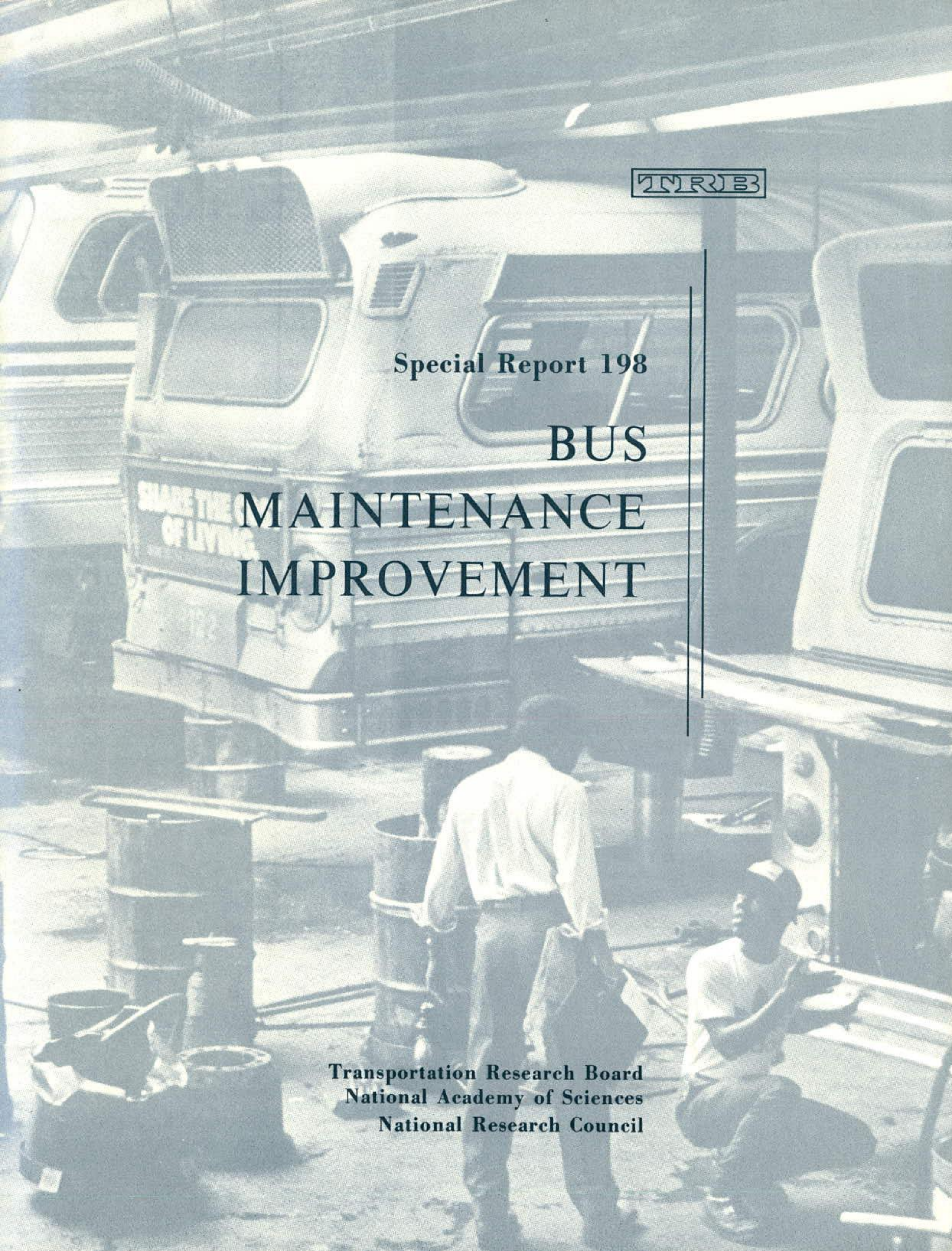

TRB

Special Report 198

BUS MAINTENANCE IMPROVEMENT

Transportation Research Board
National Academy of Sciences
National Research Council

1983 TRANSPORTATION RESEARCH BOARD EXECUTIVE COMMITTEE

Special Report 198

BUS MAINTENANCE IMPROVEMENT

Proceedings of the Bus Maintenance Improvement Workshop
April 14-16, 1982, St. Louis, Missouri

Conducted by
the Transportation Research Board
and Sponsored by
the Urban Mass Transportation Administration
U.S. Department of Transportation

Transportation Research Board
National Academy of Sciences
National Research Council
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Preface

This Special Report contains the proceedings of the Bus Maintenance Improvement Workshop held on April 14-16, 1982, in St. Louis, Missouri. The workshop was conducted by the Transportation Research Board under the sponsorship of the Urban Mass Transportation Administration, U.S. Department of Transportation. The purposes of the workshop were to exchange information on current transit industry practices related to vehicle maintenance, to define industry needs, and to generate suggestions for research, development, and technical assistance programs in the maintenance area. The 63 conference participants represented state departments of transportation, local transit properties, manufacturers, and consulting firms.

At the plenary session, A. B. Hallman of the Urban Mass Transportation Administration presented the charge to the workshop and the working groups. George Heinle of the New Jersey Transit Corporation and Robert Mora of the Denver Regional Transportation District (for Michael M. Smith) presented keynote addresses on industry needs (see Part 1).

Five topic areas were used to focus the discussion of maintenance needs:

1. Management's role in maintenance,
2. Management tools for improving maintenance,
3. Human resources,
4. Facility and equipment needs, and
5. Vehicle design, acceptance testing, and maintenance support services.

Each of these topics was addressed by issue and resource papers presented at a general session on the first day of the workshop. Subsequently, participants broke into five working groups to discuss the specific topics and develop strategies for improving maintenance effectiveness.

Working-group participants discussed the state of the art in their areas, identified current problems, and ranked suggestions for further development and technical assistance in each area. The interrelatedness of the working-group topics should be noted. Although it is possible to separate the areas relating to maintenance for academic purposes, in reality the areas are not exclusionary. Thus, although the working groups had distinct topics, many of the problems identified and suggestions made crossed over the boundaries of the individual working groups.

The findings of the groups are summarized in Part 2; the workshop reports, along with the appropriate resource papers, are presented in Part 3.

The assistance of the paper authors, chairpersons, reporters, participants, and TRB staff is gratefully acknowledged. The workshop and these proceedings would not have been possible without their efforts. I would also like to acknowledge the contribution of Jeanne Zimmer, who drafted the Conference Summary and assisted me in writing the Summary of Findings and Suggested Strategies.

James F. Foerster
Conference Chairman

Part 1

Introduction

Conference Overview

Declining productivity, diminishing cost-effectiveness, and decreasing operating efficiency all indicate that the current state of the urban mass transit industry is not good. Given the decline in the experience level of the work force, the increase in vehicle complexity, and the loss of federal operating subsidies, it appears that maintenance performance problems in particular will continue to increase rather than subside.

It has been suggested that history is repeating itself: As in the 1950s and 1960s, the industry is faced with increasing costs and declining revenues. Federal funding has created an environment in which transit management has become too reliant on external resources. Today it is essential that energy be devoted to controlling costs. It is important to determine how costs can be reduced without affecting the quality and quantity of service. The mass transit industry must begin to view itself as a private industry would--that is, using a profit-and-loss approach to management. The major cost factors influencing the delivery of good transit service are labor, materials, and equipment.

Perhaps the best way to reduce operating costs is through increasing the efficiency, performance, and productivity of the maintenance function. Beyond bus operator costs, the maintenance function is responsible for the bulk of operating costs. Maintenance managers have limited control over operating revenue, yet they have a major responsibility for operating costs as well as the type of service provided. The question that must be addressed by the transit industry is how to accomplish more with less.

The Bus Maintenance Improvement Workshop focused detailed attention on maintenance and ultimately on the formulation of suggested maintenance-related research and development (R&D) options. The workshop examined the state of the art in bus maintenance and identified problem areas and potential solutions. The exchange of information on current industry practices was of principal importance to participants, as was the generation of suggestions for R&D and technical assistance programs in the maintenance area.

A major concern of the workshop participants was the lack of emphasis placed on maintenance by other areas of the industry. Perhaps the greatest question in this regard is how to increase awareness of and appreciation for the maintenance function. In assessing the needs in this area, the working groups focused on the need to reinforce the importance of maintenance through the development of a basic package of materials that could be delivered in different modes, such as journal articles, professional meetings, and video simulation programs.

Directly related to this issue is the lack of effective communication between the various property functions. Inadequate linkages between the finance and maintenance functions, in particular, result in inadequate budget allocations. Suggestions for closing the communications gap include the establishment of credibility between the various groups, the delineation of responsibilities and relationships within the property, and the development of a comprehensive organizational plan.

The lack of information collection and dissemination on a national scale was determined to be a principal barrier to effective maintenance. Group 3 participants pointed out that many problems are shared by individual properties but that there is no effective means of communicating relevant information. This group suggested that a survey be undertaken to examine the common information needs of transit properties and to design a multichannel system or technique for meeting those needs.

Other areas identified as requiring an industrywide network for information exchange include bus defects that are manufacturer specific, part interchangeability and cross referencing, and facility construction and equipment innovations. It was concluded that the "grapevine", which is the current method of communication between transit properties, is not an effective means of disseminating information, particularly since many of the smaller properties are excluded from this network. Group 2 suggested that national centers be developed to deal with major model-specific bus defects to aid in the identification of fleet problems. It was suggested by Group 4 that exchange seminars be held to aid in the dissemination of information developed by individual properties. It is hoped that an American Public Transit Association (APTA) incentive program, similar to the bus rodeo, may encourage the submission of improved tools and techniques developed within properties.

Another theme reiterated by several of the working groups is the need for the development of industrywide standards, measures, and guidelines in diverse areas. For example, Groups 1, 3, and 4 expressed the need for property-level performance policies, measures, and/or standards. The lack of performance measures and standards not only hampers training and planning but also makes it difficult to quantify the effects of any improvement or change in maintenance. Regarding this need, Group 3 suggested that UMTA undertake a survey of properties and other industries to determine work standards and measurement techniques. The results of the survey might then be disseminated through a training program designed specifically to communicate the concepts and techniques to interested parties. Any standards, it was felt, should reflect achievable levels of performance with proven maintenance information systems and training programs and should be adaptable by individual properties.

Related to the need described above is the desire for computerized measures and standards. Group 2 participants emphasized the need for a computerized maintenance management information system (MIS). One evidence of this need is the lack of data available to a property concerning its bus fleet. Groups 1 and 4 also ranked the development of an MIS for maintenance as a top priority. It was determined that there is a need to define the functions and features of a good maintenance MIS and also to develop training materials to facilitate the transition from manual to computerized maintenance MIS.

The lack of trained mechanics, generally recognized as a major problem, was specifically discussed by Groups 3 and 5. Personnel problems such as poor attitude and lack of motivation are complicated by the increase in the complexity of vehicles and the decrease in technical information and training and/or maintenance manuals. An increase in manufacturer technical support was recommended by both groups; Group 3 suggested that manufacturers be required to deliver job performance aids with equipment. It was also suggested that UMTA undertake a survey of motivation and attitude to identify the specific nature of the problem and its causes. A second UMTA survey was suggested to discern the availability and utility of training programs, materials, and concepts.

Several problems and conditions related to the physical aspects of maintenance were identified by Groups 4 and 5. The purchase of new buses has often been given priority over the construction of new maintenance facilities and the purchase of new equipment. Because the quality of maintenance inspection has a major effect on total maintenance costs, there is a need for the development of reliable inspection equipment, particularly equipment designed to determine the structural integrity of vehicles, in order to prevent in-service structural failures. Development of diagnostic test equipment was also given high priority. Group 5 stated that reliability and maintainability should be improved through specifications and design. Manufacturers should be encouraged to simplify vehicle subsystems to make them easier to maintain, and builders should develop all test and repair equipment required to service their vehicles, including comprehensive maintenance manuals and wiring diagrams.

Various suggestions were made by the working groups regarding funding of R&D. A consensus seemed to exist that the most appropriate mechanism would involve joint funding by UMTA and individual properties, with manufacturer support. An example of the combined funding approach to R&D is the Western Transit Maintenance Consortium, which is discussed in the report of Group 2.

Keynote Papers

MAINTENANCE RESEARCH AND DEVELOPMENT NEEDS IN THE TRANSIT INDUSTRY

George W. Heinle
New Jersey Transit Corporation

It has often been said that excellence in maintenance is the key to a successful bus operation. In the days before heavy government involvement in the industry, the profitable private operation was usually the one that had best succeeded in putting together the proper combination of good equipment specifications, efficient maintenance procedures, and an experienced maintenance work force. With the advent of federal subsidies for capital equipment, far too often there was a tendency on the part of transit management to use the acquisition of a new bus fleet as an opportunity to reduce maintenance operating costs. Because of the limited availability of capital funds, the purchase of new buses was also often given priority over the construction of new maintenance facilities. Furthermore, as a result of retirements there are fewer and fewer experienced bus maintenance managers and highly skilled mechanics. Far too little has been done in the industry to train replacements, and the industry has offered neither the opportunity nor the salaries necessary to attract enough top-quality replacements. The result has been a growing reliance on operational subsidies and a declining quality of maintenance performance.

There has been far too much finger pointing as opposed to a constructive, coordinated program of improvement. We have all heard that bus manufacturers do not build the quality into new buses that they used to, or that the new buses are much too sophisticated and impossible to maintain, or that you just do not get workers who are real mechanics any more, or that the union is the real culprit for inhibiting maintenance improvements, or that maintenance managers really do not know what they are doing, or that UMTA is responsible because it dictates bus specifications and procurement practices. Of course, the real truth is that each of these items has had some impact in producing the conditions with which we are now faced. All leaders in the industry must take some responsibility as well.

The challenge that we face and the purpose of the Bus Maintenance Improvement Workshop is to evaluate where we are today and what we need to do to achieve the desired quality of maintenance performance. To do this, we need to concentrate both our management skills and the resources of the industry on producing (a) improved management systems, (b) better-qualified employees, (c) better vehicle maintenance equipment, and (d) better, more reliable vehicles. Separate sessions of this conference will concentrate on each of these areas. My purpose is to identify, from my perspective as an engineer, maintenance manager, and general manager of a bus operating property, several unmet R&D needs that this workshop should consider in its pursuit of improved bus maintenance. We also need to consider how R&D innovations can be most effectively translated into working tools for the industry and what role UMTA should take in the entire process.

I believe that an appropriate R&D program is one that recognizes not only the state of the art but also the state of the industry. It should effectively "work both sides of the street at the same time"; that is, it should be directed toward providing longer-lived, more reliable, more easily maintainable equipment while at the same time establishing systems that, to the greatest extent, remove human judgment from the maintenance process and automatically flag deficiencies and/or breakdowns in either the process or the people. Maintenance processes should be developed to the point where they are self-monitoring in terms of both quality and quantity of production. An example of this type of technological development is recording and monitoring systems for consumables (fuel, oil, and water). The ideal system for this purpose will have built-in thresholds so that the maintenance manager is not required to inspect voluminous records or make a decision as to whether or not the records indicate a deficiency. Along these lines, there is a need to develop a standardized diagnostic system for buses. Such a system should be related to the on-board daily service check and also have the capability, through the use of a chassis dynamometer, to perform a comprehensive periodic inspection. Although considerable work has been done in this area, it has been fragmented and the dissemination of information to the industry has, to a great extent, been neglected.

Much has been done in recent years with maintenance management information systems, which can provide a valuable tool for monitoring the maintenance process and determining a need for improvement in both production quality and employee performance. There is a need, however, for substantially more work in this area toward the development of packages that are easily implemented and that provide the self-monitoring capabilities required to free maintenance managers to attend to the human aspects of their job. The industry has made little use of the output of maintenance management information in establishing the service life of units and identifying the more critical product improvement needs. Practically every maintenance person today will tell you that the V730 transmission needs quality improvement because it has a high rate of failure. On the other hand, what about those units that do not show such a dramatic failure rate but nonetheless fail far too soon in their formal life cycle, increasing road failures and maintenance costs? There is a need not only to build this kind of information into maintenance information systems on a local level but also to develop these means for collection and identification problems on an industrywide basis. This type of analysis infers that we should be "working the other side of the street" to achieve improved product design and greater built-in quality. Some of the recent experiences of the industry indicate a decline in product quality instead of this kind of improvement and point to a need for R&D to achieve better-quality assurance programs along with better preproduction testing and qualification of both the bus units and the entire bus system. The introduction into the American marketplace of many new (including some foreign) buses can only tend to accentuate the need for some standard prequalification system. Although UMTA has sponsored tests in specific cases, all too often these studies have been protracted and have failed to result in substantive improvements. The lack of an adequate system for measuring new-product quality can only result in conflicting subjective evaluations by maintenance managers and costly and time-consuming retrofit programs. In this area of bus design and bus equipment, I believe that current problems related to short brake lives and transmissions also call for a new look at both retarder systems and the diesel-electric drive.

But what about the problem of translating R&D improvements into action? As one who has been involved in many of these programs, some sponsored by UMTA and some not, I am convinced that there is a need for much broader industry participation and less direct UMTA participation in R&D projects. The local property, and particularly the maintenance manager, need to feel that they have been a part of the developmental process. They have to want to implement the system and will do so if they feel that it is partly their idea. That is not to say that the R&D process does not need project managers who can give direction and control to each of the projects. It is to say, however, that this direction and control should come out of the industry and not the federal government. UMTA unquestionably needs to provide adequate financial support for R&D projects. On the other hand, care must be taken that federal controls do not impede R&D and inhibit the deployment of new systems in the industry. I believe consideration should be given to incentives that would encourage timely results and early implementation of new developments. Finally, there needs to be a commitment on the part of both the manufacturing industry and operating agencies to share a reasonable part of the financial burden of R&D. As an industry, we have been all too slow to recognize the investment that R&D represents toward future efficiency and economies in maintenance operations. Without the necessary commitment, project reports will end up on an executive's shelf gathering dust and the industry will go on in a fragmented way, complaining about how it is all somebody else's fault and how the real problem is that something was not done about it years ago. The time to take action is now. It is my hope that this workshop can come up with a definitive program for R&D that can lead to real progress, in keeping with the motto of New Jersey Transit: "Start Moving in the Right Direction."

MASS TRANSIT: A PERSPECTIVE FOR THE FUTURE

Michael M. Smith
Denver Regional Transportation District

History tends to repeat itself, and mass transit appears to be reliving the experiences of the 1950s and 1960s when private transit operators were faced with increasing costs and declining revenues. In the past 15 years, federal funding has created an environment in which transit management may have become too reliant on external financial resources rather than devoting the necessary energies to controlling costs.

Under the present Administration, federal subsidies have been reduced dramatically. The greater part of the burden has been shifted squarely on to the shoulders of the transit properties themselves, which are searching for a way to provide for present and future demands for transit service with decreased operating revenues. What innovative means do transit operators use to cope with labor, material, and equipment costs and budget restraints and at the same time provide efficient and cost-effective transit service to the public?

Alternative funding is a means but not the total solution. The increased efficiency, performance, and productivity of our established maintenance function would appear to allow us greater future control than expectations of additional funding as the cure to our present dilemma.

Transit managers are now faced with an opportunity to rise to the occasion. Many observers may believe that the difficulties now facing mass transit are insurmountable without additional sources of revenue, and they may be right. But each of us faces a significant management challenge--to find creative solutions to reduce operating costs without affecting the quantity and quality of transit service to our passengers.

Transit has often been perceived as being quasi-political in nature because it is a public service similar to other municipal functions within city government. We are often perceived as being bureaucratic and accountable to no one other than the political bodies within our service areas. Many transit managers perceive themselves as being accountable to too many groups, including boards of directors, the public, oversight committees, community groups, and state legislatures. The accountability is, in fact, there and it will increase significantly as funding decreases. Such an environment will spotlight the efficiencies and inefficiencies of mass transit.

It is time for us to begin viewing ourselves as similar to managers in private industries. Although we do not have a profit-and-loss motivation, we would be wise to adjust our thought process to this type of philosophy. In transit, the operating ratio is the equivalent to profit and loss. Operating ratio can be defined as total operating revenue (farebox revenue) divided by total operating cost (operations and maintenance cost). An increase in operating ratio can be analogous to an increase in profit. Conversely, a decrease in operating ratio can be comparable to a decrease in profit. Due to the current trends in mass transit and because it is just good business sense, our goal should be to increase our "profits" to ensure the long-term financial viability of our organizations.

Our success in meeting the management opportunities that we now face depends on increasing revenues while decreasing costs without affecting our product--quality transportation service to the public. We must greatly improve service in order to keep our heads above water in our competition against the automobile.

This paper assesses a potpourri of alternatives that might be worth considering in addressing these challenges. For the purposes of discussion, I will assess the cost side of the equation.

In any business the major cost factors that influence the delivery of a product could be defined as follows:

1. Labor,
2. Materials and supplies, and
3. Equipment.

Transit has historically been a labor-intensive business. Most transit operators recognize that labor represents as much as 75 percent of their operating cost. The bulk of this cost is for bus operator wages. The maintenance function absorbs most of the remaining operating costs. Maintenance managers have limited control over operating revenue, but they have a primary responsibility for operating costs. It should be noted that maintenance managers do have a dramatic impact on the type of service provided--i.e., the cleanliness of the equipment, service reliability, etc. These factors are clearly relevant to the marketability of the transit service and potential increases in operating revenue.

From my perspective as a director of transit operations, I am concerned with controlling costs within the maintenance function without sacrificing quantity or quality. The question I raise within my organization is, How can we accomplish more with less resources, meaning less manpower, material, supplies, and equipment?

The following issues represent key factors that are worth examining in considering how to manage more effectively while focusing on productivity.

COST CONTROL AND AVOIDANCE

Due to the pressures currently imposed on all transit managers, it becomes imperative for each manager to assess his or her function as it relates to current costs and future cost avoidance. Such an assessment should consider the acceptable standards of performance within the organization and the resultant costs. The assessment should include all major factors within the maintenance function to determine what steps should be taken to decrease costs while increasing efficiency.

Quality control of in-house functions can have a substantial influence on the reliability of our own product, help to establish acceptable standards, lower costs, and increase productivity and performance. Monitoring outside services, in conjunction with a strong warranty section, can help avoid costs that should not be incurred. A technical services function should be able to supply the necessary assistance, techniques, and information for potential long-term savings in vehicles, equipment, and material design.

Evaluating positions as they become vacant can produce substantial savings over the short and long term. Some functions may be eliminated, or man hours may be shifted to increase efficiency and thus increase potential savings. The potential for savings through the hiring of part-time employees and subcontracting maintenance functions to outside services can be substantial. It allows the normal work schedule to continue without interruption and allows for completion of necessary retrofits without full-time resources.

Labor costs certainly must be monitored and controlled. Effective training, absenteeism policies, and negotiation practices can all keep productivity up and costs down. Even layoffs, although negative (especially to those affected), can have positive results if implemented properly. Eliminating nonproductive positions can lower costs without affecting productivity. It is quite possible that productivity may even be increased due to a heightened awareness among remaining employees of the need for productivity. If improperly handled, layoffs could place more of a burden on those remaining and reduce their effectiveness.

ORGANIZATIONAL STRUCTURE FOR THE MAINTENANCE FUNCTION

Traditionally, the transit industry has segregated its functions into maintenance and transportation. Maintenance can be broken down further into vehicle maintenance, district shops (heavy repair), facilities maintenance, materials handling, etc. The result is that the boundaries get set, the walls get built, and communication decreases.

