not consistent. The circumstances of the agency listed first serves as the "base case" for the analysis. The smallest system naturally is appropriate for the most basic policies in all management areas. Thus, recalling the preceding exhibits, for a 15-vehicle system with no exceptional circumstances, the maintenance strategies correspond to the "A" level strategies from each figure, except for those activities where wider discretion is recognized. [35]

This abbreviated presentation engages in generalized types of agencies ("small," "large," etc.), and this sample table follows the base case with examples of the types that would support consistent "B"-level departments, "C"-level departments, and "D"-level departments. At each example, descriptors in the left column are being matched to the strategies across the rows, and the strategies are also being matched among themselves.

The most visible determinant in the development of a management system is the size of the agency, i.e., the number of vehicles to be maintained. It is suggested in this table that a very small system of 15 vehicles warrants the simple A-A-A-A-A-A-A configuration, that a moderately small system of 40 vehicles warrants a B-B-B-B-B-B-B configuration, that a medium to large system of 200 vehicles warrants a C-C-C-C-C-C-C; and that a large system of 450 vehicles warrants a D-D-D-D-D-D-D.

The four general types of departments, then, may provide a basic reference for this analytical framework--"all-A," "all-B," "all-C," and "all-D" properties. However, this framework is designed for flexibility, and particular details can be incorporated into the analysis, yielding far more than four basic configurations.

Not all configurations are valid. For instance, the theoretical configuration of A-A-A-A-A-A-D is nonsensical, as a department with reactive scheduling and minimal information needs for its labor, materials, and equipment management would have no cause to support highly detailed, automated, mainframe integrated information systems.

D. APPLICATION OF THE EVALUATION PROCEDURE

The framework in this report provides a practical field guide for evaluating bus maintenance management activities. The application of the evaluation procedure requires consideration of two important issues: the intended purpose of the evaluation and the intended level of analysis.

DESCRIPTION (EXTERNAL FACTORS)	WORK ASSIGNMENT	MAINTENANCE SCHEDULING	DEVELOPMENT	WORKFORCE ALLOCATION	LABOR MANAGEMENT	INVENTORY MANAGEMENT	EQUIPMENT SYSTEMS	INFORMATION SYSTEMS
BASE CASE: Small Community (50,000) Dispersed Community Light Transit Reliance Flat Terrain Warm, Moderate Climate Inexpensive Labor Market New Road Surfaces 15-Bus Fleet 72 Hrs. Revenue Service/wk. Homogeneous Fleet Abundant Capacity in Facility Nonunionized Workforce	A	AorB	AorB	A	A	A	A	
Moderately Small Community (120,000) Dense Community Moderate Transit Reliance Flat Terrain Moderate Climate Expensive Labor Market New Road Surfaces 40-Bus Fleet 90 Hrs. Revenue Service/wk. Heterogeneous Fleet Abundant Capacity in Facility Unionized Workforce	B	B	B	BorC	BorC	B	B	
Moderately Large Community (500,000) Dense Community Moderate Transit Dependence Flat Terrain Warm, Moderate Climate Expensive Labor Market New Road Surfaces 200-Bus Fleet 105 Hrs. Revenue Service/wk. Heterogeneous Fleet Abundant Capacity Facility Unionized Workforce	C	BorC	C	C	C	C	C	
Large Community (1,000,000) Dense Community Moderate Transit Reliance Flat Terrain Warm, Moderate Climate Expensive Labor Market New Road Surfaces 450-Bus Fleet 120 Hrs. Revenue Service/wk. Heterogeneous Fleet Abundant Capacity Facility Unionized Workforce	D	CorD	D	D	D	D	D	

Figure 11. Composite Profiles of Maintenance Departments

1. Purpose of the evaluation

Essentially, the purpose of such evaluation is either to examine the consistency among strategies, or to investigate the output performance of the department.

In the first case the evaluation procedure may reveal some surprising relationships from one activity to another. For instance, a large 400-bus system might assess its maintenance department as follows: B/C-C-C-D-B-C-A. In the specific example, information systems appears to be the questionable strategy (at "A") with inventory management ("B") and work assignment ("B/C") of similar question for a transit system of this size. These three strategies are instantly recognized because of their apparent inconsistency with the descriptive condition of a 400-bus fleet and their apparent inconsistency with the general pattern of other strategies.

The above evaluation examines consistency among strategies, but another application directly addresses output performance of a department. Two measures, vehicle miles/roadcall and maintenance cost/vehicle mile, provide quick aggregate assessment; and they also facilitate comparability with other organizations. If the department's performance appears inferior to other maintenance departments performance (Section 15 data provides a convenient reference for this comparison), then perhaps more intent examination of the present configuration is needed. However, in some cases the performance of a department may indeed be stellar, despite a curious configuration. In which instance, management would wish to apply caution to modifications in activities.

2. Level of Analysis

In order to accomplish the previously described evaluation tasks, some data on performance and resource management is required. The specific level of data requirements will depend on the level of analysis desired. For example, one may consider two extremes of analysis: one an in-depth case study conducted by independent experts, and one a quick response check list evaluation conducted by a transit agency official. Both types of study are appropriate for different objectives.

In-depth case study requires extensive examination, including a comprehensive on-site evaluation. For the in-depth study, a team of independent reviewers should first be selected. The transit agency should supply the team with a basic description of the maintenance department. The study team reviews the data provided and then performs a site visit for general, empirical observation. Ultimately, a report is prepared which describes the maintenance operation in terms of its activities and elements. Such a report should conclude with an evaluation statement and recommendations for improvements or change.

The case study method thus probes into the problem by extracting quantitative and qualitative (observations and interviews) data. This case study approach should be used when a major reorganization is contemplated, or when very serious productivity problems exist.

For the transit manager who wishes to review his maintenance effort immediately, a quick response check list approach is more appropriate. In this case, the major characteristics of the operation are summarized in relation to the scales shown in Figures 4 to 10, and a composite evaluation is drawn in the manner of Figure 11. The results can be compared against either established norms or comparable evaluations from similar transit agencies.

The evaluation framework of this study provides a flexible reference for conducting evaluations of bus maintenance effectiveness. It can be applied

in-depth, rapidly or somewhere in between the two examples cited, depending on the objectives of the study.

III. CASE STUDY EVALUATION OF A BUS TRANSIT MAINTENANCE PROGRAM

A. APPROACH

In order to demonstrate the ideas developed in the framework of this study, one agency was selected as a case study. The agency was selected in view of the following considerations: a bus operation within the size range roughly from small to medium, or 15 to 500 buses; and the agency should be willing to cooperate with the study team. The agency selected was the Tidewater Transportation District Commission (TTDC), of Norfolk, Virginia.

The TTDC is a special administrative arrangement which provides public transportation services for five separate municipalities in the southeastern corner of Virginia. The municipalities are Norfolk, Virginia Beach, Portsmouth, Chesapeake, and Suffolk. The number of motorbuses in the agency fleet is 180 and the agency also has an extraordinary commitment to vanpools and minibuses (165 vehicles). Operating cost for the bus operation is $13,274,422, 19.8% of which was dedicated to bus maintenance.

The appendix includes the "at-length" evaluation form that was worked up in three stages: (1) General study of maintenance management, as described in the first half of this report; (2) Preliminary visit and discussion with various TTDC officers; (3) Process of feedback and review during final stages of the site visit. In this site visit, these individuals were targeted and contacted:

Assistant Superintendent of Equipment I
Assistant Superintendent of Equipment (and Maintenance Training) II
Administrative Assistant, Equipment Office
Purchasing Manager
Transportation Planner
Computer Operator

An evaluator should seek to strike some balance between contact with a large number of individuals and positions, and an efficient process for gathering information. The evaluation form closely follows the format of the presentation of material in the earlier sections of this report, and the case study follows this format as well.

B. DESCRIPTION OF COMMUNITY AND EXTERNAL CONDITIONS

From a review of outside environmental factors from the organization, pertinent information can be summarized for the left column of the matrix. TTDC serves an area characterized by

a large community (900,000),
moderate population density,
moderate-to-light transit reliance,
flat terrain,
mild-to-warm, variable climate, and
moderately priced labor market.

The most notable factor in this group that would influence maintenance performance is the almost ideal operating conditions of mild weather and flat terrain. These factors are not significantly mitigated by any adverse conditions in the labor market or road conditions.

Organization objectives are promoted through an MBO (management by objectives) system, which stresses at the highest level that the budget deficit should not exceed $1.00 per passenger, and that the highest-level charge specifically addressed to the maintenance department is that the maintenance department should support "running equipment as efficiently, economically, and effectively as possible," although of course the objectives become more

specific as they filter down the organization. Informally, maintenance managers state that "cleanliness and mechanically stable fleet (not a lot of breakdowns)" are stressed.

The total number of buses in the fleet is listed as 180 including smaller buses and gasoline-powered "trolley-body" buses. Peak-period buses are 129, base service is 78 buses. Bus service runs 22.5 hours on weekdays (4:20 A.M. to 2:50 A.M.), and roughly one hour less on Saturday and Sunday, for a total of 153.8 hours of weekly service out of 168 possible. Buses operate 1,221 revenue hours per weekday.

The bus fleet has to be characterized as diverse, or heterogeneous, with a breakdown as follows;

Number	Year	Vehicle Model
47	1973	Grumman Flxible 53102
10	1978	Bluebird
72	1979	Grumman Flxible 53096
20	1980	GMC RTS-II
7	1981	Ford "Trolley"
13	1983	Grumman Flxette
9	1983	GMC "Trolley"
2	1980	Chevrolet Transliner

The average age of the fleet is 5.9 years.

The maintenance department supervises maintenance activities at two sites. According to interviews, four facilities exist, but one is for paratransit, not motorbuses, and another one is presently inactive. Of the two active sites it should be noted that almost all activities take place in the central Norfolk garage and shops, with only limited activities (gasoline bus trolleys) taking place in Virginia Beach. Therefore, remaining comments will only address the Norfolk site.

The Norfolk facility is very old (80 years, roughly) but it has a design capacity that still can accommodate the present bus fleet size. The facility includes 10 lifts, 5 pits, and one bay. The biggest problem observed is with the servicing operation, and the need for backup electricity in case of power failure--however, a thorough renovation of the site is being planned and will address these problems.

The labor is unionized but, as a result of a recent agreement, the base wages are extraordinarily low, at $4.33. Another feature of labor agreements is a strong adherence to a seniority system for promotion which "both helps and hurts (effective management)." Older workers are not necessarily the best performers, but seniority preference does provide an important incentive for one to stay with TTDC.

