U.S. Department of Transportation

Transit Bus Maintenance Management
Summary Report

August 1984

81

NOTE: This report includes an analysis of key issues associated with transit maintenance management. Part of its content includes recommendations for policy changes and program development based on this contractor's perceptions of the issues involved. Recognizing that there may be many alternative approaches to solving transportation problems, these positions may not reflect those of the U.S. Government. As such, no endorsement of these recommendations is either expressed or implied by the U.S. Department of Transportation.

Transit Bus Maintenance Management: Summary Report

Final Report
August 1984

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16. Abstract

Regression analysis was used to develop models of the reliability and maintenance labor statistics reported by 111 U. S. transit systems. Eight bus systems were selected for intensive analysis on the basis of deviations from the expected pattern of performance. Detailed site visits were conducted to identify local factors which were responsible for the deviations from expected performance. Comparisons of the site visit case studies identified several factors which had significant effects on performance. These included tracking and periodic evaluation of maintenance outcomes, driver involvement in pre-run inspections, cooperative worker/manager relationships, and avoidance of excessively diverse fleets. A summary of productive management actions was constructed by synthesizing the approaches used at selected case study systems.

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Executive Summary

This report surveys the wide range of factors which influence transit bus maintenance. The survey is based on eight case study systems which were selected after analysis of roadcall records and labor hours devoted to maintenance. Differences between these systems are illustrated by example in the body of this report, and factors which seem to differentiate between various levels of maintenance performance are identified.

The contents of this report include a first-level analysis of Section 15 maintenance data which illustrates how selected factors affect maintenance performance; a description of the rationale used to identify 8 systems for intensive case analysis; a report of the results of these case studies; and a set of recommendations based on a synthesis of beneficial practices identified in the systems studied.

Issues covered include system management practices, local operating environments, budget levels, and physical facilities.

Both positive and negative factors related to these areas were identified at the case study systems.

The experiences of the eight systems provide ample support for the argument that every system has unique features which make it difficult to conduct cross-system comparisons. However, a number of practices which are typical of successful maintenance operations and which logically should contribute to positive performance gains were identified. These practices are:

1. Conduct of pre and post run inspections by drivers

2. Establishment of performance targets, development of performance measures, and periodic performance trend analysis

3. Development of written statements of (or informal concensus about) maintenance policies and procedures.

4. Coordination of vehicle procurement decisions with inventory planning and staff development activities.

5. Establishment of strategies for recruiting, testing, training, and retaining skilled staff.

6. Establishment of cooperative working relationships between workers and managers.

7. Avoidance of unmanageably diverse fleets.

8. Periodic performance assessment and evaluation of alternative strategies for improving maintenance effectiveness.

Review of the cases suggested a model for maintenance planning focused on an annual performance and operating environment analysis. The major products of this analysis would include:

1. A summary of current fleet composition, a list of expected fleet changes; and a description of anticipated impacts of these changes on staff, facility and equipment needs.

2. A brief overview of current facilities and shop equipment; a description of deficiencies; and a list of anticpated needs resulting from fleet changes.

3. A list of currently budgeted maintenance staff positions; a review of needs for additional positions; an analysis of reasons for unfilled positions; and a description of the staffing impacts of anticipated fleet changes.

4. A summary of recruitment and training, focusing on reviews of the effectiveness of testing procedures used in hiring and promotion, the adequacy of training given to mechanics responsible for new equipment, and hiring strategies (including experience requirements, wage scales relative to other industries, and alternative training approaches).

5. A summary of the preventive maintenance program used in the previous year, a list of problems encountered in compliance with this program; and a description of anticipated changes in the PM program.

6. A description of pre-run inspection procedures; an assessment of driver compliance and maintenance follow-up; and a statement of changes needed to insure compliance.

7. A summary of any problems encountered with the inventory system; and an analysis of changes needed to accomodate new vehicles, special campaigns, or retrofit programs.

8. An analysis of roadcalls and missed trips to identify causes, directions of trends, and possible remedial actions, as well as an assessment of the effectiveness of strategies adopted as a result of problems encountered in previous years.

9. A comparison of budgeted and actual expenses; an analysis of the reasons for variances; an analysis of anticipated fleet changes on maintenance budgets; and a projection of next year's budget.

10. A review of policies and procedures; a statement of proposed changes; and an evaluation of the effects of changes made over the past year.

An annual updating and review of these documents is recommended as the basis for strategic maintenance planning.

Table of Contents

List of Exhibits

I. Introduction

This report summarizes a number of case studies which were conducted by University of Illinois researchers to document current transit bus maintenance practices. This study complements previous work based on the application of detailed operations research methods for work scheduling, preventative maintenance planning, and component life analysis (Muthukumaran et al, 1981; Kosinski et al, 1982; Foerster et al, 1983). The primary focus of this report is the analysis of eight case studies which attempted to capture the essence of bus maintenance operations at selected U.S. systems. The systems selected for this purpose are shown in Exhibit 1, along with a set of descriptive statistics illustrating their performance relative to other U.S. systems.

The methodology used in this study is that of the comparative case study. This means that the researchers selected systems for study with the purpose of illustrating differences and discovering sources of inter-case variation. The purpose of our method is not to pass judgement on specific systems or to test general propositions and global theories. Such enterprises would require a level of effort and a sample size too large for our current purposes. Their emphasis would also tend to obscure the ideosyncratic aspects of the systems studied, runnning the risk of violating the tranist manager's maxim that "each system is unique - so you can't compare us to anyone else." We have taken this maxim as a methodological challenge in our research. What we have done in our case studies is to focus on local conditions which are sources of uniqueness. In this report we compare selected aspects of our case study systems to determine whether or not these aspects are truely unique and whether they have any relationship to, or impact on, system costs and/or performance. In doing this we have relied on interviews with and questionnaires completed by personnel at each of the systems in question. We have cross-checked our results by reviewing the reports of persons in a variety of positions in each organization, and have tried to interpret their responses in light of the data generated in the Section 15 reporting process.

Our purposes were to (1) identify those aspects of bus transit maintenance which seem to "make a difference" (2) test certain a-priori hunches or hypotheses about what constitutes "good" bus transit maintenance practices (3) develop criteria for constructively assessing maintenance activities and identifying strategies for increasing maintenance effectiveness.

The main questions addressed in this report are as follows:

1. What effect does overall system and maintenance management have on the efficiency of the operation? This includes the effect of maintenance policies, management techniques, and maintenance methods and procedures, as well as organizational structure and intra-organizational communciation.

2. What effect does the quality of the labor force have on the maintenance operation? This includes the quality of the labor pool and the training received.

Exhibit 1
General Description of Case Study Systems

Case Study Systems	Revenue Vehicles	Maintenance Labor hrs per thousand miles	Roadcalls due to mechanical failure per thousand miles*
Milwaukee	719	.025	0.33
Miami	673	.046	1.50
San Antonio	530	.029	0.06
Madison	193	.014	0.07
Tacoma	170	.037	0.76
CNY	159	.029	0.13
Gary	115	.035	0.94
Spokane	80	.016	0.32
Comparative National Statistics			
In a sample of 111 bus systems selected from 1981 Section 15 data,			
25% had values less than	70	.015	0.19
50% had values less than	101	.023	0.36
75% had values less than	217	.030	0.60

Source: 1981 Section 15 data. A list of the systems included in this sample is given in Appendix 1. The rationale for selection of these systems is included in Chapter 3.

*Note: The Urban Mass Transportation Industry Uniform System of Accounts and Records and Reporting System defines Roadcalls for Mechanical Failures as the "count of the revenue service interruptions during the reporting period caused by failure of some mechanical element of the revenue vehicle. (Mechanical failures are to include breakdowns of air equipment, brakes, body parts, doors, cooling system, heating system, electrical units, fuel system, engine, steering and front axle, rear axle and suspension and torque converters. Tire failures and fare box failures are not included.) These revenue service interruptions require assistance from someone other than the revenue vehicle operator (or crew) in order to restore the vehicle to an operating conditions. Further, they usually require the transfer of the passengers to another revenue vehicle for the completion of their trip."

This excludes roadcalls for other reasons which are defined as the "count service interruptions during the reporting period caused by tire failure, farebox failure, air conditioning system, out of fuel-coolant-lubricant and other causes <u>not</u> included as mechanical failures."

3. What effect does the system environment external to the maintenance function have on maintenance operation? This includes the location of the system, operating environment of the fleet, and model and age distribution of the fleet.

4. What effect does the maintenance budget have on the maintenance function?

5. What effects do the physical characteristics of the maintenance department have on maintenance operations? This includes the layout, location, and age of the maintenance facilities, condition and use of maintenance equipment, and procurement, location, and quality of parts.

Our purpose in answering these questions is fourfold: First, we intend to provide a reference source for use by transit operators and persons (including students and researchers) interested in how different bus maintenance systems currently function. Second, we hope to evaluate the practical value of quantitiative approaches to maintenance planning. Third, we want to identify those factors which seem to be effective in increasing the effectiveness or decreasing the cost of maintenance performance. And fourth, we want to provide guidance for those involved in the management of bus maintenance activities.

The remainder of this report is organized as follows: Chapter 2 reviews the previous background of the study, including historical trends in federal programs, research, and policy perspectives. Chapter 3 presents the details of our research questions and methodological approach. Chapter 4 includes a descriptive summary and narrative about each system, and Chapter 5 provides answers to the general questions just posed. The results of the study are discussed in Chapter 6, and presented as recommendations for strategic maintenance management planning. Detailed case writeups are available as separate volumes of this report.

2. Background

A. Policy Environment

Bus maintenance has become a subject of growing concern at the local and federal levels during recent years. This is evident in the legislative record, in the activities of professional groups, and in the research agenda of the Federal government. This concern is understandable in view of the significant costs of transit maintenance, the increased complexity of vehicle systems, and the changing funding environment faced by transit interests.

One the basic facts about transit maintenance is that maintenance budgets are a significant part of transit operating expenses, typically accounting for 18-32% of operating budgets. These expenses are eligible for federal support through section 5 and 9 of the Urban Mass Transportation Act. Some have argued that the federal-local element of these programs is flawed, leading to less than adequate accountability at the local level. Others are quick to point out that an even more serious cause for concern is the difference between federal operating subsidy and capital grant shares. The concern has been raised that this difference in shares can lead to inadequate maintenance and a distortion of maintenance and capital expenditure patterns.

The Urban Mass Transportation Administration responded to these concerns by publishing an "advanced notice of proposed rulemaking" in the Federal Register in January 1981 (46 Fed Reg No. 14, pp 7031-7034). This notice laid out a number of alternative approaches to safeguarding federal investments against inadequate or improper maintenance. These included

- the adoption of maintenance requirements as a condition for UMTA grant assistance
- required development of maintenance plans
- on-site inspections
- earmarking of a percentage of Section 5 funds for maintenance
- encouragement of mainteneance planning activities

Because of the controversial nature of these options, the proposed rulemaking notice was withdrawn in August of 1982 (Vol. 47 Fed Reg #166 p. 37599). A subsequent GAO report noted that UMTA had

> "...encountered problems in developing universally applicable standards. For example, local variables such as climate and terrain can affect the frequency of certain maintenance activities. UMTA was also concerned about the Federal resources needed to make sure that the policy was implemented" (GAO, 1983)

The Surface Transportation Act of 1982 (PL97424, Jan. 6, 1983), however, contained language which is directly targeted to the adequacy of maintenance question. Section 9(e)(2) of the Act requires that

> "Each recipient (of block grant transit monies) shall submit to the Secretary annually a certification that such recipient.... has or will have satisfactory control, through operation or lease or otherwise, over the use of the facilities and equipment, and will maintain such facilities and equipment; (emphasis added)

Section 9(g)(1) provides for federal monitoring:

> "The Secretary shall, at least on an annual basis, conduct, or require the recipient to have independently conducted, reviews and audits as may be deemed necessary by the Secretary to determine whether
> (A) the recipient has carried out its activities submitted in accordance with Section (e)(2) in a timely and effective manner and has a continuing capacity to carry out those activities in a timely and effective manner; and
> (B) the recipient has carried out those activities and its certifications and has used its Federal funds in a manner which is consistent with the applicable requirements of this Act and other applicable laws...

Section 9(g)(2) set up a 3 year review cycle:

> "In addition to the reviews and audits described in paragraph (1), the Secretary shall, not less than once every three years, perform a full review and evaluation of the performance of the recipient in carrying out the recipient's program..."

Specific guidance on the concerns of the 3 year review cycle has not yet been developed, due in part to the difficulty of assessing the relative importance and effectiveness of various maintenance practices. However, the American Public Transit Association has addressed this question with the publication of its "Guidelines for Bus Maintenance" (APTA, 1983c). This document reviews many necessary elements of bus maintenance programs, including daily fueling, cleaning and repair, periodic maintenance and inspection, and quality assurance. It urges that local systems develop their own written bus maintenance plans, and recognizes that these plans may differ from place to place because of differing local conditions. APTA's guidelines are strongly focused on shop floor activities, giving little emphasis to management procedures and personnel questions, among others.

In view of these developments, it is important to realize that the question of transit maintenance has been addressed quite differently by analysts who have relied on alternative conceptual frameworks. These perspectives were clearly reflected in the structure and conclusions of a recent conference on bus maintenance (TRB, 1983). The perspectives developed in this conference included (i) a concern with managerial skills and the organizational design of transit systems, (ii) the use of analytical methods and management information systems, (iii) personnel questions, including recruitment, training, motivation, and testing procedures, (iv) questions of garage design and maintenance equipment, and (v) vehicle design and maintainability considerations. The wide variety of maintenance-related factors suggested by these areas is significant because most previous academic research has been focused on the use of data analysis and operations research techniques to set mileage intervals for vehicle maintenance and component change (Rueda and Miller, 1983).

The importance of taking a broad perspective in selecting strategies for improving maintenance is clear from the diversity of innovations which are occuring in the maintenance area. These include the introduction of new equipment (dynamometers, automated diagnostic systems, improved lifts), innovative analytical methods (oil analysis, lifecycle costing, and vehicle history analysis), and subsystem redesign and retrofit (air conditioning, brakes transmissions). Improved training and testing, development of automatic data entry systems, and improved management reporting are also part of this trend. The details of these approaches are recounted elsewhere (Transportation Systems Center, 1982; UMTA, 1983; Foerster, 1984), but what is important to note here is that many systems are active in experimenting with new ideas to improve their performance. This raises questions about how transit management monitors change in the industry and how it decides to implement new ideas.

B. Previous Research

A review of the available, non-proprietary literature indicates that many analysts have been putting a great deal of emphasis on technique, with less attention to existing practice and applicability of elaborate methodologies.

A number of recent studies have presented methods for maintenance management and equipment replacement. Replacement has been addressed from the perspective of fleet age profiles (Tri-State Regional Planning Commission, 1973), acquisition and maintenance costs (Hauer, 1975), annual maintenance costs (Jardine, 1976), cost trend analysis (Brown-West, 1981), average cost computations (Rueda, 1981) and lifecycle cost analysis (Jhaveri, 1978; Armour, 1980; Christopher-Flannigan, 1982). Maintenance models focusing on component replacements have been proposed by Jardine (1973), Vergin and Scriabin (1977), Bakr and Kretschmer (1974), Herniter et al (1977), and Sinha and Bhandari (1978). Statistical techniques for failure analysis have been well-developed in the engineering field (Benjamin and Cornell, 1970) and they recently have been shown to be applicable to bus system analysis (Kosinski, 1982; Kelly and Ho, 1982)

Almost all of the studies just listed have focused on methodological development and formal analysis, leaving no question about the existence of theoretical ways to make maintenance policy decisions based on cost-effectiveness criteria. The existing literature, unfortunately, shows a paucity of research on the practicality of these methods. Notable exceptions are in the 1976 Haenisch and Miller application of standard time methods at the Chicago Transit Authority and the 1980 case study by Foerster et al of the feasibility of implementing Herniter et al's strategic maintenance planning model.

Publication of empirical data on bus maintenance intervals and component life is equally rare, with notable expections being the 1977 Singh and Kankam report on the Toronto system, Wilbur Smith's report on New Jersey properties, and Kosinski et al's report on A/C Transit.

Two manuals for maintenance management have addressed some of the key questions facing transit management. The first, "Bus Maintenance Facilities" (Thurlow, et al, 1975), focuses on physical plant considerations in garage and service island construction. The second, "Vehicle Maintenance Control Plan" (Setne and Preston, 1981) gives guidelines for managment and staff organzation, labor management MIS planning, and strategic maintenance planning. Neither, however, surveys the current situation at systems throughout the industry.

The overall conclusions to be drawn from this brief review of the literature are that most of the work done in this area has been prescriptive and that information on the practicality and potential benefits of procedures and policies which have been recommeded in the past is lacking. The prescriptive focus of this literature is problematic because evaluation of the feasibility and desirability of maintenance policies and procedures can only take place when baseline descriptive information is available. The feasibility of a technique can only be understood when its data requirements are constrasted with data availability; the appropriateness of a technique can only be gauged when its assumptions are tested against experience in practice. Since analysis of maintenance policy and techniques is the overall goal of this study, analysis of data availability and procedural assumptions becomes a necessary part of its methodology. And since information on data collection and operating practices is lacking, the descriptive approach described previously in the scope of work is a necessary step in analysis of policy options.

3. Case Study Methodology

The approach taken in this study was based on the premise that there is a need to assemble a descriptive body of knowledge to document current industry practice for use in evaluating proposed prescriptive maintenance policies and procedures. The approach involved the documentation of bus maintenance procedures, data collection methods, maintenance planning activities and management policies at selected U.S. transit systems. It also involved comparison of these procedures, data collection methods, and maintenance planning activities, and the evaluation of the utility and feasibility of techiques and policies which have been previously recommended.

The scope of work necessary for implementing this approach involved:

1. Development of a set of questions about local bus transit maintenance policies and procedures;

2. Development of a methodology for gathering answers to the questions on the basis of site visits and operator interviews;

3. Establishment of an industry profile detailing maintenance performance data and fleet age and composition;

4. Selection of key systems to be visited in the field-work phase of the study;

5. Conduct of site visits and interviews;

6. Documentation and synthesis of the results of the site visits;

7. Evaluation of the effectiveness and generality of the practices and procedures identified.

A. Research Questions and Hypotheses

The case study questions, already listed in the Introductory section, were used to generate 16 specific hypotheses for use in conducting site visits. The study questions were elaborated as follows:

AREA 1: MANAGEMENT

STUDY QUESTION: What effect does overall system and maintenance management have on the efficiency of the operation?

Specific Hypotheses:

Good, two-day communication within and between all levels of management is essential for effective maintenance operations.

Policies should be flexible enough to allow for individual initiative but firm enough to ensure the orderly day-to-day operations of maintenance. All levels of management, from the governing board on down, should view maintenance as a main concern.

A preventive maintenance program is essential for the efficient, long-term operation of the transit system.

In systems with effective maintenance, management utilizes computer information system to monitor the status and condition of the fleet.

AREA 2: LABOR
STUDY QUESTION: What effect does the quality of the labor force have on the maintenance operation?