For an organization to be effective, interaction between managers is essential. It is impossible to achieve organizational goals and objectives if everyone is headed in different directions.

Currently, my own organization, the Denver Regional Transportation District (RTD), is undergoing a change in structure from the traditional approach shown in Figure 1 to the accountability-centered approach shown in Figure 2, shifting the burden of responsibility to the division and facility level. The Boulder/Longmont, Alameda, Platte, and East Metro titles represent the operating facilities of the Denver RTD.

The traditional approach, with the various line functions responsible to a different manager, may prove successful for transit companies that are not multidivisional or might continue to succeed if the current level of public funding were to continue. However, public demand for improved transit services, coupled with decreased federal assistance, increases the necessity to explore management approaches aimed at providing the best possible service in the most cost-efficient manner.

The accountability-centered approach conceptualized in Figure 2 transforms the traditional fragmented line-function management approach into a

Figure 1. Traditional organizational structure.

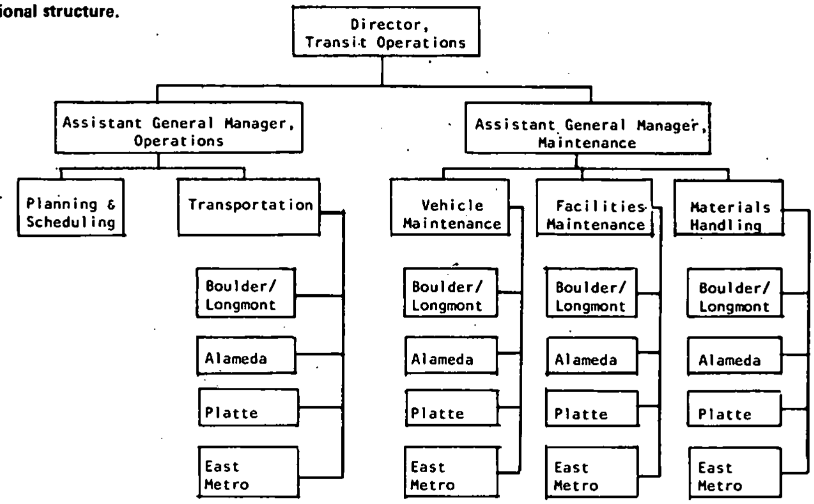
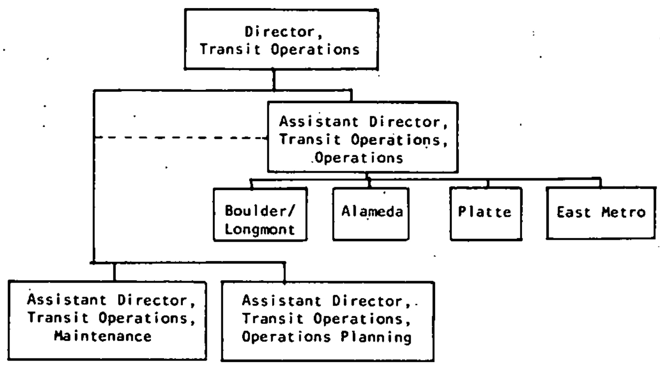


Figure 2. Accountability-centered organizational structure.



management plan that has proved successful in private business promotion. Such a plan includes

1. Budget and cost control,
2. Coordination of all necessary functions for managing an individual operating division,
3. Problem solving at the division level with access to systemwide support staff,
4. Decisionmaking at the lowest possible level within the organization, and
5. Increased accountability, responsibility, and authority.

This approach will transform the management philosophy of the Department of Transit Operations into one that is similar to a private business model and consistent with long-term organizational commitments to achieve greater cost efficiency and improve service to the public.

SUPERVISOR SELECTION AND TRAINING

The managing of any function depends on the quality of supervisory management and staff. This issue is seldom given adequate consideration in developing the strength of an organization. Quite often, organizations have a tendency to select people who are technically competent but who may not necessarily have the required management skills and abilities. Some organizations use a haphazard technique in selecting a supervisor and then spend an inordinate amount of money in attempting to develop that individual to meet the demands of the position. In reality, the selection of a supervisor or manager is one of the most critical elements in developing an effective management team.

The most logical approach to proper selection is to first define what we consider a "good supervisor". What qualities do we desire and need? Should he or she possess technical skills, interpersonal skills, or a combination of both? What does the position being filled require? How do we determine management potential? In the selection process, it is worthwhile to consider that it is quite difficult, if not impossible, to motivate people, and advisable instead to provide the atmosphere that allows people to motivate themselves.

Methods of selection are numerous. In-house supervisory trainee programs can be set up to allow individuals to evaluate the positions, and their own potential, in conjunction with management's appraisal of the candidates. Many colleges, trade facilities, and even high schools establish internship programs with various businesses to coordinate classroom learning with actual on-the-job experience. Both of these approaches provide prior exposure to positions at minimal cost. A balance between promoting from within and hiring from without can achieve positive results by demonstrating that advancement occurs through performance and not length of service. The process of choosing the right candidate can be aided through various psychological tests in the interview process, group and individual interviews (for a more balanced perspective), and even assessment centers to identify given qualities in each individual.

Perhaps as crucial as the right selection process is the additional training support that should follow. Follow-up training must continue to isolate the strengths and weaknesses of both the individuals and the training activities and update the needs arising from changing work practices and equipment. Are the personal and monetary incentives to maintain the quality and integrity of the management staff still present? Outside workshops and seminars can keep us aware of the changes around us.

Often we fail in the next step. The "Peter Principle"--i.e., promotion beyond the employee's level of competence--is often discussed and taken for granted. We should pay special attention to providing an avenue for individuals to return to their most productive level of activity. There is no need to live with the selection of an incompetent manager for 20 or 30 years. This only diminishes the productivity of the individual and those around him or her.

LABOR CONTRACTS

Nationwide, regardless of industry, it appears that the tendency in collective bargaining is to negotiate a contract--its content and duration--with minimal emphasis on long-range planning. The traditional approach of submitting, eliminating, and trading a host of proposals, with final settlement on a few, is inadequate in today's economy. The 10 minutes in allowances here, the additional 5 cents an hour there, etc., compounded over 10-20 years, in perhaps as many contracts, have created an unworkable operating environment.

The historical pattern of labor unions requesting more with each contract, be it wages or fringes or both, is hard to stop and even more difficult to reverse. The recent Port Authority Transit Corporation decision demonstrates that strikes are perhaps not a viable threat. The latest settlements in the automobile industry have shown more interest in job security and have minimized union-management, employee-employer differences. Now is the time to negotiate in the frame of reference that this is "our" company.

In the past, the labor unions have been allowed to use the transit industry as a standard in establishing wage rates. Rather than using other transit properties for wage and/or fringe comparison, more attention should be focused on the demand and corresponding wage structure of similar occupations in the general surrounding geographic area.

The concept of offering contract wage increases and cost-of-living adjustments (COLAs) seems inappropriate without defining increased productivity. Management's first attempt at controlling costs should be to reduce or eliminate COLAs. Managing on predictions of what might and might not happen is most difficult and offers little, if any, control.

The next need is to institute productivity standards wherever possible. Contract wage increases should parallel increases in productivity. The need to cement the relation between wages and increased productivity is basic.

Third, management should establish contract language that results in wage decreases for the less skilled positions, such as bus cleaners, inventory control clerks, custodians, and clerical support functions. These positions are often included in the percentage increases for the skilled positions of operators and mechanics and as a result receive a much higher wage than similar positions in private business.

Transit contracts have always included clauses that allow management the flexibility to respond to changes in the industry and the economy, clauses defined as the "rights of management". Too often, organizations have inserted language in other areas of the contract that contradict and restrict these rights and tie management's hands in effectively controlling costs.

Because labor costs account for more than 50 percent of the maintenance operations budget, it is most important to relate any wage and/or fringe demands to corresponding increases in productivity in order to at least maintain the present operating ratio and, as a future goal, to increase it.

MANAGEMENT REPORT SYSTEMS

Information management will explode in the 1980s. The more complex the function, or the more variables involved, the greater is the need for thorough information systems. This places an increasing burden on information management--data capture, processing, reports, etc.--which focuses on key factors such as labor, materials and supplies, and equipment utilization. The major issue is that managers should have adequate data available to them so that they can analyze and develop solutions that result from trends in the reporting process. Some simple rules to follow in the development of an information management system are

1. Keep it simple and easy to understand,
2. Involve the user as much as possible,
3. Make the system modular in design (whole subsystems),
4. Ensure that data are timely and accurate,
5. Accommodate user involvement,
6. Gear the system to respond to the user's needs and requirements, and
7. Design the system for directing a preventive maintenance program.

Significant progress has been made in the Denver RTD system, due in part to the effort put into the maintenance reporting system. For example, there have been increases of approximately 40 percent in mileage per road call, approximately 10 percent in the average life mileage of engines, 20 percent in inspections completed as scheduled, and increased warranty claims coverage based on the availability of improved coach history. Some of the reports generated include the following:

1. Fuel and oil consumption reports by operating facility, subfleet, coach, and exception basis (designate oil leakers and engines that need rebuild due to high mileage);
2. RTD vehicle inventory and detailed coach history (reference all pertinent coach information for the company);
3. Labor and parts reports (specialized use for maintenance cost data);
4. Maintenance and operating costs per mile (used for cost analysis);
5. Component use (mileage) report, by subfleet (integral part of component change-out and preventive maintenance program);
6. Component repeater report (identifies trouble source and subsystems on specific coaches);
7. Inspection scheduling report (schedules all inspections);
8. Coach history report, which gives activities since the last inspection (reference for the mechanic performing the inspection);
9. Fuel history report (tracks hubodometer and mileage for the entire fleet);
10. Component forecasting report, by subfleet (determines anticipated work-load requirements for all major components for the next 6-12 months); and
11. Road-call reporting, a performance indicator for facility performance and coach reliability (daily, weekly, and monthly reports for specific coach repair and trend analysis).

PREVENTIVE MAINTENANCE

Preventive maintenance is defined as a regularly scheduled program of maintenance by which periodic inspection checks are done to prevent premature failure and provide more reliable service. The initial inspection is only the first ingredient of a sound preventive maintenance program. Even more important is the actual follow-up "hands-on" repair, the essential element before any vehicle is released for service. It is pointless to go through the process of inspecting a bus at 6000-mile intervals and then place it into service with a defective radius rod, power steering pump, or air dryer. Effective preventive maintenance means both inspection and repair.

Perhaps the most difficult aspect of a preventive maintenance program is to determine at what mileage intervals a maintenance action should be taken and whether a component should be changed out before failure. As a maintenance operation becomes more centralized, more attention is given to scheduling intervals and the repair action to be taken. Scheduling intervals consistent with the skill level of mechanical diagnosis and management's confidence of operation require the most cost-effective approach for an overall maintenance operation based on planning experience and assessment.

The relationship between effective preventive maintenance and an established maintenance reporting system should be apparent. Because planning of scheduling intervals is so critical to effective preventive maintenance, the need for a system to gather and disseminate a variety of data in timely reports for proper analysis is of paramount importance.

Preventive maintenance is most productive due to the fact that it is planned. Unscheduled work assignments will be accomplished in a reactionary mode, but this is disruptive to the planned activities and results in increased inefficiencies in man-hours and parts and materials scheduling.

PERFORMANCE INDICATORS AND OBJECTIVES

A process that is often very helpful in improving the overall operation of a maintenance function is the establishment of clear expectations. One of the most effective applications is the formulation of "maintenance performance indicators". These indicators give a manager a quick overview of how a particular facility is operating and what level of performance it is achieving. They provide the "production" numbers that help gauge the operation.

Specific items can include the number of road calls, tune-ups, preventive maintenance inspections completed, brake and wheelchair lift inspections completed, engines and interiors cleaned, and total work loss. For example, the district shops (major repair) report can be on the number of power plants, transmissions, and brake jobs completed.

One of the most valuable benefits is the actual process of establishing mutual targets as part of the overall setting of objectives. The dialogue between management and supervision is enhanced by specific accountability methods that measure both productivity and performance. The Department of Transit Operations recently performed this valuable exercise in stating its 1982 goals and objectives.

In setting performance objectives for 1982, the Transit Operations staff first reviewed the problems involved in their previous goal-setting process. The staff then worked on a solution that would (a) focus departmental goal-setting activities on priority issues; (b) deal with the "vital signs" of specific sections within the department; (c) require statements with clearly stated, tangible goal commitments for each objective as well as the preparation of appropriate methods to collect data and report the information regularly; and (d) provide a framework for interpreting progress toward and achievement of performance objectives to all staff levels and the Board of Directors.

Toward these ends, each section's management team reviewed and analyzed its unique role in the Department as a whole and identified performance indicators on which to base 1982 objectives. During this process, section directors received input from key members of their staffs concerning the "vital signs" of their respective areas; this information was reviewed and discussed by the Transit Operations staff in an effort to crystallize issues of greatest concern, coordinate conflicting objectives, and promote departmentwide focus on RTD attempts to cut costs while maintaining safe, reliable, and effective public transit for the citizens of the six-county service area. The results of the process were the 1982 performance objectives for the Department of Transit Operations, including 2 departmentwide objectives dealing with absenteeism and budget adherence and 29 performance objectives set by the seven individual sections.

As an example, the performance objectives set by various sections of the RTD are outlined below.

Vehicle Maintenance

Performance Indicator
: Miles between chargeable road calls

Performance Objective
: Improve the miles between chargeable road calls by 20 percent from 2475 in 1981 to 2970 in 1982 for a net increase of 495 miles

Miles between road calls is a visible, reasonably accurate indicator of vehicle reliability and maintenance performance. The Vehicle Maintenance Section has monitored this indicator over the past year and has used the data to continually upgrade the preventive maintenance program as well as reduce the number of repeat road calls. The Section's record-keeping system allows for road calls to be reported based on whether the problem was attributable to vehicle maintenance or operator error and whether the occurrence was chargeable or nonchargeable. The information will be reported in this format in order to pinpoint responsibility for correcting problems.

Performance Indicator
: Percentage of preventive maintenance program completed

Performance Objective
: Complete 100 percent of inspections as scheduled, and clear 80 percent of all defects found in inspection process within 48 hours of date of inspection

Percentage of preventive maintenance program completed relates to the Vehicle Maintenance Section's responsibility for repairing all major defects found during the routine inspection cycle. The most tangible result to be obtained in meeting this objective will be increased vehicle reliability. In 1981, approximately 55 percent of all defects found were cleared. The 1982 objective is set at 80 percent in order to maximize the cost-effectiveness of available vehicle maintenance resources. The focus on preventive maintenance should have a positive impact on the other vehicle maintenance performance objectives for 1982.

Performance Indicator
: Repeat road calls

Performance Objective
: Reduce the overall road-call repeat percentage from an average of 15.3 percent of total road calls in 1981 to 12 percent of total road calls in 1982 for a net improvement of 22 percent

The repeat road calls indicator addresses those road calls that reappear in the same general category within 10 days. This information should be useful in detecting troublesome subsystems or identifying the need for a mechanic to acquire retraining in some areas.

Materials Handling

Performance Indicator
Bad-order buses due to out-of-stocks
Performance Objective
Bad-order buses awaiting parts not to exceed a daily average of 2 percent of the system fleet, or 14 vehicles, allocated by facility as follows: Alameda - 3; Platte - 5; East Metro - 3; NOG - 3.

The objective excludes bad-order buses awaiting rebuildable components when Materials Handling can provide the repair parts and rebuildable core. To meet this objective, each division storeroom supervisor has made a commitment not to exceed the daily average number of bad-order buses, based on the current fleet.

Performance Indicator
Total monthly inventory valuation
Performance Objective
Reduce the inventory value from $2.16 million on December 31, 1981, to $1.93 million by December 31, 1982, for a net 10.6 percent reduction

Meeting the objective would result in an approximate $230 000 reduction in valuation for 1982.

Technical Services

Performance Indicator
Monitoring and enforcement of all warranty claims related to vehicle and facility equipment for Transit Operations
Performance Objective
Satisfactorily resolve 100 percent of fleet defects and warranty issues on General Motors (GM) buses

Warranty claims, in general, are not submitted to GM until they are discussed and resolved with the GM representative. Negotiations are sometimes necessary before a problem is solved.

Performance Indicator
Verification of quality control on all incoming parts and materials received for the Maintenance Division
Performance Objective
Save the RTD $52 000 in unacceptable material in 1982, as compared with $42 000 in 1981, or an increase of 24 percent; and, through the inspection of parts and components and development of specifications, increase the reuse volume of parts and components to save the RTD $127 000 in 1982, as compared with $102 000 in 1981, an increase of 24.5 percent

In addition to verifying the quality of incoming goods, Technical Services also monitors parts and components that are rebuilt in-house to ensure their useful life and reliability. In 1982, Technical Services will continue strict adherence to established quality-control standards to reduce waste in high-volume rebuild areas by 30 percent and also continue its efforts to reduce the receipt of unacceptable incoming materials.

Performance Indicator
Project control: electric (brake) retarders
Performance Objective
Complete the retrofit of 259 buses with electric retarders by December 31, 1982, at a cost not to exceed $2 164 800

In order to meet this commitment, it will be necessary to coordinate and provide support to Grants, Contracts and Procurement and to Vehicle Maintenance in the development of the retarder program by April 15, 1982; beginning May 15, 1982, Technical Services will assist, as necessary, in the installation of the retarders, to be completed by December 31, 1982.

Performance Indicator
Project control: evaporative coolers
Performance Objective
Finalize a decision concerning the type of evaporative cooler to be used in retrofitting 525 buses, cost of installation not to exceed $3200/coach

In order to meet this commitment, Technical Services will participate in the evaluation of a rooftop evaporative cooler R&D program to be completed by July 31, 1982; specifications for installation are to be written by August 6, 1982, and an invitation for bids is to be completed by August 17, 1982.

MAINTENANCE JOB STANDARDS

Maintenance job standards are the primary source of comparison in determining and monitoring overall maintenance productivity and efficiency. It is management's means of establishing not only what is acceptable but also what is not acceptable. Its value in a production or assembly line operation has been proved. But it can also be used in a maintenance facility for the more common and identifiable tasks. If productivity issues are not addressed thoroughly and if the diagnostic process is failing, management can shift its focus to more "remove and replace" functions, similar to an assembly line practice, replacing the diagnostic trouble-shooting method with defined maintenance procedures in some areas of repair.

As stated earlier, more than 50 percent of the maintenance operating budget is attributable to labor costs. Although there could be considerable difficulty with having a job standard for every repair activity, defining an expectation for all maintenance employees has enormous management value. The standards can be extremely useful in helping managers and supervisors to be more explicit in defining job expectations for their employees.

The methods used in establishing standards can vary from the very simple to the complex. Simple communication between manager and supervisor and between supervisor and employee, although a more subjective and humanistic approach, might be the most positive method in the initial stage because it provides the individual with a sense of achievement and motivation. It also allows for mutual agreement on what the standards should be, based on individual skill levels. Since there is a demonstrated interest in each individual, the barriers associated with fixed standards are overcome.

Time and motion studies have long been used but tend to be negative in nature because they appear to overlook the human element. Industry standards throughout the country can be used for comparison as long as all factors are considered. For example, age and design of facilities, types of tools and equipment, and vehicle and material designs must all be taken into consideration before one attempts to define what might very well become an unrealistic measure of performance.

The development of job standards is closely related to the detailed repair activity codes that are set up within the maintenance system. There should be enough codes to provide sufficient detail and yet not so many as to confuse the mechanic and complicate the reporting.

The previous discussion is only the first step, however. Once the foundation has been established, it is critical that the standards be stated in concrete, definitive terms. This process will not only be beneficial to the existing work force but will also ensure the level of performance expected of all future employees. Stating in absolute terms that a tune-up will be completed in a prescribed manner in six hours, for example, heightens the level of awareness of the standards for tune-ups and gets the job done. If an employee fails to meet the standard, then positive steps should be taken to provide that individual with the necessary training.

MAINTENANCE TECHNICAL TRAINING

Training, for present and future needs, is an investment in the people side of the business. We spend millions of dollars in equipment improvement and relatively few dollars in people development. The technological advancements occurring in today's transit industry have only increased its complexity. New vehicle designs, sophisticated testing and repair equipment, and corresponding technical procedures have created a substantial burden on today's mechanic. The "old timers" retiring leave behind a relatively young and untrained work force, and an obvious void, in their organizations. The need for a structured training program to meet present and future demands on today's work force is overwhelming. Untrained people increase the cost of running the business. A formal training program consisting of classroom instruction on the latest maintenance techniques, actual hands-on application of those techniques, follow-up observation and assessment, and written and oral reviews is essential in upgrading the skill level of mechanics as well as achieving a level of consistency in determining their qualifications. The purpose is to yield a more productive, qualified mechanic whose increased efficiency and work output will more than compensate for the related training costs. The increased productivity might eventually reduce the number of positions required.

CONTROL OF ABSENTEEISM

A consistent work force is essential to work productivity. In the late 1960s, the U.S. automobile industry had an absenteeism rate on Mondays and Fridays as high as 40 percent, which prompted the expression, "Be sure your car is built on Wednesday!" A comparative study was made of how "coffee breaks" are taken by automobile workers in the United States and Japan. In Japan the assembly line shuts down completely during breaks, whereas the American system substitutes a worker and keeps the line moving. Japan's system was more productive and cost efficient and resulted in a more reliable product.

Controlling absenteeism reduces lost time and increases productivity. Management's emphasis on the urgency of "being present" creates a stable work force and increases morale by instilling job pride. Stability and reliability ensure that effective planning and scheduling techniques do happen.

Wages of union maintenance personnel have climbed so dramatically that some find it quite comfortable to work four days rather than five. Absenteeism then shifts the burden to the remaining work force, decreasing productivity and lowering morale.

Defining and enforcing guidelines on absenteeism gives all employees direction as to what is and is not acceptable and a sense of purpose in achieving management's goal. Especially in today's marketplace, where jobs are fewer, an unproductive employee must be replaced by those willing to perform efficiently.

The RTD's "Attendance Policy: All Bargaining Unit Employees" states the necessity of such a policy, defines the absenteeism problem, sets absenteeism guidelines, delineates to whom the policy applies, defines a day of absence and absence exclusions, and enumerates the positive disciplinary measures for unacceptable attendance and tardiness. For example, discipline for unacceptable attendance, starting with the date of the first infraction, is administered as follows:

No. of Occurrences in 12-Month Period	Disciplinary Measure
3	Oral reminder
5	First written reminder
7	Second written reminder
8	Decision
9	Possible termination

The RTD maintains a self-help program for the benefit of all employees. The program may be recommended to the employee at the time of a second written reminder. Participation in the program does not preclude additional positive discipline, but it may be a factor in consideration of the discipline to be applied.

The attendance policy also contains a form that is to be signed by the employee acknowledging receipt of the policy.

CONCLUSIONS

This paper has highlighted some issues for consideration in refining and improving transit operations. It is not my intention to represent this as a definite cure to the dilemma we now face. Rather, it is intended as a review of some major issues that can be used as a focal point for what we need to analyze and plan for in the future. Each transit property is confronting these issues with different degrees of success. If we can continue to learn and grow together and effectively confront the management opportunities that we now have, success is just around the corner.