From the above review of organizational policies, pertinent information can be summarized to complete the left-hand column of the matrix.

180-bus fleet, 129 peak fleet
154 hrs. revenue service/wk.
Diverse fleet
Abundant capacity in facility
New fleet, 6.0 yrs average age
Unionized workforce
28% spare vehicles

C. WORK ASSIGNMENT

Work assignment through out the day is executed in the following sequence. Buses receive a brief inspection by operators at the beginning of the run, and extended preventive maintenance inspections take place chiefly during the day (1st shift, 7 AM to 3:30 PM), unit overhaul and other shop activities take place during day (7 AM to 3:30 PM), running repair takes place during all shifts (7 AM - 3:30 PM, 3:30 PM - 12:00 AM, 10:30 PM - 7 AM) in response to breakdowns, operator-generated or inspection-generated work orders, and the servicing shift (6 PM - 2 AM) occurs in between shifts.

The pace of workload is essentially determined by the inspection intervals (see Maintenance Scheduling) and the resulting work orders, and by in-service breakdowns or operator complaints. Essentially six buses a day receive a preventive maintenance inspection. All vehicles pass through the daily servicing cycle, and the servicing cycle averages from 15-20 minutes per vehicle. During this cycle, the farebox is removed, oil and transmission fluids are checked, tires and lights are checked, fuel tank is filled, vehicle is vacuumed, and vehicle is washed and parked.

Shop activities consist of unit overhaul (rebuilds and other work that require removal of components), bodyshop, and paint booth. All these activities take place in the first shift (7 AM - 3:30 PM).

The above describes the routine assignment of work tasks. Frequently events in the day are not routine, however, and certain issues must be confronted in the assignment of work tasks.

One such issue is the contracting of work outside the agency. Some tasks of repair are contracted out, but it is the policy of the maintenance department that no item is automatically contracted. Essentially only 1% of engine and transmission work is contracted out, at times when shops become overloaded (shortage occurs in specialized personnel for those time-consuming tasks), but otherwise no contracting out occurs. In cases such as peaks of air conditioning repair work, the policy of the department is overtime instead of contracting, so as to ensure control over operations.

Another issue of work assignment is whether to execute inspection procedures entirely on the site. The department does administer regular on-site inspection procedures but in addition some oil analysis is conducted by an outside firm, which effectively amounts to contracting some inspection out. In this case, oil spectroanalysis is performed by the vendor that supplies oil to the department. This service is furnished free, to advise on the condition and performance of oil stocks. The officers believed that this service did not appreciably assist or augment on-site inspections. They suggested that it was executed because it was a free service and results were not incorporated into the inspection routine.

Another policy of work assignment is whether to improvise a schedule, or whether to pre-arrange a work schedule of tasks at the beginning of the day, or whether to pre-arrange a work schedule of tasks as much as a week in advance. Generally, at TTDC, maintenance work conforms to the second option--work is scheduled at the beginning of the day, "subject to change" as events occur in the day. However, the department does try to schedule the heavy work of the unit overhaul shop as much as one week in advance.

Lastly, the rule of queue discipline determines the sequence of work of the maintenance shop. Maintenance duties at TTDC are largely dispatched on the basis of "quickest tasks to be done first." In the running repair shop, a secondary rule was also suggested: "put new buses on the road before old buses" to promote attractiveness of service.

A review of the above discussion can be compared to the discussion of work assignment in Section II. If the TTDC maintenance department's work assignment policies are compared with Figure 4, TTDC conducts almost all heavy repair in-house, which would place TTDC at a position a littler higher than "C" on the spectrum of work assignment. TTDC also conducts some off-site spectroanalysis inspection, but the spectroanalysis plays a subdued role in operations, so this feature would place TTDC a little lower than "C" points on the spectrum. Queue discipline policy of "quickest items first" indicates that operations have not yet attained the size where scheduling difficulties would make "scheduled work over breakdown work" the dominant policy. Thus, TTDC's queue discipline would place it on the "B" point of the spectrum. Totalling the factors, and giving weight to the first point of minimal contract work, TTDC's collective work assignment policy can be summarized as "C."

D. MAINTENANCE SCHEDULING

Maintenance scheduling provides the basic foundation for the pattern of work in any maintenance department. The first decision a maintenance department faces is whether to assert a preventive maintenance schedule or simply to attend maintenance needs upon breakdowns. The TTDC maintenance department has opted to select a preventive maintenance schedule, which revolves around basic inspection intervals of 6,000 miles for most vehicle models (or units of 3,000 miles for the smaller Flxettes and "trolleys"). Table 1 shows a complete summary of the inspection schedule. This schedule is adhered to conscientiously, except for some seasonal special campaigns, such as spring's A/C, alternators and fall's water pumps and heaters. Furthermore, pre-run (check for water, windshield wiper, signals, accident damage, loose mirrors, etc.) and post-run inspections are executed by drivers at each vehicle run.

The specification of mileage for intervals is a crucial process. TTDC bases its schedule primarily on the guidelines suggested by manufacturers, although this base is frequently modified to suit agency experience. "Meeting warranty requirements is not a consideration (in our maintenance schedule) because we more than cover them," one officer suggested, because TTDC adjustments on manufacturer guidelines tended to produce smaller intervals. As an example of adjustment, the manufacturer of the smaller Flxettes recommended 6,000 miles as a basic unit for inspection. Using this schedule, TTDC experienced repeated problems, such as oil leaks and dirty transmission fluids. The department reacted to this experience, adjusting its basic inspection interval to 3,000 miles. The new interval value was arrived at through an informal process of judgement and analysis of records. Maintenance officers judge that, since this adjustment, the system has worked fine. The department estimates that $8\frac{1}{2}$-10% of items that are listed for inspection have received revised interval values.

The TTDC maintenance department has not established a strict program for scheduled replacement of components. Major components are frequently rebuilt when they are judged to be performing poorly, but precise mileage intervals are not observed.

For the purpose of reevaluating inspection intervals or arriving at a decision to pull and rehabilitate a component, the department refers to monthly computer print-out reports that display incidents of in-service

Table 1

Basic Preventive Maintenance Inspection Schedules

TIDEWATER REGIONAL TRANSIT

6,000 MILES PM INSPECTION (standard fleet)		3,000 MILES PM INSPECTION (Flxette and GMC "Trolley")
Engine Starters	72,000 miles	same
Engine Water Pumps	60,000 miles	same
Heater Water Pumps	60,000 miles	same
A/C Alternators	60,000 miles	same
Differential Grease	48,000 miles	18,000 miles
Transmission Fluid & Filter	36,000 miles	18,000 miles
Engine Oil & Filter	6,000 miles	3,000 miles
Engine Tune-Up	18,000 miles	12,000 miles
Torque Body Bolts	18,000 miles	18,000 miles
Fuel Filter	24,000 miles	18,000 miles
Air In-take Filter	36,000 miles	same
Brake check	6,000 miles	3,000 miles

troubles either according to individual bus vehicles, or alternatively according to component type. When it is judged that extraordinary problems occur with a component, action can be taken to either rebuild a particular component or to revise inspection intervals for a component.

At the time of the site visit, maintenance scheduling had been mostly computerized. The computer information system traces which vehicles are coming upon their inspection time, by comparing miles since last inspection vs. the basic interval length (usually 6,000 miles).

A comparison of the TTDC maintenance department's longterm scheduling policies with Figure 5 indicates that TTDC has opted to implement a preventive maintenance inspection system, which is to be expected from all but the smallest agencies. To develop the inspection schedule, manufacturer's guidelines for mileage intervals are used as a base, but this base is considerably adjusted according to department records and judgement. The TTDC maintenance department does not however, employ elaborate, statistical studies to establish interval values, but instead has found success with a more informal analytical process. The TTDC maintenance scheduling policy has not emphasized optimal intervals for automatic replacement of components instead of inspection intervals. Because of the informal analytic process that accompanies interval values, and because scheduling has not been taken to the extreme of studying optimal replacement intervals, one would place TTDC's maintenance scheduling policy at "C" on the spectrum of Figure 5.

E. WORKFORCE DEVELOPMENT

The personnel functions of the maintenance department are guided chiefly by labor union agreements and explicit written procedures. The subjects that are covered in this evaluation are: recruitment policy, training programs, criteria for promotion, discipline and grievance procedure, motivation programs, and work standards.

As a recruitment policy, all entry level maintenance positions are filled at the "general utility helper" position, and these positions are recruited from outside the agency considering only skilled and/or trained applicants. No one is hired without mechanical experience--despite a low starting wage ($4.33/hr.) and despite the fact that some career paths (bus cleaners, for example) do not make great use of a mechanical background. In some respects the entry level policy is a problem because it makes it difficult to attract good qualified personnel to a career with the agency. Essentially, the policy allows only skilled labor to be recruited, and at a wage that would have to be regarded as a bargain by any transit agency--but skilled labor will not be attracted to this wage. As a result of this policy, one officer stated, "There's not a shortage of mechanics, but a shortage of ability."

Further recruitment policy requires testing of "honesty, drugs, and temperament"--failure on any of these criteria will fail eligibility for recruitment. Beyond these subjects, testing is not carried out in the recruitment policy (no comprehensive skill testing). After passing the character test and qualifying in background, the chosen applicant is put on a probationary trial period. For a probation of 90 days, the employee can be dismissed for a failure to demonstrate competence or to conduct himself/herself professionally.

Training policy is such that, once an employee is recruited, he/she receives unsupervised on-the-job training, supervised on-the-job training, some classroom training with industry manufacturers, and some on-site classroom instruction. Recent examples of manufacturer training are sessions held by Bluebird school and Thermo King air conditioning school. On-site

classroom instruction is conducted by the Assistant Superintendent of Equipment II, but the time and nature of on-site classroom training is limited. Training programs are also available for senior employees as well, so as to assist them in "staying current." The Thermo King school is just such an example of training for senior employees. To assist in on-site training of personnel, manufacturer-supplied manuals are employed, but the TTDC maintenance department adds little of its own material to these manuals.

When wage positions above entry level are to be filled, then the department's promotion policy takes effect. Senior positions are filled only from inside the organization, in contrast to entry level recruitment. As soon as a senior position opens, the department goes through a bidding process whereby the job is awarded to that individual who has the most seniority for the job classification. Theoretically, if no one were to bid on the open position, then someone could be considered from outside the organization--"but this essentially never happens." Merit tests are not applied at each level of advancement, although merit is considered in the form of a review of an applicant's past records (absenteeism, discipline problems, etc.). Seniority holds sway in the hiring policy, and this particular example was offered by one administrator: "if the most senior bidder for a position is clearly not qualified in background for the position, he must still be awarded the position in recognition of his seniority." However, the worker must serve a 90-day probation period, during which he can be dismissed from his position on the basis of poor performance. Thus, merit enters into promotion as a secondary consideration.