Specific Hypotheses:

Union and management should not view their relationship as that of adversaries if maintenance is to operate effectively.

Unions and labor should have some from of meaningful input, other than that specified in the union contract, into the maintenance operation. This communication is necessary for maintenance to function effectively.

The quality of the regional labor pool has a direct impact on maintenance

Initial and on-going training of mechanics is necessary to maintain the long-term effectiveness of maintenance.

AREA 3: OPERATING ENVIRONMENT
STUDY QUESTION: What effect does the system environment external to the maintenance function have on maintenance?

Specific Hypotheses:

Heterogenous fleet composition adversely affects maintenance.

Climatic conditions can adversely affect maintenance operations.

AREA 4: BUDGET
STUDY QUESTIONS: What effect does the maintenance budget have on maintenance?

Specific Hypotheses:

The maintenance budget should be prepared jointly by maintenance and finance to insure that maintenance has an adequate operating budget

An inadequate maintenance budget signifies either a monetary crisis in the transit system or a low priority for maintenance in top management.

AREA 5: PHYSICAL FACILITIES

STUDY QUESTIONS What effect do the physical characteristics of the maintenance department have on maintenance operations?

Specific Hypotheses:

Old buildings or those not originally intended for the servicing of buses adversely affect maintenance operations.

Under or over utilization of maintenance repair equipment indicates either poor maintenance management or the lack of an adequate maintenance budget.

Good quality, readily accessible replacement parts are essential to the efficient operation of the maintenance department.

B. Site Methodology Development

Our site visit methodology was developed in an iterative process which was focused by the research questions and specific hypotheses listed above. Eleven different interview instruments, each covering a different topic, were developed. These forms contained questions and lists of information to be collected during site visits. The interview instruments were designed so that they could be grouped to obtain the maximum amount of information possible for each interview. This also allowed the same questions to be asked of several different people for future comparison. The interview instruments consisted of the following:

1. The physical characteristics form contained questions on fleet composition, operating environment, system size, and local topography.

2. The Garage and Facility form contained questions on garage (or shop) size, number of lifts, special equipment, and equipment needs.

3. The Performance Indicator form was designed to obtain information on roadcalls, missed runs, late outs and costs.

4. The System Organization form was developed to collect information on organizational structure, reporting lines, use of computers, and maintenance priorities.

5. The Policy Formulation form was designed to determine the level of management responsible for setting maintenance priorities and the balance of concerns between day to day procedures and strategic maintenance planning.

6. The Inventory and Procurement form contained questions on current procedures, inventory control, and physical distribution.

7. The Garage Level Maintenance Organization form was developed to identify individuals responsible for maintenance decisions at each garage.

8. The Maintenance Methods and Procedures form was designed to collect information on inspection and preventive maintenance policies, work order processing, roadcall reporting, and maintenance data collection.

9. The Maintenance Management Tools form contained questions on use of computers and analytical methods.

10. The Union form contained questions on contractual provisions affecting hiring, promotion, and staffing, as well as union-management communication.

11. The Personnel and Training form was designed to collect information on recruitment, testing, training, and promotion policies.

After the first draft of the questions were completed in November of 1982 it was felt that input from personnel at a local transit system would be useful in further development and planning. With the assistance of Clayton Weaver of the RTA, a meeting was arranged with the general manager Stephen Keiper and superintendent of maintenance Ernest Ferguson of West Towns Bus company located in Oak Park, Illinois. During this meeting several points pertaining to the questionnairew were dicussed. These included:

1. Applicability of questions

2. Design of questions to investigate implicit policy formulation.

3. Types of data and information that may be available, including standard forms and reports.

4. The appropriateness of question wording.

This discussion was instrumental in revising the questionnaire to focus on more specific topics and provided a basis for identifying the statistical data and forms that would be collected during the site visits. When the interview instruments had been revised it was felt that a final review by a practicing maintenance manager was needed to insure that their form and content were understandable and would provide the information needed to complete the project. Ralph Malec's comments on question wording, content and organiztion provided the base for the final draft of the questionnaires.

Our plan for conducting the site visits called for use of the resulting questionnaires as interview guides. The site visit procedures involved an initial one day visit to the case systems to establish contact with management, verify the responsibilities of the personnel selected for interviews, and collect background information such as budgets, policy statements, staffing levels, etc. A checklist of forms was developed for this purpose (see Exhibit 2). The second phase of the visits was to have involved a 2-3 day visit to conduct parallel interviews with a number of key personnel. These interviews were organized around 11 different sets of questions which were designed for interviews with 13 system personnel. The individuals targeted for interviewing are shown in Exhibit 3. A summary checklist was prepared for use in reviewing each site visit for completeness. This is shown in Exhibit 4.

C. Site Selection Analysis

The selection of case study sites was governed by the following criteria:

1. The systems should have between 45 and 1000 vehicles.

2. The systems should not be involved in the provision of rail service.

3. The systems should be selected to represent "extremes" of performance as indicated by Section 15 roadcalls and labor requirement data.

4. The effects of local operating environments on performance should be considered.

These criteria were established in consultation with UMTA staff and after review of existing Section 15 performance data. The decision to focus on moderate sized systems (45-1000 vehicles) was motivated by our desire to produce results which would be of interest to the middle range of U.S. bus systems. These systems were of primary concern because they are large enough to have formal mechanisms for managing their maintenance functions (as opposed to direct management oversight), but no so large that their performance would not be comparable to that of other systems. The size criteria was also set after review of figures showing that this range included over 60% of the total buses in federally subsidized fleets. It was felt that this study could not adequately treat very small systems because of their diversity and frequent integration with public work fleets; and that very large systems were often dominated by labor and management structures which were quite a typical of most other systems. Systems with rail service were excluded from our analyis because of the difficulty of allocating joint costs over different modes.

Case systems were selected on the basis of extremes in roadcall and labor requirements. We used mechanical roadcalls per revenue mile as a surrogate for reliability and maintenance labor hours per revenue mile to represent input requirements. The data we analyzed was adjusted to remove the effects of local factors such as vehicle age or spare ratios which obviously affect performance. By eleminating the contribution of these variables from roadcalls and labor hours before selecting the sites, we were more likely to identify those systems which have good or bad maintenance performance because of their management and policy.

Regression analysis was used to develop models to control for these variables. The criteria used for choosing the models were:

Exhibit 2

Forms Checklist

Forms Checklist for Initial Visit

1. Organizational chart; system wide ___
   garage level ___
2. System budget ___
   Maintenance budget ___
3. Most recent section 15 report ___
4. Annual system report to city/county/state government ___
5. List of job titles ___
6. Current fleet age and mix ___
7. Transit map and service schedules ___
8. Organizational goals and policies ___
9. Written maintenance policies ___
10. Preventive maintenance policies ___
    Related forms (if any) ___
11. Report of production hours vs. total hours ___
12. Report of vehicle miles operated ___
13. Roadcall reports; daily ___
    summary/monthly ___
14. Daily fuel and oil consumption card ___
15. Driver defect report of inspection card ___
16. Bus history card ___
17. Unit rebuild history (if available) ___
18. Monthly report of repairs by bus number ___
19. Vehicle inspection checklist; pre-run inspection ___
    post-run inspection ___
    other inspections ___
20. Inspection schedules, guidelines ___
    scheduling forms ___

Forms checklist for initial visit
Page 2

21. Forms or reports generated by any automatic diagnostic equipment ___
22. Parts requistion forms; sample ___
    completed ___
23. Work order; sample ___
    completed ___
24. Inventory forms; order form ___
    warranty sheet ___
    unit exchange card ___
    reclamation form ___
    mechanic report ___
    hold-out form ___
25. Personnel policies ___
26. Job description; mechanics ___
    supervisors ___
27. Placement/pre-employment test (if any) ___
28. Maintenance employee training policies ___
29. Sample of mechanic training material ___
30. Union contracts ___
31. Grievance procedures ___
32. Grievance forms ___

Exhibit 3
Organization of Interviews

The following list represents the ideal "complete" set of interviews, providing the greatest number of comparison interviews for all questionnaires. Those questionnaires marked with a least one asterisk respresent the second best option providing for all necessary comparisons of answers. Those marked with two asterisks represents the basic questionnaires that must be answered by the appropriate individuals in order to get the minimum amount of information necessary to answer the five main questions.

Interviewee	Contents of Interview Packets
General Manager	**Physical Facilities: Overall System *Performance Indicators **System Organization and General Informatio ·*Maintenance Policy Formulation
Head of Maintenance	**Performance Indicators **Policy Formulation *Maintenance Organization at Garage Level **Maintenance Methods and Procedures
Materials Manager/Head of Purchasing	**Inventory/Procurement
Head of Personnel	**Personnel/Training **Union II
Head of Engineering	**Performance Indicators
Head of Operations/Head of Planning	*Physical Facilities: Overall System *Performance Indicators *Policy Formulation
Garage Manager	**Physical Facilities: Individual Garage **Maintenance Methods and Procedures *Union II *Maintenance Organization at Garage Level
Garage Foreman	*Maintenance Methods and Procedures *Maintenance Organization at Garage Level Union II Performance Indicators
Union President/Union Steward	**Union I
Mechanics	Maintenance Methods and Procedures Maintenance Organization at Garage Level

Exhibit 4

Case Study Checklist

Summary Checklist

To insure that all topics have been covered check off all of the following questions which have been covered in at least one interview. Any questions which have not been answered should be covered during the last day of the visit.

___ How is the maintenance budget prepared?

___ What input do the garage, maintenance, and operations managers have on the maintenance budget?

___ Are there written maintenance policies? If so who initiates them and how are they developed?

___ How are unwritten policies established and by whom?

___ How effective are current maintenance policies according to system employees?

___ Are regular meetings held to discuss maintenance problems? Who is involved in these meetings?

___ Are facilities and/or information shared with other transit companies?

___ What facilities and equipment are available at each garage?

___ What functions can be handled at each garage?

___ What condition is the maintenance equipment in?

___ What are the positive/negative impacts of the garage facilities on maintenance efficiency?

___ What type of inventory system is used? Is the system computerized?

___ How are orders handled?

___ How are parts checked or monitored for quality?

___ What is the reorder policy? How was it established?

___ How are parts requisitioned by mechanics?

___ What is current condition, age, and size of the fleet?

___ What are the major maintenance problems?

___ What most effects the level of maintenance service?

___ How is maintenance evaluated?

___ What performance indicators are used in this evaluation?

___ How is the system organized?

___ How is each garage organized?

Summary Checklist
Page 2

___ Is there an adequate maintenance staff? Are there enough skilled employees to meet maintenance needs?

___ How are daily operational decisions made at the garage level? (i.e., what buses are inspected, held out) Who makes these decisions?

___ How is worke scheduled? Who schedules it?

___ How are work orders processed?

___ How is job time accounted for?

___ Are regular inspections carried out? What type(s) of inspections are carried out? How often?

___ What parts are inspected?

___ Is there a preventative maintenance program? How does it work?

___ Are job manuals/aids used? What kind(s)? Who uses them?

___ How are roadcalls defined?

___ How are roadcalls acted upon?

___ Does the system have a computer? If so what is it used for and by whom?

___ What maintenance information is collected on a daily, weekly and monthly basis? What is this information used for?

___ What is the make-up and general skill level of the maintenance employees?

___ How are maintenance staffing levels set?

___ What type of pre-employment screening is used?

___ What type of training program is used?

___ Who is trained?

___ Are periodic evaluations of mechanics carried out? How?

___ What are pay and promotion policies?

___ Is there a union(s)? What employees are covered?

___ How are grievances handled?

___ Have any unfair labor practices been filed with the NLRB? How were they resolved?

___ What is the state of union/management relations?

1. The independent variables were not of interest for the case studies.

2. The effect of the independent variables within the model was logical.

3. The coefficients of the independent variables were significant at the 10 percent level.

4. The model was significant the 10 percent level.

5. Given criteria 4, the R-squared value was as high as possible.

The data used was drawn from the 1981 Section 15 statistics. The sample was restricted to systems with from 45 to 1000 buses and excluded systems with rail service. Several systems were eliminated because of missing or inconsistent data. The final sample consisted of 107 systems. The following variables were considered in developing the regression models:

* Fleet size (total revenue vehicles)
* Peak vehicles (total vehicles operating during the peak)
* Mean age of fleet (years)
* Age distribution of fleet (proportion of fleet in each of six different 5-year age categories)
* Dispersion of the age distribution
* Speed (revenue miles/revenue hours)
* Peak to base ratio (peak vehicles/base vehicles)
* Spare ratio (total revenue vehicles/peak vehicles)
* Vehicle utilization (revenue miles/revenue vehicles).

In addition, roadcalls per 1000 revenue miles and labor hours per 1000 revenue miles were tried as independent variables. A number of functional form were tested based on a-priori expectations. The final models chosen were:

$$RC = -0.802 + 0.114 \ln (VEH) + 8.905/SPEED$$
$$R^2 = 0.175 \qquad F = 11.48$$

where RC = roadcalls due to mechanical failure per 1000 revenue miles

VEH = revenue vehicles

SPEED = average speed (miles per hour).

and $LH = -2.9 + 0.009VEH + .88/SPEED + .80AGE + 9.3RC - 6.1SPARE$

where LH = hours of maintenance labor per 1000 revenue miles

AGE = mean age of fleet

SPARE = revenue vehicles/peak vehicles.

Both models are significant at the five percent level. Only the intercept of the labor hour model is not significant; the coefficient of AGE is significant at the 12 percent level. All other coefficients are significant at 10 percent or better.

Neither model explained a large percent of variation (37 percent for labor hours only 18 percent for roadcalls). We acknowledge that this may be due to local departures from established Section 15 reporting practices, but based on our site visits, we are confident that the residual variation is also an indication that the management and maintenance practices we studied in the cases are very important in explaining variation in maintenance cost and reliability.

Exhibit 5 shows the relationships between speed, fleet size and roadcalls and between speed, fleetsize, vehicle age, spares, roadcalls and labor requirements. The graphs shown in Exhibit 5 illustrate the effect that each of the independent variables would have if they could be changed without influencing any of the other variables. The effect of each independent variable (both those that were successfully included in the models and those which were not significantly related to performance) are discussed below.

INCLUDED VARIABLES

Speed - Speed is the most significant and has the most explanatory power of any variable in both models. Both roadcalls and labor hours decrease with increases in speed (or, perhaps, decreases in congestion). We believe that speed, to some extent, captures the service profile of the various systems.

Fleet Size - Total revenue vehicles was significant in both models. This indicates that there are diseconomies of scale in bus maintenance. In the roadcall model, roadcall increase at a decreasing rate with fleet size. In the labor hour model, labor hours increase at a constant rate with fleet size.

Roadcalls - Roadcalls per revenue mile is significant in the model for labor hours. Hours of labor increase with roadcalls. One possible explanation of this result is that roadcalls are a cause of labor rather than preventing roadcalls.

Spare Ratio - The ratio of revenue vehicles to peak vehicles is significant in the labor hours model. Labor decreases with increases in spare vehicles. Presumably, having a

Exhibit 5

Effect of Independent Variables on Roadcalls and Labor Utilization

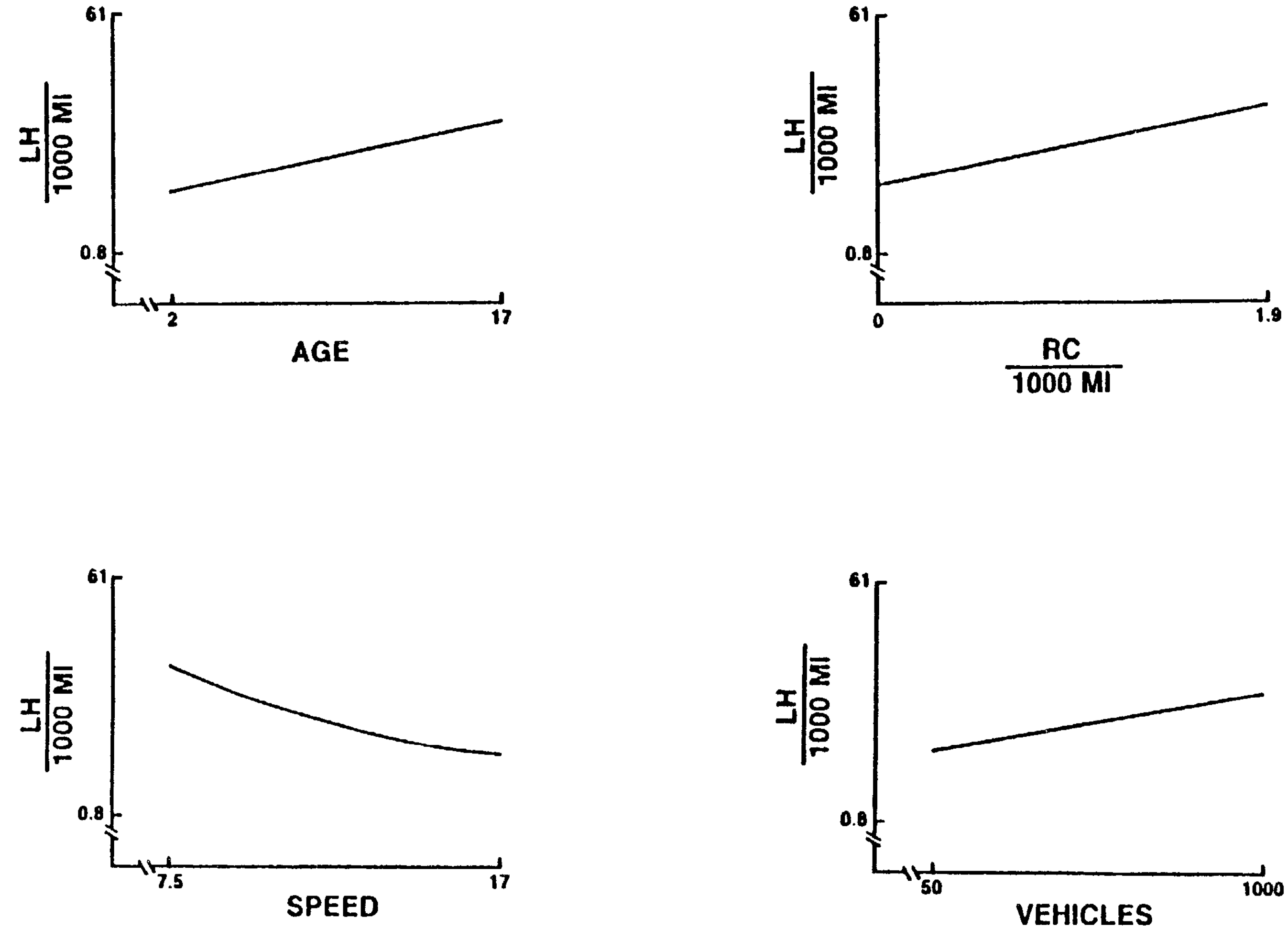
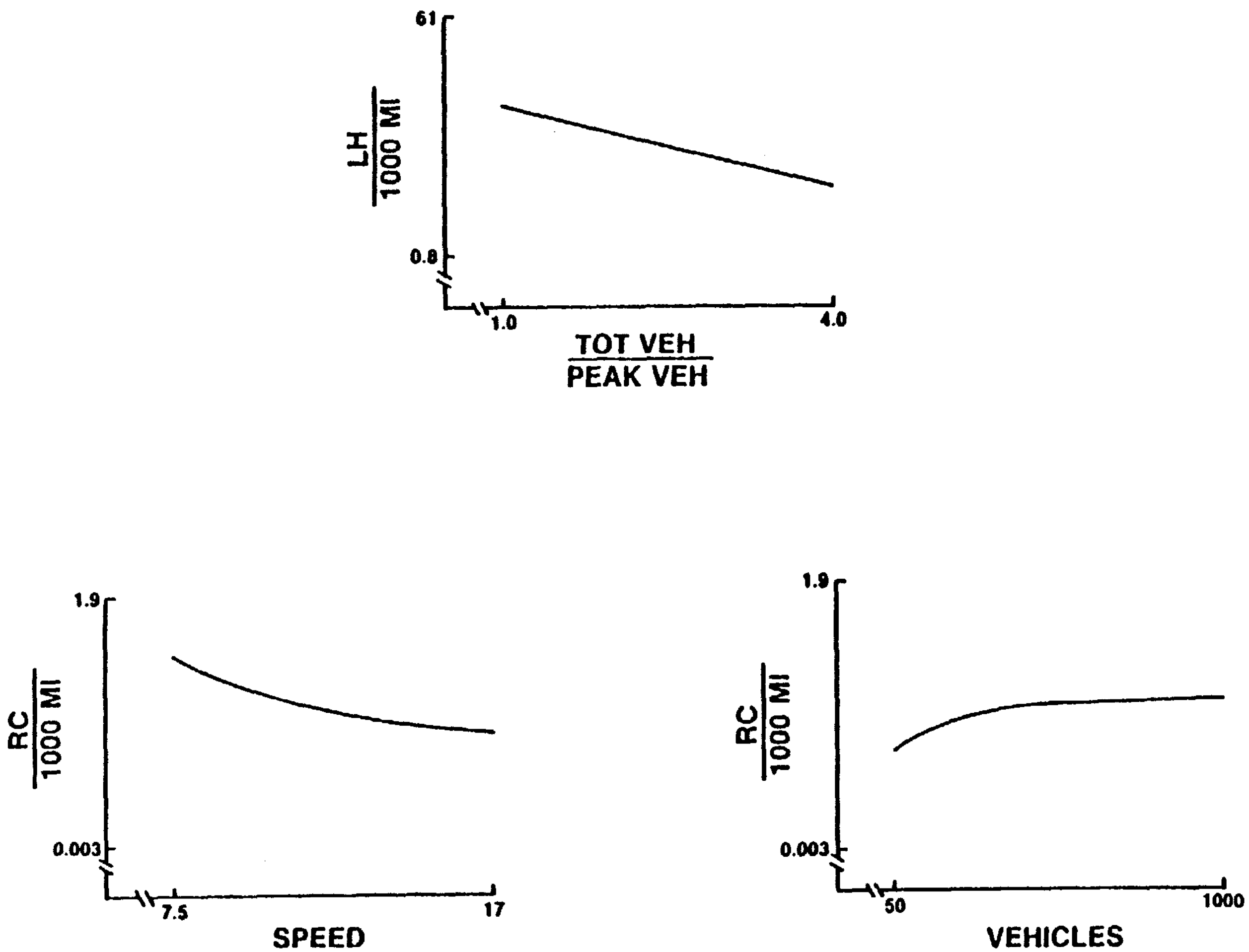