The art of managing, whether it be in transportation or any other industry, depends on maintaining a fine balance between productivity and people. Managing is often described as the ability to maximize and orchestrate the resources of an organization to accomplish the desired results. There is no right way to manage but rather a series of options or alternatives. We need to focus on the relevant issues and be wise enough to select the most appropriate alternatives. If we accomplish this, we will indeed have been succcessful.

Our concerns should be to control cost while increasing productivity in three areas: labor, materials and supplies, and equipment. Participation in the Bus Maintenance Improvement Workshop is an effective step toward increasing the productivity of our transit systems. The workshop can be viewed as an information-sharing opportunity where invaluable input can be gained toward improving the performance of the maintenance function. The value of such an opportunity can only be determined based on the ideas gathered and the individual's ability and interest in instituting positive change within his or her organization.

Charge to the Workshop

A. B. Hallman
Urban Mass Transportation Administration

It is hoped that your efforts here will benefit UMTA in the formulation of a maintenance research program and will assist your peers throughout the country by discovering and disclosing existing practices that can improve maintenance performance for all.

We all know that the public bus mass transportation industry has suffered a decline in the experience level of the maintenance work force. It is estimated that approximately 50 percent of bus maintenance workers nationwide have 5 years or less experience on the job. Many people are wringing their hands over the prospect of losing federal operating subsidies. The huge sums of federal support for capital and operating expenses in the past, although important in restocking and refurbishing mass transit systems, still leave us with maintenance performance problems. The causes of this condition are complex. But let us not debate the causes. Let us recognize the problem and identify solutions.

Two ongoing UMTA demonstration projects offer great promise for improving maintenance performance. At the Detroit Department of Transportation, an improved maintenance manual format, called a job performance aid (JPA), is being developed and tested. The JPA modules supplement maintenance manuals supplied by manufacturers. Initial results show enthusiastic acceptance on the part of supervisors. Houston is adopting the Detroit JPA even before the final evaluation is completed.

An automatic bus diagnostic system (ABDS) is being developed and tested at the Queens Village Garage of the New York City Transit Authority. This system has two units: a fuel island unit and a maintenance area unit. The fuel island unit provides a short (less than 3-minute) check of the condition of a bus and a printout of results that indicates all values measured and an identification of any out-of-tolerance condition. The fuel island unit checks 12-15 parameters and records fuel use. The maintenance area unit is used to provide a comprehensive test of buses that fail the fuel island test. It does routine preventive maintenance checks (it has 75 test sequences) and diagnoses symptoms that are not understood.

What should we be considering during this workshop? Perhaps we should ask ourselves some questions today in preparation for tomorrow. We need to ask ourselves whether we are doing enough to support maintenance personnel. We need to ask whether we are providing enough clear and unambiguous technical information and the proper tools and support equipment. As managers, we need to ask ourselves whether we are collecting sufficient maintenance information so that we can analyze problems and sort out the differences between equipment problems, people problems, and incorrect procedures. We need to ask ourselves whether we are taking advantage of support equipment and techniques that exist today.

For the future, UMTA must carefully plan research projects that will help to improve maintenance productivity in the near term. It is hoped that the deliberations here will help us do that.

Part 2

Findings and Strategies

Summary of Findings and Suggested Strategies

The Bus Maintenance Improvement Workshop provided a forum for the examination of current issues and problems related to bus maintenance. The workshop also furnished an opportunity for the exchange of ideas that would be useful for the development and implementation of bus maintenance improvement strategies.

In the plenary session and the workshop meetings, participants had the opportunity to examine and analyze the current state of the art in bus maintenance. This section summarizes the workshop findings and suggests R&D needs and strategies that may be used to stem emerging problems and to make better use of maintenance resources. These findings evolved from the participants' consideration of five subject areas: (a) management's role in maintenance, (b) management tools for improving maintenance performance, (c) human resources for maintenance, (d) facility and equipment needs, and (e) vehicle design, acceptance testing, and maintenance support services.

GROUP 1: MANAGEMENT'S ROLE IN MAINTENANCE

The first workshop group focused its attention on gaining an understanding of the impact of transit organization on maintenance and on developing a framework for managers to enable them to understand the direct and indirect impacts on maintenance of decisions made by policy boards, particularly in the areas of budgeting, finance, and levels of service. The group agreed that decisions made by policymakers at all levels of management have unintended impacts on the maintenance function.

Problems

Current conditions identified by this group as having negative effects on bus maintenance include

1. The tendency of operations and maintenance managers to involve the board of directors too deeply in day-to-day operations;
2. The lack of current and reliable information necessary to permit all managers to function effectively;
3. The inability of maintenance managers to present a meaningful budgeting case, apparently caused by a lack of management skills in this area;
4. The absence of appropriate organizational approaches to purchasing, including adequate communication links between the maintenance and finance functions; and
5. The lack of property-level maintenance policies or standards, which results in failure-based maintenance practices.

It was the consensus of this group that the industry as a whole must work to solve these problems before bus maintenance can be improved. Delineation of responsibilities and relations between operations and maintenance management and the board of directors is of major importance. The board of directors must be made more aware of the maintenance function, and comprehensive organization plans covering management objectives, standards, budgeting, and maintenance programming and planning should be prepared. It was suggested that management develop "completed staff work" and that board meetings be planned with an appropriate agenda and a staff summary for each item. These steps are important to establish the credibility of maintenance managers.

In the area of information availability, it was agreed that management education should be provided and that management should be involved in information system design in order to effect efficient management. There should also be employee development in the areas of maintenance management and planning.

Strategies

After reviewing the conditions, problems, and potential solutions, the group outlined the following strategies for the improvement of management effectiveness:

1. The Group 1 workshop called for the establishment of an appropriate, well-run R&D effort in bus maintenance. This could be achieved through the joint participation of UMTA, individual properties, and manufacturers and result in a combined R&D fund. Joint funding would ensure that the R&D effort would be properly used and that the results would be developed into hardware and implemented.
2. The development of a relatively uniform fleet management and maintenance reporting system was identified as a priority need. Such a system should be flexible enough to permit property-level adaptations, but it should include inventory leveling and performance measurement capabilities. The benefits of this type of system could be enhanced by establishing a clearinghouse to facilitate information exchange. This type of system could be developed by using both federal and local funds, and it should include software, hardware, and training materials.
3. A need for bus maintenance management courses was identified. It was suggested that an organization similar to the American Association of State Highway and Transportation Officials (AASHTO) be established to provide management of training grants and to set up the training courses.
4. The preparation of a handbook on maintenance planning and budgeting was also suggested.

GROUP 2: MANAGEMENT TOOLS FOR IMPROVING MAINTENANCE PERFORMANCE

A number of analytic tools have been developed for the planning, management, and evaluation of maintenance programs. These tools include performance indicators, management information systems, workflow projection and planning techniques, life-cycle cost models, cost-minimization algorithms for planning preventive maintenance programs, and queuing theory. Only a few of these aids have been formally adopted by maintenance managers. Group 2 investigated the appropriate role of these techniques in transit maintenance management and planning.

Problems

The current conditions and problems in bus maintenance identified by this group include

1. The lack of data within a property about its own buses and the poor quality of the data that are available;
2. The limited availability and use of computerized maintenance management information systems;
3. The difficulties associated with the transition from a manual to a computerized information system;
4. Lack of simulation and failure models for use in maintenance planning;
5. Problems related to the low-bid system, such as high defect rates, long lead times, and the large number of small vendors that must be dealt with;
6. The absence of a system for collecting and disseminating information on bus defects on a national scale; and
7. The lack of complete and useful information regarding the interchangeability of parts.

The group, after reviewing the current conditions and problems in bus maintenance, developed several possible solutions and suggested areas for further research. Two general categories that emerged from the discussions were the need to collect historical bus data and the need to develop methods to make use of the data. Seven specific areas were identified within these categories.

Strategies

The following strategies for improving management tools were suggested:

1. The need for R&D of management information systems specifically for maintenance was given top priority. Such systems would include preventive maintenance scheduling, inventory control, failure monitoring, work-order processing, and status tracking.
2. Training programs designed to facilitate the transition from manual to computerized maintenance information systems should be developed.
3. Automated data-collection methods for maintenance need to be developed.
4. There should be a national information network for sharing data on major, model-specific bus defects.
5. There is a need for R&D of management tools and information systems that would facilitate the purchasing of quality products within the low-bid system.
6. Simulation and failure models for bus maintenance should be developed to facilitate planning.
7. There should be research into the possible development of a system to cross reference data on the interchangeability of bus parts.

Participants felt that the R&D activities listed above lend themselves well to funding plans similar to that used by the Western Transit Maintenance Consortium. The main feature of this type of plan is that projects are funded partly by the properties directly involved and partly by federal agencies. The use of federal grant money would also ensure the dissemination of results to all properties.

GROUP 3: HUMAN RESOURCES FOR MAINTENANCE

Human resources are vital components of the maintenance system. It is generally accepted that more effective maintenance depends on better training and worker-management cooperation, yet no clear agenda for improvement has been developed. It is assumed that any program for improvement requires quantitative measurement of maintenance productivity. This group examined the development of strategies that may be expected to improve the management of human resources.

Problems

The existing conditions and problems identified by this group include

1. The general lack of standards for performance and performance measurements in maintenance, which hampers both training and planning;
2. The inability of maintenance manuals to provide the information necessary to support (a) entry-level training and/or (b) the journeyman technician's performance on the job;
3. The lack of knowledge among many properties as to what criteria should be used to select line-level maintenance supervisors and/or how to train them effectively;
4. The shortage of communication skills among upper-level maintenance managers;
5. The severe problems of motivation and attitude among maintenance technicians;
6. Upper-level management's lack of awareness of maintenance-related variables, as reflected in inadequate allocation of budgets to maintenance and maintenance training;
7. The need for information about the accessibility and utility of training packages; and
8. The absence of any ready and effective means of communicating information related to maintenance and maintenance training.

Strategies

The following strategies for improving the effectiveness of human resources in maintenance were suggested:

1. A survey of both transit properties and other industries should be undertaken by UMTA to determine the application of "work standards" and measurement techniques. The dissemination of the survey results should be restricted to a training program designed specifically to communicate the concepts and techniques to interested parties.
2. The application of job performance aids (JPAs) and related techniques should be continued by UMTA. Properties should learn how to integrate such information packages with training to (a) help overcome the temptation to avoid training by providing simplified manuals and (b) help the technicians learn to rely on the manuals rather than on memory. In addition, manufacturers and vendors should be required to deliver JPAs or their equivalent with all equipment.
3. A project to survey transit properties for working solutions to line-level selection and training problems should be funded by UMTA. Consideration should be given to a means of communicating this information to all properties.
4. The development of a training package that can be implemented in different modes should be sponsored by UMTA.
5. The maintenance technician population should

be surveyed to identify clearly the specific nature of the motivation problem and its causes.

6. The importance of maintenance and maintenance-related variables should be constantly reinforced. UMTA should develop a basic package of materials that can be delivered in different modes, such as journal articles, professional meetings, and video simulation programs.

7. A survey should be sponsored by UMTA to discern the availability and utility of training programs, materials, and concepts.

8. A study should be undertaken to examine the common information needs of transit properties and to design a multichannel system or technique for meeting those needs.

GROUP 4: FACILITY AND EQUIPMENT NEEDS

There is a great deal of variation in the design of fixed facilities and in associated bus maintenance equipment. Some variations can be attributed to design considerations, age of plant and equipment, and budget. Equipment requirements are functions of the type of facility, particular problems, and the talent and experience of maintenance personnel. New equipment should augment the diagnostic capabilities of maintenance personnel and assist in performing the job. Group 4 addressed the need for R&D in the areas of equipment and facility design (to accommodate future vehicle design), fleet growth, centralization versus decentralization, and energy conservation. Since the state of the art in heavy shop equipment has remained static for the past decade, this group also examined the potential for improvements in shop equipment to reduce labor time and physical effort.

Problems

The major problem in the area of facility design was determined to be the lack of dissemination of information developed by individual properties. It was agreed that there are significant differences in the requirements of large and small transit properties.

It was concluded that facility decisions on traffic flow and layout can be different even though based on the same considerations and the resulting facilities could be equally functional. The decisive factor in this equation is the experience and operational philosophy of the management and personnel operating the facility.

The current conditions and problems identified in the area of equipment include

1. The need for the development of economical and reliable inspection and diagnostic equipment to alleviate vehicle inspection costs;
2. The increase in structural failures and, thus, the need for a method to determine the structural integrity of certain types of vehicles;
3. The need for the development of automatic tire inspection equipment; and
4. The lack of dissemination of information on techniques that have been developed and successfully adopted by individual properties.

Specific desires for future action were highlighted; it was the express hope of this group that its findings would benefit transit property operators in establishing new facilities and equipment.

Strategies

The following strategies for meeting facility and equipment needs were suggested:

1. An APTA subcommittee should be formed to compile and disseminate state-of-the-art information related to facility construction and equipment. This subcommittee should participate in the development of the new Bus Maintenance Facility Planning and Design Study.
2. A design guide should be prepared that treats the shop and garage functions in modular form.
3. A series of exchange seminars should be conducted to allow the exchange of facility design and maintenance information. The seminar group could design a facility, including the physical plant layout, and specify and/or define the fixed equipment requirements.
4. R&D is needed to find a satisfactory method of automatic inspection and diagnostic testing. This program should be extended to all properties and be given the highest priority by UMTA.
5. Bus manufacturers should consider and implement changes in vehicle design to facilitate future retrofit of the sensors needed for use of automatic vehicle diagnosis.
6. A study should be initiated by UMTA to develop methods for determining the structural integrity of bus frames by using techniques such as X-ray, ultrasonics, and magnetic detection.
7. An incentive program (similar to the bus rodeo) should be introduced by APTA to encourage those involved in maintenance to submit the results of their work in developing improved tools, techniques, and equipment. This would facilitate information dissemination.
8. The development of an automatic tire inflation testing device was deemed necessary to facilitate tire inspection.

GROUP 5: VEHICLE DESIGN, ACCEPTANCE TESTING, AND MAINTENANCE SUPPORT SERVICES

Over the past several years, a number of new bus designs have appeared on the market. For the most part, these buses are built to be appealing in appearance and are not designed with maintenance personnel in mind. Group 5 considered the new procurement process and methods of improving bus reliability.

Problems

It was the consensus of Group 5 that changes in transit vehicle design have caused many serious maintenance problems: Costs have risen, breakdowns are more frequent, and buses are out of service for longer periods of time. The conditions and major problems faced by bus maintenance personnel today include

1. Increased preventive maintenance requirements;
2. The increasing sophistication of equipment, which complicates normal trouble-shooting procedures;
3. The shortage of trained bus mechanics;
4. The dramatic drop in the level of reliability of bus components;
5. The increasing frequency of transmission failures;
6. The addition of air conditioning;
7. The increase in fuel consumption;
8. The frequent failure of new-style electrical systems;
9. The increased use of turbocharged engines;
10. The decline in brake lining life;
11. The addition of wheelchair lifts;
12. The inadequacy of engine coolant systems;
13. Suspension system failures;
14. The more sophisticated door control systems; and

15. The continued use of the basic "White Book" specification (1).

It was the consensus of the group that many of the maintenance problems being encountered today on new coaches could have been averted through innovative specification preparation and diligent postconstruction follow-up. The type of coaches being sold in this country could be improved by including maintainability and reliability requirements in the specifications, component prequalification, and quality-control functions.

Strategies

The following strategies involving vehicle design and acceptance procedures were suggested:

1. Reliability and maintainability should be improved through specifications and design. Specifications should list the total service hours required to remove and replace major components; all such times would be verified through a series of demonstrations.
2. Bus manufacturers should be encouraged to simplify vehicle subsystems to make them easier to maintain. Builders should develop all test and repair equipment required to service their vehicles, including comprehensive maintenance manuals and wiring diagrams.
3. On-board diagnostic systems should continue to be explored; the test program at the New York City Transit Authority (NYCTA) should be followed closely.
4. The possibility of specifying vehicle availability by having the manufacturers guarantee the number of hours a coach is to be ready for service should be investigated.
5. Guidelines for writing specifications should be created.
6. A set of prequalification procedures for new components should be developed.
7. Problem components should be identified and upgraded. The bus manufacturer is responsible for tracking and upgrading problem components. Users are responsible for keeping the manufacturer informed of problem areas. An industrywide information-gathering and distribution system needs to be set up, perhaps through APTA.
8. Transit systems should make use of the fleet defect section of their specifications to pursue latent defects during the warranty period. After the warranty period has expired, first negotiations should be attempted and then legal action should be taken to pursue latent defects.
9. Quality-control functions should be improved. The guidelines being developed in the APTA Regional Inspection Workshops should be used.
10. Manufacturers' technical support should be increased, and they should be encouraged to develop new and innovative training programs. UMTA grants should be made available to cover the costs of warranty administration and data collection on failures.
11. Life-cycle costing procedures should be used, as required by UMTA.
12. Fuel-economy test measures should be demonstrated. A demonstration of the Society of Automotive Engineers (SAE) fuel-economy test procedure should be funded by an UMTA grant.

REFERENCE

1. Baseline Advanced-Design Transit Coach Specifications: A Guideline Procurement Document for New 35- and 40-Foot Coach Designs. UMTA, 1978, 184 pp.

Part 3:

Resource Papers and Workshop Reports

Workshop 1: Management's Role in Maintenance

Issue Areas

Workshop discussion of the role of management in maintenance was based on the premise that maintenance managers must be concerned not only with internal maintenance decisions but also with relations with top management and policy boards. Participants in Workshop 1 were asked to identify critical policy decisions that influence maintenance efficiency and effectiveness and to discuss ways in which maintenance managers should involve themselves in general management and policy. They were also asked to identify the types of information needed by top management and policy boards and to clarify the role of maintenance managers in inventory control and vehicle procurement.

Resource Paper

Conrad L. Mallett,
Detroit Department of Transportation

During the five years in which I have been the Director of the Detroit Department of Transportation, my concepts regarding management's role in the maintenance function have evolved considerably. Because of my position in the management hierarchy, I often assume the unenviable role of interpreter between policymakers and policy implementers. This is sometimes difficult because of the apparent contradiction in goals between these two groups. Nevertheless, to survive in today's world, we cannot and should not avoid the influence of so-called "outside" forces. Even if there were no need to supplement meager farebox revenues with subsidies obtained with the necessary help of outsiders, we should welcome their participation.

Once we accept the fact that these outside influences are here to stay, we must resolve to do our utmost to maximize their positive impact. This paper addresses that objective in the following manner: (a) It identifies the major sources of external influence and describes their impacts, including observations of how the political process comes into play; (b) it analyzes the classic conflict between operations and maintenance; and (c) it offers a few observations concerning the role of UMTA. The last item is particularly important due to the significant influence of UMTA in these matters.

MAJOR AREAS OF EXTERNAL INFLUENCE THAT AFFECT BUS MAINTENANCE

The first important area of external influence is money: how we get it and how we spend it. In contrast to those glorious, independent days many years ago when farebox revenues covered transit operating expenses, most bus operations today must rely on one or more sources of a political nature to obtain large amounts of subsidy revenue. From the city general tax fund all the way to the U.S. Department of Transportation (DOT), public transportation has become dependent on agencies whose administrators' jobs depend on the outcome of periodic elections. Even for those transit authorities that have been granted special autonomous taxing powers, there exists some group that determines budget policy and that relies on the electoral process for its authority.

The system requires a direct controlling link between the subsidy providers--i.e., the taxpayers--and the subsidy users--i.e., you and me. Unfortunately, this system suffers from a fault that is common to many large-scale societal endeavors: The practice does not match the theory. A phenomenon often observed in our political system is that the span of long-range planning diminishes proportionately with the amount of time remaining until the next election. Budget policy for transit subsidies is not exempt from this rule.

One of the most critical areas where this influence is felt concerns maintenance policies, especially the impact of those policies on day-to-day objectives and priorities for maintenance. A short-term response to daily crises at the expense of long-term objectives in the bus maintenance division has become the standard mode of operation for many properties. In an environment of diminishing resources and increasing demands, it is not easy to respond to unforeseen crises without sacrificing something from one's long-term program, even those elements that represent fundamental maintenance requirements, such as preventive maintenance.

In large part, this dilemma is related to a lack of understanding by policymakers as to the consequences of some of their decisions. My experience has shown that dialogue between policymakers and policy implementers results in greater understanding and fewer capricious actions. However, in the final analysis, we must all accept the political motivation behind many of the policy decisions handed down to us.

Another important area of policy-maintenance conflict is that of vehicle procurements, primarily because of the low-bid policy. Initially, this policy was viewed as being founded on a sound management philosophy: To minimize costs, the "least expensive" option must be adopted. However, least expensive has come to mean "cheaper to buy". The reason for this development is, of course, the difficulty involved in establishing the total cost of a vehicle--i.e., purchase and maintenance. This is especially true for vehicles that have not yet been in operation long enough to establish long-range maintenance costs. The industry must change its policy to include maintenance costs as a factor in procurement if it really wants to reduce expenses.

UMTA has come a long way in this regard with its efforts in life-cycle costing.

The results of a recent analysis by Detroit DOT staff illustrate the importance of appreciating the total cost of vehicle procurement and operation. For many reasons, we at the Detroit DOT have determined it to be in our best interest to keep detailed cost figures for our fleet of advanced design buses (ADBs)--i.e., slightly more than 300 RTS-IIs. Based on the first two or three years of operation, it has been determined that the cost of labor alone will be about $93 800 for the 12-year expected life of these buses. This figure is derived from a 1981-1982 mechanic hourly wage rate of $10.28, a 59.29 percent fringe rate, and 477.5 h/bus/year of maintenance labor. This cost does not include initial inspection and service preparation expenses, parts, fuel, or, of course, unforeseen maintenance failures that may appear later in the life of the fleet. Had such cost information been available early in the procurement process, our decision concerning the type of vehicle to purchase might have been different.

Another difficulty with vehicle procurement policy is accessibility requirements. In Michigan, transit properties were required by law to procure only wheelchair-accessible transit vehicles after 1978. Our maintenance problems were compounded when Section 504 regulations (Rehabilitation Act of 1973) went into effect on a national scale.

A third critical area of conflict concerns personnel practices, including labor agreements. On the national level, the Section 13c provision (Urban Mass Transportation Act of 1964, as amended) of federal grant approvals has had a heavy impact on the nature of capital programs and operations policies. As in the case of the low-bid policy, the original intent of Section 13c, protection of labor rights, has changed with implementation. In fact, many believe that this is one of the prime reasons for escalating labor costs, in that it has not been too difficult for certain segments of labor to bargain their Section 13c power in exchange for favorable decisions in wage negotiations. The apparent change in the UMTA position on this topic is welcome.

However, closer to home, there are several localized personnel and labor agreement problems that will require more study and cooperation before progress can be expected. The scope of these problems encompasses almost every aspect of personnel administration, from hiring to job work habits. In Detroit, bus mechanics are hired through the City Personnel Department in conjunction with various civil service guidelines. We know this system does not work well because the overburdened Personnel Department screens applicants by means of a written examination only. It is possible to pass a civil service examination and be unable to repair a coach.

There is currently a shortage of skilled coach mechanics in Detroit, a city with a 15 percent unemployment rate. There could be many reasons for this, including poor testing, inadequate recruitment, and an insufficient pool of skilled trades people. The latter possibility has received considerable attention in the media. Our society traditionally takes the view that the skilled trades represent a step below college-based careers in status. Of course, this view is incorrect, but it may take years to change it. In any event, more research must be done on the inability of bus properties to find, hire, and keep skilled mechanics.