Discipline and grievance procedures are established explicitly in written manuals. The expectations for behavior, and disciplinary actions taken upon failure, are very clearly expressed in writing in the agency's "Rules, Regulations, and Performance Code" booklet. Procedures for employees' grievances are also clearly outlined in writing, in the booklet copy of the TTDC union agreement, "Memorandum of Agreement Between Transit Management Company and Amalgamated Transit Union."

The TTDC maintenance department has significantly developed incentives programs. One fundamental incentive is provided through payscales. Many transit agencies are hindered by pay levels that provide very little difference between entry level and the most senior positions[36] but this is not the case for TTDC. As one can see from Table 2, lowest pay for lowest positions is only $4.33/hr., while highest pay for the highest positions reaches up to $10.94/hr. Thus, the prospect of promotion and accompanying pay raises provides a strong financial incentive for TTDC maintenance personnel to advance. Progressing from lowest to highest pay scale would realize a pay increase of 153%, which is a greater differential than many agencies can offer to their personnel.[37]

Other pay incentives are a premium for working the "graveyard shift" of 10:30 PM to 7:00 AM of $0.15 per hour, which is not highly effective in attracting interest in the shift, and the time-and-a-half pay premium for overtime, which is effective in attracting interest in overtime. Seniority remains the key criteria for the assignment to shifts. As few workers are motivated to volunteer for the off-hour shifts by the pay premiums, assignments are instead determined usually by seniority. Senior workers get first preference in shifts, which amounts to the least senior workers staffing the off-hour shifts. As for overtime, the system for assigning overtime is fixed such that all workers get equal consideration for overtime, and seniority has no impact on overtime assignment. Priority for overtime is assigned according to a "rotating board system" where the name at the top of the list

is offered overtime. Usually overtime is accepted, but whether accepted or rejected, the name at the top then goes to the bottom of the list, and that person will be offered overtime again only when that name is again at the top of the list.

Pay level differentials, shift premiums, and overtime premiums are common incentive structures, but TTDC also administers more innovative motivational incentive programs. Firstly, an "employee of the month" program recognizes 3 workers per month (one mechanic, one operator, and one salaried employee), who each receive the following awards: the name of the recipient is posted on a notice board, the recipient's picture is taken, an honorary parking space is provided for the recipient for the month, and a $50 savings bond is awarded. Furthermore, the employee of the month becomes eligible for "employee of the year," which awards either $500 cash, a week off with pay, or a $1,000 bond. Another incentive program is an attendance award program. The worker who misses the least amount of time in his/her designated group receives a $50 bond. Finally, TTDC offers an incentive program for employee suggestions, which pays an employee a percentage of the savings realized from the implementation of an idea for operational improvements. From the suggestions program, a cash award as high as $1,000 has been awarded to one recipient. From the above discussion of TTDC's special incentives programs, it is clear that nonmonetary awards are used for incentives (status, recognition, parking space), but the use of monetary incentives is less definitive. Some cash awards exist for employees, but they are not as directly tied to performance as a traditional "piece rate" type of monetary incentive, which typically awards some sum such as $1.00 per reduced roadcall or reduced absence or extra task completion. In summary, TTDC's special incentives program is a clear example of nonmonetary incentives, with a less clear emphasis on monetary incentives.

TTDC's maintenance department does not presently administer a program for studying work methods improvements for major tasks. The Assistant Supervisor of Equipment II recalled that such operational research work "was done a long, long time ago," but no such activities were being conducted at present. Furthermore, no time standards are established for workers in the completion of tasks, but the department is considering developing a system for tracking work times on its system. The proposed system would first record work times of individuals on manual sheets, and then enter those times into a computer information file. Thereby, regular monitoring could occur for individual worker's completion times and profiles could be developed for which worker is best suited to the accomplishment of certain tasks, according to his/her completion times.

From this discussion of workforce development, one can compare TTDC to the spectrum in Figure 6. The development of the maintenance department's training program relies heavily on outside training and on-the-job experience, so TTDC's training program would place between "B" and "C" on the spectrum. The seniority system of promotion would clearly place at "B" for TTDC. The extent of the TTDC special incentives program would place TTDC between "B" and "C," in recognition of nominal monetary special incentives and the monetary incentive of pay level differentials. The absence of monitoring of task completion times (no work methods or standards), would place TTDC at "B" or lower. Altogether, the composite

Table 2

Maintenance Department Wage Schedule

TRANSIT MANAGEMENT COMPANY

Hourly Wage Rate
October 7, 1984

Hired before January 1, 1980	First Six Months	Second Six Months	After One Year	After Two Years
Mechanic 1/C	$10.73	$10.84	$10.94	N.A.
Mechanic 2/C	10.42	10.53	10.63	N.A.
Mechanic 3/C	9.91	10.11	10.32	N.A.
General Property 1/C	10.73	10.84	10.94	N.A.
General Property 2/C	10.42	10.53	10.63	N.A.
General Property 3/C	9.49	9.80	10.11	N.A.
Service Station Operator	10.32	10.42	10.53	N.A.
Storeroom Clerks	8.26	8.46	8.77	N.A.
Hired after January 1, 1980				
Mechanic 3/C	9.29	9.60	9.80	N.A.
General Property 3/C	9.29	9.60	9.80	N.A.
Storeroom Clerk typist	4.85	5.26	5.68	N.A.
Information Specialist	4.33	4.75	5.16	N.A.
General Utility	5.68	6.19	6.71	$7.22
Mechanical Helper	6.19	7.22	8.26	9.29
General Utility Helper	4.33	4.75	5.16	5.68

workforce development program of TTDC could be summarized as "B" or "B/C," with noticeable low development of training, promotion, and work methods policies.

F. LABOR ALLOCATION

According to FY 1983 Section 15 Reports, TTDC filed that its motorbus transit operations has 67 maintenance labor equivalents, which amounts to 2.70 vehicles per maintenance employee, or 0.37 maintenance employees per vehicle. These figures compare favorably to the 1982 Section 15 averages for the industry. Motorbus fleets of TTDC's size bracket (100-249 buses) average 2.4 vehicles per maintenance employee or 0.42 maintenance employees per vehicle, while industry-wide averages are 1.8 vehicles per maintenance employee or 0.56 maintenance employees per vehicle. TTDC's favorable employee ratios may be attributable in part to a high spare vehicle ratio. The reliance on overtime is commonplace in the maintenance department, but it is controlled. Overtime hours are estimated at 6.6% of regular scheduled hours.

The number of shifts would have to be classified as 3 shifts, with a servicing crew set in another overlapping shift.

According to the management, specialization of mechanics is fully developed, with certain mechanics formally designated as specialists in certain areas: bodywork, transmission overhaul, engine overhaul, electrical components, air components, and welding.

Furthermore, inspection crews are somewhat separated from repair crews. Both Assistant Superintendents of Equipment indicated that no one working on inspection crew will be scheduled to work on repair. This separation avoids the conflict of incentives that could be experienced where an inspector might be inclined to avoid issuing work orders that he himself might have to attend. However, inspection and running repair are formally grouped into the same shop, and thus the separation between inspection and repair is obscured.

As for staffing the roadcall crew, the roadcall team is typically pulled off the running repair crew as needed. Lower-ranked workers such as mechanic helpers are picked first in the case of non-mechanical roadcalls, but as a general rule, "everyone is subject to working the roadcrew."

The TTDC maintenance department does not carry specialization to the extreme of independent work teams. It approaches this level of specialization, as personnel sign up for 6-month assignment in separate functions of inspection and running repair, unit overhaul, body shop, and paint shop. For 6 months the personnel are committed to work in the area they sign for, but they can be put to work in other functions if there are no imminent tasks in their particular function. Thus the barriers of separation from one function to another are not so inflexible as they might at first seem, and after a 6-month stint the personnel are free to circulate to other functions. Thus, the maintenance department's organization cannot be summarized as one of fully specialized teams.

A review of the above discussion can be compared to Figure 7. TTDC clearly supports three shifts of maintenance operations, thus placing it toward the "C/D" range on the spectrum. Inspection crews, furthermore, are effectively separated from repair crews. However, road crews are not regularly staffed but are instead improvised according to worker availability. Thus crew organization at TTDC would be squarely placed at "C" on the spectrum. Although functional teams are nominally set up on the maintenance department, the separation is very flexible over the long run (new sign-ups

every 6 months) and very flexible over the short run (idle team members being temporarily assigned to other productive tasks). Thus, TTDC's policy of administering specialized teams would place it just slightly above "C" on the spectrum. Individual mechanics do receive specialized status and training (such as electricians, welder) and thus TTDC's orientation of mechanics would qualify as "specialized" and would place TTDC in the "C/D" range of the spectrum. Altogether, the combined profile of the labor allocation system would be classified as "C": specialized mechanics, somewhat specialized crews, minimally specialized teams, and 3 shifts.

G. INVENTORY MANAGEMENT

Like other maintenance activities, inventory management has recently been computerized at TTDC. It has been noted that one of the perceived problems in the maintenance department is the duplication of effort involved in the break-in period of the computer system. Manual systems are still being maintained alongside computer records so as to compare the benefits of one against the other during the trial period, and also to provide a manual backup system, in case an unforeseen failure occurs in the new computer system.

The basic system of the inventory office is one of a sequestered stock room whose flow of stock is directly monitored by purchasing personnel, both at the point of receiving and release for work order. The stock for a part is ordered by the purchasing office department when a computer review indicates that a part is at or below the minimum on-hand level. At this point a purchase order is generated in triplicate, one copy going to the vendor, one copy remaining with purchase office records, and one copy going to the receiving area for check-in purposes. An outstanding order is entered on the part profile on the computer, and the order remains on outstanding status until the order arrives. When the order arrives at receiving, the package is checked against the packing slip and the receiving area's copy of the purchase order. The receipt of stock is also entered on the part profile in the computer, and the outstanding status is amended. The stock takes its place on its shelf in the stock room (each item has a designated shelf location recorded on its part profile), and it next moves when a maintenance employee brings a work order release form. The parts are issued 24 hours a day, as needed by maintenance floor activities, but their issue is recorded on computer records only during the day shift, due to the availability of qualified purchasing personnel. When the number of parts released for work order causes stock to sink below the minimum level, the stock cycle is begun again.