Exhibit 5 cont'd

Effect of Independent Variables on Roadcalls and Labor Utilization



large number of spare vehicles allows labor time to be used more efficiently. The spare ratio was also significant in one roadcall model, but it had a positive coefficient. This may be because systems with unsuccessful maintenance programs are substituting additional vehicles for improvements in maintenance reliability. We did not include the positive relationship of spares to roadcalls in our site selection models.

Age - The average age of the fleet is significant at the 1 percent level in the model for labor hours. Hours of labor increase for fleets with higher average ages. Age was not significant in the roadcall model.

VARIABLES NOT INCLUDED IN THE ADJUSTMENT MODELS

Age distribution of fleet. The only models in which the age categories had significant coefficients included all but one of the age categories plus the mean age of the fleet.

Dispersion of age. The standard deviation of the age categories was not significant in either model although it had a correlation of -.17 with labor hours per revenue mile.

Peak vehicles. The number of vehicles used during the peak was significant when it was substituted for revenue vehicles; it had a similar effect but was not as significant as revenue vehicles.

Peak to base ratio. This variable was not significant in any of the models although it had a +.19 correlation with labor hours per revenue mile. Its lack of significance in the model was probably due to the +.51 correlation between speed and utilization.

Labor. Although roadcalls per revenue mile was significant in the labor hours models, the opposite was not true.

The regression models were used to obtain estimates of the residual variation in our Section 15 data which could not be explained by the system variables just discussed. Residuals from the roadcall and labor models were plotted against one another to develop a display of departures from expected performance. Inspection of these plots allowed us to identity those systems that were along the low roadcall - low labor/high roadcall - high labor axis by the standards of the two models.

After identifying several of these systems, we analyzed them individually. First, we checked the consistency of their data by comparing the 1981 data used for selection to the 1980 and 1979 Section 15 data. If the 1981 data appeared to be inconsistent with the two previous years, the system was less likely to be chosen for the case studies. For instance, the consistency check showed that Duluth, which was a likely candidate by the other criteria, had a 50 percent drop in roadcalls from 1980 and 1979 levels.

In addition, the APTA Fleet Inventory for 1981 was checked. The percentage of the fleet by manfacturer, the percentage of the fleet that was air conditioned, and the percentage that was lift equipped were noted as possible causes of variations in labor hours and roadcalls.

The general criteria for choosing our first four sites were:

1. The sites were along the low roadcall-low labor/high roadcall high labor axis (i.e., the system was either very successful of very unsuccessful at maintenance).

2. The systems were either medium (100 to 200 vehicles) or large (600-800 vehicles).

3. The 1981 data was consistent with itself and with the data from the previous two years.

Based on these criteria, the following sites were selected.

Low roadcall-low labor systems
- Madison, Wisc.
- Milwaukee, Wisc.

High roadcall-high labor systems
- Dade Co. Fla.
- Gary, Ind.

We later added 2 more sites to the sample to give us points of contrast to the previously selected systems. This involved the addition of two systems with good roadcall records and high labor utilization:

Low roadcall-high labor systems
- San Antonio, Texas
- Syracuse, NY

We finally chose Spokane and Tacoma, Washington to complete our design. Tacoma was selected because its data represented it as a low labor, high roadcally system with Spokane (low labor and low roadcalls) added because of its proximity to Tacoma. Subsequent evidence, however, showed that Tacoma had much higher labor requirements than previously thought.

The final result of this selection process resulted in selection and categorization of the eight case systems as shown below.

		Roadcalls per Mile Adjusted for Local Conditions: Low	Roadcalls per Mile Adjusted for Local Conditions: High
Labor per Mile Adjusted for Local Conditions	Low	Madison Milwaukee Spokane	---
	High	Syracuse San Antonio	Dade County Tacoma Gary

An illustration of the characteristics of the case cities is shown in Exhibit 6. This figure shows the observed labor input to maintenance and roadcall record and the values expected on the basis of regression analyses as vectors. The tails of the vectors are the values expected on the basis of the regression models, and the heads represent observed values. The length of the vector for each system represents the difference between the expected and observed values. Our study design allows us to interpret the location of the tails of the vectors as the result of service profile severity and diseconomies of scale (for roadcalls), as well as fleet age, in-service breakdowns, and spares (for labor hours). The length and direction of the vectors tells us how much better (or worse) than expected each system performs. Short vectors indicate little variation from the expected pattern, while long vectors are a sign of significant departures from expected performance. It is these departures that we hope to explain in terms of site characteristics.

The pattern of residual vectors observed suggests three types of questions to be pursued:

1. Why is it that Miami, Tacoma and Gary use more labor and have more roadcalls than expected?

2. Why is it that Milwaukee, Spokane and Madison use less labor and have fewer roadcalls than expected?

3. Why is it that Syracuse and San Antonio use more labor, but have fewer roadcalls than expected? Are they "purchasing" reliability with labor intensive practices?

D. Site Visits and Interviews

Each of the sites identified according to the procedures discussed above was approached in a similar manner. This involved the mailing of a general introductory letter to management describing the purposes of the study and indicating our intention to telephone to arrange for the intial site visit and travel to the site to make arrangements for data collection. Our procedures diverged from our pre-planned methods at this point becaus of variations in local interest, candor, time constraints and cooperativeness. In some cases, we conducted on-site interviews as planned. In others, question packets were left behind and were filled out by their intended subjects (some of whom were subsequently interviewed), and in still other systems, responses were obtained from only one or two system personnel. Exhibit 7 summarizes the type and extent of our fieldwork at each site.

As each case study was completed several draft copies of the study were sent to the participating transit agency for review. Each agency was requested to return any comments and corrections within four weeks of receipt of the draft copies. All agency comments and suggestions were reviewed by the research team and appropriate alternations were made in the study if needed. Copies of these cases are listed in the references section of this report, and are available as separate publications.

Exhibit 6

Expected and Observed System Performance

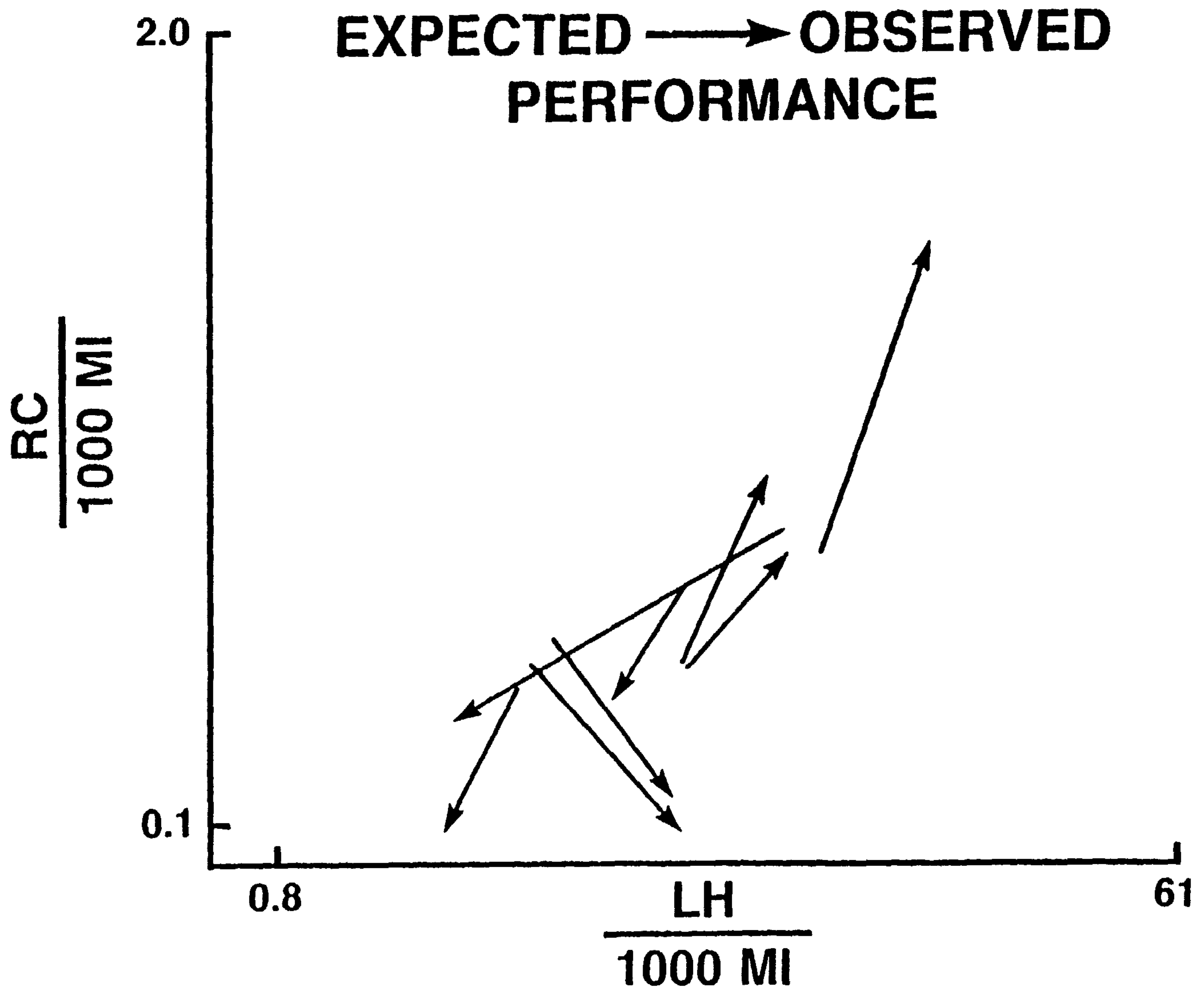


Exhibit 7

Nature and Extent of Site Visits

System	Personal Interviews	Other
Milwaukee	General Manager Supt. of Maintenance Asst. Supt. of Maintenance Union President Personnel Director Purchasing Manager	Management collected written responses to interview questions from all persons indicated in Exhibit 3.
San Antonio	Director of Maintenance	Management collected information by telephone from some of the persons listed in Exhibit 3 and prepared written summaries
Miami	Director of Operations General Supt. of Maintenance Maintenance Engineer Asst. General Supt. of General Maintenance Asst. General Supt. of Support Services Supt. of Administration and Budget Supt. of Garages (3) Maintenance Supervisor Maintenance Production Coordinator Mechanic Union Steward Manager of Training Chief of Materials Management	
Madison	General Manager Asst. General Manager Maintenance Manager Maintenance Superintendent Shop Foreman Finance Manager Parts Superintendent Personnel, Safety, and Training Manager Union President	Management collected written responses to interview questions from all persons listed in Exhibit 3.
Tacoma	Executive Director Director of Transportation Maintenance Manager	Management collected written responses to interview questions from all persons listed in Exhibit 3

Exhibit 7 (cont'd)

System	Personal Interviews	Other
Syracuse	General Manager Asst. General Manager Director of Purchasing Director of Maintenance Director of Human Resources Management President of CNYRTA	Management collected written responses to interview questions for all persons listed in Exhibit 3
Gary	General Manager	Management collected written responses for some of persons listed in Exhibit 3.
Spokane	Executive Director Supt. of Maintenance Supt. of Transportation Associate Supt.	Management collected written responses for persons listed in Exhibit 3.

E. Analytical Approach

We used three different procedures in analyzing the information generated by the case studies. The first consisted of a close reading of each case and the development of summaries addressing each of our hypotheses. These summaries were condensed into Exhibits to highlight the most notable features of each system. The second step was to relate the conditions observed at each system to its performance characteristics, as defined by deviations from expected roadcall and labor values generated in our regression analyses. The purpose of this step was to identity local conditions which seemed to account for differences not explained by the Section 15 regression models. Our third step was to combine the results from the first two steps with general impressions and insights gained by our staff during the course of the research. This resulted in the development of a summary of the conditions and practices which seemed to account for variations in maintenace performance at the sites in question.

4. Site Characteristics and System Highlights

This Section gives a brief overview of each case study system and an evaluation of the data used in site selection.

A. Milwaukee, Wisc. The Milwaukee County Transit System (MCTS) provides fixed route bus service throughout Milwaukee County. Its service area contains 965,000 people. The climate in Milwaukee is extreme, with 46 inches of snow per year on average. Low temperatures in January average 11 degrees and August highs are in the 80's.

MCTS is overseen by a special committee of the County Board and is managed by a private, not-for-profit corporation, Milwaukee Transport Service. The three major divisions of Milwaukee Transport Services (Transportation, Schedules, and Equipment and Plant) all report to the operating company's assistant manager for operations. A summary of maintenance experience at MCTS is shown in Exhibit 8. These figures show that MCTS's roadcall record has been relatively stable, and that its 1981 labor data is not out of line with pervious years. It is reasonable to classify Milwaukee as a site which has achieved a high degree of reliability in recent years with a relatively low labor requirement. But it should be noted that its labor data shows an upward trend. Other significant aspects of the MCTS case prepared by Kosinski (1984a) are shown in Exhibit 9.

Milwaukee benefits from its private not-for-profit approach to management, high mechanic salaries, open communication, and willingness to innovate. Monitoring with dynamometers and oil analysis have proven useful (APTA, 1982). Due to budget cutbacks and staff reductions, use of written procedures was gradually discontinued during the era of private ownership but MCTS has continued to insist on pre-run inspections. Training programs, special door repair classes, and a brake "hot line" are all attempts to deal with emerging problems. The upward trend in MCTS labor costs may reflect the impact of new equipment or inadequate staff and skill levels.

B. Dade Co., Fla. The Metrobus System in Dade Co., Florida is the fixed route bus portion of the Metropolitan Dade County Transportation Adminstration. It serves an urban area of 1.6M people. The climate in Dade Co. is characterized as subtropical marine, with long, warm, wet summers and mild, dry winters. Low temperatures in January average in the 50's and August highs are about 90 degrees. High heat, humidity, and air borne salt cause maintenance problems for Metrobus.

The Dade Co. system is a department of the County government. Its executive director reports directly to the County board. Bus maintenance, planning and scheduling, and transportation all report to the Director of Operations at Metrobus. A summary description of maintenance performance at Metrobus is shown in Exhibit 10. These figure reflect an expansion of Metrobus's fleet and growth in both peak and base service over the last 4 years. What is of particular note is the relatively high degree of agreement in revenue miles, total roadcalls, and labor hour figures for 1981 and 1982. This establishes a fair amount of credibility for those data points. (Less credence is owed to

Exhibit 8

Milwaukee County Transit System Data Profile

	1982	1981	1980	1979
Fleet size	611	719	585	597
peak	497	499	472	458
base	264	268	264	250
Revenue miles (RM)	21,912,734	21,843,463	20,894,000	19,882,000
Revenue hours	1,740,602	1,750,223	1,854,000	1,542,000
Average speed	12.5	12.5	11.3	12.9
Total roadcalls	11,180	12,575	10,551	7,722
Roadcalls (mech. fail)	6,900	7,278	6,668	5064
Roadcalls (mf.)/1000 RM	0.31	0.33	0.32	0.25
Hour of maintenance labor	593,498	555,825	448,050	375,355
Labor hours/1000 RM	27.08	25.3	21.4	18.9
Average fleet age	9.0	12.9	15.2	13.5

Fleet composition in 1981

% GM : 84% includes 150 RTS's
% Flx : 16%
% AMG : --
% Other : --

% Lift equipped: 40%
% air conditioned: 40%

Source: Section 15 Data and APTA Fleet Inventory

Note: The internal working definition of a roadcall in MCTS is a dispatch of a mechanic for a bus change or a bus repair. This is different from the definitions used in Section 15 reporting.