Policies related to worker productivity have also had detrimental impacts on bus maintenance efficiencies. As a departmental director, I can appreciate the advantages of emphasizing accurate, standardized maintenance job practices as opposed to fast, seemingly highly productive activity. We must stress prevention over cure, and an excellent method of doing so would be within labor agreements. This could take the form of incentives for high standards of work reliability and disincentives for shoddy workmanship. Once specific job standards and methods of measurement are established, such policies would be fairly easy to implement. However, the development of the standards will be a time-consuming, involved process requiring input from a wide range of experts. Furthermore, the determination of an accurate and objective compliance mechanism will be difficult. Eliciting the cooperation of union leadership may not be easy. However, this effort must be made if bus maintenance is to improve significantly.

REASONS FOR CONSTANT CONFLICT BETWEEN OPERATIONS AND MAINTENANCE

By their very nature, the operations and maintenence functions of any bus property are constantly waging war against each other. In fact, a director or general manager should be concerned if there is no conflict between these two divisions, since their respective goals are inherently contradictory in situations of resource deficiencies.

If bus reserves are insufficient, then all operational vehicles are on the road during most of the day. If there are not enough skilled mechanics to cover all shifts, then required preventive and corrective maintenance cannot be performed during the late afternoon and midnight shifts. If there are not sufficient operating funds to provide enough service to meet public demand, then drivers and buses are subjected to overloaded, stressful on-the-road conditions and high levels of overtime are required. Of course, such conditions cannot be endured for too long before premature breakdowns occur and there is evidence of high absenteeism and increasing road calls.

The conflicts persist and at times worsen. Operations keeps buses on the road too long, and thus necessary preventive maintenance cannot be performed. Maintenance keeps seemingly operable buses tied up with inspections and checks while passengers wait in the cold at many city street corners.

Can this dilemma be resolved? Perhaps, but the answer involves facing some tough realities.

First of all, there must be an acceptance by all parties of the proper balance between public service schedules and available resources. I am convinced that this vicious circle of declining revenue, budget shortages, service cuts, etc., can be broken only by establishing a reliable level of service. Of course, this means a built-in factor for adequate preventive maintenance coupled with reasonable expectations of operations and maintenance. After the transit agency establishes a sense of confidence in its patrons, service improvements can be requested through local tax increases, for example, without fear of ridicule.

In Detroit, this approach was implemented after many years of the vicious circle. During the first few years of my tenure, operations and scheduling staff convinced me that we had to continue the established policy of publishing public service schedules in accordance with travel demand. Since our resources had dwindled to a level well below this demand, we could not, of course, meet schedules. The reaction of our patrons was understandable: anger and frustration. We were finally convinced to revise public service schedules to match available resources--i.e., buses, mechanics, and drivers. The public response was positive: People appreciated our honesty and were better able to plan their bus trips because the service was far more reliable.

Second, we must convince policymakers to change the way they measure our success. Too often, the simplest, most convenient statistic at hand is used to determine whether bus transit is doing its job. Measures such as revenue miles and passengers per mile say nothing about the quality of service. It is through improvements in quality that bus transportation will build a wide base of public support, a necessary first step in increasing the quantity of service.

Finally, we must foster a more open dialogue between operations and maintenance managers. Each side must understand the motives behind seemingly unproductive practices and work together in maximizing departmentwide effectiveness. At the Detroit DOT, regular meetings between middle-level managers from these two divisions have done much to improve interdivisional cooperation.

ROLE OF UMTA IN IMPROVING BUS MAINTENANCE

Currently, UMTA affects almost every aspect of a bus property's existence, especially those areas already mentioned in this paper. Because of this influence, UMTA will continue to play an important role in shaping budget, procurement, labor, and maintenance policies in spite of rumors concerning a diminished UMTA profile. There will be an ever-increasing need for a central focus for the numerous bus maintenance improvement programs taking place or about to take place. Initially, the role of UMTA should be one of facilitator--that is, encouraging and guiding activities such as research and program development. Thereafter, UMTA should assume the important function of information dissemination and program support. The requirements for the implementation of many bus maintenance improvement programs may be found to be beyond the means or expertise of some transit properties.

As an example of the facilitator role, UMTA is currently sponsoring a research project at the Detroit DOT in which job performance aids (JPAs) are being tested for impacts on the effectiveness of mechanics while implementation procedures are refined. Through this project, certain standards for repair and inspection actions are being established. These standards will be beneficial in supporting the vehicle reliability objectives mentioned earlier as a fundamental requirement for an effective preventive maintenance program. A possibility for the UMTA support role would be the establishment of regional training and workshop sessions in which maintenance managers could learn how JPAs can be used to improve mechanics' skills, increase bus reliability, and reestablish preventive maintenance practices.

I do not envision an UMTA role that involves the strict enforcement of a uniform set of maintenance standards, as has been suggested by some. Due to differences in operating conditions, political settings, availability of resources, and many other uncontrollable variables, such an approach would inevitably result in unfair treatment. The tremendous staff effort required to monitor compliance with such standards would be well beyond the capacities of the UMTA organization. In addition, transit managers would have to spend time and energy in dealing with statistics that should be spent in taking care of operations and maintenance.

CONCLUSIONS

In review and conclusion, we must make certain that policymakers are aware of our maintenance problems, and they must be enlisted in support of long-term solutions to those problems. Procurement policies must be altered so that maintenance costs of transit vehicles are carefully weighed. Personnel practices must be restructured so that high productivity and high-quality craftsmanship are integral parts of the contract between the transit agency and its maintenance personnel.

The adversarial nature of labor relations in the industry must be replaced by a mutual concern for vehicle reliability and high-quality public service. Operations and maintenance personnel must replace mutual hostility and defensiveness with attitudes that reflect understanding and cooperation.

UMTA's concern with maintenance should focus more tightly on its role as facilitator, information gatherer, and disseminator and supporter of better research and training programs.

The role of maintenance managers is to see that these objectives are their objectives and that a major portion of their energy is devoted to achieving these goals.

Workshop Report

Robert Prangley, Chairman
Al Alaimo, Recorder

Management plays a significant role in the maintenance process. This role is sometimes played unwittingly; i.e., decisions are made that have an impact on maintenance effectiveness without the decisionmaker being aware of the ripple effects of the decision. Workshop 1 looked at some of the conditions that contribute to management problems, defined some of these problems, and then developed potential solutions.

CURRENT CONDITIONS

Some of the current conditions that have deleterious effects on bus maintenance are as follows:

1. Operations and maintenance managers tend to have the board of directors too deeply involved in the details of day-to-day operations.
2. There appears to be insufficient current and reliable information to permit managers to function efficiently.
3. Many maintenance managers are unable to present a meaningful budgeting case. This appears to be caused by an insufficiency of management skills and analytic tools.
4. Many properties do not have an appropriate organizational approach to purchasing and lack adequate communication links between the maintenance function and the finance function and other organizational functions such as planning, scheduling, and marketing.
5. There is a lack of property-level maintenance policies and standards and a somewhat widespread use of failure-based maintenance.

These conditions are creating a whole host of problems in the industry that must be solved before we can get on with the business of improving bus maintenance. As each of the conditions cited is discussed, it will become evident that the industry as a whole must correct the problems.

PROBLEMS AND POTENTIAL SOLUTIONS

Overinvolvement of Boards of Directors

If boards of directors become too involved in the details of operation, it can be assumed that property management and staff are not communicating issues effectively. Presentations to the board must include alternatives and a clear picture of the consequences that may occur if specific actions are not taken. Managers must provide completed staff work and not dodge the issues. From time to time, a board of directors may become too involved because management and staff have not anticipated related issues and problems. Sometimes the board of directors will become involved in developing administrative rules and regulations when it sees signs of incomplete program planning and lack of a maintenance planning process.

Responsibilities and relationships between operations and maintenance management and the board of directors need to be delineated. Second, the board of directors must be made increasingly aware of the maintenance function and its crucial interplay within the organization. Finally, there must be development of a comprehensive organization plan in the areas of management objectives, standards, budgeting, and maintenance programming and planning. Management must develop "completed staff work", and board meetings must be well planned, with an appropriate agenda and a staff summary for each agenda item. Clear courses of action must be laid out by managers to deal with the political aspects of operating a transportation system. Finally, credibility must be established between the board and management.

Need for Current and Reliable Information

Another condition in the bus industry today is a lack of the current and reliable information required for efficient management. This leads to problems in determining what response is needed. For example, there are no peer-group comparisons or trend analyses to help evaluate situations and needs. Data validation is poor, and there is a lack of differentiation between project problems and ongoing operational problems. Another problem that exacerbates the condition is the lack of timeliness of reports. When information is neither current nor reliable, both operations and maintenance managers, as well as the general manager, are functioning at a tremendous disadvantage. Because of this, many managers dismiss information systems as too unwieldy.

We should be providing management education and involving management in information system design. It is the manager who knows what information is needed, but this same manager requires assistance in obtaining the appropriate information. Scheduling of information reporting to management must be timely to make it useful. Some examples are developing board reports on a monthly or quarterly basis, general manager reports daily and/or weekly, and project reports monthly or periodically. In addition, it would be very useful to produce an annual report of accomplishments that could be disseminated to the public. Usually, the reporting requirements indicated would be made available through a management information system. The sophistication of such a system would depend on the size of the transit property. However, whatever the size, there should be some organized system for management reports.

Inability of Maintenance Managers to Make a Budgeting Case

Many maintenance managers lack the ability to put forward a hard-hitting, positive budgeting presentation to make a case for maintenance. There appears to be a lack of analytic tools for the maintenance manager. In addition, there is a depletion of current skills through attrition; i.e., skilled managers are retiring and there are not enough suitably skilled people available as replacements. Recently, we have seen rules and regulations developed outside of the organization that place serious restrictions on maintenance managers' ability to predict budget requirements. Some of these have been developed by organizations such as UMTA. In other cases, local political groups may project requirements that have not previously been planned for.

To overcome the lack of management skills in this area, there should be employee development in the areas of maintenance management and planning. Other means should be considered to involve the maintenance manager in the propertywide decisionmaking process.

Perhaps one of the best tools a maintenance manager requires is a forecast of long-term equipment and facility replacement and rehabilitation needs. This forecast must have a suitable justification, usually an economic evaluation of the problems and solutions. A word of caution: The evaluation process should be prepared to consider significant factors from the perspective of other parts of the organization. To make this program work, a property requires stable funding for at least five years. This would permit appropriate replacement and rehabilitation decisions to be made when the economics become justifiable.

Other tools to assist the maintenance manager might be in the area of disbursement accountability to accompany purchasing responsibilities. The lowest-level maintenance supervision personnel--i.e., foremen--should be competent enough to make disbursements. (Involving foremen in disbursements is viewed as a means of developing their skills, awareness, and responsibility in fiscal areas and thus enabling upper-level management to control costs at their source. It is recognized, however, that such competence does not now exist in many systems.) Finally, rules and regulations should be kept to a minimum to provide maintenance managers with flexibility in performing their function.

Inappropriate Organizational Approach to Purchasing

A perennial situation in many bus properties is the lack of an overall organizational approach between maintenance and finance in the area of purchasing. This situation is created by the differing operational requirements of each of these organizations. One of the principal factors aggravating this condition is a poor organizational design that exacerbates relations between maintenance, purchasing, and finance. Maintenance is saddled with a fleet mix that requires extensive stock levels of parts to maintain fleet availability, whereas finance is attempting to reduce the financial commitment of stockrooms. These seemingly conflicting goals need management's attention and resolution. Sometimes organizational problems are created by low skill levels in both maintenance and finance. This makes it difficult for staffs to compare the economics of in-house versus outside repairing and leads to poor stockroom control and a lack of adequate checks and balances to maintain the credibility between maintenance and finance. When these problems arise, there is usually an inadequate parts supply that leads to unnecessary bus downtime.

Some of the problems associated with the purchasing and inventory forecasting function might be solved through appropriate review of current inventory forecasting techniques. These techniques are fairly straightforward and should be reasonably easy to learn. One of the major steps that might be taken is to automate the stock control system for automatic reordering based on use. This should then be cross-linked into the maintenance cash management plan. Parts are a significant cost item in the maintenance function. Again, we might be able to make appropriate use of an education process to assist maintenance managers to understand the reasoning and techniques associated with inventory control. It should be possible to help the inventory control process by developing tight controls at each depot, contracting with parts suppliers versus local consolidated parts supply houses, and, finally, attempting to encourage "in-house bids" for maintenance while at the same time attempting to remove restrictions on outside contractors. This would provide maintenance employees with an incentive to increase productivity and improve the quality of their work.

Lack of Property-Level Maintenance Standards

Far too many transit properties have failed to develop maintenance policies or standards. An ongoing condition develops when the maintenance program becomes failure based rather than planned. Many properties may have failed to do this because they lack skills in the understanding of statistical analysis and life-cycle predictions. Again, the reason may be managers who are unable to "manage". The problems that lead to these conditions include a lack of broad-based maintenance systems and/or technology that would permit information feedback so as to diagnose and predict failure. There might be some difficulty in developing universal maintenance systems and policies because of the great variety of property characteristics. But any systems developed should include the ability to audit, an ability not currently found to any large extent.

The host of problems created in this area may be solved by developing and implementing an appropriate maintenance management system. The system must be capable of providing an ability to develop criteria for life-cycle prediction and some justification for the use of failure-based maintenance in the areas of nonoperating or safety components. In addition, maintenance managers should have appropriate diagnostic systems to predict component condition and failure. An example of this might be an in-house oil analyzer. In addition, it is important that information developed by one property be made available to other properties on a regular basis. This will help local property maintenance management to do a better job.

SUGGESTED ACTIONS

Perhaps the major element needed to improve bus maintenance is a reasonably uniform fleet management system. Preferably, this would be computerized and be adjustable for minor deviations to accommodate variations in property size and organization. As a minimum, the system should provide information on (a) mean distance between failures, (b) maintenance man-hours per 1000 miles, (c) spare bus ratio, and (d) bus availability. These indicators of maintenance effectiveness must be available for review by management on a regular basis. Other reports that could be add-ons to the system would indicate ridership, cost, and quality of service as measured by customer complaints.

Once the decision to develop a fleet management system is made, it will be necessary to provide the appropriate capital funding for both software and hardware plus some means of training to use the system. This funding might come from a central source--i.e., UMTA--with local-share participation. A clearinghouse for information exchange, perhaps in UMTA or APTA, could result that would permit transit properties to compare their performance.

Perhaps even more important than a fleet management system might be the establishment of an appropriate, well-run R&D effort in bus maintenance. This might be accomplished by increasing the availability of R&D funding at UMTA and by the appropriate funding involvement of manufacturers and properties. A combined fund could thus be established. This would ensure that the R&D effort was properly used and that the results of research would be developed into hardware. There has been some discussion to the effect that the current state of R&D implementation is poor. By bringing the manufacturers and properties into the mainstream of the R&D process, a greater degree of effectiveness might be developed.

A third course of action is to develop bus maintenance management courses that would be available, at reasonable cost, to local property management. Training grants could probably be used as a means of subsidization, through UMTA or an industry association such as APTA. Another suggestion might be to establish organizations such as AASHTO and the Highway Users Federation for Safety and Mobility to both provide management of training grants and set up the appropriate training courses.

Another process, which could be coupled with the fleet management system, is the development of an automated inventory leveling system. This system would reduce stock outages and prevent the accumulation of excessive stock levels with its associated tying up of capital. This system could be funded in much the same way as previously outlined for the fleet management system.

A handbook on planning and budgeting is a tool that would be useful to maintenance managers. An appropriate document might be developed through the R&D process or a capital grant in a way similar to that suggested previously for the development and implementation of a fleet management system.

Project delays and roadblocks in procurements have manifested themselves in the procedural process at UMTA. We recognize that UMTA requires accountability; however, excessive interference in the procurement process can be very costly. It is hoped that UMTA may streamline its procedures to permit timely project reviews and expedite the procurement process.

Workshop 2: Management Tools for Improving Maintenance Performance

Issue Areas

A number of analytic tools have been developed for the planning, management, and evaluation of maintenance programs. These include performance indicators, management information systems, work measurement systems, work-flow projection and planning techniques, life-cycle cost models, cost-minimizing algorithms for planning preventive maintenance programs, and queuing theory. Only a few of these decision aids have been formally adopted by maintenance managers.

Workshop 2 was charged with identifying an appropriate role for these techniques in transit maintenance management and planning. Participants were asked to discuss the role of various performance indicators and to identify desirable features of management information systems. They were also asked to review the applicability of several operations research methods for work scheduling, budgeting, and maintenance planning and to identify barriers to more widespread adoption of various management tools.

Resource Paper

B. W. Kliem and D. L. Goeddel
Transportation Systems Center

Priorities in transit have changed significantly over the past year. Today the industry is entering a very difficult phase in which proposed federal cutbacks in transit operating assistance and increased competition from other public service programs for local tax dollars pose a serious challenge to the existence of many transit systems across the nation. Financial constraints in the form of rapidly escalating transit operating deficits, increasing reliance on public funds for support, and dwindling availability of local funds have fostered a climate in which costs must be reduced through service cutbacks and improved management and operating efficiencies. Faced with limited and reasonably predictable financial resources, transit managers have in recent years become vitally concerned with making the most effective use of their capital equipment and operating resources.

BACKGROUND

Transit Maintenance Costs

The cost of performing maintenance is so great that it cannot be ignored. Transit maintenance costs nearly $1.8 billion/year, and the burden is increasing at a rate of $400 million/year [see Figure 1 (1)].

Maintenance material, personnel, and equipment costs have accelerated rapidly, and, for many transit systems, these cost increases have far outpaced the rate of inflation. Approximately two-thirds of all transit personnel work in the transportation departments of operating agencies; most of these are vehicle operators. The second-largest group of transit workers is the maintenance staff, which typically constitutes 15-20 percent of the work force. For most urban bus systems, maintenance labor usually constitutes about 25 percent of the total labor cost.

In recent years, the costs of transit maintenance have perplexed many transit operators because of the lack of specific supporting data. Most transit operating budget and control reports provide lump-sum expenditure calculations without any specific accounting for cost items. When analysis is directed to these areas, most transit managers can only develop broad generalities concerning the maintenance situation, leaving many matters subject to question and concern.

More elusive is the cost of not performing maintenance. Industry estimates indicate that the deferred maintenance currently accumulated on transit vehicles is far greater than current-year maintenance expenditures. Although it cannot be proved conclusively, deferred maintenance is strongly believed to be the primary contributor to the unreliable performance of most transit equipment, the high percentage of missed runs and road calls, and the

Figure 1. Transit maintenance expenses: 1975-1980.

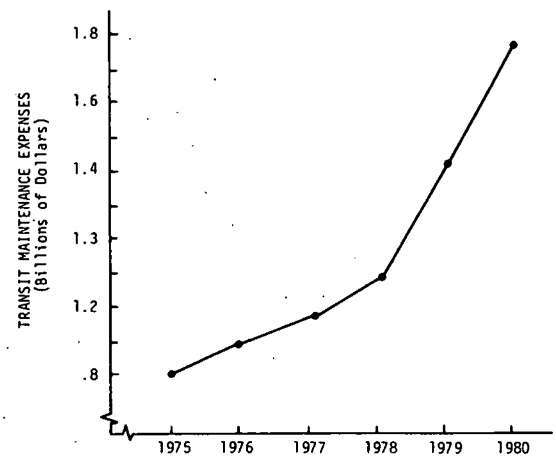


Table 1. Use of maintenance management and inventory control systems in U.S. transit industry.

System	No. of Buses in Fleet	MIS			
		Purchasing	Materials and Management Inventory	Fleet Maintenance	Facilities and Plant Maintenance
New York City Transit Authority (NYCTA)/Manhattan and Bronx Surface Transit Operating Authority (MaBSTOA)	4568	*	*	*	*
Chicago Transit Authority (CTA)	2420	*	*	*	
Southern California Rapid Transit District (SCRTD), Los Angeles	2817		*		
Southeastern Pennsylvania Transportation Authority (SEPTA), Philadelphia	1552	*	*	*	
Washington Metropolitan Area Transit Authority (WMATA)	2154		*	*	
Massachusetts Bay Transportation Authority (MBTA), Boston	1085				
Transport of New Jersey, Maplewood	1703				
Greater Cleveland Regional Transit Authority (GCRTA)	888		*	*	
Port Authority of Allegheny County (PAT), Pittsburgh	937	*	*	*	
Mass Transit Administration of Maryland (MTA), Baltimore	1038				
Bi-State Transit System, St. Louis	1031		*	*	
San Francisco Municipal Railway (Muni)	848				
Detroit DOT/Southeastern Michigan Transportation Authority (SEMTA)	1156		*	*	
Municipality of Metropolitan Seattle (METRO)	1021		*	*	
Metropolitan Transit Commission (MTC), Minneapolis-St. Paul	961				
Metropolitan Transit Authority (MTA), Houston	890		*	*	
Metropolitan Atlanta Rapid Transit Authority (MARTA)	840		*	*	*
Oakland/Alameda-Contra Costa County (AC) Transit	823		*		
Regional Transportation District (RTD), Denver	623		*		
Metro Dade County Transportation Administration, Miami	609	*	*	*	
Milwaukee County Transit, Milwaukee	597				
Tri-County Metropolitan District of Oregon (Tri-Met), Portland	565		*	*	
Niagara Frontier Transportation Authority (NFTA), Buffalo	538	*	*		
Santa Clara County Transportation Agency, San Jose	458		*	*	*
New Orleans Public Service, Inc.	458		*	*	
Dallas Transit System	456		*		
Southwestern Ohio Regional Transit Authority (SORTA), Cincinnati	447	*	*		
Metropolitan Bus Authority, San Juan	411		*	*	
Orange County Transit District, Santa Ana	400	*	*		
Via Metropolitan Transit, San Antonio	430				
San Diego Transit Corporation	393		*		
Honolulu DOT	367		*		
Utah Transit Authority, Salt Lake City	343				
Kansas City Area Transportation Authority	333	*	*	*	
Greater Hartford Transit District	314				
Memphis Area Transit Authority	284		*		
Tidewater Transportation District Commission, Norfolk	187				
Central Ohio Transit Authority (COTA), Columbus	273				
Transit Authority of River City (TARC), Louisville	242		*	*	
Capital District Transportation Authority (CDTA), Albany	236				
Rochester-Genesee Regional Transit Authority	235				
Rhode Island Public Transit Authority (RIPTA), Providence	240				
Regional Transit District, Sacramento	218			*	
Greater Richmond Transit Company	212				
Phoenix Transit	208				
Greater New Haven Transit District	207				
Transit Authority of the City of Omaha	206				
Toledo Area Regional Transit Authority	201				
Central New York Regional Transit Authority/Centro, Syracuse	163			*	
Metropolitan Transit Authority, Nashville	160			*	*
Long Beach Public Transit	149				
City of Tucson DOT (SunTran)	131				
City Transit Service of Fort Worth (Citran)	120			*	
Metropolitan Transit Authority, Des Moines	110	*	*		

declining transit market share of ridership within the industry.

The potential for reducing transit maintenance costs is considered to be very high and should be pursued more vigorously. Cost controls and performance measurements on material, labor, and use of fixed equipment must be implemented if transit systems are to properly manage their maintenance and inventory operations in modern conditions.