The above description applies to all parts over $2.00 in cost, but for the many high-volume, low-cost parts (such as screws, nuts, washers), storage is provided outside the stock room, on the garage floor. Each of these "pink tag" items occupies a bin on the garage floor, and the bin stock is simply regulated by "eyeballing." When the bin is near empty, it is replenished from a bulk storage location in the storage room. Stock levels are thus monitored for reorder in bulk storage and not in the garage floor bins. Except for the matter of storage location, and requisition process, the inventory cycle for these "pink tag" low-cost items is similar to other stock.

Certain key issues must be decided in the design of an inventory system. Distinctions are made between sets of parts with different characteristics. For instance, the purchasing office recognizes the expected time of procurement for each part. If a part has an expected procurement time of one week, one month, or two months, its minimum lead time is

adjusted accordingly, and reorder points (minimum levels) for parts with long lead times will be higher than if they had short lead times.

The purchasing department does informally recognize the importance of some parts by applying a somewhat different criterion to their stock levels. One example offered is that of a crankshaft, whose availability is critical at the moment of need (a vehicle cannot function without an operable crankshaft), but whose need is so infrequent as not to warrant regular stocking. At TTDC, the decision has been made to stock a minimum of crankshafts anyway "--one or two--." Similarly, the distinction of discardable vs. rebuildable parts is also noted on a rather informal basis. In some cases old parts are exchanged with vendors who will rebuild the old parts.

With the diverse fleet that TTDC handles, monitoring stock parts for interchangeability is a top priority in the inventory system. According to the Acting Purchasing Manager, "I am confident there is no interchangeable duplication of items in our stock." The office maintains its own "strip file" which lists parts that are found to be interchangeable. Some vendors supply interchangeability lists, but TTDC also performs its own investigation of interchangeability. "At the moment when a new item is entered into stock, we investigate it for interchangeability with other parts in stock." Of course, when parts are interchangeable, TTDC can favor those versions of parts that cost less, and it can also consolidate stock and thereby reduce on-hand inventory. Interchangeability was regarded by the acting manager as one of the office's two strengths (the other being its monitoring of vendor information).

TTDC employs a reorder point system. Projected usage rates for parts are based on past records when possible, and the reorder point for parts is generally 30 days worth of on-hand inventory, and order quantities are generally 90 days worth of stock--but this order quantity may be larger if an exceptional volume discount is available from a vendor. Thus, fixed order quantities are established for each part, but these quantities are "recommended rather than mandatory." Since parts are ordered according to usage, orders are issued at irregular intervals and are not ordered according to a periodic system plan.

Reorder points and order quantities depend on the projected usage rates for each part. Thus, reorder points and order quantities are primarily revised through adjustments made to the projected usage rate. The Acting Purchasing Manager indicated that usage rates for each part are regularly reviewed, "every time we order," but revisions of reorder points and order quantities remain based on "experience and judgement."

In addition to setting reorder points according to projected usage rates, some safety factor is also added to the minimum stock level, especially for those critical parts (such as the crankshaft example) or for parts that are difficult to acquire (such as steering parts). In these cases, minimum levels might be the projected use for 30 days plus one extra part for safety stock. The decision to provide safety stock is again based on "experience and judgement."

Presently, the inventory system is monitored both manually and automatically (computer). The manual component of the system consists of request forms (work order release forms that later entered into the terminal), purchase order forms, copious vendor records, and the interchangeable "strip file." The computerized component consists of a profile of each part which provides the following information:

Part number as assigned by TTDC
A list of vendors who supply the part, with preferred (lowest-priced or fastest fulfillment) source listed first
Order point for part
Order quantity for part
Lead time for part order
On-hand inventory
On-order inventory
Cost of part

Other computer reports also provide a profile of actual parts usage over time, so as to assist in revisions of reorder points or order quantities.

Certain measures of performance for TTDC's inventory management are available. Total parts inventory was taken on Sept. 29, 1984 as $567,800, which amounts to $3,138 per vehicle. Furthermore, stock-outs occur on the average 3-4 times per day. This incidence is greater than the previous year, and it is seen as a problem. But the increase in stock-outs may be due to the diversity of TTDC's fleet or the burden of maintaining both manual and computerized information systems during the trial period. Overall, the performance of the inventory office is perceived as sound.

From the above review of TTDC's inventory management system, TTDC can be directly compared to the discussion of inventory management in the general report, Figure 8. The TTDC inventory can be summarized as "computerized" as of now, despite the many manual procedures that are being carried through the trial period. The computerization of inventory would place TTDC at "C" on the spectrum. TTDC also has a formally developed inventory cycle using reorder points and order quantities. The determination of these quantities remains somewhat informal, as does TTDC's practice of incorporating safety levels of stock into its system. Together this array of features would place TTDC at the overall "C" level of development. The system is below the "D" level of development because of the informal determination of order points, quantities, and safety levels, and because the inventory computer program has not yet been directly integrated with a maintenance scheduling computer program (see Information Systems).

H. EQUIPMENT MANAGEMENT

As befits a maintenance facility for an agency of TTDC's size, the maintenance department has equipped itself with specialized maintenance equipment. The maintenance department carries most of the equipment that is generally found in the larger agencies, such as automatic bus washers, large bus vacuum systems, automatic farebox removal equipment, transmission and engine stands, heavy duty press, brake lathe and grinder, transmission test stand, valve body tester, and tig and mig welder. However, the department still does not possess its own dynamometers, frame straighteners, shapers, or mill. There was no strong indication among officers that these missing items are necessary, although some, like dynamometers, were regarded as "nice to have."

The requisition process for major equipment items is as follows. The maintenance department submits a yearly projection of what its needs will be, listing major equipment needs. The department than compiles the necessary information on the equipment requested--model number, price, how the equipment addresses the expressed needs. This information is then submitted with the request to the finance manager, and the information must be accompanied by the maintenance department's justification of why it is needed (what savings will occur, how the present on-site equipment is obsolete). Explicit

financial analysis of return on investment does not take place in the maintenance department. Such analysis and the ultimate authority for purchase rests with the finance department.

Department policies about the use of equipment are not restrictive. Specialized equipment is freely available on the shop floor. Regarding the use of hand tools, TTDC requires that maintenance personnel provide their own hand tools.

As indicated in previous discussions, TTDC does possess computer information equipment, which is accessible to the maintenance department. The equipment is a Datapoint minicomputer system, with terminals available in the following locations of the maintenance department: the stock room, purchasing office, and the equipment manager's office.

From the above review of TTDC's equipment management system, TTDC can be compared to the spectrum shown in Figure 9. Considering the equipment that has been identified at TTDC, the agency's maintenance department should be classified as significantly capital intensive. It possesses the necessary equipment to execute almost all maintenance operations on-site (less than 1% of work is contracted out--see Work Assignment), but it still omits some highly specialized equipment (such as dynamometers). In conclusion the TTDC equipment management system can be summarized as "C/D" on the spectrum.

I. INFORMATION SYSTEMS

As indicated previously, TTDC maintenance department relies on both manual information and automated information. At present, significant overlap exists between the two, but in the future more and more reliance will be placed on the automated (computer) system, as more program features are brought on-line, and as present computer programs prove themselves.

Some of the significant paper forms that are circulated through the maintenance department are:

Preventive maintenance inspection form
Work order form (white form)
Work order form for accidents and vandalism (pink form)
Stores requisition form (work order release form)
Purchase order form

Some of the chief records maintained by the computer system are:

Monthly fuel and oil report
Monthly roadcalls report, chargeable roadcalls (classified by type of breakdown)
Monthly roadcalls report, chargeable roadcalls, (classified by vehicle identification number)
Monthly roadcalls report, nonchargeable roadcalls (classified by type of breakdown)
Monthly roadcalls report, nonchargeable roadcalls (classified by vehicle identification number)
Inventory item master file report
Inventory item usage report in units

The computer system is a minicomputer system with several terminals available in the bus maintenance facility. The software is a "turnkey system," supplied by a vendor who acts as consultant in matters of programming new features or attending problems of use. Although minicomputer capabilities are broad and execution occurs rapidly, TTDC's information program can be distinguished from other, more elaborate, automated systems, in a number of key ways.

First, the level of detail in TTDC's maintenance information system is still somewhat aggregated. Specifically, two key benchmarks of information disaggregation are not present. TTDC does not as yet track and analyze individualized work time records of personnel on the computer--nor does it do so manually. TTDC is, however, planning to introduce such a program in the near future, "perhaps a year or so." Secondly, failure histories of mechanical components are not kept. Although the "monthly printout" generates a record of breakdown failures related to specific components, it does not record inspection-generated observations of component failure. Nor are the monthly printout records stored permanently. However, in manual records, failure information is permanently recorded, but not in a form that can be practically retrieved. Although TTDC is considering putting all past such records on computer storage, such a transcription will be very time-consuming. If such a system were ever brought on-line, then of course rich possibilities would exist for the analysis of inspection intervals based on the precise historical data.

In another sense, the department's automated information system is a simple one in that, as yet, only specific maintenance personnel (clerks and administrators) interface with the computer terminals. Terminals are not present at work sites nor are portable recorders employed at work sites. Thus, all information generated from work sites must still be entered indirectly, i.e., entered on paper forms to be entered later at a terminal by a clerk.

Lastly, TTDC has not implemented a system for integrating information programs. The maintenance department employs computer programs for monitoring inspection schedules and for monitoring inventory, but these programs remain independent of each other. Although results of the two programs are closely coordinated by the maintenance department, one result does not automatically precipitate an action in another program. Officers indicate that they are presently "working on the idea" of trying to implement a system where the occurrence of certain parts needs will be automatically triggered by the scheduling of work. Inventory levels could be more closely tied to parts needs in this way, and monitoring time could be reduced. However, such an integrated information system is extremely advanced for the industry, and it is not likely in TTDC's immediate future.

Using the above review of TTDC's information system, TTDC can be compared to the spectrum in Figure 10. The maintenance department's information system can be summarized as: aggregated information, automated information system, minicomputer hardware system, indirect entry, non-integrated system. This configuration comes closest to the "C" level on the spectrum, with the indirect data entry being a notable exception. Although this exception is significant, the TTDC information system is on the verge of pursuing the disaggregation of worker time information, and in general supports a fairly sophisticated reporting system. Therefore, TTDC's information system could be summarized as between "B" and C", but favoring "C" somewhat.