Exhibit 9
Highlights of the Milwaukee Case

Management

1. Communication between management levels is frequent and open. Most members of the current management team were employees of the predecessor private Milwaukee bus system.

2. Written policies were gradually discontinued because of budget constraints during the era of transition from private ownership to public ownership.

3. The Board of Directors is not actively involved in maintenance policy decision-making.

4. PM is done on a 2.5, 5, 30, 100 thousand mile cycle. Oil analysis and dynamometers are used. Mandatory pre-run inspections are done.

5. A computer inventory and record system is being planned.

Labor

1. Both sides view their relationship as cooperative.

2. Employee suggestions are viewed as part of maintenance policy development.

3. Until recently, most mechanic openings were filled by driver-cleaner-mechanic progression. However, recruitment has lagged behind need, so an apprenticeship program has been developed.

4. Testing is used as the basis for hiring and promotion. Six and twelve month training programs are available for those seeking promotion.

Operating Environment

1. RTS and new look GM vehicles were in use in 1981. The recent addition of a Neoplan subfleet has led to inventory difficulties. Average vehicle age was 12.9 years in 1981.

2. Local weather-related factors include extremes in temperatures, heat, cold, potholes, snow and roadsalt.

Budget

1. The budget is prepared using an incremental line-item process.

2. Maintenance accounts for 18% of operating costs.

Physical Facilities

1. The shop and one garage were originally built for streetcars. Two new garages have been built since 1981. Not all garages can service all vehicles.

2. An engine washer and dynamometer are needed in one garage, but space limitations prevent installation. Frame straightening and wheel alignment equipment is needed. Homemade lubricating equipment was recently replaced.

Exhibit 10
Metrobus System Data Profile

	1982	1981	1980	1979
Fleet Size	865	673	654	673
peak	441	428	425	413
base	361	317	309	286
Revenue miles (RM)	22,952,993	21,660,833	-	19,365,000
Revenue hours	1,969,634	1,703,771	-	1,654,000
Average speed	11.65	12.7	-	11.7
Total roadcalls	35,769	38,893	24,354	24,643
Roadcalls (mech. fail)	24,899	32,596	21,652	21,401
Roadcalls (mf.)/100 RM1)	1.08	1.50	-	1.11
Hours of maintenance labor	1,097,682	1,001,600	773,900	563,200
Labor hours/1000 RM	47.82	46.2	-	29.1
Average fleet age	8.1	9.0	9.0	7.3

Fleet composition - 1981

% GM : 65% This includes 260 RTS-II-04
% Flx : 15%
% AMG : 16%
% Other : 4%

% Lift equipped: 0
% air conditioned: 99%

Source: Section 15 Data and APTA Fleet Inventory

Note: The internal working definition of roadcall in Miami is a driver reported defect. This is different from the definitions which are used for Section 15 reporting.

the 1980 and 1979 data becuase of known problems in the startup of the Section 15 data program). The one discrepancy which shold be noted is that the 1982 and 1981 mechanical roadcalls/1000 mile figure. The difference between these values indicates a need for caution in interpretation, but even if 1.1 is used as a plausible figure, this system still represents a case where labor and roadcalls are higher than expected.

It should be noted that our selection and review of the Metrobus system was completed prior to the opening of Metrorail in 1984; however, some of the effects of system expansion on bus opertions were documented in the case analysis.

There were many notable features about the Miami case. These include Miami's new rail system, construction of several new garages, and the organization of the bus system as a part of county government. Other observations based on the case prepared by McKnight (1984a) are listed in Exhibit 11. Miami is a system with both internal and external problems. Its external problems include weather and service conditions, frozen mechanic positions and understaffing, and its lack of autonomy in purchasing and hiring. Its internal problems include a history of transitions in management, some outmoded and poorly designed facilities, high overtime expenses and the absence of formal or traditional mangement processes. There appears to be a great deal of activity in Metrobus to improve the overall efficiency and effectiveness of the system. This includes the County Board's mandated MBO system, the development of department-level performance measures, the institution of a major training program, and an agressive program of garage construction and test equipment acquisitions. In addition, Metrobus management seems to be pursuing innovations in equipment improvement, and increasing its ability to test and monitor vehicles on a daily basis.

Metrobus has been very aggressive in dealing with the backlog of work which resulted from past mismanagement and equipment problems. For example, its engineers pioneered the AMG air conditioner retrofit. It has created an inspector general position and organized a quality assurance section. It has hired a number of "production coordinators" whose primary responsibilities are to analyze and interpret computer reports on system performance. It has also decided to contract out a significant portion of its backlog to avoid engagement in a constant "catch-up" regime of maintenance. It has established a training program to develop a more qualified internal staff.

C. <u>San Antonio</u>. Via Metropolitan Transit is the third largest system included in our study. It serves Bexa County, Texas which covers 1157 square miles and has a total population of 982,000 people. The climate in San Antonio is hot and arid. Low temperatures in January are near 40 degrees and summer highs average about 96.

VIA Transit is organized as a Regional Transit Authority which is supported by a ½ percent sales tax. The Board has 11 members appointed by elected officials. The predecessor agency to VIA, the San Antonio Transit System was extremely active in a variety of maintenance activities, including contract maintenance for municipal vehicles such

Exhibit 11
Major Characteristics of the Miami Case

Manangement

1. A series of management transitions has occured in recent years. This has resulted in some reorganization and lack of clarity about departmental roles. A new management team seems to be improving communications by implementing a management-by-objective approach.
2. A new rail system is being built. A signficant amount of management time and staff resources have been diverted from bus to accomodate this new development.
3. Management policies are being formalized as part of the new MBO system.
4. The Board of Directors has requested performance targets from the maintenance division.
5. PM is performed on a 6, 18, 54 thousand mile cycle. Some oil analysis is done. No pre or post run inspections are done.
6. An in-house computer system for inventory and maintenance record-keeping is being developed. A service bureau is now used for roadcall reporting. Attempts to use off-the-shelf inventory software were unsuccessful.

Labor

1. The relationship between union and management is defined as adversarial.
2. Labor and management meet regularly in formal meetings.
3. A new 7½ months training program has been established because of problems in recruitment. The union says that salaries are too low, and management claims applicants are not well qualified and have language deficiencies.
4. Testing programs are used for hiring and promotion. Tuition rebates and refresher courses are available.

Operating Environment

1. The fleet incluedes FLX, RTS, AMG, and older GM vehicles. This has severe inventory effects.
2. Heat, humidity and air conditioner design cause significant problems. Airborne salt causes corrosion.

Budget

1. The budget is prepared as a group effort. Data processing support is inadequate. Management hopes to go into a 3-5 year maintenance planning and bus acquisition cycle.
2. Maintenance accounts for 25% of operating expenses. The average for systems of this size is 18.3%. A number of staff positions are frozen, and there have been budget cuts in the past.

Physical Facilities

1. New garages were built in 1969 and 1981. An older facility was recently rebuilt. Lift orientation and design is a problem in the newer garage.
2. No equipment problems were noted, except that space for a dynamometer was eliminated to accomodate an electrical substation for the new rail system.
3. Physical distribution of inventory is not a problem, but purchasing through the county and a new materials management division are sources of delay and parts shortages.

as fire trucks, tow trucks and automobiles. This same facility now serves VIA's transit fleet. It has a large floor area, and an extensive machine shop.

A summary of Section 15 data describing VIA's recent history is shown in Exhibit 12. These figures show a reasonable amount of consistency. The recent change in age, labor, and roadcalls are not dramatic enough to alter the pattern of expected and observed indicators shown in Section 3.

The case description of VIA (Kosinski, 1984b) does not include as much information as those on Miami and Milwaukee because of differences in management preference about the conduct of site visits, but there are a number of notable features in the VIA case. Exhibit 13 lists the major points. Among these are the facts that it controls its own intentory and procedurement, it handles its own hiring procedures, and does not follow the practice of recruitment of mechanics from the driver and cleaner ranks. Its involvement of both maintenance and transportation personnel in pre-run inspections is also unusual. The relatively low number of roadcalls at VIA should be interpreted in light of the fact that it has the highest average speed of any of our case systems and rather low load factor (passenger miles per revenue mile). It should also be remembered that VIA can afford to be labor intensive because San Antonio has a very low (non-transit) average wage rate. An example of this is VIA's practice of reworking cylinders and bearings, and rewinding generators, as opposed to purchasing of new or contract rebuilt units. Still, VIA has the lowest maintenance cost per mile, and the highest ratio of mileage to total roadcalls of any of our 8 case systems.

D. CNY Centro, Inc. CNY Centro is a public corporation which provides transit service for Syracuse, NY and surrounding counties. The population of its main service area is 390,000. Centro is located in upstate New York. This region has long, cold winters with average January lows of 16 and short, mild summers with highs near 82 degrees. Syracuse receives moderate amounts of rain and heavy amount of snow.

CNY Centro is part of the Central New York RTA. It was created in the public takeover of the private Syracuse Transit Corporation in 1972. CNYRTA's board includes two directors with transportation backgrounds. CNY Centro's maintenance profile is shown in Exhibit 14. These figures are among the most consistent in our sample of eight systems, with the exception of the 1979 labor hour report. The most visible feature of CNY Centro is its new facility, a multipurpose building which provides space for bus storage and servicing, repair shop, CNY Centro, and CNYTRA adminstrative offices. Details about this facility are included in our detailed case discussion (Kosinski, 1984). The major highlights of the CNY system are noted in Exhibit 15.

CNY Centro is remarkable because it was performing well even before it moved into its new facility. CNY Centro relied on 8 old garages prior to completion of its new garage. These new scattered throughout the city, and most were quite small, resulting in severe inventory access problems. It seems to confirm the importance of good management, pre and post run inspections, and qualified labor. It is, in many ways, similar to San Antonio in these regards.

Exhibit 12
VIA Metropolitan Transit Data Profile

	1982	1981	1980	1979
Fleet size	454	530	403	
peak	372	338	329	
base	148	151	177	N
Revenue miles (RM)	14,00,3118	14,230,963	13,214,279	O
Revenue Hours	997,975	1,010,278	900,594	T
Average speed	14.0	14.1	14.7	
Total Roadcalls	2,660	2,767	2,992	I
Roadcalls (mech. fail)	644	926	1,087	N
Roadcalls (mf)/1000 RM	0.05	0.09	0.08	B
Hours of maintenance labor	405,663	420,375	267,051	O
Labor hours/1000 RM	28.9	29.5	20.9	O
Average age of fleet	8.2	8.9	10.4	K

Fleet composition in 1981
- % GM: 89% 50% RTS
- % Other: 11%
- % Lift equipped: 5%
- % Air conditioned 100%

Source: Section 15 Data and APTA Fleet Inventory

Note: The internal working definition of a roadcall in San Antonio is a mechanic being dispatched for either a bus change or a bus repair. This is different from the definitions used for Section 15 reporting.

Exhibit 13
Highlights of San Antonio Case

Management

1. The head of maintenance is extremely experienced and is a strong force in the organization.

2. A written set of policies and procedures covers all aspects of maintenance.

3. PM is done on a 4 and 48 thousand mile cycle. Pre-run and post-run inspections are required; pre-run inspections include tire pressure testing. Both maintenance and transportation personnel are involved in the pre-run check. In-house oil evaluation for liquid contaminants is done.

4. No plans have been made for computerization.

5. Inventory and procurement are the responsibility of the maintenance department.

Labor

1. A cooperative relationship with labor exists.

2. Only experienced mechanics are hired. Only 5% of all applicants are hired. 30% of new hires are terminated during their probationary period. Salary levels are low relative to the industry, but promotion increments are high and San Antonio's heavy industry was generally impacted by the recent recession.

4. A tuition rebate program is available.

Operating Environment

1. VIA's fleet is predominatly GM, with 50% RTS vehicles. No inventory problems have occurred.

2. Heat and humidity, and air conditioning design have caused problems.

Budget

1. Maintenance prepares its own budget.

2. Savings of 1-3% have been realized in recent years. They were attributed to the addition of newer vehicles to the fleet.

Physical Facilities

1. The current garage, built in 1948, has ample space and shop equipment; it formerly maintained other vehicles as well as buses.

2. No equipment needs were noted. No unit rebuilding is contracted out, expect for crankshafts.

3. No inventory logistics problems were noted.

Exhibit 14
CNY CENTRO Data Profile

	1982	1981	1980	1979
Fleet size	165	159	161	163
peak	114	114	114	131
base	70	63	63	56
Revenue miles (RM)	3,879,126	3,955,412	4,092,133	4,103,022
Revenue hours	334,028	341,019	345,512	339,186
Average speed	11.6	11.6	11.8	12.1
Total roadcalls	960	881	862	1158
Roadcalls (mech. fail)	527	545	602	903
Roadcalls (mf.)/1000 RM	0.13	0.14	0.14	0.22
Hours of maintenance labor	122,800	118,000	115.986	10,900
Labor hours/1000 RM	31.6	29.8	28.3	2.7
Average age of fleet	8.6	9.4	8.5	7.4

Fleet Composition in 1981
- % GM 22%
- % Flx 55%
- % AMG 14%
- % Other 9%
- % Lift equipped 3%
- % Air conditioned 81%

Source: Section 15 Data and APTA Fleet Inventory

Note: The internal working definition of a roadcall in CNY Centro is a defect which causes a service disruption. This is the definition used for Section 15 reporting purposes.

It should also be noted that CNY Centro owns and operates the fleet shown here, but maintains an additional 17 buses for another transit system. See the Case Study for details (Kosinski, 1984C).

Exhibit 15
Highlights of the Syracuse Case

Management

1. The General Manager has taken an active team management approach which involves high levels of staff interaction and an emphasis on staff development.

2. General Manager and Maintenance Manager emphasize continuous reevaluation of maintenance procedures. Maintenance performance reports are reviewed by the Board of Directors.

3. PM is done on a 6000 mile cycle by a team of dedicated mechanics. Both pre and post-run inspections are required. Tire pressure is checked daily because tires are owned, not leased.

4. An extensive computer system is used for work order processing, inventory control, record keeping, and cost accounting.

Labor

1. Union-management relations are cooperative, but there are occasional disputes about overtime and attendance.

2. Frequent, informal meetings are held between labor and management.

3. Emphasis has recently changed from on-the-job training of unskilled workers to an apprenticehsip program.

4. Testing is used for hiring and promotion. No formal training programs for current employees have been developed.

Operating Environment

1. Over 50% of the fleet is FLX, with the remainder being GM and GMC. No inventory problems were reported.

2. The climate causes problems because of cold and snow, road salt and potholes.

Budget

1. Detailed cost accounting is done to allocate changes for contract work.

2. Parking facilities are a revenue source.

3. No budget problems were reported.

Physical Facilities

1. The system's new garage has a number of state-of-the-art features, but prior to 1982, work was performed at 8 sites scattered throughout the city.

2. The new garage has a drive on dynamometer, a special lift-equipped bus painting booth, an overhead crane to transport engines from service bays to shop areas; automatic diagnostic equipment is being installed.

3. Inventory is centrally located.

E. Gary Public Transportation Corporation. GPTC provides transit service for Gary, Indiana's 152,000 residents. The service area of GPTC is 60 square miles. Gary's climate is extremely variable, with summer highs in the eighties and winter lows averaging 17°. Gary typically gets 42 inches of snow per year.

The GPTC is headed by an appointed Board of Directors which serves without compensation. Management, hiring, and procurement - as well as transportation-are handled by Gary Intercity Lines, Inc. Gary Intercity Lines was the city's private carrier. The City of Gary purchased the company's interest in the system in 1975, but retained it to manage the actual provision of service.

Indicators of GPTC's maintenance profile are shown in Exhibit 16. These figures show several inconsistencies. The first is in the 1980 labor data. The figure is obviously too low, and it quite out of line with previus and succeeding years. However, if we discount the 1980 data, it appears that Gary has increased its labor comitment to maintenance each year. The second inconsistency is in the number of mechanical and non-chargeable roadcalls. The 1979 data can be disregarded because of known problems in the startup of the Section 15 collection effort. However, there is a dramatic drop in the 1982 data which is not consistent with the published performance indicator for roadcalls in the 1982 data. We believe that 0.86 is the appropriate figure to use based on calculations made with raw section 15 data. This number, taken in conjunction with the increasing labor figure, shows that GPTC is slowly increasing its reliability - but at the cost of increases in its labor committment. This may indicate that Gary is moving toward the situation at San Antonio and Syracuse (higher than expected labor, but fewer roadcalls), but it is still in the early stages of such a movement.

The most visible feature of the Gary Case is the system's extermely old maintenance facility which originally was constructed as a factory in 1890. This facility has only one lift capable of servicing RTS vehicles, and severe problems with vandalism and cold weather are caused by outside vehicle storage. These problems should be alleviated shortly be the construction of a new garage. Other characteristics of Gary's operations, as noted by Crnkovich (1984), are listed in Exhibit 17.

Gary is extermely important case in our study because it is a small system in a large urban area, and it is still operated by the original for-profit company. Its current situation, however, seems to indicate that it has suffered from the lack of public attention-and funding-since it was taken over by the public sector. It appears that Gary has a relatively low number of mechanics for its fleet size, one for every 12 vehicles. Madison, San Antonio and Tacoma, in contrast, had a one-to-five mechanic vehicle ratio. This variance cannot be explained by the system's spare ratio because Gary ran 288,000 revenue miles per mechanic in 1981, compared to 89,878 miles per mechanic in Miami. These figures indicate an understaffed system, with excessive reliance on overtime.

Exhibit 16
Gary Public Transit Corporation Data Profile

	1982	1981	1980	1979
Fleet size	115	115	99	100
peak	81	88	84	89
base	50	53	50	50
Revenue miles (RM)	2,276,806	2,593,826	2,212,142	2,144,420
Revenue hours	166,265	205,070	171,514	161,686
Average speed	13.6	12.7	12.9	13.9
Total roadcalls	1566	2675	3087	1,805
Roadcalls (mech. fail)	600	2451	2916	1,451
Roadcalls (mf.)/1000 RM	0.26/.86*	0.94	1.32	0 .68
Hours of maintenance labor	97,188	91.904	7.072	68,035
Labors hours/1000 RM	42.68	35.4	3.2	31.7
Average fleet age	10.3	9.3	10.0	7.9

Fleet composition in 1981

% GM	:	100% including 15% RTS-03
% Flx	:	--
% AMG	:	--
% Other	:	--

*0.26 was computed from these data. The Section 15 report, however, shows 0.86 as the performance indicator.

Source: Section 15 Data and APTA Fleet Inventory

Note: The internal working definition of a roadcall in Gary is a driver reported defect. This is different from the definitions used for Section 15 reporting.

Exhibit 17
Highlights of the Gary Case

Management

1. Management meets daily.

2. No written policies have been established

3. System management is involved in maintenance on a daily basis, but the Board is not.

4. The city council and transit management staff reflect Gary's changing population characteristics.

5. PM is on a 4 and 9 thousand mile cycle. No pre or post run inspections are conducted.

6. Inventory and vehicle records are kept manually.

Labor

1. Management described its relationship with the union as adversarial.

2. Meetings with the union are restricted to grievances and contract terms.

3. A need for mechanics qualified in air conditioning and electrical systems was noted. Salary levels are low relative to other transit systems and to Gary's heavy industry.