CURRENT INDUSTRY APPLICATIONS OF MAINTENANCE MIS

Over the past decade, many transit systems have adopted the use of automated data processing and management reporting systems as one means of improving the control and measuring the performance of their maintenance-inventory activities. In the late 1960s and early 1970s, applications of maintenance MISs were centered in the larger transit systems and involved the use of large-scale "batch processing" programs by specialized data processing personnel on large, expensive, main-frame computers. Now, with the emergence of lower-cost miniand micro-computers and operating systems that facilitate distributed processing by many users in an easily understandable, interactive environment, automation is making significant inroads into the operations of many small and medium-sized transit authorities.

To provide some perspective on the current applications of these systems, Table 1 (2) summarizes information on the extent to which maintenance management and inventory control systems are being used within the transit industry. As the table indicates, of the 54 transit properties identified (representing approximately 65 percent of the total industry vehicle fleet), 28 have reported the use of automated information systems for vehicle fleet maintenance and 23 are using automated systems for materials management and inventory control.

Some of the more innovative vehicle maintenance and inventory MISs noted below have either been applied or have served as a model for the design of many of the systems that exist within the transit industry.

At the Chicago Transit Authority (CTA), a highly sophisticated, on-line maintenance management system has been in use since 1975. Its functions include reporting road calls and defects, scheduling preventive maintenance, monitoring vehicle availability, analyzing the history of vehicle repairs, and evaluating maintenance employee performance (3). Variations and refinements of this system are now under development and application at the Houston METRO and the Los Angeles Southern California Rapid Transit District (SCRTD). Seattle METRO has developed an on-line management information system that uses a data base management system to perform a variety of functions, including vehicle status monitoring, inventory control, payroll, and personnel accounting. Several transit systems (e.g., Portland Tri-Met, Denver RTD, Santa Clara, and Orange County) have in operation on-line maintenance MISs on minicomputers. For small transit agencies, the existence of a general-purpose MIS called TRANSPAC (capable of operating on a desk-size minicomputer) produces management information reports on system operations, fleet maintenance, inventory status, payroll, and finance and accounting as well as data and statistics required by the UMTA Section 15 Reporting and Accounting System.

Besides information reporting systems, the transit industry has also seen the emergence of automated data collection, data entry, and diagnostic systems to facilitate the collection and processing of vehicle service and maintenance data. Applications include on-line fuel meters and data collectors to record the fuel, oil, and coolant servicing of vehicles (Dallas, Detroit DOT, and Houston), the use of employee identification cards to record job work order on-off times and parts issues and receipts (Chicago, Portland, Flint, and Nashville), and on-board vehicle sensor and diagnostic systems to facilitate the detection and trouble-shooting of maintenance problems (New York Metropolitan Transit Authority) (4).

These systems do not provide a full indication of the potential that remains in the application of automated data processing and information reporting systems in the areas of transit operations and management. New applications in the area of vehicle maintenance and inventory management will eventually include systems and techniques that:

1. Determine optimum subsystem and component maintenance and replacement policies,
2. Perform effective scheduling of maintenance jobs consistent with labor skills and equipment availability constraints,
3. Maintain an adequate spare-parts inventory without stock-outs at a minimum financial investment, and
4. Provide to all levels of management effective accounting and reporting of all maintenance activities, parts and labor costs, and system performance.

ISSUES FOR DISCUSSION

As identified above, there has been a considerable amount of interest and work within the transit industry to foster the development and application of management tools to improve the performance of transit maintenance and inventory control. Much work remains. In order to focus discussion on the problems that have been experienced, the important issues that must be considered, and the opportunities for future R&D, three major topic areas have been selected for consideration:

1. System goals and objectives,
2. System design considerations, and
3. System applications.

System Goals and Objectives

Before consideration can be given to development, implementation, and application of new techniques or automated data processing systems in the area of maintenance management and inventory control, there must be clear identification of the goals and objectives of their use by transit management. Far too often, projects are undertaken without a clear definition of how such systems will be used, how they will affect existing work procedures, and how much cost and effort will be required to maintain and operate them once they are installed.

Ideally, an underlying goal in the design and implementation of these systems should be to aid transit managers and department heads to manage their operations more efficiently. But the development and implementation costs of these systems cannot be "sold" by transit management to transit governing boards based on this objective alone. This, in turn, has led to the citing of a number of other anticipated benefits (i.e., reductions in maintenance costs, improved system reliability, lower investment costs in parts inventory, and improved information reporting) to further justify the application of these systems.

Critical to the establishment of the objectives and design requirements of the system are the following considerations by transit management:

1. System environment--There should be a careful examination of the environment in which the system will be installed and operated. Factors such as organizational structure, plant and facility requirements, implementation and training requirements, and changes to existing work procedures must be considered at the outset.
2. System costs--In many cases, total system costs for development, installation, and operation are not fully realized and are often underestimated by transit management. For many maintenance and inventory MISs, the costs associated with installation and implementation can approach or exceed the design and development costs of the system.
3. Project commitment--Finally, there must be a strong commitment to the project at all levels of management. This should include a commitment of necessary transit resources (funding, personnel, and in-house facilities); active participation of assigned transit personnel in all phases of system design, development, and implementation; and frequent reviews of project progress, schedules, and costs by transit management.

System Design Considerations

Transit systems have always generated a wealth of operations data; however, the development and implementation of effective methods of collecting, processing, and analyzing these data as part of day-to-day operations have always been a problem for transit management.

Principal barriers and/or problems encountered in the implementation and application of automated data processing techniques in the area of transit maintenance and inventory control can be attributed, in many cases, to inadequacies in the original concept and design of such systems. Far too often, systems are developed without adequate consideration of the types of information a manager needs to run the department and as a result the system soon becomes too complex, too structured, and a burden to manage.

Some of the more important issues that are not always fully addressed in the design of an effective transit maintenance and inventory information system are the following:

1. Existing maintenance practices and work procedures--Consideration of existing maintenance practices, daily work procedures, scheduling, and data collection processes within a transit maintenance and inventory department is an important initial step in the design of a maintenance information system. A recent survey and analysis of the maintenance practices of 10 transit systems, summarized in Figures 2-11 (5), showed that there are substantial differences in the objectives, practices, and procedures used in many transit maintenance departments. Poor documentation of maintenance guidelines, work procedures, and work status and performance is also common. To facilitate the introduction and application of such systems in maintenance and inventory departments, the design of the system should reflect and make use of the existing principles, practices, and work procedures of the department to the maximum extent possible.

2. Information requirements--Another important issue often neglected in the design of a maintenance and inventory control system is a clear definition of the types of information a manager needs to manage the department effectively. Although large volumes of data and associated reports--representing physical parts inventory, outstanding work orders, vehicle maintenance histories, etc.--are typically required to maintain the day-to-day functions of the department, the design of these systems should focus on the development of more relevant information reports that can be used in making management and operating decisions. Reports reflecting trends in vehicle component failures, frequency of road calls, parts availability and use, and planned versus actual work accomplishment would provide maintenance and inventory managers with more useful information and a better tool for assessing the reliability and life of vehicle components, the effectiveness of alternative inspection and maintenance practices, and the overall performance of the department.

3. Information processing--All of the factors and issues that can influence the design of an information system in the collection, processing, and reporting of transit maintenance and inventory data are too extensive to enumerate and discuss here. Among the issues and design concerns are questions concerning how much automation should be introduced; the degree to which the information processing should be integrated with other MIS functions; the usefulness of on-board sensors, diagnostic systems, and other communication devices for the collection and recording of data; the use of advanced data processing techniques (i.e., data base management systems) for the management and organization of the data; and the use of low-cost microcomputers to perform some of the data collection and analysis functions.

Clearly, the trend in the industry in the design of new maintenance and inventory information systems is directed toward the use of on-line, interactive computing systems, the operations of which are nor-

Figure 2. Maintenance practices: MARTA, Atlanta.

BUS EQUIPMENT

No. of Buses

841

No. of Models

10

DEFINED SYSTEM STRUCTURE

- Not Defined
- No Codes
- No System Breakdown

MOST TROUBLE

- Air cond. compressors
- Pressure switches
- Leaking fuel tanks
- Low-profiles, tires
- Windows debonded
- Rear axle

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Maintenance personnel ratings
- Follow-up inspection by special inspection foreman
- Training program for mechanics
- Guidelines for all inspections & preventive maint.
- Guidelines for dynamometer, transmission & engine tune-up
- GM diesel service manual

SCHEDULED & PREVENTIVE MAINTENANCE

- Cleanliness of rolling stock
- Daily inspection
- Weekly inspection
- Inspection, 7K miles
- Dynamometer engine test & tune-up, 25K miles
- Major components
- Before ADB's, 70K miles/air conditioner failure
- 300K miles/new engines
- 200K miles/rebuilts
- 40K miles with Goodrich tires

SPARES INVENTORY/PARTS

- Computerized inventory-automatically issues PO whenever stock in bin gets down to minimum as set on stock record cards

DATA COLLECTION

DATA SYSTEM

- All forms processed manually
- Computerized inventory

PROGRAMMING/COMPUTER

N/A

FORMS

- Monthly Maintenance Record
- Actual work on bus
- Air Cond. PM
- Dynamometer test
- Daily bus record
- Interior cleaning
- Special inspec. for charters
- Garage-foreman's report of bus trouble
- Work order
- Equip. in Garage
- Gas Only
- Sight insp.

COMMENTS

- Maintenance coverage is all manually processed

DATA REPORTS

MAINTENANCE

N/A

OPERATIONAL

N/A

CONSUMABLES

N/A

INCIDENTS/ROAD CALLS

N/A

COMMENTS

- No reports issued

Figure 3. Maintenance practices: MTA, Baltimore.

BUS EQUIPMENT

No. of BUSES

1038

No. of MODELS

11

DEFINED SYSTEM STRUCTURE

- Road Call (Trouble) Codes
- System Breakdown-26 systems
  - 19 Mechanical Trouble Codes
  - 7 Misc. Trouble Codes

MOST TROUBLE

- (1979) - % of equip. road calls
- 19.7% Road Calls = Clutch, transmission
- 18.8% Road Calls = Engine
- 11.7% Road Calls = Cooling system
- 11.6% Road Calls = Mechanical brakes
- 10.4% Road Calls = Starting & charging

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Specific guidelines for insp.
  - Checklist for major & minor inspection
- Follow-up on repairs by foreman

SCHEDULE & PREVENTIVE MAINTENANCE

- Tire inspection

SPARES INVENTORY PARTS

- Daily Diesel Fuel & Oil Purchase Report
- Daily Inventory of Storage Tanks
- Monthly inventory & motor fuel & oil distribution
- Fuel & Oil Delivery Log

DATA COLLECTION

DATA SYSTEM

- Data collection manual, & hand processed
- Form flow is well documented

PROGRAMMING/COMPUTER

- Done by outside consultant
- Few in-house programmers

FORMS

- Inspection - 8 forms
- Road calls/defects - 7
- Availability - 12
- Miles, Fuel & Oil Consumed - 9
- Repairs/Replacement - 7
- Coach Record - 1
- Work Log - 1
- Inventory - 3

COMMENTS

- An automated, computerized system is currently planned. It will cover an extensive amount of data and will be under the authority of the Dept. of Transportation, Maryland.
- Use a large number of forms to cover much information. Those indicated are a good sample.

DATA REPORTS

MAINTENANCE

- Monthly Maintenance Reports
- Annual Maintenance Reports
  - Fleet Mileage, Consumables. Fuel & Oil Averages
  - Inspection, Cleaning, Painting
  - Road Call Summary
  - Component Mileage

OPERATIONAL

- Vehicle Inventory & Availability
- Vehicle Disposition & Mid-week report on vehicles down for major repair

CONSUMABLES

- Monthly & Annual Fuel & Oil summary & averages

INCIDENT/ROAD CALLS

- Road CAll Summary by System
- Road Call Summary - Miles/Call
- Road Call Summary - Miles/Mechanical Call

COMMENTS

- Reports provide a detailed breakdown of information

Figure 4. Maintenance practices: CTA, Chicago.

BUS EQUIPMENT

No. of BUSES

2420

No. of MODELS

8

DEFINED SYSTEM STRUCTURE

- Extensive coding system for bus equipment
- One identifying code for maintenance work-6 digits:
  - 2 digits for job category
  - 2 digits for detailed description of item
  - 2 digits for repair (completion) code

MOST TROUBLE

- Transmissions (VSl converters)
- A/C
- Engine

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Personnel input employee and information about the task they are currently working on through a computer terminal. When the task is completed, the employee logs the job off via the terminal.

SCHEDULED & PREVENTIVE MAINTENANCE

- PM-every 6K miles
- 2K miles-brake adjustment
- 4K miles-oil sample
- 36K miles-torque fluid change

SPARES-INVENTORY/PARTS

- Inventory not interfaced with VMS

DATA COLLECTION

DATA SYSTEM

- Automated, on-line, real time system (named Vehicle Maintenance System)

COMPUTER

- IBM 370/158 Mainframe
- Amdahl
- IBM System 7 minicomputer (as backup)

PROGRAMMING

In-house

FORMS

- None-Terminal input of maintenance information at every division to computer

COMMENTS

- Examples of data reports that could be generated on-line are: Bus Availability Report, Vehicle Technical Data, Hours & Cost Per Job, Planned Maintenance for Components on Vehicle, Road Call Summary by Vehicle, Fleet Garage, Time, etc.

DATA REPORTS

MAINTENANCE

None due to the on-line of VMS. Hard-copy reports containing particular data types can be generated on-line from a terminal, also.

COMMENTS

- Consumables are not input to VMS.

Figure 5. Maintenance practices: COTA, Columbus.

BUS EQUIPMENT

No. of BUSES

273

No. of MODELS

6

DEFINED SYSTEMS STRUCTURE

- 40 codes defined to describe bus equipment
- 12 codes for reason for repairs
- Unit change codes

MOST TROUBLE

- Brake (manual slack adjusters) 6-7 road calls/wk

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Guidelines for safety inspections

SCHEDULED & PREVENTIVE MAINTENANCE

- Inspections at 2K mile intervals covering brakes steering, tires, etc.

INVENTORY/PARTS

- Manual inventory system

DATA COLLECTION

DATA SYSTEM

- Manual
- Track component data
- Track manhours data

COMPUTER/PROGRAMMING

N/A

FORMS

- Coach defect report
- Work order
- Inspection & overhauling record of equipment
- Bad order vehicle report
- Road call report
- Coach mileage reading
- Diesel & oil report

COMMENTS

- Computerized maintenance data collection system expected in future
- 2 years to full operation, expect to copy CTA operation

DATA REPORTS

MAINTENANCE

N/A

OPERATIONAL

N/A

CONSUMABLES

N/A

ROAD CALLS

N/A

Figure 6. Maintenance practices: SEMTA, Detroit.

BUS EQUIPMENT

No. of BUSES

331

No. of Models

14

DEFINED SYSTEM STRUCTURE

- No codes

MOST TROUBLE

- V730 transmission (1st & 3rd clutches fail most often)
- Brake lining
- Electrical system
- Front end suspension system

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- All repairs followed up by foremen
- Repair-diagnosis time tracked
- Inspection guidelines
- Perform failure analysis of equipment determining failure modes

SCHEDULED & PREVENTIVE MAINTENANCE

- Pit inspection every 3 weeks at 12K, 24K, etc. miles
- No. parts & material cost/bus reported @ inspection
- Mileage, fuel, coolant & oil recorded daily
- Torque converter checked @ daily fill-up

SPARES-INVENTORY/PARTS

- Computerized inventory system with automatic reordering (when bin @ minimum)
- Terminals budget - $250,000 parts terminal

DATA COLLECTION

DATA SYSTEM

- Manual data collection system

PROGRAMMING/COMPUTER

N/A

FORMS

- Inspection
- Symptom & repair
- Road call
- Daily mileage, fuel, oil, & coolant
- Failure analysis
- No. parts & material cost/bus
- Pit inspection
- Consumables

COMMENTS

- Plans are underway for automating data collection system

DATA REPORTS

MAINTENANCE

- Weekly } including
- Monthly
  - Total operating fleet
  - Road calls
  - Overtime
  - Fuel & oil usage-MPG, MPO
  - Miles between breakdowns

OPERATIONAL

- Availability recorded

CONSUMABLES

- Recorded in weekly & monthly inputs

ROAD CALLS

- Recorded in weekly & monthly reports

Figure 7. Maintenance practices: MTA, Houston.

BUS EQUIPMENT

No. of BUSES

890

No. of MODELS

10

DEFINED SYSTEM STRUCTURE

- Defined, but not used
- Bad Order Bus & Road Call Codes

MOST TROUBLE

- FLX panels, doors & gas tanks

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Checklists for performing inspections

SCHEDULED & PREVENTIVE MAINTENANCE

- Inspection @ 6, 12, 18, 24, 30K miles
- When due for inspection flagged on computer printout of scheduled (rte) miles

SPARES-INVENTORY/PARTS

- Computerized inventory with many problems

DATA COLLECTION

DATA SYSTEM

- Data collection is manual
- Computer for inventory, mileage & fuel oil consumption

PROGRAMMING/COMPUTER

- Purchased system
- New system is planned
- In house programming

FORMS USED

- Repair Order
- Fleet Performance
- Road Call Analysis (Daily)
- Daily Maint. Perf. Indicator
- Daily Bad Order Bus Summary
- Weekly Personnel Status
- Central Shop Unit Overhaul Perf. Ind.

COMMENTS

- Data Collection system has many inaccuracies
- Much information entered is not valid, has errors and does not verfy actual values as in the case of inventory stocks.
- Current plans call for a complete revision of data collection and processing

DATA REPORTS

MAINTENANCE

- No monthly or annual reports
- Daily maint. performance indicator
- Daily bad order bus summary
- Overhaul performance indicator
- Raw data available

OPERATIONAL

- Fleet performance summary: (by day of week)
  - Buses assigned
  - Pulled, AM
  - AM runs cut, % runs cut
  - % AM lates
  - Pulled, PM
  - PM runs cut, % runs cut
  - Late PM pulled
  - % PM lates
  - Total & % Bad Order Buses

CONSUMABLES

- Montly fuel & oil consumption report

INCIDENTS/ROAD CALLS

- Daily road call analysis

Figure 8. Maintenance practices: SCRTD, Los Angeles.

BUS EQUIPMENT

No. of BUSES

2817

No. of MODELS

33

DEFINED SYSTEM STRUCTURE

- General categories for inspection & maintenance
  - Engine
  - Drive
  - Chassis
  - Brakes
  - Electrical
  - Body
  - Doors
  - Lifts

MOST TROUBLE

N/A

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Checklists for all inspections. Computerized printout available for road call summary problems

SCHEDULED & PREVENTIVE MAINTENANCE

- 6K, 12K, 18K & A/C inspections
- Weekly brake & safety inspection report

SPARES-INVENTORY/PARTS

- Inventory control computerized
- Complex warehousing of components

DATA COLLECTION

DATA SYSTEM

- Manual data collection
- Computerized tally of road calls by division & codes, oil consumption, fuel performance by division

PROGRAMMING/COMPUTER

- UNIVAC
- IBM VMS System currently being installed
- In House

FORMS

- 6K, 12K, 18K & A/C inspection forms
- Farebox key log
- Mechanical Road Supervisor Report
- Automotive repair card
- Road failures defect & work report
- Brake & safety inspection
- Warranty claim tag
- Wheel chair p.m.

COMMENTS

- Complete revision of data collection and system is planned.
- One division used as a test division for the new system

DATA REPORTS

MAINTENANCE

- No summary, monthly, or annual reports

OPERATIONAL

N/A

CONSUMABLES

- Oil consumption
- Fuel performance by division

INCIDENTS/ROAD CALLS

- Road calls by division and codes

Figure 9. Maintenance practices: RIPTA, Providence.

BUS EQUIPMENT

No. of BUSES

240

No. of MODELS

10

DEFINED SYSTEM STRUCTURE

- Not defined
- No codes
- No system breakdown

MOST TROUBLE

N/A

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Manuals are used from GMC for buses
- Informal guidelines for performing maint. under supervision of foreman

SCHEDULE & PREVENTIVE MAINTENANCE

- Inspection - 2k day
- Oil change 9K miles
- Oil gas - 1st & 15th of each month-tally

SPARES INVENTORY/PARTS

- Track all spares required. A max-min review of all parts is made
- Parts consumption tracked monthly
- With careful review can account for monthly and annual consumption

DATA COLLECTION

DATA SYSTEM

- Data collection is manual
- All data hand processed

PROGRAMMING/COMPUTER

N/A

FORMS

- Bus defect each day
- Daily work assignment
- Coach record
- Bus master mileage
- Road call summary

FORMS (Contd.)

- Minor inspection
- 9K miles
- 27K miles
- 54K miles
- 209 Supply Req.
- TA281 Material issued

DATA REPORTS

MAINTENANCE

- Monthly Maintenance Cost Summary

OPERATIONAL

- Bus Master Mileage Summary
- Coach Record

CONSUMABLES

- Oil and Gas Summary

INCIDENTS/ROAD CALLS

- Road Call Summary

Figure 10. Maintenance practices: Via Transit, San Antonio.

BUS EQUIPMENT

No. of BUSES

430

No. of MODELS

8

DEFINED SYSTEM STRUCTURE

- No equipment breakdown
- No codes

MOST TROUBLE

- GMC-ADB Air Conditioning System

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Inspection guidelines for all vehicles
- Repair procedures for brakes
- Work orders
- Heavy equipment inspection checklists
- Security checks

SCHEDULED & PREVENTIVE MAINTENANCE

- Brake records
- PM schedule

SPARES-INVENTORY/PARTS

- Inventory stores requisition forms-part description, factory no., company no., location

DATA COLLECTION

DATA SYSTEM

- Bus summary card as major means for tracking

FORMS

- Consumables
- Coach record including - all repairs during bus-life
- 16 inspection forms
- 1 bus change & trouble calls
- 1 waranty adj.
- 7 bus status forms

COMMENTS

- Individual history on each bus is only data available for immediate study

DATA REPORTS

MAINTENANCE

- No reports

OPERATIONAL

- Delays due to mech. failures
- Buses dead as of 7:30 AM daily
- Bus status

CONSUMABLES

N/A

COMMENTS

- Data is available but not structured into reports

Figure 11. Maintenance practices: METRO, Seattle.

BUS EQUIPMENT

No. of BUSES

1021

No. of MODELS

11

DEFINED SYSTEM STRUCTURE

- Coding system for bus equipment & repair types

MOST TROUBLE

- Transmission - V730
- Brakes - life = 30-35K miles in rear and 40-50K in front
- Electrical system

MAINTENANCE PRACTICES AND PROCEDURES

PROCEDURES & GUIDELINES

- Inspection guidelines for regular and articulated coaches
- Training program

SCHEDULED & PREVENTIVE MAINTENANCE

- Coach inspection types: 5
- Articulated inspection types: 6
- 1K miles safety inspection-brakes primarily
- 2K miles for major components
- Oil change @ 6K miles for articulated coaches, 12K for other coaches
- Other PM @ 4K, 6K, 12K, 24K, 36K, etc.