J. MONITORING AND EVALUATION

Key general performance measures of TTDC are guaranteed by the agency's compliance with Section 15 filing requirements. These measures are: roadcalls; vehicle miles per roadcall; maintenance cost per vehicle mile; fuel use (mpg); spare vehicle ratio. Other key general measures are not required by the federal Section 15 guidelines, and thus their presence is not guaranteed throughout the industry. For this reason, these additional

measures have not been centrally incorporated into this report's evaluation procedure, as comparability between agencies may not be easy to achieve. Nonetheless, this report does acknowledge whether or not additional measures are tracked by the agency being studied, as it reveals something of the thoroughness of the agency's monitoring activities.

According to officers of the maintenance department, the Transportation Department tracks missed bus runs and late bus outs. These measures are regularly reviewed by the maintenance department. Buses that remain inactive over time ("dead buses") are regularly tracked daily on the department's "report of operations" report. Oil use is regularly monitored using the maintenance department's monthly fuel and oil printout, and life mileage of vehicles is regularly monitored. Measures of labor hour productivities associated with vehicle miles, breakdowns, or such, are reportedly available through present department information procedures, but these measures are not formally involved in a monitoring program. As for measuring records of personnel work times, work methods, and work standards, it has been mentioned previously that work times are not monitored in a comprehensive program.

The evaluation framework used in this report focuses on general measures that can be obtained from Section 15 information, with primary emphasis on the measures of vehicle miles per roadcall and maintenance cost per vehicle mile. The values are presented in Table 3 for the fiscal years 1981, 1982, and 1983. For each year, the values for the TTDC agency are presented, but in the last year comparative information is lacking.

For the earlier years, where Section 15 publications are available, values for average performance for TTDC's size class (100-249 vehicles), and for the bus transit industry as a whole, are presented alongside agency performance for comparison.

The indicators of chief interest are "vehicle miles per roadcall" and "vehicle maintenance cost per vehicle mile." However, other measures of secondary interest have also been listed. "Fuel use" is directly available from Section 15 Reports, and the "spare vehicle ratio" is available with minimal calculation from Section 15 reports. Furthermore, in response to comments of the Assistant Superintendent I during a general interview, a profile of the effect of non-mechanical roadcalls is included in the last 5 rows of the table.

TTDC's vehicle miles per roadcall improved slightly from FY 1981 to FY 1983, but even so, values are less than the average for its class size for the years with available data (FY 1981 and FY 1982), and there is every reason to believe that the 1983 data would bear the same relationship. (Comparison with the industry average for this measure is less meaningful as there appears to be some serious distortion of data in another size class for 1982).[38]

Based on the preceding values, TTDC's performance may be somewhat unfavorable, although further considerations must be weighed. A desirable standard for roadcall incidence might not agree with the industry or peer group average, but instead may be some value determined according to the policy of the agency in question. For instance, if an agency is extremely budget-conscious, it may be willing to accept a lower level of performance in the prevention of roadcalls if it can simultaneously realize a higher level of budgetary thrift. Interpreters should also be aware that the measurement of vehicle miles per total roadcalls may still include some factors which are out

Table 3 TTDC Evaluation

	FY 1981			FY 1982			FY 1983
	AGENCY	SIZE CLASS	INDUSTRY	AGENCY	SIZE CLASS	INDUSTRY	AGENCY
Vehicle miles per road call	1386.7	1687.2	1461.5	1453.4	1748.2	1265.2	1450.9
Vehicle maintenance cost (cents) per vehicle mile	34.6	41.7	58.8	36.8	47.6	66.7	50.3
Fuel use (GPM)	.300	.273	.273	.300	.282	.280	.310
Spare ratio (%)	31.0	29.2	24.4	26.7	30.9	26.3	39.2
Mechanical roadcalls	3324	n.a.	n.a.	3005	n.a.	n.a.	2288
Non-mechanical RC's	1345	n.a.	n.a.	1534	n.a.	n.a.	1324
Total roadcalls	4669	n.a.	n.a.	4539	n.a.	n.a.	3612
% non-mechanical roadcalls	28.8	19.5	21.0	33.8	25.7	18.0	36.7
Vehicle miles per mechanical roadcall	1947.6	2095.9	1850.0	2195.5	2372.0	1554.3	2292.1

of the maintenance department's control. Non-mechanical roadcalls (as distinguished by Section 15) may account for a significant amount of roadcalls, and by definition this category of roadcalls (bus vandalism, illness on buses, farebox problems) may not be a direct responsibility of vehicle maintenance. A general interview with the Assistant Superintendent of Equipment I indicated that non-mechanical roadcalls may have been an exceptional problem, and therefore, further investigation was conducted.

Examination of the last five rows of the table indicate that the officer's perception was justified. Over the three years, TTDC's percent of non-mechanical roadcalls has grown from 28.8% to 36.7%, and these agency values appear to be dramatically greater than that of TTDC's class size peers and the industry average. This unusual incidence may be a result of unusual farebox problems, as TTDC operates a sophisticated farebox system on its vehicles to accommodate a complex zone fare system. Farebox problems were also noted by the Assistant of Superintendent I.

When performance is adjusted to reflect vehicle miles per mechanical roadcall only, TTDC's performance is more encouraging. The value of miles per incident has increased convincingly over each year (from 1947.6 to 2195.5 to 2292.1). However, in the latest available year for peer comparison (1982), the value still compares unfavorably to class size average, and it is reasonable to assume the 1983 TTDC value is also at or below the class size average. One might therefore conclude that TTDC's roadcall performance is disappointing, but one should also note that TTDC's value of vehicle miles per mechanical roadcall is above the industry wide average for both years 1981 and 1982, and that TTDC's performance would also surely outstrip the industry average. Thus, indications are that the TTDC maintenance department's roadcall performance is acceptable, but it remains an area to consider for improvements.

The department's performance in vehicle maintenance cost per vehicle mile exhibits an opposite trend to its roadcall performance. In 1981 and 1982, the maintenance cost was very low, at 34.6 and 36.8 cents per vehicle mile, respectively. In comparison to both class size and industry-size averages, TTDC has delivered its services at an impressively low cost. However, in 1983 that status is endangered, as TTDC's cost figure jumps to 50.3 cents per vehicle, which probably will be at or just below class size average, and which certainly exhibits sharp growth from TTDC's 1981 value of 34.6 cents. Surely, a small part of this growth is attributable to inflation, but further investigation is necessary. Undoubtedly, likely causes should be increased fleet diversity with increasing emphasis on smaller buses and "trolley-type" buses, which require more frequent inspection and repair; increased inventory costs associated with fleet diversity; burden of farebox problems on the maintenance department's operations; and the burden of maintaining overlapping manual and automatic information systems during the trial period. However, two factors must be regarded as extremely favorable for low cost operating expenses, and the recent growth in expense must be explained in the light of them: First, the payscale (effective October 1984) institutes a very low base wage level, which in time should mitigate growth in maintenance expenses as the proportion of new employees becomes greater. Also, the very high spare vehicle ratio, allows the maintenance department to avoid staffing for peaks in workflow.

In conclusion, it might be observed that both roadcall and cost performance have been moving from extreme values toward more conventional, central values over the three years. It might further be suggested that some trade-off has existed between these values; that perhaps vehicle miles per

mechanical roadcall has been improved through an increase in vehicle maintenance cost per vehicle mile. However, such an assertion requires further investigation. The most important outcome is to recognize the values of these two measures, their relationship to other values in the industry, and their trends. The decision of whether these values are acceptable remains one of policy.

As mentioned earlier, secondary measures of fuel use and spare vehicle ratio are also presented. The values of gallons per mile exhibit considerable conformity over the years, and from category to category. At 0.300 to 0.310, TTDC's fuel consumption might be regarded as slightly less favorable than class size or industry averages, but little conclusion about the maintained condition of vehicles can be drawn from this small disparity.

Spare ratios, however, reveal a more telling statistic. Due to recent cut backs in peak service, TTDC possessed a high surplus of vehicles in 1983 (39.2%, far greater than the 25-30% range of average values for the other categories are 1981 and 1982). This situation, although providing comfortable cushion for maintenance scheduling, should normally require the liquidation of some vehicles. However, TTDC appears to have remedied the situation since 1983, as recent expansions in peak service have brought the spare ratio back to a moderate value of 28.3%.

Concluding this review of TTDC's monitoring and evaluation, TTDC does appear to administer a thorough program of monitoring important general measurements. However, increased attention to work standards and work times of employees may be an area for improvement. Regarding the values for certain general measures, the TTDC maintenance department experiences a roadcall incidence within acceptable levels, and it appears to enjoy a cost schedule slightly better than acceptable levels. Lastly, the agency's spare vehicle ratio has fluctuated to high values in recent years, but it has moderated at present.

K. CASE STUDY CONCLUSIONS

After the different categories have been reviewed, the TTDC maintenance department can be expressed in Figure 12. Through the summary of the matrix, the maintenance department is quickly described, and general patterns or relationships are readily apparent. Furthermore, TTDC's maintenance department could quite easily be compared to the maintenance departments of other agencies, if they were to be expressed in the same framework.

A review of Figure 12 indicates that the TTDC operates a fairly large fleet of 181 vehicles, and serves a comparatively large urban area. Furthermore, many positive conditions exist for bus maintenance: the fleet is young, the present maintenance facility accommodates operations easily, ample spare vehicles are provided, and terrain and weather are nearly ideal for vehicle maintenance. Countering these positive conditions are the diverse character of the fleet, and an almost around-the-clock delivery of revenue service. All in all, the conditions appear to be quite favorable in balance, but each management activity area will be differently affected by each listed characteristic. For instance, the heterogeneous character of the fleet will place special burdens on maintenance scheduling, workforce development (training), and inventory management.

Using Figure 12, one can compare the development of the different management areas with the expected impacts of the surrounding characteristics. For instance, one might expect a general level of development

Figure 12. TTDC Profile

Description	WORK ASSIGNMENT	MAINTENANCE SCHEDULING	WORK FORCE DEVELOPMENT	LABOR ALLOCATION	INVENTORY MANAGEMENT	EQUIPMENT MANAGEMENT	INFO SYSTEMS	MONITORING & EVALUATION
Large community (900,000)								
Moderate population density								
Moderate-to-light transit reliance								
Flat terrain								1450.9 vehicle miles per road call.
Mild-to-warm, variable climate								
Moderately priced labor market	C	C	B	C	C	C/D	B/C	2292.1 vehicle miles per mechanical road call
180 bus fleet, 129 peak fleet								50.3¢ vehicle maintenance cost per vehicle mile.
154 hrs. revenue service/wk								
Heterogeneous (diverse) fleet								
Abundant capacity in facility								
New fleet (5.9 yr. avg. age)								
Unionized workforce								

approaching "C" for operations of 180 buses--a size of operations that is considerably far along the size scale being considered in this study: 15-500. In general, this pattern is strikingly born out: the array of C-C-B-C-C-C/D-B/C is consistent in its orientation around the "C" level. But, the condition of a heterogeneous fleet may lead one to expect a fairly developed structure for training, when in fact workforce development is indicated as somewhat modestly developed--at level "B". From this observation, a reviewer may wish to probe further into the details of the workforce development system, to judge whether the arrangements are properly matched to the needs of the agency. One basis for further examination should be the records of the evaluation process that were used to classify workforce development as "B".