4. No testing is used for hiring or promotion. Tuition rebates and 23 hours of on-the-job training are provided to employees.

Operating Environment

1. The fleet consists of 8 models of GM equipment with a 15% RTS subfleet.

2. Maintenance is difficult in Gary due to heat, cold, snow, and potholes.

Budget

1. The budget is prepared on a line item incremental basis.

2. 24% of the cost of operations is attributed to maintenance. There are unmet equipment needs and staff shortages.

3. Local funding is paid out of general municipal revenues; this source has been severely impacted by the recent recession.

Physical Facilities

1. The current facility was constructed as a factory in 1930

2. The current facility provides inadequate space for inventory and has precluded acquisition of test equipment.

3. The current facility has two pits and 1 lift.

F. Madison Metro. Madison Metro serves an urbanized area of 251,000 people, including the University of Wisconsin. Its temperature range is extreme averaging 8° - 81° in January and July. It typically has 40 inches of snow per year.

Madison Metro was taken over the city in 1970. It was managed by a private firm until 1982 at which point a different firm, ATE, took over its management functions. This change in management wa significant because of ill-will and labor disputes involving the old management company. Metro also has a new garage and office building which was completed in 1981. Metro's operating contract is monitored by the City's Department of Transportation, an appointed Transit Utility Committee, and a Transportation Commission which reports to the City Council. Madison Metro's maintenance profile is shown in Exhibit 18. These figures are among the most stable in our sample.

Notable elements of Metro's operation, as described by McKnight (1984) are shown in Exhibit 19. Madison is unlike other systems in our sample because it has a stated, quantifiable, and realistic (attainable) target for roadcalls, as opposed to zero defect, cost minimization goals. It requires pre and post run inspections like other systems which seem to be good performers, but it does not use computerized diagnostics or oil analysis. The value of its maintenance system was proven in 1981 when it experienced severe problems with RTS air conditioner performance. It is remarkable that its reliability record actually improved during this period due to careful management. It is also notable that Madison had to increase its PM Internal from 6,000 to 9,000 miles during this period because of the increased air conditioner workload--and that this did not have a noticeable effect on reliability.

G. Tacoma. Pierce Transit, headquartered in Tacoma, Washington, provides service for Tacoma and several other cities in Pierce County. Its service area is 275 square miles and contains 436,000 people. Tacoma has a moderate climate, with rainy winters and an annual temperatures range of 30-80 degrees. There are a number of steep grades on Tacoma's streets.

Pierce's predecessor was taken over by the City of Tacoma in the early 1950's. It was reorganized as an independent municpal corporation, similar to an authority in 1980. Its new executive director has introduced MBO techniques and initiated development of a new management information system. Pierce's supervisory board is composed of 7 appointed commissioners who recieve monthly performance data-including maintenance indicators.

Pierce's maintenance profile is shown in Exhibit 20. This profile shows significant growth in service provided, and, in 1981 and 1982, a simultaneous improvement in labor productivity and reliability. The 1980 labor data appears to be out of line with previous and subsequent years. Although ¼ of the fleet is equipped with wheelchair lifts, but these are not heavily used.

Exhibit 18
Madison Metro Data Profile

	1982	1981	1980	1979
Fleet size	193	193	193	159
peak	141	146	142	122
base	104	111	54	54
Revenue miles (RM)	4,473,483	4,694,295	3,980,395	3,687,166
Revenue hours	325,026	338,612	317,175	301,953
Average spped	13.7	13.9	12.5	12.2
Total roadcalls	560	414	524	352
Roadcalls (mech. fail)	451	361	491	327
Roadcalls (mf.)/1000 RM	108	0.077	0.123	0.089
Hours of maintenance labor	72,256	70,073	95,320	69,888
Labor hours/1000 RM	16.1	14.9	23.9	19.0
Average fleet age	10.0	9.0	7.9	10.2

Fleet composition *

- % GM : 100% 48 RTS II's; Remainder New Look
- % Flx : --
- % AMG : --
- % Other : --
- % Lift equipped: 0
- % air conditioned: 86%

* Based on 1982 APTA Inventory. Madison was not listed in 1981.

Source: Section 15 Data and APTA Fleet Inventory.

Note: The internal working defintion of a roadcall used in Madison is a bus change. This is different from the definition used for Section 15 reporting. Madison staff made a point of showing us that they have records which are consistent with the Section 15 definitions.

Exhibit 19
Highlights of the Madison Case

Management

1. Weekly staff meetings, including maintenance, finance and operations, are held by the general manager.

2. None of Madison's witten policies govern maintenance.

3. Maintenance performance indicators are reported to the local utility committee on a monthly basis.

4. PM is done on a 6000 mile cycle. Pre and post-run inspections are required and they are regularly conducted.

5. Vehicle records and inventory systems are manual.

Labor

1. There was a major strike in 1980, but relations between the new management team and labor are viewed as cooperative.

2. Management credits workers with many useful innovations.

3. Driver-cleaner-mechanic progression is viewed a problem by management. This mechanism is not adequate to fill current vacancies, and does not attract skilled mechanics.

4. A test for entry level mechanics is being developed. There are no tests for promotion.

Operation Environment

1. Madison has an all GM fleet, with 24% RTS equipment.

2. Cold, heat, snow and potholes were listed as maintenance problems.

Budget

1. A line item incremental budget process is used. An attempt to use unit cost information identified unmet data needs.

2. The budget seems to be adequate (21% of operating costs), but additional staff positions are needed to reduce overtime.

3. Madison enjoys strong support from the public and muncipal government.

Physical Facilities

1. A new garage was constructed in 1981.

2. New lifts are needed to accomodate RTS equipment.

3. Parts storage is satisfactory.

Exhibit 20
Pierce Transit Data Profile

	1982	1981	1980	1979
Fleet size	191	170	115	116
peak	132	104	92	--
base	75	44	41	41
Revenue miles (RM)	5,073,735	3,487,776	3,200,610	3,200,610
Revenue hours	350,543	260,549	238,084	238,804
Average speed	14.4	13.4	13.4	13.4
Total Roadcalls	4,342	3,043	1,505	1,343
Roadcalls (mech fail)	3,114	2,670	1,369	1,167
Roadcalls (mf)/1000 RM	0.61	0.77	0.42	0.36
Hours of maintenance labor	146,160	131,200	2,080	78000
Labor hours/1000 RM	28.8	37.6	0.64	24.4
Average fleet age	16.1	14.5	15.0	17.0

Fleet Composition in 1981

% GM 60%
% Flx 19%
% Other 21%
% Air conditioned 24%
% Lift equipped 25%

Source: Section 15 Data and APTA Fleet Inventory

Note: The internal working definition of a roadcalled used In Tacoma is a bus change or repair which requires the dispatch of a mechanic. This is different from the definitions used in Section 15 reporting.

Pierce is a very interesting case because its executive director has 20 years experience in transportation, including 4.5 years in fleet management. In an interview, he identified three causes of maintenance problems in the transit industry (1) lack of managerial talent, (2) lack of recognition of the importance of maintenance, (3) deferral of maintenance.

Other significant aspects of Pierce, as described by McKnight (1984c) are shown in Exhibit 21. Pierce is an example of a system whose management is implementing a number of measures to control maintenance. Like Madison, it has stated, attainable goals and objectives and its monthly reports track performance over time and compares performance to previously established targets. Pierce's drivers do not always do pre and post-run checks, but the maintenance department compensates for this with an extensive, calendar based inspection schedule which probably accounts for its high labor utilization. Management seemed quite open about the labor intensiveness of using its manual history system for anything but vehicle-specific analysis, but it is planning a computerized MIS.

H. <u>Spokane</u>. The Spokane Transit Authority is the smallest system included in our study. It has a fleet of 80 vehicles in 1981, but it grew by 50% in 1983 to 120 vehicles (McKnight, 1984d). Spokane's Section 15 maintenance data (shown in Exhibit 22) shows year-to-year changes. Its 1980 and 1981 data are very similar, but its 1982 statistics show an extremely low revenue hour figure and a labor commitment more comparable to 1979 than 1980 or 1981. There is a major difference in speed between 1981 and 1982 (imputed from revenue miles/revenue hours). These factors raise some questions about the magnitude of Spokane's departure from expected performance, but in any event it is a low labor-high reliability system. Major differences between Spokane and Tacoma (besides fleet size) include Spokane's more extreme climate (20-85° F temperature range), higher snowfalls amounts, and the absence of lift equipment.

The Spokane system was purchased by the city from the National City Lines in 1968, but National continued to run it under a management contract. Spokane Transit was established as an independent authority in 1980. Its board is appointed, and receives monthly reports concerning maintenance. The major points of Spokane's system are summarized in Exhibit 23.

Exhibit 21
Highlights of the Tacoma Case

Management

1. Working relationships between managers is good. There has been a reorganization since 1981.

2. Maintenance has quantified goals and objectives.

3. The Board of Directors receives maintenance reports but are not involved in maintenance.

4. PM program involves bi-weekly (1300 mile) inspections and occasional oil analysis. Frequent inspections are necessary because pre-run and post-run checks are not always conducted.

5. Computerization of repair records is planned. An outside vendor manages inventory data.

Labor

1. Union and management disagree on the tenor of working relationship.

2. Meetings are held to discuss employee relations and maintenance performance.

3. Recruitment does not seem to be a major problem. Wage rates are above average.

4. Testing is used for hiring and promotion. An apprentice program is being developed.

Operational Environment

1. The fleet is 60% GM, 19% FLX, and 21% Grumman 870. Parts stocking is made difficult by this diversity.

2. Hilly terrain has required changes in gear ratios.

Budget

1. The maintenance budget is a relatively small percentage of operating costs (17%).

2. It was reported that, in recent experience, "adequate funding has led to increased quality in maintenance."

Physical Facilities

1. The present 1948 facility has hoists and pits which cannot accomodate 40 ft. vehicles. A new garage is planned.

2. No equipment problems were reported.

Exhibit 22
Spokane Data Profile

	1982	1981	1980	1979
Fleet size	80	80	80	68
peak	71	—	71	62
base	45	—	45	41
Revenue miles (RM)	2,307,387	2,183,774	2,183,774	2,043,792
Revenue hours	162,615	226,296	266,296	182,023
Average speed	14.1	8.2	8.2	11.2
Total Roadcalls	696	743	872	616
Roadcalls (mech. fail)	671	711	828	584
Roadcalls (mf)/100 RM	0.29	0.32	0.38	0.28
Hours of maintenance labor	55,860	34,848	33,131	52,836
Labor hours/1000 RM	24.2	16.0	15.2	25.9
Average age of fleet	8.3	8.1	7.8	7.6

Fleet composition in 1981

% GM 100% includes 21 RTS-II
% Air conditioned 82%
% Lift equipped: 0%

Source: Section 15 Data and APTA Fleet Inventory

Note: The internal working definition of a roadcall in Spokane is a bus change. This is different from the definitions used in Section 15 reporting.

Exhibit 23
Highlights of the Spokane Case

Management

1. The heads of Operations and Maintenance enjoy a good working relationship. There are some differences in managemnent philosophy, but this does not seem to have affected performance.

2. Management is implementing an MBO system.

3. The board of directors receives maintenance trend reports, but is not involved in setting procedures.

4. PM is done on a 5000 mile cycle, with major 100,000 mile inspections. Pre-run inspections are required, and usually are done.

5. There are computer systems for inventory and maintenance.

Labor

1. Labor-management relations are cooperative. Foremen are members of the union.

2. Daily meetings with employees are held to disucss safety, efficiency, and equipment.

3. No problems in attracting qualified labor were identified.

4. Testing is used for hiring and promotion. A 3 year apprenticeship program has recently been developed.

Operating Environment

1. The all-GM fleet includes 26% RTS buses.

2. Hills, heat, cold and snow cause maintenance problems.

Budget

1. The budgeting process is incremental

2. Maintenance feels that its budget is in adequate.

Physical Facilities

1. The garage is 100 years old, but a new facility is planned.

2. Maintenance would like new equipment, but the necessary funding is not available.

3. Physical layout makes access to inventory difficult.

5. Findings

Our field efforts were intended to answer five general questions about the effect of management, labor, budget, equipment, and operating conditions on maintenance. These questions were refined and restated as hypotheses about the characteristics of good maintenance practice. Each of these question areas and hypotheses will be reviewed in turn in this chapter. We have not conducted any formal tests of the hypotheses because of our case study orientation and because of the great latitude for interpretation built into our procedures, but several important observations were generated about the areas upon which the hypotheses focused our attention.

Our analysis will be presented in five section. Each section will review the initial hypotheses we advanced before conducting our fieldwork and our findings on these points. In most cases, we will be unable to draw definitive conclusions about our hypotheses, but we will to highlight examples of good practice and problem areas. Other significant findings, not anticipated in planning our fieldwork, will be discussed at the end of each section. These are findings which are based on post-hoc comparisons. We believe that equal weight should be given to both of these types of results.

A. Management

The concerns of our management questions were communication, policy statements and performance evaluation, organizational priorities, preventive maintenance and computerization.

i. Communication in Management. Few systems reported any strain in the relationships between managing directors and maintenance managers. Some of the systems we visited depended on formal, regularly scheduled meetings, and others relied on frequent, informal discussions. Madison, for example, holds weekly staff meetings involving finance, operations, and general management. Tacoma, in contrast, emphasized the high degree of trust and respect among management as opposed to rigidly scheduled meetings. The only hints of difficulty in this area were found in Spokane and Miami. The Miami case outlines the long history of management transitions that have interfered with communication - and the apparent improvements being effected by the new management team. It is apparent that these improvements have not completely eliminated misunderstandings in Miami, as evidenced by its inventory control problems and staff confusion over the status of computerization. The Spokane case is one of differences in management style, more than communcation difficulties.

Our cases did identify two approaches to improving communication. Tacoma and Miami are developing Management by Objectives systems which should clarify responsibilities. This mechanism seems to have been well received. Syracuse (which already has a strong accountability system), on the other hand, has established a highly interactive team management approach in all of its departments. We are unable to identify any strong pattern related to communication failure among management for contrast. However, Miami's experience can be used as an illustration of management's (apparently successful) attempt to improve accountability.

ii. Policy Statements and Performance Evaluation. Our questions about policies and procedures were intended to determine if maintenance procedures were developed in reaction to organizational conditions or if there was a firm sense of direction to them. Because our questions were general, and because there were no common understandings of what principles and priorities govern maintenance activities, we received a great variety of answers to our questions about maintenance policy. Every system said that it subscribed to the goals of minimizing costs and roadcalls and maximizing service. And every system also said it had informal understandings about how these goals should be accomplished. Some systems had written sets of policies and rules (e.g., San Antonio), while other said that they relied on tradition and informal communication. In many systems, preventive maintenance schedules were the only written documents mentioned. Milwaukee was unique because its staff reported concerns about the abandonment of written policies which had occurred during the era of private management. They also indicated a desire to see the reestablishment of written rules and procedures to insure continuity in the event of staff turnover.

The existence or lack of written policies is not simply related to system performance; neither the best or the worst system in terms of miles per roadcall has written policies. The important factors appear to be whether the policies, written or unwritten are known to all levels of management and, more importantly, whether management in general is willing and able to change policies in response to changes in the operating environment. Systems which formally or informally reviewed their policies on a regular basis and cited recent changes in policy in response to specific problems consistently had more miles between roadcalls than those systems with no review process. As with most private sector businesses, the ability to change seems to be a key factor in good performance.

All of the sytems we visited, except Gary, said that their management reports include either comparative analysis of performance against past trends, or evaluation against set objectives. Trend reporting was noted in Milwaukee, San Antonio, Tacoma and Spokane; and Miami, Madison, Tacoma, Syracuse, and Spokane reported quantitative performance targets. In addition, Miami and Tacoma have included performance targets in their management-by-objective system.

Our site visits seem to sugges that organizational goal setting and accountability - or at least trend reporting or establishment of performance targets - are related to performance because Miami and Tacoma have only recently begun their MBO programs (presumably in response to local problems), and Gary (our third high-cost/high-roadcall system) did not report any method for evaluating its performance indicators.

Two conclusions can be drawn from our policy and procedure questions. The first is that most systems have or are developing performance monitoring systems. The second is that the implementation of such systems is related to the relative positions of the 8 systems on the performance dimensions of costs and roadcalls per mile. It appears that one of the strongest correlates of the reliability history of the 8 systems is a formal accountability mechanism. Systems which have low roadcall to revenue mile ratios have firmly established trend reporting mechanism.

iii. Organizational Priorities. Our major finding in this area concerns the relative amount of attention given to maintenance by top management and boards of directors. Differing points of view have been stated about boards in the past. One view has been that boards get too deeply involved in maintenance, and the other is that boards do not care about maintenance. Our results showed that boards are generally uninvolved except for passive monitoring. All of our case systems, except Milwaukee, send maintenance performance reports to their boards. A few systems did report direct intervention in maintenance by governmental entities. Miami's board, for example, mandated an MBO system which is to include maintenance and Syracuse reported that a state-level action had resulted in the downsizing of its new garage.

Responses to our study questions did not identify any variation in management concerns about maintenance. However, our fieldwork did confirm the importance of, management expertise. The presence of at least one individual with knowledge of, or experience in, and dedication to good maintenance was quite notable at 5 of our 8 sites. This person was typically the maintenance manager but in one case was the general manager of the system. The importance of this factor seems clear becasue all of our low roadcall systems had experienced, dedicated maintenance managers and the three poorest systems either lacked experienced staff or had ambivalent direction in maintenance management. We also noted that most systems with strong maintenance direction had a visible second level manager who was being given increased responsibilities for maintenance in preparation for eventual staff changes.

iv. Preventive Maintenance Our review of PM practices yielded very interesting results regarding the philosophy of preventive maintenance. Previous research (see Section 2) has generated a large body of literature on mileage-based maintenance and unit exhange. Much less attention has been given to the practice of maintenance by monitoring. A notable exception is Etschmaier (1984) who has argued that maintenance resources could be more effectively utilized by monitoring vehicle condition instead of performing inspection, adjustments, and replacement at pre-scheduled intervals. Our data do not show a strong cross-system relationship between the frequency of PM activities and performance, but it is clear that the conduct of pre-run and post-run inspections is very strongly related to roadcall levels. This is an extremely important result which holds true for each of the 8 case systems. Exhibit 24 shows the PM regimes for each system. Our analysis of these programs is as follows:

1. San Antonio and Syracuse, which are low roadcall, high labor systems, have pre and post run inspections procedures.

2. Milwaukee, Madison, and Spokane, which are low roadcall, low labor systems, require mandatory pre-run inspections, Madison also requires a post run report.

3. Miami, Gary, and Tacome, which are high roadcall, high labor systems, do not have, or do not enforce their inspection program.