SPARES-INVENTORY/PARTS

- Computerized inventory system (MSA) for inventory control, purchasing, & rates. Also, automatic reordering with quotamatic min & max setting

DATA COLLECTION

DATA SYSTEM

- Automated data collection utilizing ARMS financial accounting system), CORS (Coach Operations Reporting System), SIMS (Service, Inventory and Maintenance System), and MSA inventory control (Management Science of America)

PROGRAMMING/COMPUTER

- King County IBM 370
- In-house programmers
- CORS-batch system

FORMS

- Inspection forms
- Trouble call forms
- Bad Order form
- Coach Repair record

COMMENTS

- CORS Phases in METRO:
  - Remote data entry:
  - Coach history reporting;
  - Print coach history @ base

DATA REPORTS

MAINTENANCE

- SIMS report of mileage, scheduled inspections, consumables, fuel economy. Daily on-line mileage based on assignment, not hubodometer
- Daily Coach Problem Report from CORS

OPERATIONS

- Monthly Management Report
- Daily CORS operations report
- Cost/mile fleet from CORS upon request

CONSUMABLES

- SIMS daily reports on consumables

ROAD CALLS

- Daily CORS report isolating Trouble Calls and Bad Orders

COMMENTS

- Capability of trends analysis, parts cost & labor cost per component

Figure 12. Transit maintenance and inventory management system.

SUBSYSTEM	FUNCTION	SUBSYSTEM	FUNCTION
Inventory Management	·Inventory Transactions ·Usage Reporting ·Stock Status Reporting ·Reorder Processing ·Special Requirements/ Campaigns ·Vendor Parts History ·Physical Inventory ·Inventory Costing	Work Order Processing	·Work Order Control ·Repair History ·Labor Performance Reporting ·Cost Reporting ·Warranty Processing ·Reimbursable Cost Reporting
		Failure Monitoring	·Vehicle Trouble Call Processing ·Vehicle Defect Processing ·Vehicle Defect Analysis ·Support Equipment Reporting
Preventive Maintenance	·Consumables/Mileage Monitoring ·Component Scheduling ·Support Equipment Maintenance Scheduling	Status Tracking/Reporting	·Vehicle Fleet Inventory ·Vehicle Availability ·Subfleet Assignment
Planning	·Backlog Status ·Short-Term Personnel Scheduling ·Long-Term Resource Planning	Management Reporting	·Performance Indicator Reporting ·Summary Reporting ·Project Reporting ·Special Reporting

mally shared with other departments of the agency. System software designs tend to be modular and structured to reflect the basic transit maintenance and inventory processing functions [see Figure 12 (6)]. Data entry and information reporting are usually handled through remote terminals and data entry devices located within the maintenance and inventory departments.

System Applications

Recent applications of automated data processing techniques and information reporting systems in transit maintenance and inventory departments have provided transit managers with an improved awareness of the day-to-day functions and operations of these departments. Now, with increased emphasis being placed on improving management techniques and making more effective use of existing resources and facilities, the application of these systems to the measurement and evaluation of transit performance can be expected.

Transit performance indicators have been proposed in a number of management studies (7-9) as a potentially useful and feasible means of monitoring and improving the allocation and use of transit resources. A number of transit systems across the country have established performance monitoring procedures, and it is likely that the use of performance measures will become widespread throughout the transit industry in the future.

Because U.S. transit systems differ substantially with respect to operating environment, organizational structure, service characteristics, and operating procedures, it is clear that no single performance measurement system will be universally applicable. Rather, the designs of performance measurement systems will have to be tailored to meet the needs and characteristics of each transit system.

Measuring the performance of transit maintenance practices and policies requires the establishment of realistic goals and the specification of appropriate indicators for those goals. Although there is no industrywide concensus as to what constitutes representative goals and performance measures for transit maintenance, the following are some of the most often cited and used goals and indicators (7-9):

1. Reduction in system maintenance costs--Maintenance cost per vehicle, maintenance cost per vehicle mile, bus miles per mechanic, buses per mechanic, and maintenance cost per maintenance man-hour;
2. Improved vehicle reliability--Breakdowns per passenger mile, breakdowns per vehicle, breakdowns per vehicle mile, and bus miles per maintenance-related road call; and
3. Improved maintenance performance--Vehicles out of service, vehicle hours out of service for maintenance, mean time to repair per breakdown, and maintenance man-hours per breakdown.

Traditionally, transit systems have relied on such performance measures to recognize trends and to determine strengths and weaknesses in system performance. Often, comparisons are made with respect to average performance measures of transit systems with similar characteristics (i.e., size, operating characteristics, etc.) to identify areas for potential improvement. More recently, performance measures have been used by transit management to establish goals and to evaluate the performance of various departments (various maintenance garages, operating divisions, etc.) internal to the organization (10).

FEDERAL R&D EFFORTS

UMTA, together with industry groups such as APTA, is engaged in efforts to improve an industry that has been in decline over the past two decades. R&D efforts are being directed to improving the performance and reliability of vehicles and the management practices for maintaining and operating such equipment. The key problems, however, appear to be inefficient maintenance practices, inadequate maintenance considerations in vehicle design, the lack of adequate and consistent data on vehicle subsystem and component reliability, inadequate training and instruction of transit maintenance labor, and the need to use modern systems management techniques in establishing work standards, life-cycle costing procedures, and performance measurements. The recognition of these problems and the need for solutions should form the basis of UMTA's transit management R&D program.

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Workshop Report

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Two broad needs were identified by participants in Workshop 2. These were the need to develop good historical bus performance data for use in maintenance management and the need for further R&D in the area of quantitative analysis.

Participants agreed that complete and readily accessible data in the form of vehicle histories are a key ingredient in the successful management of a maintenance operation. In many cases such information does not exist, but several successful examples can serve as models for the development of such an information base. Participants noted that several methods for inventory control, failure monitoring, budget analysis, and preventive maintenance scheduling offer promise but that further research and analysis, as well as suitable data bases, are required before their costs and benefits can be evaluated.

Throughout the discussion, much attention was given to three concerns: (a) the development, installation, and use of computerized MISs for maintenance; (b) nationwide collection and dissemination of bus maintenance data; and (c) the use of historical data in analyzing purchasing options.

CURRENT CONDITIONS AND PROBLEMS IN BUS MAINTENANCE

The main priority of bus maintenance is a safe coach on the road. To this end, information pertaining to the bus must be collected, processed, and acted on quickly and accurately. Many problems currently prevent this from occurring. These include the following:

1. Lack of data on the history and current condition of vehicles within a system--This may result from a limited number of methods for collecting data. Compounding this problem may be the failure of management to stress the importance of good data to those actually involved in the collection process--namely, mechanics and first-line supervisors.

2. Limited availability and use of computerized maintenance MISs--The use of computers for bus maintenance varies greatly from property to property, currently running the gamut from completely manual information systems to highly computerized maintenance and inventory systems. Participants cited as major areas of concern a need to define the functions and features of a good maintenance MIS and a need to ensure applicability to small systems.

3. Problems associated with the transition from a manual to a computerized information system--Currently, this transition is often brought about by increasing amounts of data, the need to reduce labor costs, and "crisis" situations resulting from severe subsidy cutbacks. These hasty transitions often ignore the problems of training, the increased work load involved in the changeover, and the limitations of the system.

4. Lack of simulation and failure models for use in maintenance planning--Currently, poor data bases limit the development and use of such models in manpower planning, facility development, inventory control, and preventive maintenance scheduling.

Related to these problems with internal information systems are the following problems that currently exist with regard to national information dissemination:

1. The lack of a system to collect and disseminate information on bus defects on a national scale was identified as an especially important problem by property maintenance managers attending the workshop. Currently, information about specific bus model problems is passed along through the industry "grapevine", but this approach often misses the smaller properties, which get little help from the manufacturers because of their limited fleet size.

2. The lack of complete useful information on the interchangeability of parts was identified as a minor problem. There are currently several sources of limited information, but cross-indexing among different manufacturers is not available.

The final problems identified were all related to the low-bid system. These included high defect rates, the large number of small vendors that must be dealt with, and the long lead times, which result in increased inventory overhead. Current specifications are often not specific enough, and information on vendor reliability and quality is not available. Currently, the State of Washington has procurement laws applying to professional services that allow the bid sponsor to identify the most qualified bidder before costs are discussed. It was felt that this approach might work well if extended to cover purchasing.

POSSIBLE SOLUTIONS AND SUGGESTED AREAS OF RESEARCH

After reviewing current conditions and problems in bus maintenance, workshop participants developed several possible solutions and suggested areas for further research. In addressing the collection of maintenance data and the design maintenance MIS, the workshop drew the following conclusions:

1. Areas for which data should be collected on a continuous daily basis include the reporting of consumables such as oil and fuel, labor, and materials used, based on a bus number identification system. Research should be continued or initiated in the areas of automated data-collection methods. Specific examples cited by participants were continued development of automated fueling systems and research into the use of optical and voice-activated mechanisms for bus data collection and employee identification.

2. The desirable features of a good maintenance MIS are low cost, ease of control by maintenance personnel, "user-friendly" features, ease of interpretation, and the ability to display key performance indicators. Regarding the desired functions of a system, the workshop studied the proposal of the Western Transit Maintenance Consortium, which is currently developing a modular maintenance management system under the joint sponsorship of five western transit properties and UMTA. The top-level function chart of this system served as the basis for discussion in this area. Of the seven major categories developed by the Consortium, three--preventive maintenance scheduling and monitoring, inventory management, and failure monitoring--were identified as essential functions of a good maintenance system, and work-order processing, including labor time standards, and status tracking and reporting were cited as highly desirable functions. Participants felt that further R&D related to MISs for maintenance should be a top priority of transit systems as well as UMTA. This research should stress the transferability of systems between properties, particularly properties of small and medium size.

3. The transition from manual to computer information systems could be facilitated by better user understanding of system capabilities and limitations, specific definition of user requirements, and increased emphasis on training. Participants also stressed the need for management commitment at all levels in order for a smooth transition to occur. R&D is needed in the areas of preinstallation and postinstallation training of employees. It is essential that the people directly responsible for data collection and system input be aware of the benefits they will derive from the system as well as the limitations inherent in the system. To this end, training programs that emphasize these factors and are capable of being transferred between properties need to be developed.

4. Improvements in data-collection and processing capabilities should be followed by the development of simulation and failure prediction models. Such models would be part of a management decision support system and closely linked to the maintenance MIS. Further R&D of understandable, "user-friendly" simulation models should be undertaken, particularly after improvements have been made in the area of data collection. Participants felt that such models would aid in the planning of preventive maintenance scheduling, facility development, and establishment of acceptable reliability and service levels.

Participants felt that the R&D activities listed above lend themselves well to funding plans similar to that used by the Western Transit Maintenance Consortium. The main feature of this type of plan is that projects are jointly funded by the properties directly involved, with partial funding from federal agencies. The use of federal grant money would also ensure dissemination of the results to all properties regardless of their size.

Possible solutions that were proposed with regard to the lack of nationwide information were the establishment of two centralized national information centers. The first center--and the most important, according to participants--would aid in the identification of fleet problems. This could possibly take the form of a national fleet inventory for defect and problem identification to which maintenance managers could refer. Information available through this system would include bus model, identified problems, other properties that own similar buses, and the name and telephone number of a contact person at each property listed. Development of such a system could possibly be funded by UMTA, and its continuing operation could be funded by the participating properties.

The second national information center would provide cross references on the interchangeability of parts. Due to the massive amounts of information and the facilities that this would require, the feasibility of this idea should be studied carefully before further development takes place.

Suggested solutions to the problems associated with the low-bid system centered around the collection and sharing of vendor history information, especially concerning reliability and quality. Development of computer programs tied in with a maintenance and inventory system that would directly compile and report such information should be considered. Also suggested was the development of a method for comparing component reliability and life expectancy with cost for use in competitive procurement procedures.

SUMMARY

Participants in the workshop discussed management tools for improving maintenance. Two general categories of concern emerged from the discussion: the need to collect historical bus data and the need to develop methods to use the data. Within these categories, seven specific areas requiring R&D were identified. These are listed below in order of importance (from major to minor). The first four items pertain to data collection and the last three to data use:

1. MISs specifically for maintenance, including systems for preventive maintenance scheduling, inventory control, failure monitoring, work-order processing, and status tracking;
2. Training programs that would aid in the transition from manual to computerized maintenance information systems;
3. Automated data collection methods for maintenance;
4. A national information network for sharing data on major, model-specific bus defects;
5. Management tools and information systems that would facilitate the purchase of quality products within the low-bid system;
6. Simulation and failure models for bus maintenance that would facilitate bus maintenance planning; and
7. A system for cross referencing data on the interchangeability of bus parts.

Workshop 3: Human Resources for Maintenance

Issue Areas

The role of human resource management in maintenance is of critical importance. It is generally accepted that more effective maintenance depends on better training and worker-management cooperation, but no clear agenda for improvement has been developed. Workshop 3 participants were asked to discuss ways of improving employee selection and training and to identify other ways in which maintenance manpower can be made more productive. Participants were also asked to discuss union relations and cooperation among drivers, mechanics, and management.

Resource Paper

James Gregory Mitchell
Detroit Department of Transportation

In spite of hundreds of millions of dollars spent by federal, state, and local mass transportation agencies in the United States over the past two decades, significant improvements in the delivery of public service have not materialized. Such a statement is difficult for many of us in the mass transportation industry to accept, since it implies that we have not been doing our job. However, we are beginning to realize that this problem is almost universal in the transit industry. In fact, declining productivity, diminishing cost-effectiveness, and lower operating efficiency are fast becoming the rule rather than the exception in many U.S. industries.

It is time for us to openly acknowledge the scope of this problem and work together in finding solutions. But you do not need me to tell you this. UMTA Administrator Teele was quite clear and thorough in opening our eyes to this situation during his testimony to the House Committee on Public Works and Transportation, Subcommittee on Investigations and Oversight, in June 1981 (1). I urge those who have not done so to read the transcript of his address because it presents UMTA's justification for its diminished role in local mass transportation functions. In other words, we will be receiving fewer federal dollars in the years ahead for wages, new equipment, diesel fuel, etc.

For most of us, the choices are tough but crystal clear: We must either cut service, raise local revenue (higher fares or more taxes), or improve efficiencies. I believe all of us here understand which of these three unpleasant options will be the most popular with the people or agencies that direct us. I also realize how difficult it will be for most to improve cost efficiencies--not because of any deficiency in management expertise or commitment but because of the depth and breadth of the problem.

This paper focuses on the human resource component of the bus maintenance system. It is my feeling that this component represents the single largest element of the mass transportation cost-efficiency problem and therefore that its solution will result in the highest level of improvement. Although exact percentages are difficult, if not impossible, to determine, it has been estimated that roughly 50 percent of the total bus maintenance workload on a typical day at the Detroit DOT is directly attributable to human resource problems--e.g., absenteeism, wrong diagnosis, improper application of maintenance procedures, or misallocation of labor resources. This percentage may sound high until one considers the numerous aspects of the human resource element and the many ways in which each can influence bus reliabilities and availabilities. For any maintenance manager, human resources should be evaluated whenever the percentage of "downed" vehicles exceeds about 20 percent during the peak, scheduled evening operations are often neglected in order to respond to corrective maintenance needs, or more than 5 percent of the operating fleet requires on-the-road service during an extended time period. At the Detroit DOT, we know we are in trouble because all of these key indicators are present.

Many U.S. maintenance managers are familiar with such symptoms. Because human resource difficulties are shared by a large number of transit properties, it is likely that common solutions can be found. In working together, we can minimize the resource drain on individuals that usually accompanies such involved problem solving. Finally, because human resource problems have been experienced by other U.S. industries in recent years, there is a good chance that much of our work has already been done for us. All we need to do is to evaluate the success of other improvement programs and determine their applicability to bus maintenance.

WHERE WE ARE

In attacking any problem of such large scope, it is best to begin by identifying the nature of the problem--what it is and how it got to be that way. It is hoped that this preliminary step will prevent us from wasting time on symptoms and help us to focus on the deeper causes. Although my perspective has been formulated through close contact with the Detroit DOT over the past five years, I think many similarities with other urban bus operations will be apparent.

Because I so often hear senior maintenance personnel compare the dismal performance of today's work force with that of the "good old days", I decided to take a closer look at what made the old days so good, especially concerning the labor force. For obvious reasons, I limited this examination to four fundamental elements: skills, motivation, work environment, and organizational structure. No specific point in time was selected to separate "then" from "now" because there was an extensive period in

Table 1. Operating statistics for Detroit DOT: 1951-1981.

Year	Journey-man Mechanics	No. of Buses in Fleet	Revenue Miles Operated	Revenue Miles per Mechanic	Vehicles per Mechanic	Miles per Vehicle	Passengers Carried	Passengers per Mechanic	Passengers per Vehicle	Passengers per Mile
1951	409	2043	64 813 363	158 468	4.96	31 725	180 244 863	440 696	88 226	2.78
1960	268	1285	41 570 454	155 114	4.79	32 351	135 002 366	503 740	105 060	3.25
1965	204	1144	38 530 003	188 873	5.61	33 680	115 049 533	563 968	100 568	2.99
1970	186	1180	37 734 444	202 873	6.34	31 978	115 203 635	619 374	97 630	3.05
1981	198	803	26 999 883	136 363	4.06	33 623	66 017 000	333 419	82 213	2.45

Note: Data taken from annual reports and annual fleet inventories of the Detroit Department of Street Railways (1951-1973) and the Detroit DOT (1974 to present).

which things were neither all good nor all bad but in transition. A brief examination of the past 30 years at the Detroit DOT illustrates the extent of this transition period.

In Table 1, four important operating statistics are traced over three decades, from 1951 to 1981. Some of these statistics are combined to produce popular efficiency ratios, such as vehicles per mechanic and passengers per vehicle. Clearly, some ratios have changed dramatically while others have not. It is especially interesting to note that very little change has taken place in the miles-per-vehicle ratio, a commonly used measure of bus maintenance efficiency. All other factors being equal, this would indicate a fairly consistent level of mechanic efficiency for the 30-year period. Even though vehicles per mechanic decreased about 36 percent between 1970 and 1981, varying levels of coach reserves or spares could account for such differences. Concerning revenue miles per mechanic, a large percentage of the Detroit DOT labor force in the 1965 and 1970 figures included helper mechanics (not counted in the journeyman mechanic figures) whereas the 1981 data include almost none. In summary, the overall systemwide operational load has not really changed in terms of how much road service is delivered by the maintenance work force through annual mileage accumulations per vehicle.

As with many other areas of human experience, senior bus maintenance employees may be selective in recalling the positive aspects of their job while suppressing the negative. The summary data here do not imply that there was a higher level of maintenance skills in the "good old days". However, the perception that mechanics were better skilled can be as damaging to present worker performance as the actuality would be. If employees feel that their individual contribution to the overall operation is of little value, there is no reason to expect from them a high degree of concern over work quality, attendance, or cooperation.

If the historical data from the Detroit DOT do nothing else, they should demonstrate that the human resource problem is not as simple as we once thought--i.e., better-skilled mechanics. If mechanics in the past were better skilled and therefore more effective in maintaining the fleet, then the Detroit DOT should have experienced dramatic decreases in miles per vehicle during this 30-year period. We need to look deeper at this problem, analyze other aspects of the human element of bus maintenance, and offer solutions that include skills improvement as one component rather than as the entire answer.

Two other important aspects of the bus maintenance function that affect worker performance are workplace environment and organizational structure. In the old days, the workplace environment was more amenable for several reasons. In general, garage and shop facilities were newer, cleaner, and in better operating condition. The Detroit DOT division that had responsibility for facility construction and maintenance was larger and hence more effective prior to the City's budget crises in the early 1970s. In addition, the important function of building cleaning, heating, ventilating, and repairs was properly addressed through an adequate budget and staffing level.

Another important aspect of workplace environment concerns the homogeneity of the work force. At no other time in the history of the Detroit DOT has the character of the maintenance staff been so varied. Differences in age, race, and sex have created the setting for many potential conflicts--conflicts between coworkers and between mechanics and supervisors. It is probably a natural human instinct to attribute many interpersonal conflicts to the most "obvious" cause--i.e., age, race, or sex. Because we are such visual creatures, it is difficult to go beyond what we see to determine the root cause of on-the-job conflicts, hostilities, and fears. However, we have discovered that differing value systems are usually the cause of many interpersonal conflicts. This subject is discussed in more detail later in this paper.

Organizational structure is often neglected as a contributing factor in worker performance, but its effect has been observed at the Detroit DOT. The most critical manifestation of this phenomenon is the widespread perception by maintenance personnel that there is no clear-cut line of control and responsibility within the organization. In the old days, there were, at most, five layers of management responsibility between the lowest-level worker and the highest level of authority, the general manager. Everyone knew exactly who made what decisions. The most involved issues were settled in a few days. The line between acceptable and nonacceptable behavior or performance was clear. Today, the organizational structure at the Detroit DOT is complex. Several peripheral agencies influence the activities of the Detroit DOT and its bus maintenance function, although little direct contact is ever made between these organizations and the employees. Through funding relations with UMTA, the Michigan DOT, SEMTA, and various City of Detroit departments, many key policy issues are decided by interests far removed from Detroit DOT employees and passengers. Because of the influence of the City's Civil Service Commission, the Human Rights Development and Personnel Department, and numerous state and federal agencies that are often involved in employee disciplinary actions, labor relations are not always consistent.

All of these organizational changes have affected the way mechanics and supervisors view their job and their employer. It is understandable that uncertainties related to budget and labor relations are transferred to work performance. Unclear or changing departmental goals and policies are easily filtered down to all levels of maintenance.

Employee motivation is, of course, determined by factors such as skill level (or perceived skill level), workplace environment, and organizational structure. If employees are not satisfied with these three fundamental job requirements, they probably lack motivation and have developed poor attitudes. So high motivation and good attitudes will, to a large degree, develop automatically as skill level, workplace environment, and organizational structure improve. Managers must realize that motivation and attitude are extremely difficult to shape without the presence of these other factors. Such efforts have been attempted without very much long-term or widespread success. Incentives ranging from individual attendance record awards to intergarage performance competitions have been attempted, but such efforts only result in rewarding those who already possess high motivation due to extraneous factors. The vast majority of employees who need help are not affected.

The causes of the human resource problem in public transportation, as in many other U.S. industries, are fundamental in nature, relating to the basic tenets of job satisfaction: self-esteem, workplace environment, organizational structure, and motivation. However, before we establish a plan of action, an examination should be made of studies and findings in other industries.

CHANGING VALUES OF WORKERS

Many research efforts have been undertaken in this country over the past few years in order to define the national human resource problem and establish an agenda for improvement. Many of the findings from these investigations indicate that the problem is largely related to a changing value system among workers.

The traditional profile of a typical worker as a man working full time to provide full support for his wife and children has drastically changed. Today, fewer than 20 percent of American workers conform to this profile (2). With this transformation, the labor force has also changed its view of the job itself--what it should be and what the worker can get out of it. Unlike their parents, today's workers want more than money out of a job; they also want self-fullfillment. If this desire is not met, workers can easily become dissatisfied, unproductive, unreliable, and, ultimately, part of the increasing number of job nomads.

Psychologists Abraham Maslow and Morris Massey, among others, have contributed a great deal to the understanding of this aspect of human nature. Their studies have helped us to analyze the causes of job dissatisfaction as being closely tied in with the individual's overall success in attaining higher-order needs. More exactly, when the basic human needs of food, shelter, health, love, etc., are met (or, as Massey points out, taken for granted), people set their sights on higher life goals. The bountiful good life portrayed on television and ingrained in the American Dream constantly reinforces such thinking. What are these higher life goals? They probably vary among individuals, but most include a deeper value of job satisfaction--i.e., attaining esteem and self-actualization through one's career. For many people, these higher-order needs can only be met at the workplace.