One management area can also be directly compared against another management area. For instance, it would be unusual for an inventory system to be very out of step with the development of an information system. If such a situation were observed, then perhaps a reviewer would wish to examine these two areas of management activity together. In the instance of TTDC, the development of inventory management policies ("C") does appear to be closely matched with information system development ("B/C").

Finally, the table offers some key, general measures for the performance of the maintenance department. If the values appear disappointing, then a very close look may be warranted at the possibility of either overdeveloped or underdeveloped areas of the maintenance management system. For instance, a high vehicle maintenance cost per vehicle mile might cause a reviewer to consider whether an equipment management system is over-developed--carrying too much specialized equipment when the size of operations or some other factor may argue for relying more heavily on contracting work out for specialized tasks--or whether it is under-developed--arguing for the acquisition of further specialized equipment so as to achieve economies or to increase control by reducing reliance on outside contractors. A low ratio of vehicle miles to roadcall might of course lead a reviewer to carefully consider the maintenance scheduling system, or the workforce development system.

Performance measures can also act in another way. Particularly strong values may caution a reviewer to take moderate action on perceived imbalances in a management area. For instance, in another study, one very large agency (650 buses) was documented as having a maintenance information system that would measure "A" in this framework.[39] Nevertheless, the performance of the maintenance department was very strong according to indicators, due partly to strong informal practices that had been built up over time. Although the "A" level of development in information appears to be clearly inappropriate for that agency, any actions that might upset the present informal systems should be carefully considered.

In the case of Tidewater, the performance measures of vehicle maintenance cost per vehicle mile and vehicle miles per mechanical roadcall both approach intermediate values. Therefore, no immediate conclusion should be reached from either, except that recent trends might be kept in mind; that is maintenance cost has been worsening recently, while mechanical roadcalls has been improving recently. Lastly, the performance value for total roadcalls is rather low. However, this measure may not reflect the direct responsibility of the maintenance department, and further investigation of non-mechanical breakdown problems should proceed. Ultimately, the decisions based on performance values will depend heavily on the policies of

the particular agency involved, for that agency will determine which performance values are acceptable values.

Reviewing the matrix collectively, TTDC's maintenance department appears to be internally consistent and well-suited to its environmental conditions. The values of performance measures for roadcalls and maintenance cost indicate acceptable performance, but both measures also suggest room for improvement--especially in light of recent trends of cost and a roadcall value that still remains somewhat low despite recent improvement.

The array of symbols would indicate that those management activities that deserve further attention would be workforce development and information systems. At values of "B", and "B/C", respectively, these levels of development may appear somewhat low for an agency of TTDC's size. However, the deviance for information systems is slight, and the rating of "B/C" is not unusual for an agency that has already begun a transition period to automation of its information system. Furthermore, the TTDC maintenance department appears to be firmly committed to further development of information systems, including the imminent introduction of a monitoring program for worker task times. Therefore, no recommendations appear to be required by the present state of the department's information system. In contrast the workforce development area appears to be a strong candidate for improvements.

Certain circumstances, such as the many vehicle models with newer, complex design features, make special demands on the skill and knowledge of the workforce. Furthermore, as more and more new recruits are absorbed into the organization, added burden will be placed on the department's ability to train personnel. The new pay scales will most likely accentuate the need for training, as it cannot be expected that applicants of significant mechanical experience will be attracted to the low wages that must be offered to all new recruits. Although some of the problems associated with applicants could be lessened through a revision of the recruitment policies, attention still needs to be directed to the present training structure. In the Assistant Manager of Equipment II, the agency appears to have an experienced, competent trainer, but more resources should be directed to assist his training program (more training time, more materials, or more assigning of personnel to outside training programs). A program for monitoring worker task times should also greatly assist the development of personnel.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

This project which encompassed the development of a methodological framework and its application to a cooperating transit agency provides insight into the process through which transit maintenance is delivered. The lessons learned can be summarized in terms of rules governing future analyses of bus transit maintenance that are designed to enhance this basic task of the transit agency. They also can be interpreted to assist in formulating other support activities which will ultimately improve the bus transit maintenance function.

The bus maintenance department's mission can be described by a set of management activities that are associated with the functional tasks that comprise the entire maintenance process. Different environmental features and organizational characteristics are shown to influence the complexity and structure of a transit agency's maintenance program; the major influence being the size of the fleet.

The framework that is presented in this report provides a procedure to address resource allocation and organizational planning issues. It can be applied at various levels of detail, from quick and cursory to lengthy and deliberate.

The rating system using designations A-D is a simple, yet efficient way to characterize the maintenance activity. The methodology provided can be applied to transit agencies regardless of size. This is particularly useful for small and medium size agencies.

The framework simplifies the case study process by providing analysts with a straightforward format that will enhance consistency and transferability of results among different cases. It encourages comparative analyses.

The experience of the case study confirms the above observations and the utility of the framework developed in this report. The evaluation exercise compresses a great deal of information into a simple one-page summary.

The evaluation form, given in the Appendix, assists in the quick collection of information. The bulk of the data collection process for the case study was performed comfortably within a two-day site visit by one investigator. Data was collected in four simple steps: targeting the appropriate respondents and arranging for interview appointments, conducting interviews along the lines of the evaluation form, general empirical observation of the facility and operations, and the collection of the agency's most recent Section 15 reports.

The format used assures recognition of the unique circumstances that each maintenance department faces, thus avoiding any impulse to generalize the experience of one agency to the whole industry. At the same stage, the format also provides an orderly classification of the management activities that are the direct responsibility of the maintenance department. Through the classification of management activities, the framework establishes a helpful approach for identifying critical characteristics in the complex arrangement of maintenance operations. The framework also suggests promise for promoting comparability among maintenance departments--something that has been elusive in the study of maintenance so far.

The framework can be used to tie together the results of different studies into a ready reference on various topics associated with bus transit maintenance. In the same fashion, it can be used to suggest and prioritize areas of needed research and, at the same time, indicate their relevance to the broad problem of transit maintenance management.

Finally, the framework provides a logical way to organize short courses on bus transit maintenance management. The eight areas of maintenance management provide a logical breakdown of topics whose interrelationships are shown by the model. The topics can be treated jointly, partially or individually as the need arises. This will enhance the training of transit administrators in the elements of maintenance.

B. RECOMMENDATIONS

Based on the findings and developments accomplished in this study, the following actions are recommended to UMTA and the transit industry.

1. UMTA should encourage use of the model by transit agencies. In-house evaluations should be done with assistance from UMTA, or a designated university or consultant to assess the practicality of the method.
2. UMTA should use the framework to make comparisons of different transit maintenance programs. The results should be interpreted to provide realistic performance objectives.
3. Workshops or seminars should be held to apprise transit operators of the method and to encourage implementation at the agency level.
4. As experience is gained with the method by transit operators, the procedure should be updated to reflect what has been learned.
5. UMTA should provide the industry with a loose-leaf version of the report so that it can accept revisions as experience is gained.
6. UMTA should use the format that was developed in this project to guide and prioritize new research on bus maintenance.
7. Short courses should be supported that use the format of this report to structure an understanding of bus maintenance.

NOTES

1. This report implicitly restricts its focus to properties larger than 14 buses and smaller than 501 buses. Smaller and larger properties are not considered due to their exceptional administrative arrangements.

2. Transportation Systems Center, National Urban Mass Transportation Statistics: 1982 Section 15 Report. Transportation Systems Center, Cambridge, Massachusetts, 1983.

3. Other departments may be identified in organizational charts. Larger properties often support formally separate materials, personnel, and finance departments. This analysis primarily concerns small and medium-sized properties, however, which tend to favor a leaner organizational structure.

4. Giuliano, G., "Effect of Environmental Factors on the Efficiency of Public Transit Service, Transportation Research Record 797, 1981.

5. Thurlow, V. S., Bachman, J. A., and Lovett, C. D., Bus Maintenance Facilities: A Transit Management Handbook. U.S. Dept. of Transportation, Urban Mass Transportation Administration, Nov. 1975. And see also Roberts, G., and Hoel, L., Survey of Transit Bus Maintenance Programs in Virginia. Virginia Highway and Transportation Research Council for the U.S. Dept. of Transportation, Federal Highway Administration, July 1981.

6. Consult Thurlow et al., 1975 for a good description of servicing routines, and consult Roberts and Hoel, 1981, and Haven, P., Transit Vehicle Maintenance: A Framework for the Development of More Productive Programs, Ph.D. Dissertation, Massachusetts Institute of Technology, July 1980, for good discussions of the distinction between the functional activities of inspection, minor repair, and major repair.

7. The one instance of dissimilarity is that of daily servicing with regard to maintenance scheduling. By definition, daily servicing performs service on all vehicles each day, thereby avoiding any need for long-term maintenance scheduling of operations.

8. Roberts and Hoel; 1981, and Thurlow et al., 1975.

9. Payne, T. C., "Fleet Mix: Implications for Maintenance Management." Maintenance--the Right Mix of Resources. Session III of 1983 APTA Annual Meeting. U.S. Dept. of Transportation, Urban Mass Transportation Administration.

10. Setne, P., "A Three-level Process for Controlling Engine Life in Transit." Improving Maintenance Management Productivity, Session III of 1982 APTA Annual Meeting. U.S. Dept. of Transportation, Urban Mass Transportation Administration. A thorough discussion of spectroanalysis. See also "NYCTA Strives for More Cost-Efficiency," Metro, Jan.-Feb. 1984.

11. Surti, V. H., and De Hsu, J., Evaluation of Bus Maintenance Procedures Through Systems Analysis: A Case Study. U.S. Dept. of Transportation, Urban Mass Transportation Administration, Sept. 1973.

12. Haven, 1980, Roberts and Hoel, 1981, and Maze, T. H., et al., "Bus Maintenance Planning with Computer Simulation," ASCE TE Journal, May 1983.

13. "NYCTA Strives for More Cost-Efficiency,"1984, reports how one agency discovered that manufacturer interval recommendations were costlier to enforce than they needed to be.