Exhibit 24

<u>Preventive Maintenance Program Features*</u>

<u>Miami</u>	6,000/18,000/54,000 mile cycle oil analysis on some vehicles no pre-post run inspections
<u>Milwaukee</u>	2500/5000/30,000/100,000 mile cycle oil analysis Dynamometer monitoring Mandatory pre-run inspection
<u>San Antonio</u>	4000/48,000 mile cycle pre-run inspection requires involvement of both driver and maintenance personnel post-run report required in-house oil analysis for liquid contaminants
<u>Syracuse</u>	6000 mi cycle dedicated staff for PM both pre and post-run inspections required
<u>Gary</u>	4,000/9,000 mile cycle no pre-run inspection
<u>Madison</u>	6000 mile cycle pre and post run inspection required
<u>Tacoma</u>	Bi-weekly (approximately 1300 mile) inspection interval. No analog to heavy maintenance schedules used at other systems Occasional oil analysis Pre and post run inspections not enforced
<u>Spokane</u>	5000/10000 mile cycle pre-run inspection required

* The details of each system's PM program are included in the case study reports.

San Antonio is a very interesting example of pre and post run procedures. Its pre-run inspection forms require the signature of the driver, and, if any defect is noted, a signature from maintenance as well. This involvement of both operations and maintenance is key to assigning accountability for in-service failures. It is designed to prevent the reporting of roadcalls by drivers who want a replacement vehicle - a problem reported by a number of sytems. (Miami and Tacoma reported that they are in the process of developing driver inspection procedures). Our conclusions are that while conventional preventive maintenance activities are essential to the long run stability of the system, operations as well as maintenance should play a role in the maintenance program. This is a significant finding because the major thrust of recent GAO and APTA reports have stressed mileage-based inspection programs, almost to the exclusion of other concerns. We believe that a better balance between these two strategies is necessary.

Our results should not be interpreted as indicating that preventive maintenance is unnecessary. The effects of deferred PM emerge slowly. For example, well known problems with new equipment at Madison were said to "have almost ruined a good PM program" when warranty work forced PM intervals from 6,000 to 9,000 miles. Yet during this period - and perhaps because of pre-run inspections - Madison achieved a record 11,000 miles between charageable roadcalls. Madison's subsequent 1982 performance, however showed a dramatic drop to 6000 miles between roadcalls. This was attributed to the cumulative effects of deferred maintenance for 1981 by the staff at Madison. Thus, our findings do not mean that periodic adjustment, inspection, and draining and refilling of fluids is not essential, nor do they mean that mileage based maintenance is not warranted. What is indicated is the need for driver participation in maintenance inspections, and some mechanisms for enforcement of the inspection procedure, such as madatory post-run inspections or a reporting system which attributes problems to either operations or maintenance.

v. Computerized Recordkeeping and Data Analysis

Exhibit 25 summarizes the status of computer systems at the sites we visited. Our initial hypothesis concerning computers was that their use would be prominent at systems with low labor requirements and high reliability records. Since none of our eight case sites had operating computers in use for maintenance in 1981, it was not possible to attribute any causal effect to computerization.

Only three of the eight systems visited in the case research had installed computer systems since 1981. Of the 3 systems which did have computerization, two (Miami and Spokane) reported problems with their systems. The impact of these problems is not simply related to preformance, however, because of the different results generated for Miami and Spokane in our site selection analysis.

Our observations about computerization do not imply that computer systems are not useful. But because none of our systems had computers during the 1981 period and those which have introduced computerization have only done so recently, it is too early to tell what the effects may

Exhibit 25
Computerization

System	Status in 1981	Current Status
San Antonio	no computerization	no plans for computerize
Gary	no computerization	no plans for computerize
Milwaukee	no computerization	an inventory and maintenance MIS are planned
Syracuse	no computerization	inventory, work order processing, and vehicle records are now on computer
Miami	had previously and unsuccessfully tried to use standard inventory package	in-house inventory and MIS being developed; in recent past service bureau was used to summarize roadcalls
Spokane	no computerization	maintenance MIS and inventory system in place
Madison	no computerization	no applications in place; procurement pending
Tacoma	no computerization	computerization of vehicle histories is being implemented; in past data processing company maintained inventory.

be. Installation of the Miami system had not been completed at the time of our site visit, and the Syracuse system had been in place for only 10 months at the time of our visit. While the system at Spokane has been in place since 1982, Spokane's maintenance personnel did not have the background or time to fully utilize the results of computer analysis.

Several points should be noted. First, both Syracuse and Spokane had efficient maintenance organizations before they purchased computers so any positive effects that their computers may have may be difficult to detect in the future. Second, the response of the maintenance departments surveyed in our study to computers was by and large positive. Third, the perceived costs and benefits of computer systems vary widely among users and nonusers. This includes misconceptions about how computers can be used and the real extent of a computer's capability. These misconceptions appear to cause problems when purchasing computers such as undersizing systems when writing specifications. This indicates a need for guidelines for use in planning and purchasing a computer systems for maintenance use.

B. Labor

The focus of our labor interests was on union-management relations, involvement of labor in maintenance improvement, wage rates and skill levels, and testing and training of employees.

i. Union Relationships.

Assessment of the tenor of union-management relationships in a short interview is difficult at best. However, we were able to obtain general descriptions from each system. Union representatives and management in Milwaukee, Spokane, and Madison all described these relationship as cooperative. Both union and management in Miami said that their situation was adversarial, as did management in Gary. The union in Miami was especially forthcoming in their explanation of problems with working out-of-classification, supervisors performing work, overtime distribution, punctuality and job completion rates. Mixed views were offered in Tacoma. Syracuse reported a generally cooperative atmosphere, but management claimed that the union sometimes protects unreliable employees and the union indicated that there are frequent disputes about overtime.

ii. Worker Input. Our information about employee input into maintenance seem to conform to the patter of union-managment relations. Indications from Miami, and Tacoma are that there is a formal structure for union members to meet with management, but there was no information given on the impact of worker suggestions. Gary reported that labor and management do not meet except to disucss contracts and grievances.

In contrast, both mechanics and management in Syracuse and management in San Antonio reported frequent informal meetings. The Milwaukee, Spokane, and Madison cases indicate productive informal communication. Milwaukee, for example, reported that employees' suggestions were considered in developing maintenance procedures. Spokane indicated that daily meetings are held to discuss safety, efficiency and equipment and that "both sides participate equally and feel that the meetings are useful." Management in Madison commented that its employees were "aggressive and depenable," noted that 3 regularly scheduled meetings provided a formal mechanism for worker input, and said that workers were responsible for making many useful suggestions. These responses, taken together with those elicited by union-management relations questions, indicate that there is some relationship between performance and labor-management relations in the 8 systems. At the least, it is remarkable that Spokane and Madison have better relationships between mechanics and management than the systems with the least impressive performance data.

iii. Quality of the Labor Pool. This question has several dimensions. One is the level of wages offered to entry mechanics; a second is the mechanism for recruitment; and a third is the wage scale of experienced mechanics. All of these factors interact to define the "labor pool." Exhibit 26 shows the resulting situation at each of our 8 systems. Several dimensions of difference are clear. Milwaukee and Madison are the only systems that have a driver-cleaner-mechanic progression. Milwaukee has established a new apprenticeship program because of problems filling positions in this way, and Madison has indicated that over 50% of it hirings are from outside the system because of lack of driver interest. San Antonio stands alone in its practice of only hiring skilled mechanics.

Entry and advanced salary levels are also shown in Exhibit 26. This shows a wide variation in absolute and relative salary levels. San Antonio, for example, increases mechanic wages by 44% from entry positions to top positions, while Gary shows only 6% increment as reported by APTA (1983b), Spokane pays the highest starting hourly salary ($11.11), and San Antonio the lowest ($6.50). Tacoma pays the highest top wage ($13.00) and San Antonio pays the lowest ($9.40). In addition, some systems pay longevity increases. For example, Gary has a $1.38 longevity increment and Syracuse's is $2.50.

Evaluation of these wage structures and recruitment practices is difficult. Initial comparisions to average regional production wages showed that Tacoma, Syracuse, and Gary pay entry level workers less than average local production worker wages; and that Gary and Milwaukee pay senior workers less than the regional production worker salary. Thus, some of the systems follow compensation and recruitment patterns designed to attract, develop, and retain labor by paying high initial salaries. This strategy, when coupled with training in nontransferable skills is characteristic of segmented labor markets. This strategy does not always work; for example, mechanics in Miami often quit to take other, higher paying jobs in trucking and aircraft maintenance.

These observations lead to the conclusion that compensation, recruitment and training all interact to determine the kind of worker who comes into the maintenance department, and the skill levels represented on the maintenance staff. In relation to system performance, it can be observed that Syracuse and San Antonio pay top wages which are above regional production wage rates, while Gary has a low absolute and relative wage scale and progression increment. Madison and

Exhibit 26
A. Regional Labor Pool Conditions

Milwaukee	Normal progression is from driver to cleaner to mechanic. There are some problems in recruitment. An apprenticeship program has been established.
Miami	Union claims starting salaries are too low; superintendent of budget and administration claims testing is too stringent. An apprenticeship program is successfully attracting applicants.
San Antonio	No problems reported. Management is very selective in hiring, only skilled mechanics are considered. Many mechanics let go during probation period.
Madison	Normal progression is from driver to cleaner to mechanic, but this is not recruiting enough staff. New contract may change this provision.
Tacoma	Maintenance Manager and personnel officer feel that applicants are qualified. An apprenticeship program is being developed.
Syracuse	Emphasis has changed from on-the-job training of unskilled workers to an apprenticeship which draws upon a local vocational education program.
Gary	The system has a need for mechanics with better skills in air conditioning and electrical systems.
Spokane	No problems cited in hiring qualified mechanics; an apprenticeship program has been developed.

B. Entry and Top Salary Levels
(as reported for first half of 1983)

	Entry level*	Top wage level* (non-supervisory)	% Increment
Milwaukee	9.95 -	12.48 +	25
Miami	8.46 +	9.75 +	15
San Antonio	6.50 +	9.40 +	44
Madison	9.52 +	11.20 +	17
Tacoma	9.25 -	13.00 +	40
Syracuse	7.27 -	9.52 +	30
Gary	9.24 -	9.88 -	6
Spokane	11.11 +	12.27 +	10

Note: A "+" indicates that the wage rate for maintenance worker is greater than the average wage rate for production workers in manufacturing for the region; a "-" indicates the maintenance worker's wage rate in less than the average.

Sources for wages for maintenance workers: APTA, 1983A and 1983B.
Source for average wage: Bureau of Labor Statistics, 1983.

Spokane pay relatively high salaries, but have low progression increments, and Milwaukee's entry wage level is lower than the regional norm. This pattern is not simply related to performance because Miami and Tacoma pay rather high salaries. The need for further analysis is indicated because, in spite of top salaries, Miami is not competitive with local aircraft and trucking industries.

iv. Training. Our interests in training focused on staff selection and development. The general strategy for recruitment was addressed in the previous section. Approaches to selection and training are summarized in Exhibit 27. Testing of applicants before hiring is a standard practice except in Gary and San Antonio. This seems understandable because Gary is not actively recruiting new mechanics and VIA Metropolitan Transit uses its interview and probation processes as an alternative selection process. Testing for advancement is less uniform, and training programs for employees seeking advancement are not common. Notable exceptions are as Tacoma's practice of testing candidates for promotion to determine mastery of skills required for their current position, and Milwaukee's formal training programs for advanced mechanic positions. None of the sytems retest mechanics remaining in their current job level to check for retention and updating of skills, but Miami does conduct optional refresher courses. Heavy reliance on on-the-job training by mechanics (or trainers) who had gone through manufacturer' programs was reported. This approach was favored in most systems because lean staffing levels do not allow full participation by all mechanics in manufacturers' training programs.

The effect of training programs on the performance of the 8 case systems is hard to quantify. Syracuse and San Antonio have very different approaches to training, but both deliver reliable service. Madison, Milwaukee, and Spokane, all good performances, have testing programs and provide some form of training. Miami has and Tacoma is planning to established training and testing programs, and these will presumably improve their staff skills. It is difficult to attribute Gary's situation to lack of training because of external limits on budgeted mechanic positions. However, training may be the best way to approach the problem in Gary because the low pay scale is not competitive with local industry.

C. Operating Environment

The effects of fleet composition and operating conditions are widely cited as important local factors affecting maintenance. These are clearly active in the 8 systems.

i. Fleet Composition and Inventory Factors. Vehicle age and mix are obviously different in our cases. Spokane had the newest and most homogeneous fleet in 1981, with a 100% GM fleet, of which 26% were RTS models. Since then, however, Spokane has added a number of 870's. This has increased the complexity of its inventory significantly, and created some problems in procurement, but the computer system used for inventory has accomodated the fleet expansion. The addition of the new vehicle types has, however, led to some problems including the double-stocking of identical parts under different identification codes, limited space for inventory expansion, and identification of local sources for parts.

Exhibit 27

Components of Training Programs

Gary	No classroom training 23 hours OJT* no formal testing
Miami	7½ month training program (OJT and classroom) weekly refresher courses (optional) testing for hiring and promotion
San Antonio	New employees must have 3 years experience as a mechanic 8 hours of classroom training*
Madison	Test for new mechanics being developed Tests for promotion are being developed Most training is OJT
Tacoma	Apprentice program being developed Testing for hiring and promotion
Milwaukee	Testing for hiring and promotion Apprenticeship program being developed 1 day orientation seminar 6 mo. program for B and C level mechanics 12 mo. program for A level mechanics
Spokane	Testing for hiring and promotion 3 year apprentice program recently developed
Syracuse	Testing for hiring and promotion Apprentice program being developed All other training OJT No tuition rebates

* primarily employee and system orientation

The situations at the other systems are shown in Exhibit 28. This shows a variety of fleet-related factors which could account for performance differences. For example, Miami has the most diverse fleet in our sample resulting in a 9800 item inventory, as well as space problems and an unsatisfactory computerized inventory system, while San Antonio has a much higher percentage of GM vehicles, no space problems, and a time tested manual inventory system.

Two side issues related to inventory were identified in our exploration of fleet mix. The first is costs accounting issue. This was mentioned in Spokane as on the drawbacks of its otherwise well-regarded inventory system. It turns out that Spokane cannot charge inventory or purchasing costs to individual buses, although they would like to do this to track life costs. The system in use at Spokane is not designed to do this, and, moreover, it only retains costs for a one-month period. Further investigation of this point showed that only Syracuse can currently do vehicle level cost analysis.

The second issue is control of inventory and purchasing in the maintenance organization. Until 1981, inventory and ordering of parts was handled by the Maintenance Division in Miami. In 1981, the County investigated Metrobus and discovered that there was no inventory control. As a result, a Materials Management branch was formed to track purchasing, but the stock rooms were left in the Maintenance Division. The stock clerks did not cooperate in efforts to improve the record keeping, and in April 1983, the stock clerks were reassigned to Materials Management in an attempt to improve communication and inventory control. However, the Maintenance Division now feels that the stock clerks do not understand its needs and the clerks are filing grievances and requesting overtime because of increased clerical duties.

An entirely different situation - and absence of problems - was found in San Antonio where both procurement and inventory are internal to the maintenance department. This is somewhat similar to Milwaukee, where inventory, purchasing and maintenance supervisors all report to the Superintendent of Equipment and Plant. Spokane offers an interesting contrast to Miami because it has stores clerks who report to maintenance, while purchasing department controls procurement. No problems were reported with this arrangement in Spokane.

In summary, the cases do show that fleet diversity had led to problems with inventory space and record-keeping systems. It appears that manual systems for inventory are adequate for some systems and that computerization does not necessarily solve inventory problems arising from mixed fleets. We have also found differences in reporting lines for purchasing and inventory which can lead to (as in Miami) or solve (as in Spokane and San Antonio) problems. Fleet mix has been found to increase the complexity of maintenance.

Our fieldwork reinforces the need for a cross-listing system for parts which was identified by the 1982 TRB Bus Maintenance Improvement Workshop. It also indicates the need for an inventory control system which can be easily updated and expanded when new vehicles are introduced or when cross-lists are updated. The fieldwork suggests that new

Exhibit 28

Fleet Age Composition (1981)

Fleet Composition

System	GM		Other			Average Age	Percent with	
	TOTAL	RTS	Flx	AMG	MISC		Lifts*	A/C
Miami	65%	22%	15%	16%	4%	9.0	0	99%
Milwaukee	84%	20%	16%	0	0	12.9	40%	40%
San Antonio	89%	46%	0	0	11%	8.9	5%	100%
Madison	100%	15%	0	0	0	9.0	15%	55%
Tacoma	60%	0	19%	0	21	17.5	25%	24%
Syracuse	22%	0	55%	14%	9%	9.4	22%	81%
Gary	100%	15%	0	0	0	9.3	0	86%
Spokane	100%	26%	0	0	0	8.1	0	82%

Source: APTA (1981)

*Many systems do not use this feature.

bus acquisitions should be supported by an analysis of inventory impacts and plans for accomodating them.

ii. Climate and Operational Factors. Nor surprisingly, all our our systems repported that fleet age and climate affect maintenance. But there were differences in the types of problems reported, in the relative ranking of fleet characteristics and climate as problematic factors and in activities undertaken to deal with problems. Milwaukee and Tacoma both cited fleet age as major causes of maintenance problems, and since their fleets average over 12 years of age, this seems reasonable. Gary and Syracuse also responsed in this way - but their fleets are closer to the mean fleet age in our sample, 9.2 years. Every system reported air conditioner problems, but this problems is more severe in some places because of climate factors. San Antonio and Miami, for example, both reported probelms with heat and humidity; and both are actively pursuing air conditioner modification programs. Madison and Spokane both reported problems with air conditioning and recognized that fleet characteristics were a major factor. Cold and snow were mentioned frequently by Spokane, Gary, Milwaukee and Madison. Spokane and Gary noted that they must help the city in snow removel.

It is difficult to quantify these factors and even more difficult to isolate their effects on performance. But we can note that the systems vary in their reponses to environmental factors. For example, San Antonio, Miami, and Madison all reported active air conditioner retrofit campaigns. Miami also indicated that it was experimenting with air starters to reduce electrical problems. Tacoma uses modified transmission gear ratios to increase power on hils.

Our interest in operating conditions focused on stop spacing and passenger loads. Vehicle speed was one of the Section 15 variabels which figured prominently in our site selection data analysis. This variable was used as a proxy for the characteristics of local service (e.g. traffic conditions and stop spacing). But another proxy, not included in our initial analysis, casts additional light on this subject. The variable is passenger miles per revenue mile. This is a proxy for load factor. This variable, which ranges from 6.4 passenger miles per revenue mile (San Antonio) to 17.31 passenger miles per revenue mile (Dade Co.), is strongly correlated with the pattern of expected and observed performance, with the exception of Spokane which has a very high load factor (but performs well) and Tacoma whose load factor is similar to Milwaukee (but whose labor costs and roadcall levels are higher). This departure may be due to differences in vehilce age, because Tacoma has the oldest fleet (14.5 years) and Spokane has the newest (8.1 years).