WHAT MUST BE DONE

As was done on a small scale at the Detroit DOT, the bus maintenance industry must evaluate the nature and extent of the national human resources problem. Because of the severity of the symptoms, I think we will find out that the problem reaches all the way to the core of the job concept.

A relatively inexpensive means of starting this evaluation process involves mailed surveys or questionnaires. In this way, management and union leadership from many U.S. bus maintenance properties could provide valuable input within a short time. If a significant degree of commonality were found among a large number of transit properties, then a coordinated and comprehensive approach would be justified. It may be appropriate to select a small, representative group of properties for in-depth analysis and pilot program implementation. Once improvements are demonstrated, final versions of the program can be disseminated to other sites.

Preliminary investigations in this area at the Detroit DOT have indicated that two important job elements can be addressed in order to meet many of these basic deficiencies. The first involves improving the effectiveness of the mechanic through better on-the-job reference material. Job performance aids (JPAs) are designed to provide clear, simple, and easily used instructions to the mechanic in completing repairs, adjustments, removals and replacements, and even trouble-shooting activities. Currently, we are about halfway through an UMTA pilot program for RTS-II JPAs, and the signs are encouraging. Not only are mechanics capable of doing more complex jobs with fewer errors, but their self-esteem and job pride are improving. We think this will help lift their low motivational levels.

The second job element on which we have spent a considerable amount of effort is improving first-line supervisor effectiveness. The Detroit DOT has given classes in both the technical and humanistic aspects of supervision. Through videotape lectures by Morris Massey, we have attempted to enlighten our supervisors on the changing values of today's mechanic and how that influences job behavior. However, many of these supervisors are inexperienced and need guidance on the fundamental aspects of their job. Furthermore, their lack of experience in bus maintenance limits their effectiveness in assigning work and providing technical support to mechanics. The Detroit DOT simply does not have the capabilities to address properly this critical element of the human resource problem. It is hoped that successful programs from other transit properties can be easily transferred to Detroit.

We have also discovered, through management-by-objectives sessions, that it is important to clearly express departmental goals, objectives, and priorities to the mechanics through first-line supervision so that everyone knows how they relate to the overall organization.

As mentioned earlier, many of the deficiencies in human resource utilization are common to the vast majority of U.S. "blue collar" industries. Research should be done to determine the degree of success experienced by other industries in improving these deficiencies. In Detroit, automobile manufacturers have done a great deal of research on the applicability of successful practices in other countries--Japan and Sweden, for example--in attaining high levels of worker motivation, commitment, reliability, and productivity. These and similar studies should be examined for possible use by bus maintenance operations.

Another important factor to consider in this problem approach concerns management-labor cooperation. It must be understood by all parties that the goals being sought will benefit both sides and that this is not an attempt to merely squeeze more work out of employees for the same amount of pay. Union leadership must recognize that improvements in labor efficiencies are required in order for the industry to reverse declining trends. Management must understand that an employee's ability and willingness to properly perform assigned duties are inescapably tied in with fundamental elements of human behavior that go beyond a good day's work for a good day's pay.

Again, the Detroit automobile makers provide an example of an increasingly cooperative relationship between management and labor. In many cases, management has given up a certain degree of policy control while labor has sacrificed pay and fringe benefits, all for the common good of the organization. It took a financial disaster for both sides to recognize that their respective fates were inseparable.

We must be cautious, however, about placing too much emphasis on the traditional role of union leadership. Many indicators suggest that union members are becoming as alienated from their leadership as they have traditionally been from management. According to the June 24, 1980, Wall Street Journal "Labor Letter", workers voted to repudiate their unions in 75 percent of the 1979 decertification elections nationwide, the second highest percentage in 30 years (figures are not available for 1980-1981). Furthermore, in a survey published in the Journal's "Labor Letter" on May 16, 1980, the number of union members favoring laws that state workers cannot be required to join a union or pay dues rose from 43 to 72 percent. These and other signs show that employees themselves must be dealt with directly in solving major human resource problems. Union representatives, though elected, should no longer be viewed as being capable of speaking for their membership in all matters.

Another important task to be completed in the early stages of this effort is to convince the policymakers of the importance of the undertaking. Without their continuing support, the comprehensive and time-consuming job of human resource improvements cannot take place. At the core of this selling job is the familiar trade-off between long-term goals and short-term, day-to-day responses. Unlike private enterprise, we do not have an objective improvement measure like the profit margin to help us monitor success. Our criteria will be much less tangible and therefore less likely to be understood by the policymakers. However, a nationwide, coordinated approach should be helpful in this regard.

Organizationally, the bus maintenance industry must establish a coordinated, comprehensive approach. Human resource problems are shared by many properties, and the needed solutions are too complex for a piecemeal attack. Entities such as UMTA or APTA provide the type of organizational structure needed. In fact, there probably exist committees or subgroups at both of these agencies that have been charged with such responsibilities.

SUMMARY AND CONCLUSIONS

The human resource problem in bus maintenance has developed over many years. The decline of the workplace environment and the increasing complexity of the organizational structure are major contributors to this condition. Diminishing worker skills, or the perception of diminished skills, and motivational deficiencies have also had significant impacts on labor's effectiveness. Research indicates that workers' changing view of the job and the concomitant need for self-actualization and self-esteem also influence the present situation.

Better on-the-job reference material improves the motivation and self-esteem of the mechanic while also improving vehicle reliability. Enlarging the scope of the traditional supervisor's role to include an awareness of changing job values and difficulties related to worker motivation also helps overall human resource management. Furthermore, standardizing personnel practices and clearly defining departmental objectives and priorities through supervisory staff improve staff harmony.

Once the industry confirms these findings nationwide, a series of pilot programs can be developed in order to refine improvement actions. It may then prove cost effective to set up regional "schools" where managers and supervisors can be taught these techniques and be provided with the appropriate written documentation to take back to their bus properties.

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Workshop Report

Kay Inaba, Chairman
Susan R. Butler, Recorder

Participants in Workshop 3 identified the following eight problem areas in their review of the topic, human resources for maintenance:

1. Performance measurements and standards,
2. Technical information and training,
3. Line-level maintenance supervisors,
4. Upper-level maintenance managers,
5. Motivation,
6. Upper-level management awareness of maintenance needs,
7. Training packages, and
8. Communication.

All were felt to warrant action. High priority was assigned to performance measurement, training, and line-level supervision. Medium priority was assigned to technician motivation and communication skills of upper-level maintenance management. Lower priority was assigned to upper-level management's awareness of the importance of maintenance, training packages, and interproperty communication.

PERFORMANCE MEASUREMENTS AND STANDARDS

Problem

The general lack of performance standards in maintenance hampers both training and planning. The associated lack of performance measurements makes it very difficult to quantify the effects of improvement techniques, such as better management techniques and better maintenance training and information packages.

The need for computerized performance measurements and standards is especially acute in maintenance because of management's general lack of interest in maintenance and maintenance-related variables. One way to communicate effectively with upper-level management is to show the effect of budget and manpower allocations in dollar terms or in other system-level parameters meaningful to upper-level management (miles between road calls, missed runs, etc.). Computerization is important to ensure timely measurements and feedback.

Although many properties share the problem, discussions indicate that some properties have developed effective standards and measurements. In addition, it was generally agreed that the problem is not unique to mass transit. Therefore, it appears reasonable to assume that organizations in other industries will have solution concepts or techniques that would be readily applicable to mass transit properties.

Solution

The workshop group suggested that UMTA fund a survey of both transit properties and other industries regarding application of "work standards" and measurement techniques. This survey should pay special attention to the abuse of work standards and to making managers sensitive to the dangers of such abuses.

Time-related work standards are especially vulnerable to misuse or abuse by managers. Workers often feel that such standards can rapidly lead to pressure to perform faster without compensatory pay. Studies have shown that error rates are far more important to maintenance than time of performance. Consequently, standards that emphasize time only without considering errors could lead to counterproductive techniques.

It is also important to recognize that many maintenance errors today are being committed by experienced technicians. Thus, standards should not merely reflect the current work of experienced technicians but should reflect a level of performance achievable with proper maintenance information and training.

A prime example of how work standards can be used effectively is the program at Seattle Metro, where the standards are used to establish productivity measures and diagnose problems rather than apply pressure to individual workers.

Due to the potential for abuse in this area, the dissemination of the survey results should be restricted to a training program designed specifically to communicate the concepts and techniques to interested parties; that is, in disseminating the information by a noninteractive method, there is too great a potential for misuse of techniques. Therefore, the training technique should be communicated by specific training programs or extensive workshops that would provide ample opportunity to communicate the dangers of abuse and misuse.

TECHNICAL INFORMATION AND TRAINING

Problem

Maintenance manuals in mass transit do not provide the information necessary to support (a) entry-level training and/or (b) journeyman technician performance on the job. As a consequence, training tries to overcome the problem through extensive application of standard training techniques. Experience in other fields indicates that such an approach will not meet the maintenance needs of mass transit: Technicians prepared in this manner normally have a relatively high rate of errors due to overreliance on memory and/or their knowledge of fundamentals.

The military has recognized the interaction between maintenance information and training. The U.S. Army is committed to a new type of manual that will be usable on the job. All new systems require the use of these simplified manuals and integration of the manuals with training. Both the U.S. Navy and Air Force are moving in the same direction.

The military has learned that problems of poor maintenance performance cannot be resolved without first providing maintenance information (e.g., procedures) that can be used on the job. However, this information is necessary but not sufficient; training and other components of the personnel subsystem must still be adjusted to take advantage of the availability of usable maintenance information.

As more equipment technologies are applied to mass transit vehicles, the problem is expected to become even more severe.

Solution

The workshop group felt that UMTA should continue the program for solving the maintenance manual problem by applying JPAs and related techniques. Transit properties should learn how to integrate such information packages with training to (a) help overcome the temptation to avoid training by providing simplified manuals and (b) help technicians to learn to rely on the manuals rather than on their memory. Also, manufacturers and vendors should be required to deliver JPAs or their equivalent with the equipment as a useful supplement to other manufacturers' manuals, training programs, and service bulletins.

LINE-LEVEL MAINTENANCE SUPERVISORS

Problem

In many transit operations, not enough is known about what criteria should be used to select line-level maintenance supervisors and/or how to train them effectively. In many cases, technicians are promoted to the supervisory level based on their technical capabilities but fail as supervisors due to inadequate "people skills". Similarly, new supervisors often encounter difficulties in supervising others due to either inadequate technical knowledge or erosion of such knowledge.

In contrast, some properties have been quite successful in both identifying and training line-level maintenance supervisors. Therefore, there is a need to both find and communicate proven selection and training techniques.

Solution

The workshop group suggested that UMTA fund a project to survey transit properties for working solutions and develop a means of communicating this information to all other properties. An example of a potentially effective approach is the "lead man concept" being tried at Seattle Metro and the "supervisory trainee concept" being tried at Denver RTD. Both approaches provide an opportunity to observe the potential of an individual before selecting him or her for a supervisory role. The training method thus serves as a selection process as well.

UPPER-LEVEL MAINTENANCE MANAGERS

Problem

Some of the problems attributed to the lack of awareness of maintenance-related variables by upper-level management can also be attributed to upper-level maintenance managers who do not have proper communication skills. This need is often cited by the managers themselves. The lack of proper communication skills compounds the problems of "inadequate allocation of resources for maintenance", especially for properties with upper-level managers who are biased against or ignorant about maintenance.

Solution

The workshop group suggested that UMTA sponsor the development of a training package that can be implemented in different modes. This package should focus on the necessary communication skills, including the type of data needed to get the attention of upper-level management. The package should be distributed to all interested properties, including existing management training programs.

MOTIVATION

Problem

There are severe problems in motivation and attitude among maintenance technicians, problems that are significantly greater in some properties than in others. This variance between properties would indicate that management awareness and techniques can resolve some of the problems. However, it is recognized that even the best of management techniques will not completely solve the motivation problem. In addition, it is recognized that the problems are not unique to transit maintenance technicians. Nevertheless, a solution specific to transit maintenance is needed.

A significant part of the motivation problem seems to stem from low self-esteem, which in many cases is reinforced by both the physical surroundings and management's attitude toward maintenance.

Solution

The workshop group called for a survey of the maintenance technician population in mass transit to clearly identify the specific nature of the problem and its causes. Currently, there is a wide range of opinion regarding the magnitude of the problem, its nature, and its causes. A professional survey would help to make the problem visible and therefore subject to investigation. This survey should also include other industries, searching for management and other related techniques to solve the problem. The project should develop a means of disseminating the information to interested parties and properties.

UPPER-LEVEL GENERAL MANAGEMENT

Problem

There was general agreement that a significant part of the human resource problem in maintenance stems from upper-level management's lack of awareness of maintenance-related variables. In the eyes of many, "upper-level" management consists of not only the general manager but also those with fiscal control and responsibility and the board of directors when it is active in the budget allocations for maintenance and maintenance training. The problem is generally manifested in inadequate budget allocations. However, there are other manifestations, such as a general lack of sensitivity to maintenance-related problems that often negates advancements made by lower-level managers. An example of this would be failure to complete a preventive maintenance task because of pressure by upper-level management to dispatch a given number of buses.

Solution

It was generally agreed that the problem of upper-level management's lack of awareness of the importance of maintenance is sufficiently great that a "one-shot" solution, such as a seminar or workshop, would not be adequate to solve the problem. In addition, there is a need to constantly reinforce the importance of maintenance and maintenance-related variables through various means of delivery. Therefore, the workshop group felt that UMTA should develop a basic package of materials that can be delivered in different modes, such as articles in journals normally read by upper-level managers, UMTA meetings including panels that require interaction between general managers and maintenance managers, and video simulation programs that would allow managers to visualize the consequences of their decisions--e.g., what happens when preventive maintenance is bypassed--and that could be introduced at transit meetings and subsequently used in regional training centers or even by individual properties. The solution should include a detailed implementation plan that can be manned by different organizations.

TRAINING PACKAGES

Problem

There is limited information on what training packages or materials have worked and/or are available. Due to the general training problem, various organizations (including individual properties, vendors, schools, and consultants) have developed training packages and materials to meet specific needs. Some have worked quite well, whereas others have not worked. Thus, merely having information about what is available will not be of much use to a training director. Information about both the accessibility and the usefulness of these materials is important to training directors of mass transit properties.

Solution

The workshop group called for UMTA sponsorship of a survey on both the availability and the usefulness of training programs, materials, and concepts. Copies of the materials should be obtained and evaluated to aid potential users. Because it is anticipated that the evaluation will take some time, it is important to provide information first about what is available and provide an update on the usefulness of the materials as they are evaluated.

COMMUNICATION AMONG TRANSIT PROPERTIES

Problem

Each transit property is faced with a multitude of problems related to maintenance and maintenance training. Many of the problems are shared by other properties, but there is no ready or effective means of communicating such information.

Solution

The workshop group saw a need for UMTA to sponsor a study to examine the common information needs of transit properties and to design a multichannel system or technique for meeting those needs.

Workshop 4: Facility and Equipment Needs

Issue Areas

The workshop on facility and equipment needs focused its attention on the related areas of fixed maintenance facilities and diagnostic and maintenance tools. Workshop 4 members were asked to identify reasons for the high degree of variation in facility design and equipment sophistication and to define research needs related to garage design and new equipment requirements.

Resource Paper

Cecil M. Tammen
Minneapolis-St. Paul Metropolitan Transit Commission

The current generation of bus operators has an opportunity that is unique and exciting and also a bit terrifying. Most present-day bus facilities have their origin in the streetcar era, and throughout the country the vintage of these facilities is such that replacement is necessary, from the standpoint of both age and function.

It is exciting to know that in a period of 10-20 years fixed bus facilities will either be replaced or will have undergone major renewal. Considering past history, it has to be awesome to think that decisions made today will be in place and affecting bus operations up to 75 years from now.

It is certainly appropriate today to look to that future and be concerned with how we can improve on past performance. And there is room for improvement. But, before we throw over everything we know and do, let us define our present delivery system for facilities.

Let us compare a major commitment to a facility with a similarly sized commitment to our other big expenditure--buses. To produce a bus, millions are spent on design and research involving some of the most highly trained and skilled people available. Prototypes are built and tested. Production lines are built. Finally, through the miracle of mass production, buses are delivered. Nothing this sophisticated goes into a facility. The designer produces a custom (one-of-a-kind) design with input from the bus property, a property that probably has not had the experience before. Shortly after, a contractor with as many as 75 subcontractors sets about custom building the facility. Soon it is complete, ready for use. The difference in service delivery is dramatic. The results are also. A comparison of the warranty claims is revealing. When one compares the maintenance effort that goes into keeping the buses on the street--the refurbishing, rebuilding, etc.--with the benign neglect with which the facilities are treated, it is amazing that the facilities survive and serve so well.

I do not believe that the methods of facility delivery are wrong; rather, they appear to be very good. They certainly are in need of some improvement but not major surgery. Some well-thought-out refinement and development are suggested.

FACILITY DESIGN

Of unique importance in facility design is the relative size of properties and their resultant capability to help themselves. The larger properties have the resources to devote time to the study of future trends, to conduct research on new materials and equipment, perhaps even to visit other properties to view their progress and innovations. This is not true for the smaller properties. Better communication and publicity concerning improved facility design will be of help to all properties. The smaller properties, with their problems, will gain the most insight in this process.

There are a great many considerations to be thought through in any facility improvement. Budget capability is perhaps paramount. Deciding whether to build new or to remodel and renovate is always difficult. Some properties have rehabilitated automobile and truck sales and repair facilities at low cost. Site location as it affects highway access, soil conditions, environmental considerations, and present cost of acquisition, weighed against future operating costs, is also an important design consideration. The operating costs of pull-ins and pull-outs and the cost of driver relief are often overlooked in site selection and comparative site costs. But these operating costs go on forever and inflate whereas initial site costs are one-time costs paid for with today's dollars. Climate also has a major effect on facility design. Parking buses out of doors may work well in Florida, Texas, and California but would be a nightmare in Minnesota, Michigan, and Pennsylvania.

Two major questions must always be considered prior to planning a facility: (a) fleet size, both present and future, and (b) the nature of the bus to be housed now and for years to come.

For a multifacility property, the size of a facility is perhaps more logically determined by considering the maximum desirable size. The smaller property has the real dilemma: To accommodate even a modest unplanned growth in the size of the bus fleet--say, from 75 to 125 buses--at some time in the future will be a major undertaking.

Future vehicle design affects everyone and is one of the great unknowns. In 10 short years we have seen air conditioning in quantity and electronics in air conditioning, welded body skins, stainless steel bodies, a return of underfloor engines, the articulated bus, double-decker buses, foreign manufacturers, metric dimensions, advanced-design buses, and wheelchair lifts. The list could go on and undoubtedly will in the future.

Two new phenomena are also having their impact on facilities and equipment--safety and security. The large increases in absenteeism and compensation claims plus the recent activities of the Occupational Safety and Health Administration (OSHA) strongly suggest the need for an increased awareness of safety at the workplace. An increase in theft and vandalism is making mandatory built-in security controls that were not considered only a few years ago.

The value of better facilities and equipment to repair and operate buses is obvious. Adequate space for bus parking and maneuvering drastically reduces bus damage on many older properties. Adequate space for mechanics to service and maintain buses not only gets the job done faster but also encourages better work. Sufficient equipment properly located and properly selected to perform the task also contributes greatly to quality work.

A properly designed area is easier to maintain, which contributes greatly to employee morale. Absenteeism is reduced, and there is renewed interest in doing a good job. The results can be seen in better, self-enforced housekeeping. You need only open a new garage and watch the job bidding interest to know that something good is about to happen.

Less rigid planning and less permanent construction are also suggested. Use of techniques that allow for easy and inexpensive changes and additions will do much to alleviate future problems.

The question of centralization or decentralization of all maintenance functions should also be determined prior to major facility changes. Again, the smaller properties probably have no real choice because everything is in one location. The larger properties do have a choice. My limited investigation into this area for larger properties has favored decentralization. The service garage should include those maintenance functions that allow it to reasonably control its own activities and its own quality control. This includes component replacement, inspections, engine tune-up, brake work, and limited body work. Functions such as major body work, painting, and component rebuilding are better left to a heavy repair facility. In addition, repair of spark ignition vehicles seems to work best if treated separately.

These decisions can be made on two bases. When the cost of equipment and manpower, as well as scheduling, gets excessive it fits best in a heavy repair facility. The second choice is usually somewhat controlled from the outside by building codes, OSHA, etc. (e.g., paint spray booths are too expensive to have in each facility, and body shop equipment, heavy welding, and engine rebuilding all require special safeguards and equipment and highly skilled people).

If the service garage is made adequate for normal service and maintenance, it aids in the garage planning for on-street bus service. The garage can schedule repair and maintenance directly without reliance on another facility and group of mechanics. The savings in time and operating expense to move buses between facilities for repair are substantial. The benefit of on-time performance of the bus service is easily apparent.

There are some real advantages in a specialized central shop for some types of work. The skills required for body work, painting, engine building, machine shop, woodworking, and component rebuilding can be put to better use on an ongoing basis. The specialized equipment needed to perform these functions on a larger property can easily cost $500 000 for one central shop. The capital cost to equip a group of service garages could be prohibitive. There is further advantage in scheduling this work for an entire fleet on a full-time basis as opposed to the sporadic scheduling that would be required in a single service garage.

PLANT INFRASTRUCTURE

One of today's planning considerations that is likely to be a factor in the future is energy conservation. Funds are available if plant design reflects a conscious choice to conserve both heat and electricity. Building materials, control of open doors, restricting the number of doors, and adequate insulation are all "passive" choices that can be made. "Active" choices are also available--e.g., better preventive maintenance, clean filters, tuned-up boilers and fans, and clean light fixtures. Automated control of building equipment is a relatively new and highly successful method. Today, we can sense the presence of diesel fumes and ventilate only as needed, sense external temperature changes and control internal equipment accordingly, control preventive maintenance, and diagnose faulty equipment and performance before it is a major problem. Computer-controlled automation of buildings will not only cut operating costs but also reduce labor costs. It should be investigated.

EQUIPMENT

Bus maintenance equipment must also be considered. Fortunately, much of the equipment can be added without major facility changes. The single largest maintenance cost is labor, and any labor-saving equipment that can be added should be investigated. In addition to saving labor, equipment such as hoists and fork trucks can reduce injuries and worker's compensation claims.

Using diagnostic equipment is faster and more reliable in many cases than doing the work manually. The current diagnostic demonstration project in New York, which allows frequent checks of bus performance, bears close watching. Recent developments in dynamometers bode well for future diagnostic efforts. As the older, more skilled mechanics who have worked since World War II retire, it is becoming increasingly difficult to find staff replacements with the same skills. The future use of diagnostic equipment is rapidly becoming a necessity. It would appear that combining a diagnostic system with a chassis dynamometer to check a bus under load would be an excellent addition to present capabilities. By and large, designers and vendors of bus maintenance equipment have been and are doing a good job.

INFORMATION NEEDS

There is actually very little that maintenance departments require or want that is not available. In my view, it is again the problem of small versus large properties. Small properties are limited by budget constraints and in many cases are not aware of equipment availability. The profit margin prohibits contact by manufacturers. Perhaps the bus manufacturers should provide lists of tools and equipment that would aid in the repair and maintenance of their vehicles along with their maintenance manuals and parts lists. They have the information and could provide a real service.