14. Foerster, J. F., et al., Implementing Cost-Effective Service Interval Planning Methods for Bus Transit Vehicles: A Case Study. U.S. Dept. of Transportation, Urban Mass Transportation Administration, Nov. 1980; and Bakr, M. M., and Kretschmer, S. L., "Scheduling of Transit Bus Maintenance," ASCE TE Journal, Jan. 1977.

15. Rueda, A. G., and Miller, F. G., "A Comparative Analysis of Techniques for Determining Transit Bus Maintenance Intervals for Components," Dept. of Systems Engineering, University of Illinois, Chicago, 1982; Bakr and Kretschmer, 1977; Maze, T. H., et al., "Role of Quantitative analysis in Bus Maintenance Planning," Transportation Research Record 915, 1983; and Foerster, et al., 1980.

16. Haven, 1980; Roberts and Hoel, 1981; Ward, P., "The Fleet Maintenance Management Cycle," Transitions, Winter/Spring 1984; and Etschmaier, M. M., "Transit Bus Maintenance Management: Assessment and Needs," paper presented at 1984 meeting of the Transportation Research Board.

17. Utah Transit Authority, "Maintenance Practices and Schedules," Utah Transit Authority, July 1980.

18. For an interesting case on the issue of seniority, see Goodlatte, A., "Supervisor Training for the Maintenance Function," Improving Maintenance Management Productivity, Session III of 1982 APTA Annual Meeting. U.S. Dept. of Transportation, Urban Mass Transportation Administration.

19. Foerster, J., McKnight, C., and Kosinski, M., "Impact of System and Management Factors on Bus Maintenance." Report prepared for the January 1985 meeting of the Transportation Research Board. University of Illinois at Chicago, August 1984.

20. Clark, S., Warren, K., and Greisinger, G., "Assessment of Quality-of-Work-Life Programs for the Transit Industry, Research Report," National Cooperative Transit Research and Development Report 5, December 1983.

21. Foerster, J., et al., Management Tools for Bus Maintenance--Current Practices and New Methods, U.S. Dept. of Transportation, Urban Mass Transportation Administration, April 1983; Mundle, S., et al., "A Framework for Evaluating Transit Maintenance Resource Utilization," paper presented at 1984 meeting of the Transportation Research Board; and Malec, R. E., "Bus Maintenance: Keeping the Lid On," Maintenance--the Right Mix of Resources.

22. Ward, 1984.

23. Kosinski, M., "Case Study of VIA METROPOLITAN TRANSIT, San Antonia/Bexer County, Texas," Preliminary Draft for U.S. Dept. of Transportation, Urban Mass Transportation Administration, March 1984.

24. Ward, 1984.

25. Roberts, G., and Hoel, L., 1981.

26. Kosinski, M., "Milwaukee County Transit System Bus Maintenance Management Case Study," Preliminary Draft for U.S. Dept. of Transportation, Urban Mass Transportation Administration, Feb. 1, 1984, provides an example of a special brake team.

27. For further reference on this and other inventory subjects, see Colley, J., Landel, R., and Fair, R., Operations Planning, and Control (San Francisco: Holden-Day, Inc., 1978).

28. Colley et al., 1978.

29. Roberts and Hoel, 1981; Thurlow et al., 1975.

30. Kosinski, M., "Milwaukee County Transit System," 1984. This case demonstrates that old-fashioned manual systems are still capable of supporting large operations.

31. Utah Transit Authority, 1980.

32. Pence, "Meanwhile Back in the Shop," Transitions, Winter/Spring 1984; and Kosinski, M. L., "Case Study of CNY CENTRO INC, Syracuse, New York," Preliminary Draft for U.S. Dept. of Transportation, Urban Mass Transportation Administration, Feb. 1, 1984.

33. Transportation Systems Center, 1983.

34. Monitoring and evaluation has not been summarized in this format. It shall instead be used to evaluate the effectiveness of the strategies in the other activities.

35. Some activities do not receive a simple "A" rating even in this base case; they instead receive an "A or B" rating. In the case of maintenance scheduling, the alternative of no scheduled intervals is available as the most basic option, but the alternative of manufacturer's intervals represents a more sophisticated system at little extra effort. The alternative of manufacturer's intervals is therefore recommended for any but the simplest operations. --In the case of workforce development, the question of training remains paradoxical: the smallest property may be the most strapped for resources and thus is justified in curtailing its efforts. Yet, at the same time, the smaller property may have the greatest need for formal maintenance instruction from outside the organization, as a small maintenance department will have the fewest senior mechanics to act as mentors in the apprenticeship format.

36. Foerster et al., 1984.

37. Foerster, et al., 1984. In a survey of 8 agencies, this study reported payscales which averaged a gap of 23% between lowest and highest pay. The Tidewater gap of 153% appears to be highly exceptional.

38. Transportation Systems Center, 1983, p. 2-67.

39. Kosinski, M., "Milwaukee County Transit System," 1984.

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APPENDIX

MAINTENANCE DEPARTMENT INFORMATION FORM

The following information collection procedure is designed to provide the data necessary to implement the analysis in this report. In this method, the bus maintenance department is evaluated according to eight identified management activities:

WORK ASSIGNMENT
MAINTENANCE SCHEDULING
WORKFORCE DEVELOPMENT
LABOR ALLOCATION
INVENTORY MANAGEMENT
EQUIPMENT MANAGEMENT
INFORMATION SYSTEMS
MONITORING & EVALUATION

This procedure yields a composite profile of the maintenance department in the form advocated in this report (see Fig. 11).

DESCRIPTORS

Characterize roughly the following environmental conditions.

1. Community size:
   (express in thousands of inhabitants)

2. Density of Community
   A. Express in terms of inhabitants/sq. mi.

   B. Characterize as:
      ___dense
      ___moderately dense
      ___medium
      ___moderately dispersed
      ___dispersed

3. Community Values
   A. Transit use
      ___high transit reliance
      ___moderate transit reliance
      ___light transit reliance

   B. Local support for funding
      ___high local support
      ___moderate local support
      ___light local support

4. Terrain
   ___flat
   ___hilly

5. Climate
   A. Indicate:
      ___mean temperature in January
      ___mean temperature in July
      ___annual precipitation, in inches
      ___average annual days with snowfall

   B. Summarize as:
      ___hot
      ___mild
      ___cold

   C. Summarize as:
      ___variable
      ___moderate

6. Street conditions
   (indicate the exceptional presence of any of the following)
   ___potholes
   ___narrow streets
   ___new road surfaces

7. Local labor market
   Characterized by union climate (yes or no)
   ___region characterized by high wage rates
   ___region characterized by low wage rates

Characterize roughly the following organizational polices

8. Identify guiding organizational objectives, with special identification of those objectives demanded of the maintenance department.

9. Total number of vehicles in fleet:___

10. Hours of revenue service per week:___
    A. Hours of weekday service___. Also, specify number of vehicles and headways that operate at peak, non-peak, and night owl service:

    B. Hours of Saturday and Sunday service___. Also, specify number of vehicles and headways that operate at peak, non-peak, and night owl services:

11. Composition of fleet
    A. ___Homogeneous (one or few types of vehicle)--indicate vehicle type.

    B. ___Diverse (many types of vehicle)--indicate vehicle type and number of each type.

12. Physical facilities
    A. Facility can be characterized as new___ or old___

    B. Design capacity exceeds___ or fails to accommodate___ present bus fleet size

    C. Identify any notable obstructions in facility design.

13. Labor agreements
    A. Unionized___ or Nonunionized___

    B. Indicate base wages___

    C. Identify any pertinent conditions (work rules, shift restrictions, etc.)

14. Budgeting allocation
    A. Maintenance annual operating budget, as an absolute sum:

    B. Maintenance annual operating budget, as a percentage of total property operating budget:

WORK ASSIGNMENT

Work Assignment is the matching of work, as it arises, to the departmental resources at hand. It includes such management policies as:

In-house repair vs. contracting out
In-house inspection vs. contracting out
Queue discipline

Maintenance scheduling may also be regarded as a management policy of work assignment, but because of its importance this subject it receives separate treatment in the following section. Please evaluate the status of maintenance department for the following subjects.

1. In-house Repair vs. Contracting Out
   A. Briefly describe all repair items that are automatically contracted out: (i.e., air conditioners, crankshaft, etc.)

   B. For repair items that are alternated between in-house execution and contracting, quickly describe the issues that guide such a decision (capacity factors due to labor, equipment, facilities; cost factors--contractor does it cheaper, etc.---; response times)

   C. Estimate roughly what percent of repair work is contracted out.

2. In-house Inspection vs. Contracting Out
   A. Does the department administer systematic inspection procedures?

   B. Is fluid analysis performed?

   C. Is fluid analysis performed in-house or is it contracted?

3. Assigning of Floor Tasks
   Does the supervisor assign vehicles, tasks, and workstations to individuals: (check one)

   ___on an ongoing basis
   ___by a schedule, at the beginning of each day
   ___on a weekly schedule

4. Queue Discipline
   Briefly describe what criteria is used to assign work as it arises. In the event of two vehicles arriving for work at roughly the same time (say that one arrives through a preventative maintenance schedule and one arrives through in-service breakdown), how is it determined which vehicle has priority over the other?

   Summarize the criteria: (if more than one criteria is applied, rank numerically in terms of priority--or indicate the dominant consideration)

___First come, first serve
___Scheduled work attended before breakdowns
___Quickest tasks to be done first
___Essential before non-essential
___Other: specify_____

Upon completing this review of Work Assignment, please refer to Fig. 3 in report and place department at its approximate position (A,A/B, B, B/C, C, C/D, D).

MAINTENANCE SCHEDULING

Maintenance Scheduling concerns the assigning of periodic intervals to maintenance tasks. It contains such management strategies as:

Breakdown-oriented, reactive maintenance
Manufacturer guidelines for inspection, mileage-based intervals
Custom-tailored inspection intervals
Scheduled replacement of components

Please evaluate the status of the maintenance department for the following subjects.

1. Are repairs attended to only upon breakdown or reported difficulty? (yes or no)

2. Are preventive inspections procedures systematically administered by department? If so, briefly describe preventive inspection system.

3. Reviewing above description, is maintenance scheduling essentially a matter of following manufacturers' suggested mileage intervals?

4. In addition to (or in place of) manufacturer suggested guidelines, have certain components' intervals been modified to reflect the department's experience with that item (reflecting either exceptional difficulty or exceptional longevity)?

   If only a few components have modified intervals, itemize those components. If many components have modified intervals, express modified component intervals as a % of all intervals.

5. In addition to, or in place of, established inspection intervals, are intervals established for routine replacement of components?