In summary, it is clear that climate and operating conditions do vary between cities. These factors allow us to construct explanations for most of the differences between expected and observed performance however, the relative impacts of these factors as opposed to management and labor factors are difficult to deduce from our case studies and quantative data.

D. Budget

Our budget hypotheses involved preparation and adequacy. From the case studies it appeared that a third factor, budget stability, may be more important than the first two factors.

i. Budget Preparation. Budget preparation was described to us as an interactive process in five of our case study cities. The exceptions are Gary (where the General Manager prepares the maintenance budget), Syracuse (where evidence seems to indicate that interactive preparation occurs), and San Antonio (where no information on this subject could be obtained). Joint preparation, however, does not seem to insure that an adequate budget will be provided. For example, Miami's staff claimed that they were suffering because of understaffing which is partially due to board imposed freezes on hiring and across-the-board budget cuts, and Madison, according to an ATE study, requires additional staff positions.

Each of the 8 systems does line item incremental budgeting for maintenance. Unit cost data, we found, was either non-existent or not complete enough for use in budgeting. Interesting items regarding budget preparation came from Spokane and Miami. Spokane's executive director holds budget workshops with the Board to compare his budget with those of other agencies and previous years in order to justify increases. Miami is beginning a long-range budget process which will result in 3-5 year budget for vehicle acquisition and maintenance.

ii. Budget Adequacy. What the staffs of the systems consider to be an adequate maintenance budget may not be related to the amount of money allocated to maintenance. Exhibit 29 shows the percentage of total operating budget that is allocated to maintenance and mainteance cost per revenue mile for each of the case studies. Cost per vehicle mile is strongly affected by wage rates (labor and benefits compose about 60 percent of maintenance cost on average) and regional price levels so comparisons must be made with care. Because the cost of operations and administration would also be affected by wage and price levels, albeit not necessarily proportionally, the percentage figures may be more comparable between systems.

San Antonio, which pays relatively low wages, has the lowest cost per mile among our eight cases although it is fifth lowest in terms of percentage of budget allocated to maintenance. San Antonio's maintenance department has reduced its budget for FY 1983 by 2.98% and for FY1984 by 1.03%. The reductions were attributed to the recent replacement of older vehicles with ADB buses by the maintenance manager. VIA's maintenance cost of 31.6¢/mile in 1981 is in the lower 25% of our sample systems.

Madison's maintenance cost per mile of 32.2¢ is the second lowest, although its wage rates appear to be about average. Its maintenance budget proportion, however, is above average at 21.1%. The only person citing budget as having a significant effect on maintenance was the general manager.

Exhibit 29

Maintenance Budget Statistics
Section 15 Data for 1981

	Maintenance as % of Operating budget		Maintenance Cost per revenue mile ($/mile)	
Milwaukee	18.0	(2)	40.2	(3)
Miami	26.2	(8)	60.6	(8)
San Antonio	20.0	(5)	31.6	(1)
Madison	21.1	(6)	32.3	(2)
Tacoma	17.7	(1)	49.0	(6)
Syracuse	18.7	(4)	44.2	(4)
Gary	24.1	(7)	58.8	(7)
Spokane	18.3	(3)	45.2	(5)
Median for 111 systems	18.7		40.0	

Note: Number in parentheses is rank, one being lowest.
Source: Transportation Systems Center, 1982.

In Milwaukee, which has the third lowest maintenance cost per mile, the Managing Director said that the budget process works well. The study, however, does contain refernces to staff shortages and old factilities, but budget was not mentioned as a cause of these problems. Milwaukee allocates a low fraction ot its operating budget to maintenance (18%).

Syracuse is slightly above average in its costs per mile, and has a percentage of its operating budget which is about average for the 8 systems. Spokane's 1981 maintenance budget was 18.3% of the operating budget, or 45.2 cents per revenue miles. This puts Spokane near the median level of budget commitment of our sample, and slightly above average with respect to maintenance cost per mile. Spokane's executive director observed that this budget was adequate, but the maintenance personnel interviewed observed that management is supportive but does not provide an adequate budget and that it is "hard to get new tools and equipment because management tends to say that there is no money in the budget." Spokane has a dedicated state revenue source of funding because of its Public Transit Benefit Area Status.

Tacoma committed 17.7% of its operating budget to maintenance in 1981. This is the lowest among the case sites. However, its cost per mile (49.0¢) is the third highest among the case sites. Tacoma also has the highest wages for mechanics among the cases; if driver wages are correspondingly high, this could explain the contrary evidence of high cost per mile and low proportion of budget for maintenance. There was no strong sentiment indicating that the budget was inadequate, and it was also noted that "adequate funding has led to increased quality in mainteneance." Tacoma had planned for more severe federal subsidy cuts and it had budgeted for a school contract which was not renewed. (This resulted in the layoff of 4 mechanics and the decision not to replace 2 who quit). Thus, the budget was not a major problem when the site visit was conducted in 1983.

The Gary system has the second highest maintenance costs per mile among the eight cases and its maintenance budget accounts for 24% of its operating costs which is also second highest. The maintenance superintendent and general superintendent cited several problems including lack of mechanics and helpers, equipment deficiencies, and space as current problems, but neither mentioned budget levels as a significant determinant of the level and type of maintenance performed. Overtime for maintenance workers was cited as a significant budget item in Gary. Our calculations for 1981 indicate that overtime may range between 10 to 30 hours per week. However eight mechanics have been laid off recently due to budget cuts. The General Superintendent cited a need for a dynamometer and servicing equipment for air conditioning, heating, and electrical systems.

Miami's 1981 budget allocated 26% of operating dollars to maintenance. This is the highest among the cases, as is the cost per mile of 60.6¢. The wage rate is about average for the cases. The superintendent of administration and budget said that the current budget would be adequate if all personnel positions were filled (11 were frozen and 14 were vacant). This lack of skilled applicants, and absenteeism, has resulted in 18.6% of salary expenses going to overtime.

The last two sites, Gary and Miami, have the highest maintenance cost per revenue mile, the highest portion of budget for maintenance and also have the highest roadcalls per revenue mile. San Antonio and Madison, on the other hand, have the lowest maintenance cost per mile and the lowest roadcalls per mile, although maintenance cost as a percentage of budget is a little above average. This appears to indicate that good maintenance is not a result of large expenditures. This is supported with information from the site selection models which seem to imply that increased roadcalls increase labor hours rather than more hours of maintenance labor reducing roadcalls. However, the two lowest roadcall sites allocate average proportions of total budget to maintenance. This suggests that there may be an optimal level of expenditures; having too little money may preclude adequate maintenance, but after a certain point additional money does not produce additional benefits. However, the third factor to be discussed also throws light on these relationships.

iii. Budget Stability. Being assured of an adequate budget appears to be a key factor in an agency's successful performance. In terms of revenue miles between roadcalls, three of the top four systems, San Antonio, Syracuse, and Spokane, have dedicated funding sources in the form of either a local sales tax, real estate transaction tax, or percentage of state sales or motor vehicle tax. The good performance of these systems may be attributed to their ability to undertake long term planning based on an assured income. Also, managment does not have to fight to protect the system's piece of a county or city revenue "pie" and therefore can expend its energies on planning or other internal functions. The executive directors of both Spokano and Tacoma, which only recently became autonomous agencies with dedicated revenue sources, both commented on the advantages of this system.

Although Madison, which as the second highest miles per roadcall, does not have a dedicated revenue source, it has a strong local commitment to transit on the part of both citizens and city officials. For example, the city of Madison recently increased, rather than decreased, a proposed transit budget by simultaneously loweing the fare structure and increasing the city's subsidy to transit. Further, the security of having an adequate budget was illustrated by the confidence the staff showed that pending budget requests (for a microcomputer and additional staff positions) would be approved.

In contrast, the systems with low miles per roadcall, Miami and Gary, are part of local governments, do not have dedicated revenue sources, and do not have assurance of receiving the budget requested. The board in Miami does make budget cuts, has frozen mechanics positions and has put a cap on overtime. Interestingly, this has not resulted in lower expenditure of labor for maintenance; Miami has the highest labor hours per revenue miles and the lowest peak buses per maintenance employee (0.9) of the eight case systems. (The six systems, not including Miami or Gary, range from 1.4 to 2.6 peak buses per maintenance employee.) Miami has an additional problem in that the bus system has to compete with the new (and therefore more interesting) rail system, which has recently opened, for both money and upper management attention.

The City of Gary, which owns its transit system and helps to subsidize it from general revenue funds, is suffering from a declining tax base and lack of revenue. Further, the transit agency's budget goes to the state for approval and the state has shown more interest in low taxes than support for transit. Gary's budget problems are illustrated by their recent reduction in the number of mechanic positions; they currently have the highest peak bus to maintenance employee ratio (4.0) of the eight cases. Both Gary and Miami have high rates of overtime.

It appears clear that the budget process in Gary and Miami does not lead to low expenditures for maintenance; just the opposite is true. However, budget instability does interfere with management's ability to plan for maintenance. It may mean that special projects that would allow the agencies to catch up on their maintenance problems can't be undertaken. It appears to lead to large amounts of overtime, which are not efficient due to reductions in the energy, alertness, and motivation of workers. And it probably means that management time is absorbed in fights for money rather than improving the effectiveness of the maintenance process.

While Madison shows that it is not essential, autonomy of the transit agency along with a dedicated revenue source appear to promote budget security. Autonomy (i.e., the independence of the agency from other governmental bodies) also has other advantages for good maintenance in that management and policy decisions are governed by their affect on transit alone, rather than wider concerns. For example, in Tacoma, where the transit system is autonomous, the maintenance department has been able to design a computerized MIS to fit their particular needs. In Miami, where the transit system is part of the county government, the computerized MIS is being designed for all county vehicles, and maintenance personnel are concerned that it will not be appropriate to their needs.

E. Maintenance Equipment and Facilities

Only a few of the systems we studied reported equipment problems. Spokane noted a need to replace drill presses, lathes and chain hoists, but had decided to defer replacement until moving into its new garage. Milwaukee had experienced problems with the availability of metric tools, but had plans to deal with this in its next labor negotiation. A larger number of systems reported problems accomodating newer vehicles (RTS and articulated buses). This has resulted in the need to rely on blocks for support, to purchase portable lifts, or to restrict new vehicle types to a limited number of garages.

Old and inadequate facilities were a special problem in Gary and Spokane. Gary's garage, with only 2 lifts and 1 pit clearly is inadequate for its needs. Its space problems are so severe that it has to use scattered, shop floor storage of major components (e.g., engines and transmissions). Spokane's garage, which is over 100 years old, has layout problems that make supervision difficult and inventory access time consuming and inconvenient.

It was notable that a number of new facilities had deficiencies in layout including lack of space for maneuvering newer vehicles and for installing dynamometers. It was also the case that many new garages had failed to reduce roadcalls as had been hoped. However, it was reported that they do improve worker morale. For example, workman's compensation claims fell by 20-30% and absenteeism dropped by 20% after Syracuse moved into its new facility. Exhibit 30 summarizes the physical facility situation in the 8 case systes. Our finding with respect to the 3 pre-specified hypotheses follow.

i. Facility Age. Results are mixed on the question of whether old buildings, or those not built for bus servicing adversely affect maintenance. This is true for Milwaukee, (which as 1 garage and shop facilities originally built for streetcars), for Gary (whose garage is an 1890's vintage factory), Spokane's 100 year old garage, and Tacoma's 1948 garage. However, San Antonio is quite satisfied with its 36 year old bus garage. New vehicle types (RTS, articulated vehicles) may be partially to blame, but there is also evidence of compromises in design (e.g., Miami eliminated space for test equipment to build a substation for its rapid rail system, and Syracuse's facility design was modified for financial reasons). Older facilities generally do have problems, but so do newer garages. No dramatic reductions in roadcalls have been attributed to new facilities, but some savings has been realized.

ii. Equipment. Our case work did not determine the extent to which over or under utilization of maintenance repair equipment indicates poor management or lack of budget because our field procedures did not focus on equipment utilization. We did hear of unmet needs for dynamometers, electrical and A/C test equipment, and computer information systems, and we did hear that such procurements were contingent on budget, but we did not collect enough information to determine if there had been a consistent pattern of management neglect or under-funding.

iii. Access to Parts. Our concern about readily accessible replacement parts being essential to the efficient operation of the maintenance department was supported by the Miami and Spokane cases, but only Spokane reported problems with inventory location. Madison and Syracuse reported some minor difficulties, but no major impact on departmental efficiency. The souce of the problem in Miami was largely organizational, not physical.

In looking at performance, it is notable that San Antonio is doing quite well in its 36 year old garage and that Syracuse was doing well in its now vacated 8 garage system. Syracuse, however, does except to gain labor efficiencies with the move to its new garage. Madison and Milwaukee were also good performers before moving to their new quarters. No significant roadcall changes have occurred since they moved, but some labor productivity gains may be reflected in the 1982 data. Tacoma does have problems with its old garage, as did Miami, but in the latter case staff and skill levels seem to be a more important factor. Gary's garage, with 2 lifts and 1 pit, is clearly inadequate.

Exhibit 30
Facility and Equipment Analysis

	Facility	Comments
Madison	Moved into new garage in 1981	No impact on roadcalls. Labor reduction has occured. RTS could not be accomodated on lifts; vehicle must be put on blocks
Milwaukee	Two new garages built since 1981. Shop and third garage were built for streetcars	Difficult to service buses with street car pits. Portable lifts must be used for articulated buses. Newer garages did not reduce roadcal[ls]. Engine washer and dynamometer desire[d] but cannot be accomodated because of space limitations in new garages.
Miami	1 garage built in 1969, 1 in 1981 1 recently rebuilt and shop is being remodeled.	New facility has poorly oriented lif[ts]. Decline in roadcalls may be due to faclilities - but management changes have also occured. Some equipment was not in use, but this was due to staff training.
San Antonio	Garage is 36 years old Has extensive shop equipment	No problems noted
Gary	Current facility was built in 1980 as a factory	A new garage is being built. Current garage does not have adequat[e] space for work, inventory, vehicle servicing, or test equipment.
Spokane	Garage is over 100 years old	A new facility will be built. Inventory is not centrally located Shop tools need replacement.
Tacoma	Garage was built in 1948 space is extremely limited	Lifts and pits inadequate for 40 ft. vehilces. A new facility is planned.
Syracuse	The new garage is considered "state of the art."	New garage was not in use in 1981 No reduction in roadcalls noted, but some staff savings anticipated. Storage space is somewhat limited and lift location is not optimal.

6. Discussion

This review has identified a number of practices which seem to have a positive impact on maintenance; it has also uncovered a number of problem areas. Exhibit 31 lists both the positive factors and problem sources identified at each case system.

Our findings regarding day-to-day operations and preventive maintenance programs are similar to those of previous studies (Roberts and Hoel, 1982; Illinois Department of Transportstion, 1982) which found that the major emphasis was on inspections, adjustments, lubrication and breakdown maintenance, with less emphasis on cost analysis, use of failure data and unit exchange planning. Our results confirm the results of these previous studies regarding vehicle design problems, space, staff and budget. They also verify that unit cost and component life statistics are generally not used in planning maintenance programs because the raw data for developing those figures are not available in many systems, and where available, are in forms which are inconvenient to use.

Our findings confirm that pre-run inspections are not always carried out at all systems. But more importantly, we have found that the absence of pre-run inspections is highly correlated with vehicle reliability. It is not clear why this occurs, but at least two reasons can be advanced: (1) the inspection procedures prevent driver use of roadcall procedures to obtain bus changes or (2) driver inspections are important in monitoring vehicle condition.

A major difference between our findings and those of others is that several of our case systems had established maintenance performance indicators, tracking systems, and (in some cases) performance targets. Two of the systems we visited were in the process of developing management-by-objective systems. Other notable findings were the establishment of formal training and testing programs at a number of systems, and increased integration of maintenance into budgeting and management decision-making.

These findings indicate that the organizational perception of maintenance is changing in U.S. transit systems and that many of the elements of a strategic planning approach to maintenance are developing (Bullock, 1979). We believe that the systems we have studied illustrate some of the critical elements of this approach to maintenance management. The emergence of this approach is timely in view of the recent search for a Federal policy approach in transit maintenance (see Chapter 2), and the pending development of guidelines for implementing current policy. This process can be traced back to 1981 when UMTA published a list of approaches for improving maintenance of equipment purchased with its grant program monies. (Fed. Reg. Vol. 46, No. 14, pp. 7031-34). The approaches included:

1. Reinforcement of the requirement that vehicles be maintained, leaving determination of methods, evaluation and monitoring up to local discretion.

Exhibit 31
Summary of Site Analysis

System	Positive Factors Influencing Maintenance	Problem Sources
Miami	*New Management System (MBO) *Performance Targeting Mechanic Training Program Testing Program Refresher Courses	Understaffing due to hiring freeze and loss to other firms History of Transitions and re-organization. No Driver Inspections Inventory Management Adversarial Labor Relations Low Salary Levels Diverse Fleet Climate and Air Conditioning High load factor High overtime utilization Lift orientation in garages Relationship to County
Milwaukee	Stable Management Good, informal, management process *Oil Analysis Dynamometer Pre-run inspections Good worker input to management *Mechanic Training program Testing for hiring and promotion Relatively uniform fleet	Lack of written procedures Older fleet Old garage and shop built for streetcars
San Antonio	Stable, experienced management Written rules and procedures Performance Trend Analysis Pre and post run inspections In-House shop capabilities Vigorous use of probationary period Uniform fleet Air conditioner retrofit program Low load factor Extensive In-House Shop Facilities	Climate and air conditioning
Madison	Weekly management staff meetings Performance trend analysis Pre and Post run inspections Worker suggestions implemented Uniform fleet Positive management-staff relations Budget security	Staff position shortages Cold weather and outdoor storage Lift Capacity for RTS Transmission failures

* = Innovations or changes occuring since 1981.

Exhibit 31 (cont'd)

System	Positive Factors Influencing Maintenance	Problem Sources
Tacoma	*Management by Objective System *Performance Trend Analysis and Targeting High salary levels *Apprenticeship program Transmission Ratio Modifications	Poor enforcement of pre and post run inspections Undifferentiated bi-weekly maintenance program Old (14.5 years ave.) fleet Terrain Inadequate garage
Syracuse	Team management system Performance trend monitoring and trageting Supportive board Pre and post run inspections *New computer record system Frequent labor-management meeting *Apprenticeship program *State of the art garage	Old system of 8 garages (recently replaced)
Gary	Uniform fleet *New graage (planned)	No trend reporting No pre-run inspections Adversarial Union Relationship Low wage structure Low number of mechanics and high overtime No formal testing City snow removal Inadequate inventory and garage space Budget not secure
Spokane	Performance targeting and trend analysis Pre-run inspections Frequent supervisor-mechanic meetings High wage rates Testing for hiring and promotion *Apprenticeship program Newer, uniform fleet Good Union relations	Management style conflicts Inadequate city snow removal 100 year old garage Inadequate shop tools Inadequate inventory space High load factor

* = Innovations or changes occuring since 1981.

2. Establishment of a requirement for maintenance planning at the local level, with UMTA involvement in compliance monitoring.

3. Establishment of a requirement for maintenance planning at the local level, subject to UMTA standards and compliance monitoring.

4. Establishment of a requirement for maintenance plans to be developed (and made available on request)

5. Establishment of a requirement for manufacturers to develop maintenance plans, and for properties to follow them.

6. Dedication of a percentage of Section 5 funds to maintenance.

7. Establishment of a vehicle replacement policy.

The approach currently being developed is essentially that of required maintenance planning subject to certain standards regarding establishment of performance measures and targets. This mechanism is flexible because it allows local discretion in formulating local programs, but also forceful enough to require local action and accountability. Because of the variations in management planning at our case systems, we believe that the Congressional mandate for periodic reviews of local maintenance programs will have a positive effect on maintenance. The periodic reviews will serve as a reminder of the importance of maintenance to those involved in the budgetary process, and should also serve as a way of focusing management attention on the evaluation of maintenance strategies as opposed to daily servicing actions. Our cases indicate definite need for this sort of emphasis to insure that practices and procedures are periodically evaluated to determine if any changes would be beneficial.

During the analysis of transit system policies and policy evaluation procedures it became evident that the existence or lack of written policies had no apparent correlation with system performance; neither the best or the worst systems in terms of miles per roadcall have written policies. The important factors appear to be whether the policies, written or unwritten, are known to all levels of management and, more importantly, whether management in general is willing and able to change policies in reponse to changes in the operating environment. Systems which formally or informally reviewed their policies on a regular basis and cited recent changes in policy in response to specific problems consistently had more miles between roadcalls than those systems with no review process and few, if any changes in policy in the previous year. We therefore recommend that the new Section 3 and 9 requirements for maintenance planning, annual certification, and tri-annual review be implemented as follows:

1. The maintenance planning process should be left to local discretion, but the process should be expected to generate statements of existing conditions, anticipated changes, problems encountered, effectiveness of remedial actions, and expected performance.

2. The planning process should not be focused exclusively on PM schedules.

3. The annual certification of maintenance capability should be substantiated by submission of an updated maintenance plan.

4. The tri-annual review should consist of a review of the previous three year's maintenance plans to determine whether or not all relevant categories were addressed and if the performance and system information included in the plan can be verified.

The following sections persent our ideas about the substance of these maintenance plans and review procedures. We are in general agreement with the guidelines developed by APTA (1983c), but we have recommended that the focus of maintenance planning be broadened to include budget and staffing issues and to put adherence with preventive maintenance mileage targets on an equal level with other performance targets. We have stated a number of questions which can be used as a the basis of periodic audits mandated in Federal legislation, but we have tried to focus on a cycle of review and self-evaluation as opposed to simple verification of performance statistics and attainment of performance targets.

A. Maintenance Planning Guidelines

Our research has shown that there is a need to establish clear, quantificable maintenance goals on an annual basis. These goals can be stated in terms of locally defined measures of reliability and cost; they can also be stated in terms of targeted percentage reductions in roadcalls, budget levels, and labor requirements. Thse goals should be determined locally because of exogenous factors that influence maintenance. We recommend that both cost and reliability goals be established because most maintenance personnel acknowledge that an implicit, undefined tradeoff between cost and maintenance performance is involved in the budget process. This tradeoff should be made explicit in the development of goals and performance targets. Our research has also highlighted the importance of tracking system performance and evaluating performance in comparison to past trends and performance targets. Tracking systems provide managment with a tool for monitoring performance and measuing progress towards achievement of stated goals. Analysis of performance and comparison to locally developed goals should serve as the core of a yearly assessment of maintenance effectiveness. The establishment and tracking of maintenance goals should lead to the establishment of long term strategic planning for transit systems. Such planning, long seen as crucial to continued success in other industries, was notably lacking in the systems studied.

The absence of internal planning documents and procedures at many of our case sites indicates a need for the development of a maintenance planning cycle to periodically assess the effectiveness of operational policies and procedures and emerging maintenance issues. The actual details of this cycle and planning methods should be left to local discretion, but we believe that the following information should be generated in the planning process.

1. A summary of the current fleet composition; a list of expected changes in the fleet due to new procurements, rehabilitation, retrofits, and vehicle retirement; and a description of the anticpated impacts of these changes on maintenance staff, facility, and equipment

2. A brief description of current facilities and shop equipment; a description of current deficiencies; and a list of anticipated needs resulting from expected fleet changes

3. A list of currently budgeted maintenance staff positions; a review of the need for additional positions and reasons that existing positions are unfilled; and a description of staffing impacts of anticipated fleet changes

4. A summary of recruitment and training, focusing on reviews of the effectiveness of testing procedures used in hiring and promotion, the adequacy of training given mechanics to insure that they are qualified to maintain new equipment, and hiring strategies (including experience requirements, wage scales relative to other industries, and alternative training approaches)

5. A summary of the preventive maintenance program used in the previous year; a list of problems encountered in compliance with this program; and a description of any anticipated changes in the PM program

6. A description of pre-run inspection procedures; an assessment of driver compliance and maintenance follow-up; and a statement of changes needed to insure compliance with these procedures

7. A summary of any problems encountered with the inventory system; and a description of changes needed to accomodate new vehicles, special campaigns, or retrofits

8. An analysis of roadcalls and missed trips, to identify casues, direction of trends, and possible remedial actions, as well as an assessment of strategies adopted as a result of problems encountered in prior years.

9. A comparison of budgeted and actual expenditures; an analysis of the reasons for variances between budgeted and actual figures; an analysis of the impact of anticipated fleet changes on budget needs; and a statement of expected future budget needs

10. A review of any problems with current written (or unwritten) policies or procedures; proposed changes; and an evaluation of the effects of any changes made over the past year

While this list may appear imposing, our case studies suggest that systems which engage in periodic reviews of these factors are likely to have positive performance records. A planning process based on these elements would encourage long term maintenance planning at transit systems, and it would result in the generation of written evidence of problems, remedial actions taken, and performance and cost benefits.

B. Quality Assurance

The need to establish an independent quality assurance program for maintenance emerged during our study. This program, whether conducted by an entire department or one person in a full or part time position, should monitor the performance indicators identified as measures of system goal attainment. This individual or department could also be responsible for supervising the preparation and monitoring of the maintenance plans. They should also be responsible for spot checking maintenance work to insure adequate inspection and correct repair and replacement. This course of action is strongly suggested by our research which found that the scope and level of detail of written policies and procedures and the frequency of inspections are secondary to the quality of inspections and work performed. The establishment of an independent check of maintenance work would closely parallel existing quality assurance programs in other industries. The existence of such a function would facilitate compliance with federal requirements since one person or group would be monitoring systems performance on an annual basis. This centralization of information would make UMTA's required tri-annual easier review and quicker to conduct and possibly increase the accuracy of information reported.

C. Review Issues

We recommend that the Federal triennial review of maintenance effort be confined to a review of local efforts as reflected in annual maintenance plan documents. The focus of attention in each of the topic areas listed in Section A could be guided by the questions listed under the following headings.

1. Fleet Composition
   Have year-to-year changes in the fleet been assessed to determine probable impacts on and changing needs for staff, equipment, garages, and shops?

2. Facilities and Equipment
   Have known deficiencies been elminated? Have fleet-related needs been accomodated?

3. Staff Positions
   Have needed staff changes been made?

4. Recruitment and Training
   Has there been a review of hiring, training, and testing practices? Have necessary modifications been made?

5. Preventive Maintenance
   Has the system monitored compliance with its stated PM intervals? Have reasons for variations from mileage targets been analyzed? Has the effectiveness of the PM program been reviewed?

6. Pre-Run Inspections
Have pre-run inpsections been conducted on a regular basis?

7. Inventory
Have inventory system adjustments been made to accomodate fleet changes.

8. Roadcalls and Missed Trips
Have causes of these events been identified? Has the effectiveness of remedial actions been evaluated?

9. Budget
Have budget impacts of system changes been analyzed? Is there documentation indicating that variances between budgeted and actual amounts have been analyzed? Have problems resulting in excessive overtime or unfilled positions been remedied?

10. Policies and Procedures
Has the plan been updated on an annual basis? Have goals and performance targets been established/

We recommend that the UMTA review team be prepared to offer constructive advice as part of the review. This should include information on equipment, training, work scheduling, management control, inspection procedures, and new products. It should also include specific recommendations on alternative approaches for dealing with problems in the areas which are covered by the maintenance plan. The review should not focus as strongly on the question of compliance with PM intervals as did the recent GAO Report, "DOT Needs Beter Assurance that Transit Systems are Maintaining Buses" (GAO, 1983) because there is little evidence that 500-1000 mile departures from planned targets are critical to vehicle performance. Our field work indicates that the quality of inspections is more important than strict adherance to scheduled inspection intervals. The timeliness of preventive maintenance inspections is one indicator of overall maintenance performance and management, but it snould not be the sole measure of maintenance effort. We note that unit cost analysis and component failure rates are not and most likely will not be available at the vast majority of transit systems because current industry practices concerning maintenance data and the limited use of computers for maintenance severely limit the number of systems which could easily and accurately report this information. Therefore, the absence of these data should not be used as a major measure of maintenance adequacy.

D. Research and Technical Support Needs

Several research and technical support needs were suggested by our site visits. An important topic for technical assistance is pre and post run inspection procedures. Our results showed that the establishment and enforcement of this procedure is perfectly correlated with the roadcall experience of our case systems. A very small study should be conducted to confirm this result, identify potential barriers to driver involvement in inspections, and develop a strategy for introducing this conception in systems which do not currently require such inspections. Three other technical assistance needs were noted: (1) There was strong sentiment that a cross-listing of interchangeable parts would reduce inventory space and control problems; this list could take the form of a paper list with periodic updates, or a computerized cross-reference program. (2) Inventory clerks and managers cited a need for a flexible computerized inventory control system which could accomodate fleet mix changes and automatically cross-reference interchangeable parts. (3) Technical support for computerization of management information systems was also noted as a need; several of our sites reported unsuccessful attempts at computerization, and other noted that their staffs need to be educated about the capabilities of computer systems.

Fruitful research efforts could be conducted in several areas. The first area is maintenance inspection and preventive maintenance policy. We found that there were no strong indications that PM mileage intervals are strongly correlated with performance. We also found that unit cost and component reliability data are not routinely collected. We also heard that the quality of PM inspection work is often suspect. There is, therefore, little basis in our cases to decide upon the appropriate mix of inspections, monitoring, and unit changeout in maintenance. What is needed is a careful compaison of these methods in an environment which would provide for a fair test of the costs and effectiveness of these maintenance strategies. This enviromment should include unit costing and failure tracking capabilities as well as quality controls on mechanic and driver compliance with inspection and servicing schedules.

A second research topic is that of manpower planning. Our findings regarding training, testing, and salary levels indicate that practices in these areas are changing, but there is little consistency in the pattern we have observed. The need for further information on this topic is especially important because none of our systems had any formal mechanism for evaluating the effectiveness of their manpower approaches. We did not analyze the content of training programs in detail, but we did find that a broad range of approaches were used, ranging from minimal system orientation sessions to elaborate classroom and on-the-job apprenticeship programs.

A related topic is worker-management communication. Our case studies indentified a number of instances where labor and management had adversarial relationships and where there were morale problems. But we also found several systems which actively utilized worker input in developing and evaluating maintenance procedures. Detailed analysis of the reasons that systems differ on these dimensions could identify ways to improve labor-management relations.

A final research topic is the reinforcement of models of maintenance performance. The regression analyses we did in our site selection process has relatively low predictive ability, and our cases identified a number of factors not included in the Section 15 data which should be tested in a formal modeling effort. This would include quantification climatological variables and pre-run inspection policies; it should also include staffing levels and policies on utilization of old and new vehicles. A time series analysis of the effects of PM intervals on reliability could also be conducted. These efforts would be useful for future attempts to define the range of resource requirements and performance which can be expected given changes in local service profiles and management policies.

7. Conclusions

The experiences of the eight systems reviewed in this report provide ample support for the argument that every system has unique features which make it difficult to conduct cross-system comparisons. However, we have identified a number of practices which are typical of successful maintenance operations and which logically should contribute to positive performance. These practices are:

1. Conduct of pre and post-run inspection by drivers

2. Establishment of performance targets, development of performance measures, and periodic review of trend analyses

3. Development of written statements of or informal consensus about maintenance policies and procedures

4. Coordination of vehicle procurement decisions with inventory planning and staff development activities

5. Establishment of strategies for recruiting, testing, training, and retaining skilled staff

6. Establishment of cooperative working relationships between workers and management

7. Avoidance of unmanageably diverse fleets

8. Periodic performance assessment and evaluation of alternative strategies for improving maintenance effectiveness.

Our review of these cases has also generated a model for maintenance planning which may be of use to both maintenance managers and general managers as a tool for improving performance and expressing organizational priorities. Key elements of this planning model could serve as a basis for Federal monitoring of the maintenance of equipment purchased with capital grant funds.

The cases have also led to the development of a number of research questions which are related to the elements of the maintenance planning model. These include analysis of the role of drivers in vehicle condition monitoring, evaluation of alternative maintenance policies and PM intervals, development of worker-management quality improvement models, and analysis of recruitment, training, and compensation issues.

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Appendix A

Systems Included in Section 15 Regression Analyses

AC Transit
Oakland CA

Transit Authority of Harris Co.
Houston, TX.

Milwaukee County Transit
Milwaukee, WI.

Metropolitan Dade Co. Transit
Miami, FL.

Denver RTD
Denver, CO.

Orange County Transit
Garden Grove, CA.

Tri County MTD
Portland, OR.

VIA Metropolitan Transit System
San Antonio, TX.

Santa Clara County Transit District
San Jose, CA.

Niagara Frontier Transit Authority
Buffalo, NY.

San Diego Transit Corp.
San Diego, CA.

Kansas City Area Transit Aurthority
Kansas City, MO.

Utah Transit Authority
Salt Lake City, UT.

Memphis Area Transit
Memphis, TN.

Metropolitan Suburban Bus Authority
East Meadow, NY.

Transit Authority of River City
Louisville, KY.

Phoenix Transit
Phoenix, AZ.

Central Ohio Transit Authority
Columbus, OH.

Connecticut Transit
Hartford, CT.

Rochester-Genesee RTA
Rochester, NY.

Sacramento RTD
Sacremento, CA.

Omaha Transit Authority
Omaha, NE.

Rhode Island RTA
Province, RI.

Capital District Transit Authority
Albany, NY.

Pioneer Valley Transit
Springfield, MA.

Indianapolis Public Transit
Indianapolis, IN.

Queens Transit Corp.
Flushing, NY.

Green Bus Lines
Jamaica, NY.

Madison Metro
Madsion, WI.

Long Beach Public Transit
Long Beach, CA.

Toledo Area RTA
Toledo, Ohio

Birmingham/Jefferson County Transit
Birmingham, AL.

Appendix A (cont'd)

Greater Richmond Transit
Richmond, VA.

Jacksonville Transit
Jacksonville, FL.

Central New York RYA
Triboro Coach Corp.
Jackson Heights, NY.

Nashville MTA
Nashville, TB.

Suntran of Tuscon
Tuscon, AZ.

Broward County Commission
Ft. Lauderdale, FL.

North Surburban Metropolitan Transit
Des Plaines, IL.

Jamaica Buses
Jamaica, NY.

Steinway, Transit Corp.
Flushing, NY.

Santa Monica Motor Bus Lines
Santa Monica, CA.

Pentram-Hampton
Hampton, VA.

Connecticut Transit-Hartford
Hartford, CT

Des Monies Metropolitan Transit
Des Moines, IA.

Akron Metro RTA
Akron, OH.

MASSTRANS
Oklahoma City

Oceanside County Transit
Oceanside, CA.

Lane County MTD
Eugene, OR.

Transit Authority of Northern Kentucky
Newport, Kentucky

Gary Public Transit
Gary, IN.

Charlotte, Transit
Charlotte, NC.

Bridgeport MTD
Bridgeport, CT.

CITRAB-Fort Worth
Forth Worth, TX

Riverside Transit
Riverside, CA.

Duluth Transit
Duluth, MN.

Dart-Wilmington
Wilmington, DE

City of Spokane Transit System
Spokane, WA

Metro Tulsa Transit
Tulsa, OK

Omnitran
San Bernardino, CA.

El Paso Transit
El Paso, CA.

Canton RTA
Canton, NY.

SUNTRAN
Albuquerque, NM

Riverdale Tranist Corp.
Mount Vernon, NY

Winston-Salem MTS
Winston Salem, NC.

Knoxville Transit
Knoxville, TN.

BERTA
New Bedford, MA.

Tampa MTA
Tampa, Fla.

Capital Area Transit
Harrisburg, PA.

Austin Transist System
Austin, TX.

Santa Cruz MTD
Santa Cruz, CA.

Worcester, RTA
Worcester, MA.

Kanawha Valley RTS
Charleston, WV.

Chattanooga Area RTA
Chattanooga, TN.

Western Reserve Transit
Youngstown, OH

Wichita MTA
Wichita, KS.

Erie MTA
Erie, PA.

St. Petersburg MTS
St. Petersburg, F.

Flint Mass Transit
Flint, MI.

Lincoln Transit
Lincoln, NE.

Club Transportation Co.
Yonkers, NY.

Kalmazaoo MTS
Kalamazoo, MI

Fort Wayne PTC
Fort Wayne, IN

Lehigh/Northhampton TA
Allen town, PA

Luzerne County TA
Kingston, PA

Champaign-Urbana MTD
Urbana, IL

Greater Portland Transit
Portland, OR.

Central Pirellas TA
Clearwater, FL

Colorado Springs Transit
Colorado Springs, CO

Corpus Christi Transit
Corpus Christi, TX.

Savannah TA
Savannah, GA.

City of Salem MTD
Salem, OR

South Bend PTC
South Bend, Ind.

Shreveport Transit
Shreveport, LA

City of Raleigh Transit System
Raleigh, NC.

Baton-Rouge CTC
Baton Rouge, LA

Central Arkansas Transit
Little Rock, AR

Stockton MTD
Stockton, CA

Westport Conn. DOT
Westport, CN.

Lexington/Fayetteville
Lexington, KY

METRA
Columbus, GA

Ann Arbor Transit
Ann Arbor, MI.

Sorta
Cincinatti, OH.

Dallas Transit
Dallas TX.

Santa Barbara MTD
Santa Barbara, CA.

Bay County MTA
Bay City, MI.

Westchester Transit
Yonkers, NY.

New Bedford SEMTA
New Bedford, MA.

Command Bus Co.
Brooklyn NY.

Lane County MTD
Eugene, OR.

Rockford MTD
Rockford, IL

Florida Transit Management
West Palm Beach, FL.

Mountain View Coach Lines
West Cotsack, N.Y.

Fresno Transit
Fresno, CA.

Connecticut Transit
Hartford, CT.

Tacoma Transit
Tacoma, WA.

San Mateo County TD
San Mateo, CA.

Brockton Area Transit
Brockton MA.

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