   Either itemize the number of components with specified "change out" intervals (if only a few), or, (if many) express "change out" components as a % of all components.

6. Are maintenance intervals arrived at through manual or automated (computer) procedures?
   Are maintenance intervals administered through manual or automated (computer) procedure?

Upon completing this review of Maintenance Scheduling, refer to Fig. 4, and place department at its approximate position (A, A/B, B, B/C, C, C/D, D).

WORKFORCE DEVELOPMENT

Workforce Development refers to the many personnel policies that take place within the maintenance department. According to the structural organization of the transit agency, some of these activities may fall under the authority of a separate personnel department, or they may fall under the direct authority of the maintenance department. In either case, the policies retain immediate importance for the performance of maintenance.

Workforce Development contains such management policies as:

Training programs
Criteria for promotion
Motivation systems
Work standards

Please evaluate the status of the maintenance department for the following subjects.

1. Recruitment

   How are entry positions in maintenance filled? (If more than one criteria, rank according to priority)

   ___from other departments in property
   ___from local unskilled labor markets
   ___from skilled and/or trained applicants

2. Training Programs

   A. Upon recruiting an employee, what form of training does employee receive? (check as many items as appropriate)

      ___Unsupervised on-the-job training
      ___Apprenticeship on-the-job training
      ___Training through classes held outside organization
         ___local vocational school
         ___industry manufacturer or industry association
         ___another transit property
      ___Formal training classes offered within organization

   B. Is there a formalized, ongoing training program for senior employees?

   C. Are procedure manuals made readily available and incorporated into department routine?

      If yes, indicate approach:
      ___Manufacturer manuals
      ___Property updates manufacturer manuals
      ___Property produces own manuals
      ___Other: specify_____

3. Criteria for Promotion

   A. Regarding promotion to senior positions,
      ___Are positions filled only from within organization?
      ___Are positions also accessible to applicants outside organization?

   B. Are positions filled on the basis of seniority? (answer yes or if entirely or mostly)

C. Are positions filled on the basis of merit? (check one or both if appropriate)
___merit assessed by regularly administered skill and knowledge tests at each level of responsibility.
___merit assessed by history of employee's work records (attendance, error history, task completion times)

4. Discipline and Grievance Procedure
Are criteria formally established, in writing, for:
___What behaviors are expected of employees
___What aspects of performance will be measured
___How performance is to be measured
___What actions will be taken for specific, identified low levels of performance
___What avenue for grievance is available form employee to management, and how that procedure is executed

5. Motivation
A. Do substantial incentives exist within payscales? What is lowest and highest possible wage?

B. Are pay premiums offered for off-hours shifts? (specify)

C. Is priority for overtime duty awarded on the basis of seniority or on the basis of record?

D. Do formal incentives programs exist for specific targeted behaviors? Describe such programs briefly.

Check one or both of the following blanks, as appropriate:
___Incentive bonuses are awarded in nonmonetary forms (status, recognition, etc.)
___Incentive bonuses are awarded in monetary forms (for instances, $0.03 per reduced absence, reduced roadcall, or extra task completion).

E. NOTE: Other special motivation approaches abound in the filed of workforce development, such as quality circles or job enrichment. Please take this opportunity to describe any other special developmental programs to promote motivation and satisfaction.

6. Absenteeism measures
A. What is the average absenteeism per maintenance worker? (days absent per worker per year)

B. What is the total absenteeism for department, in days per year?

7. Work Standards
   A. Are work methods studied for each major task?

   B. Are time standards and standardized procedures generated as a result of work methods studies?

   C. Are individual workers then monitored regularly for their performance alongside standards?

Upon completing the review of Workforce Development, please refer to Fig. 5, and place department at its approximate position (A, A/B, B, B/C, C, C/D, D).

LABOR ALLOCATION

Labor allocation concerns the deployment of labor as a resource. It contains such management strategies as:

Number of shifts: 1, 2, or 3
Specialized vs. generalized orientation of mechanics
Inspection vs. repair crews
Specialized teams

Please evaluate the status of the maintenance department for the following subjets.

1. Crew Sizing
   A. Number of maintenance employees: (express in full-time equivalents)

   B. Maintenance employees per vehicle:

   C. Maintenance employees per vehicle mile:

   D. Overtime hours/non-overtime hours:

2. Number of Shifts
   ___1
   ___2
   ___3

3. Specialization of Mechanics (check one)
   ___All mechanics available for all repair duties
   ___Certain mechanics informally specialize in certain areas (A/C, bodywork, transmission, etc.)
   ___Certain mechanics formally designated as specialists in certain areas.

   Itemize areas of specialization.

4. Specialization of Crews
   A. Check one:
      ___Inspections and repair performed by same crew
      ___Inspection and repair responsibilities formally separated: one crew performs strictly inspections, and one crew performs strictly repair

   B. Check one:
      ___Roadcall crew pulled off ranks as needed
      ___Independent full-time road crew established

5. Specialization of Teams
   Are certain repair laborers organized into independent, full-time teams to attend to one function? (i.e., a brake team, A/C team, etc.)

   If so, itemize specialized repair teams.

Upon completing this review of Labor Allocation, refer to Fig. 6 and place department at its approximate position (A, A/B, B, B/C, C, C/D, D).

INVENTORY MANAGEMENT

Inventory Management contains such management strategies as:

Classification of parts
Management of inventory quantities
Concept of safety stock levels
Concept of inventory service levels
Manual vs. automated control and supervision

Please evaluate the status of the maintenance department for the following subjects.

1. Parts classified by: (check as many as applicable)
   ___high-volume vs. low-volume use parts
   ___long procurement vs. short procurement parts
   ___high cost vs. low cost parts
   ___criticalness of parts (i.e., is part's value critical--regardless of acquisition price--because its absence will prevent operation of vehicle?)
   ___discardable vs. rebuildable parts

2. Are parts of different vehicle models examined for interchangeability?

3. Management methods (check as many as appropriate; elaborate each response when necessary)
   A. Are inventory levels monitored for reorder points?

   B. Are reorder points explicitly, formally established?

   C. Are order quantities set at fixed sizes?

   D. Are times between orders fixed at regular intervals? (periodic)

   E. Are maximum ceilings established for on-hand inventory?

   F. Are reorder points, order quantities, or order intervals regularly reviewed and revised?

   G. Are special policies in effect for small, low-value high-use parts?

4. Establishment of safety levels for stock of each part
   Are safety levels of stock ("buffer stock") developed beyond any forecast use of parts?

   How are safety levels arrived at? Describe.

5. Inventory system monitored and supervised

   ___manually
   ___automated (computer)

6. Inventory measures
   A. $inventory:

   B. $inventory per revenue vehicle:

   C. Number of annual stockouts:

Upon competing this review of Inventory Management, refer to Fig. 7 and place department at approximate position (A, A/B, B, B/D, C, C/D, D).

EQUIPMENT MANAGEMENT

Equipment Management contains such management policies as:

Review of types of functional equipment
Analysis of operational savings vs. annualized cost
Information systems hardware

Please evaluate status of department for the following subjects.

1. Tools policy
   A. Check one:
   ___Hand tools provided by organization
   ___Hand tools provided by workers

   B. Check one:
   ___Specialized equipment is freely available on shop floor
   ___Specialized equipment must be requisitioned from equipment room.

2. Itemize equipment on site
   A. A great variety of specialized equipment is available for bus maintenance operations. Included below is a list of equipment items which are optional, whose presence or absence may help to distinguish one department's equipment management system from another's. (Check all items that are present on site.)

   ___Automatic exterior buswashers
   ___Large Interior vacuum systems
   ___Automatic farebox removal equipment
   ___Transmission and engine stands
   ___Heavy duty press
   ___Brake lathe and grinder
   ___Transmission test stand
   ___Valve body tester
   ___Tig and mig welder
   ___Dynamometer test equipment
   ___Frame straightener
   ___Shaper
   ___Mill

   B. Take this opportunity to list any other items that department does not have but that it is believed would be valuable for maintenance operations. Include any general comments about the need for any equipment item that may be pertinent to this section.

3. Analysis of operational savings vs. annualized cost
   A. Are explicit capital calculations performed for acquisition of shop equipment?

   B. Describe the general process that is observed in the acquisition of equipment.

4. Information systems equipment
   A. Mainframe hardware___

   B. Minicomputer hardware___

   C. Microcomputer hardware___

Upon completing this review of Equipment Management, refer to Fig. 8 and place department at its approximate position (A, A/B, B, B/C, C, C/D, D).

INFORMATION SYSTEMS

Information Systems contains such management strategies as:

Level of information detail
Manual systems
Automated systems
Direct vs. indirect data entry systems
Integrated vs. non-integrated programs

1. Physical characteristics of information system
   ___Entirely manual (card system, circulation of forms)
   ___Automated
      ___Microcomputer
      ___Minicomputer
      ___Mainframe

2. Level of detail
   Disaggregation (check one or both, as applicable)
   ___individualized work time records kept on each worker
   ___failure history kept for each component
   ___aggregation (check if no items above are checked)

3. Data entry (check one)
   Direct data: system data entered at work station
   ___portable disk recorders
   ___on-site terminals
   ___indirect data: clerical transcription of floor data into departmental information system (check if other items above are not checked.)

4. Integration of programs
   Do results in one program trigger action/response in another program? Give examples. (For instance, does the scheduling of a particular repair task in the week trigger a response for reorder of related parts from the inventory program?)

Upon completing this review of information systems, refer to Fig. 9 and place department at its approximate positions (A, A/B, B, B/C, C, C/D, D).

MONITORING AND EVALUATION

Monitoring and Evaluation concerns the employment of performance measurements for the maintenance department. Some measures have already been presented, as they directly reflect the performance of a specific area of maintenance management. Other measures, however, tend to reflect the performance of the maintenance department on a more general scale. General measures are presented in this section.

1. Are the following measures monitored, and if so, please enter the respective values
   - ___Roadcalls:
   - ___Vehicle miles/roadcall:
   - ___Vehicle maintenance cost/vehicle mile:
   - ___Fuel use (mpg):
   - ___Spare ratio (total vehicles - peak vehicles)/total vehicles):

2. In addition, simply indicate whether the following measures are monitored
   - ___Missed runs
   - ___Late outs
   - ___Inactive buses (number of vehicles inactive, and number of vehicle days inactive) inoperable
   - ___Oil use (miles per quart)
   - ___Life mileage
   - ___Labor hour productivities (i.e., vehicle miles/maintenance labor hour, roadcalls/maintenance labor hour, etc.)
   - ___Work standards