All of this is not to suggest a big hole in our knowledge of facility and equipment changes. Rather, somewhere among all the properties in this country almost every problem has been encountered and solved. The real problem is how to communicate and distribute this knowledge. A number of efforts have been made by special UMTA-funded manuals and studies.

Facility design manuals have tended to be a bit narrow in their results. They have been "how-to" books reasonably void of philosophy and background and have failed to supply a full range of ideas and solutions. Thus, a property using one of these manuals may find that only a portion of the document is applicable to its unique problems.

I strongly urge a continuation of this type of study and data collection. I would, however, suggest that UMTA fund an organization such as APTA to prepare a manual on facility design and equipment on an ongoing basis. The wealth of information and solutions available can then be gathered and presented in the most beneficial way to the industry.

In addition to these planning manuals, UMTA has funded a number of technical studies managed by individual properties. Although provision is made for distribution of the results on request, it is not widely used. There is no doubt that a great amount of thoughtful and useful research is available--in fact, so much that volume may be the problem. Again, having a group such as APTA collect and review these data and provide capsulized reports would perhaps be a more effective way to disseminate already available information.

PUBLICATION

Another strategy that could be expanded is a case-study presentation of ideas and facilities. APTA attempts this at its regional conferences. Friendship Publications does an excellent job once a year at its seminar.

Several bus-related magazines, most notably Friendship Publications' Bus Ride, also carry stories in their issues. Several architectural magazines such as Architectural Record and engineering magazines such as Construction Specifier have developed techniques and include facts and details that give a better, more rounded view. I am sure that, if sufficient interest were expressed in in-depth stories on facilities and equipment, they would be forthcoming from the present publishers, and I believe we would all benefit from such coverage.

NEEDED IMPROVEMENTS

Bus operators do need assistance, most notably from UMTA and the bus manufacturers, in addition to an improved communication network among themselves. This will result not only in improved facilities and equipment but also in a better-maintained bus fleet. The following are some major steps that could be taken toward improving the current situation:

1. Research and field visits by properties contemplating changes,
2. Study and use new building operation technology,
3. Do thorough space and functional planning,
4. Obtain a diligent effort from the designer,
5. Analyze future needs and plan for change,
6. Temper decisions based on life-cycle cost input,
7. Provide adequate amount and type of equipment,
8. Develop an ongoing preventive maintenance program,
9. Consult with bus manufacturers on bus maintenance program and equipment needs,
10. Improve communications between properties,
11. Provide an organization such as APTA to coordinate and distribute present information in technical studies and design manuals, and
12. Encourage more periodic case studies.

Workshop Report

Peter Wood, Chairman
Henry J. Mercik, Recorder

A broad spectrum of topics related to facility and equipment state of the art and function was discussed in Workshop 4. To focus the discussion, examples of facility design and equipment (existing and desired) were highlighted. The broad background of knowledge brought to the group by the participants was impressive and resulted in a reasonably in-depth exploration of the issues and topics. Specific actions were suggested to assist operators in making decisions about establishing new facilities and defining equipment needs. There was a consensus that there are significant differences in the requirements of large and small transit operations. Attention should be focused on the requirements for both large and small operations.

FACILITIES

The general discussion of facilities was initiated by a description of the new St. Louis Maintenance Facility by Paul Hampton. The major functions of the facility were defined, and the rationale and philosophy of operation were presented and discussed.

The needs of the St. Louis transit property and the needs of other properties were considered to be similar. The rationale used in the decisionmaking process was considered sound and similar to rationales used by other properties. However, facility layout and traffic-flow decisions were different in each case. Considerable time was spent discussing the pros and cons of facility layout and equipment. There was general agreement among the properties on the rationale for layout, but it was recognized that other, equally effective designs were possible.

In the area of facility design, the workshop group agreed on the following:

1. An APTA subcommittee should be formed (Cecil Tammen and Paul Hampton volunteered to serve) to compile and disseminate state-of-the-art information related to facility construction and equipment. This subcommittee should participate in the development of the new Bus Maintenance Facility Planning and Design Study (the request for proposals for this study has been issued by UMTA).
2. A design guide that treats the building functions in modular form should be prepared. It should include the rationale and philosophy for facility decisionmaking, including trade-offs. The guidelines should include modules such as brake repair bay, engine change-out bay, paint booth, fuel island, body shop, parking, and upholstery shop.
3. The main problem in this area is the dissemination of the information developed by various transit properties.
4. A series of seminars should be conducted for the purpose of exchanging information on facility design and maintenance. These seminars could be set up by region. The format could be a case study involving the design of a facility, including the

physical plant layout and the fixed equipment requirements.

5. There does not appear to be any need for a significant R&D program in this area.

EQUIPMENT

State-of-the-Art Practice

Equipment is commercially available to perform most of the tasks and measurements that are required for bus servicing, inspection, maintenance, and repair. These include engine, chassis, and transmission dynamometers; brake-testing equipment; special-purpose gauges for measuring pressure drops; and so forth. Spectrochemical oil analysis is being used to determine the presence of conditions that could result in equipment failure and to identify the cause of that condition.

Equipment for automatic inspection and diagnosis of bus conditions is currently being demonstrated in New York City. Inspection and diagnosis are performed both at the service island and in the maintenance area. The successful completion of this program is considered important and beneficial to the industry.

A number of special-purpose tools and test and measurement devices have been developed at individual transit systems to meet specific needs. Frequently, the problem addressed exists in many transit systems but knowledge of the technique or equipment being used is limited to the system that performed the development.

Selection of the equipment to be used is very much dependent on individual system preferences. Systems that use dynamometers generally consider them to be indispensable; by testing a complete package (engine, transmission, and cooling) prior to installation in the vehicle, it is possible not only to test the capability of the complete system to meet the desired specification but also to correct minor operational problems such as oil leaks. In contrast, many transit systems do not consider that dynamometers are required. Because of the number of other variables involved, until now it has not been possible to determine any differences in maintenance performance resulting from the use of, or the decision not to use, dynamometers for test purposes.

Problem Areas

The area in the transit maintenance and servicing cycle that has most impact on maintenance costs is inspection. This is not to imply that inspection itself is a major cost item but that the quality of inspection has a major impact on total maintenance cost. In this connection, the development of economical, reliable inspection and diagnostic equipment is considered to be the major R&D priority. However, because of the development time involved, the impact of such a system is likely to be long term.

A more immediate need is a method to determine the structural integrity of a bus chassis. Failures are beginning to appear in buses manufactured approximately six years ago, and a method of testing frames to determine structural integrity would be a major aid in preventing in-service structural failures.

Current tire inspection procedures are considered to be burdensome and subjective. A need for automatic tire inspection equipment was identified.

As in other areas, dissemination of information on techniques that have been used successfully to overcome problems has been a barrier to more effective maintenance for many transit systems.

The conclusions of the workshop discussion were as follows:

1. The R&D program that will have the most significant impact on service and maintenance costs is the development of a satisfactory method of automatic inspection and diagnostic testing. It was the consensus of the group that UMTA should give this program the highest priority and that its extension to other properties should be expedited.

2. It was also felt that bus manufacturers should consider and implement changes in vehicle design that would facilitate future retrofit of sensors needed in the use of automatic inspection and diagnostic equipment.

3. It was the consensus of the group that UMTA should immediately initiate an R&D study on methods for determining the structural integrity of bus frames by using techniques such as X-ray, ultrasonics, and magnetic detection techniques.

4. It was suggested that APTA initiate an incentive program (similar to the bus rodeo) to encourage maintenance staff to submit the results of their work in developing improved tools, techniques, and equipment for reducing bus maintenance costs. This would facilitate widespread dissemination of the information.

5. The need for an automatic tire inflation testing device was discussed and considered to be of high priority.

6. A minority of workshop participants felt that the advanced approach of X-ray technology and automatic diagnostics is premature and that emphasis should be placed on tools and fixtures to facilitate repair once a problem has been identified.

Workshop 5: Vehicle Design, Acceptance Testing, and Maintenance Support Services

Issue Areas

Discussion in Workshop 5 was guided by the premise that vehicle design is a major determinant of maintenance cost. Participants were asked to suggest improvements in vehicle design that might lead to reliability improvements and to address necessary changes in procurement and acceptance testing procedures. The question of postdelivery quality-control responsibility was also an issue.

Resource Paper

H.H. Buckel
Booz-Allen and Hamilton, Inc.

The relation between bus design and maintenance requirements can be assessed only in light of the historical events that led to the current situation. Up to 1960, the history of design innovations in transit buses can be divided into four developmental phases, during each of which reliability, efficiency, and productivity were steadily improved. The chart presented in Figure 1 (taken from the March-April 1974 issue of Motor Coach Age) shows these developmental phases: Specific technological improvements are indicated in the middle of the figure, and design milestones are listed at the bottom.

Innovation and improvement in bus design were primarily the result of two factors: competition among numerous bus manufacturers and private ownership of transit properties. Competition among bus manufacturers was most intense during the 1920s and 1930s. This level of competition resulted in bus designs that were responsive to operators' needs for improved cost-effectiveness in operation and maintenance. The competitive picture changed radically in the years following World War II. At the end of World War II, General Motors Corporation (GMC) introduced its 5100 series bus (see Figure 2), which was 40 ft long, seated 51 passengers, and was powered by a six-cylinder diesel engine. In many respects, this model represented the peak in American bus design for efficiency and productivity. GMC's success with the 5100 series, however, spelled doom for a number of its competitors. Unable to develop reliable, high-capacity buses with efficient diesel engines to compete with the GMC model, Mack, White, Fageol, ACF, and Brill failed in the postwar transit market. Flxible remained the sole American competitor of GMC in the postwar years.

This period also saw the beginning of the change from private to public ownership of transit properties. This transition began with a postwar decline in ridership, caused by the automobile boom and suburban sprawl. Streetcars and trackless trolleys were eliminated from the transit scene by this decline in ridership. Municipal authorities were reluctant to authorize fare increases to help private operators overcome the financial losses caused by the declining number of riders. This situation resulted in the financial failure, one after the other, of the private transit operators. Various public agencies were formed to take over the operations of the failed companies, aided by the Urban Mass Transportation Act of 1964. At present, nearly all major transit systems are publicly owned.

"NEW LOOK"

In 1959, a significant milestone in transit bus design occurred: GMC introduced its 5300 series bus (Figure 3). Its nickname, the "New Look", was a statement by GMC that the period of major mechanical innovations in transit buses was ended. Instead, the future lay in improving the motor bus as an environment for passengers and drivers. Although the New Look bus had larger passenger windows, a high visual impact, and other passenger amenities, the cost of operation and productivity were not compromised in comparison with the previous model. The transit industry responded very positively to the New Look bus, and many transit systems that purchased them experienced a break in their declining ridership.

GMC's successes were not without problems. In the early 1950s, the federal government became concerned that GMC was obtaining a monopoly in transit bus manufacturing, and an antitrust action was brought by the U. S. Department of Justice. A suit was filed against GMC on July 6, 1956, and on December 31, 1965, GMC signed a consent decree under which it agreed to sell key bus components, such as engines and transmissions, to competitors. Flxible was GMC's sole American competitor at this time and, along with Flyer Industries of Canada, had developed new bus designs that appeared virtually identical to GMC's New Look. Immediately after GMC signed the consent decree, Flxible adopted the GMC drive system and became a viable second supplier of New Look transit buses. In the early 1970s, AM General, a subsidiary of American Motors, also entered the bus market with a New Look design that included slight styling changes. All New Looks were mechanically identical and similar in body design and appearance, but construction quality was not consistent over time and between makes.

Procurement of New Looks with hardware-type specifications developed by transit operators was relatively straightforward. Specification development was a simple process since proven components were

Figure 1. Transit bus development phases.

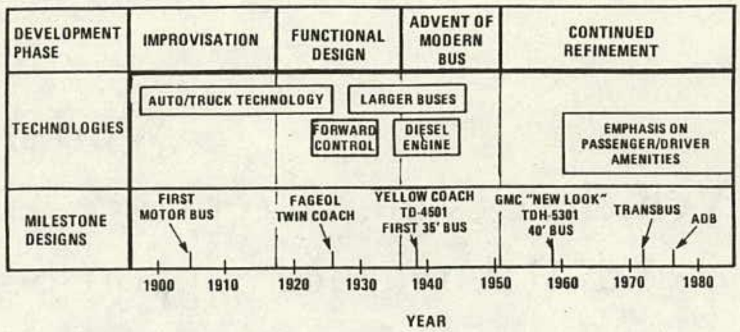

Figure 2. GMC 5100 series bus.

Figure 3. GMC 5300 series New Look bus.

well-defined and, with few exceptions, available from all three manufacturers. Some operators were able to purchase the buses they felt were superior by tailoring their procurement specifications to include only one manufacturer's product. However, by this time the federal government had become an important factor in the procurement process. Publicly owned properties were eligible for federal capital equipment subsidies totaling 80 percent of the cost of new buses. The government declared all New Look buses to be equal for bidding purposes and ruled that procurement awards would be made on a low-bid basis. As a result, operators had virtually no control over which manufacturer supplied their buses. Many operators with engineering capabilities sent inspectors to the bus manufacturing plants to ensure the acceptable construction quality of their new buses, and other operators conducted small-scale test programs before accepting completed buses. This activity forced manufacturers to implement design changes and revisions in their manufacturing techniques that resulted overall in the production of improved buses. Transit operators who received low bids from manufacturers of buses of less-than-satisfactory quality were faced with accepting the low bid or canceling the entire procurement and doing without buses altogether.

Bus procurements continued to be made in this fashion through the mid-1970s, during which time each of the three manufacturers secured about one-third of the American market. The two primary problems with this procurement system were the following:

1. Transit operators could not control which make of bus they received and thus could not control the design quality of the product.
2. There was no method for introducing new technology into buses if it involved an increase in the initial vehicle price.

Concern about the second problem inspired UMTA to implement the Transbus program in 1971. Briefly stated, this program established a design competition for the development of the next generation of transit buses. The five goals of the Transbus program were to

1. Increase trip speed,
2. Improve passenger comfort and safety,
3. Improve environmental compatibility,
4. Improve aesthetics, and
5. Reduce maintenance and repair costs.

The trend toward increased passenger comfort, amenities, and visual style, begun with the New Look, was to be advanced by the Transbus program. Three prototype designs were developed (Figure 4) that incorporated numerous innovative features, including very low floor heights. Unfortunately, the cost penalties associated with the low floors and some of the new design features contributed to the prototypes' failure to meet the fifth program goal of reduced maintenance cost. This problem, in conjunction with UMTA's failure to implement a viable plan for developing the best features of the prototypes into a production design, doomed the program.

INTRODUCTION OF ADBs

The failure of the Transbus program was hastened by an activity that occurred simultaneously at GMC--the development of a new bus design called the Rapid Transit Series (RTS). The RTS (Figure 5) incorporated many features of Transbus, but it had a standard-height floor and some underfloor components common to the New Look. In September 1975, GMC formally introduced the RTS after UMTA in essence stated that capital grant funds could be used to purchase buses that had advanced features (such as the RTS) but were not in competition with the New Look (1). Flxible rushed to bring out a competitive design, the model 870 (Figure 6). The model 870 was also very much like Transbus but with a standard floor height and many New Look underfloor components

Figure 4. Transbus prototype buses.

Figure 5. GM Rapid Transit Series ADB.

Figure 6. Flxible model 870 ADB.

such as brakes and axles. The RTS and the model 870 were generically named advanced-design buses (ADBs). The introduction of the ADB was surrounded by controversy: AM General sued to allow its New Look bus to be bid against the RTS and the model 870. AM General lost the suit and withdrew from transit bus manufacturing.

Because design and construction techniques for the RTS and the 870 were dramatically different and each offered distinctive design features, low-bid competitive procurement to operator-developed hardware-type specifications was considered by UMTA to be impossible. UMTA therefore asked Booz-Allen and Hamilton, Inc. to develop, in conjunction with the APTA Bus Technology Committee (BTC), a performance-type specification that encompassed both of the existing ADBs. An unsuccessful effort was made during the specification development to preclude those features in the existing ADB designs that transit operators felt would not be satisfactory in service. The veto power of the manufacturers prevented inclusion of these requirements in the specification. This specification become known as the "White Book" and has been used for all ADB procurements since 1978. In addition, a system of price offsets was developed that rewarded manufacturers for providing certain advanced features and equipment. Price offsets were established, for bid evaluation purposes, that lowered the quoted price of manufacturers supplying such features. Seventeen features were subject to price offsets that could total $8400.

As increasing numbers of ADBs were placed in service, it became apparent that these new buses were unreliable. In comparison with the New Look buses, ADBs required as much as three times more maintenance and delivered poorer fuel economy. In fact, some features subject to price offsets contributed to vehicle unreliability and escalating operating costs. The new components and features incorporated in one or both ADBs that have proved costly to maintain in service and have contributed to the buses' poor service records include

1. Automatic interior climate control systems,
2. V-730 automatic transmissions,
3. Independent front suspensions,
4. Maintenance-free batteries,
5. Pantograph passenger doors,
6. Plastic interior trim panels and instrument panels,
7. Wedge-type brakes, and
8. Kneeling front suspensions.

Both ADBs are heavier than their predecessors, and this additional weight has contributed to poor fuel economy and increased brake wear. One ADB had to be removed from service because of major structural design defects.

The ADB experience is an example of costly and unreliable vehicles resulting from poor vehicle design and limited preintroductory testing. The specification was inherently defective because it was developed to accommodate two existing, unproven bus designs. In addition, it was a performance-type specification that would have required a test program costing approximately $500 000/bus to verify conformance. Had such a test program been conducted and had transit operators refused to accept nonconforming buses, the manufacturers would have been forced to improve their products to meet the specification requirements.

In the past, transit operators have developed specifications in committee that resulted in highly successful transit vehicles. Two such committees were the Electric Railway Presidents Conference Committee (PCC), which created the "modern" standard street car in 1934, and, more recently, the Verband Offentlicher Verkehrsbetriebe (VOV) association of public transport companies, which created the West German standard transit bus. Both the PCC and VOV specifications were of the hardware type--highly detailed, complete designs that allowed manufacturers little opportunity for innovation. The performance and reliability of required components and equipment had been proved in previous transit service. Equipment suppliers were represented on the specification committees but, in contrast to the ADB situation, they were not permitted to veto provisions of the specifications.

LOOKING FORWARD

The poor performance of ADBs has resulted in changes to the transit bus procurement strategy, and these changes are continuing. Many transit operators have turned to Canadian-manufactured New Look buses for improved reliability and lower maintenance costs. These buses, supplied by the GM Diesel Division or Flyer Industries, are being accepted with little or no qualification or acceptance testing. The Canadian buses are generally satisfactory in both quality and performance.

An unprecedented number of older buses, primarily GMC New Looks, are being completely rehabilitated. Operators who select this strategy obtain a fiveto seven-year extension of the service life of a reliable and cost-effective bus for half the cost of an ADB. Rehabilitation will continue to be a popular alternative to the purchase of new buses until the ADBs are improved or another competitor offers a better model.

Other foreign and domestic bus manufacturers have entered the unsettled American bus market and have secured orders. They include Gillig, Crown, Neoplan, and M.A.N. In addition, manufacturers from Japan, Sweden, France, and other countries are considering entering the U.S. market. This will result in a level of competition among bus suppliers unparalleled since the 1930s.

An even more substantive change in the transit industry is the reduced role of the federal government as part of the current Administration's policy of defederalization. The stated intent of the Administration is to reduce local transit dependence on federal subsidies and to allow local authorities and transit operators to make their own decisions. The local political situation around the country runs the gamut from total support of the national plan to total opposition. Defederalization offers transit operators the opportunity to take the initiative in managing their systems and requires unprecedented improvements in transit management. Operators need to work more closely than ever with local authorities to determine the service levels, fare structures, and level of local tax support most suitable for the community. This may range from highly subsidized fare systems in some areas to elimination of transit service in others. Even before these constraints on the systems are completely defined, transit operators must demonstrate that they have in place, or are capable of implementing, improvements leading to reduced bus operating costs. Efficiency improvements can be made in every aspect of transit operations, including management structure, strategic planning, labor relations, staff skill levels, and the approach to maintenance. Transit management must recognize the importance of effective maintenance in the overall cost-reduction strategy and assign proper priority to maintenance activities.

OPERATING COSTS

The efficiency of a transit system can be grossly evaluated by examining system operating cost. Table 1 gives a recent operating cost summary for a large urban transit system. The first total, in this case $3.24/mile, is normally used for cost comparisons since it includes only 20 percent of capital costs. The federal government contributes 80 percent of equipment and facility acquisition costs. The real operating cost, which should include the additional amortized expenses for vehicles and facilities, in this case totals $3.55/vehicle mile. The total bus amortization cost of $0.30/mile is not significantly different from the $0.25/mile fuel cost and illustrates the fallacy of selecting buses by low-bid price instead of by demonstrated performance. For example, a difference of only 0.1 mile/gal in fuel economy between competing buses changes the fuel cost factor by $0.06/mile, or twice as much as a $1500 difference in bid price.

Table 1. Estimated operating cost for a large urban transit system.

Item	Cost ($/mile)
Revenue vehicle maintenance	
Labor	0.518
Parts and supplies	0.166
Contracted services and miscellaneous	0.007
Support vehicles and equipment	0.016
Utilities and taxes	0.012
Subtotal	0.719
Transportation	
Labor	1.403
Running	
Fuel	0.247
Oil	0.013
Tires	0.028
Materials and other services	0.006
Taxes	0.017
Subtotal	1.714
Nonvehicle maintenance	
Labor	0.033
Materials and services	0.021
Casualties, liabilities, and utilities	0.003
Subtotal	0.057
General and administrative	
Labor	0.212
Materials and services	0.075
Utilities, taxes, and miscellaneous	0.007
Casualties and liabilities	0.235
Subtotal	0.529
Interest, rentals, and 20 percent of depreciation	0.218
Total	3.237
Vehicle amortization, 80 percent	0.240
Garage and office amortization, 80 percent	0.070
Total	3.550

Vehicle maintenance cost, the first subtotal, is not an accurate measure of the effectiveness of the maintenance function, just as the running cost, a part of the second subtotal, is not an adequate measure of vehicle efficiency because there are many other factors to be considered. To assess accurately the efficiency of the maintenance function, the following six fleet performance measures can be used:

1. Running cost--Fleet average for consumables, such as fuel, oil, and tires (cents per mile);
2. Road calls--Total miles operated divided by the total number of breakdowns in a unit of time, over a unit of time such as a month or a year (miles);
3. Schedule adherence--Runs served divided by the runs scheduled (percentage);
4. Spare buses--Number of buses in inventory above the minimum required to meet the schedule divided by the minimum number of buses required to meet the schedule (percentage);
5. Staff ratio--Operating schedule miles (hours) divided by the number of maintenance personnel (all levels) measured over a unit of time; and
6. Spare parts ratio--Dollars of spare inventory divided by operating schedule miles per month or year.

Each of the six performance measures can be easily improved in the short run; however, adjustments in one affect others. For example, the spare parts ratio can be excessively reduced, which will adversely affect schedule adherence since a large portion of the fleet will be down for parts. Geographical, political, and other factors make it impossible to establish hard national standards for fleet performance. However, every operator should have the current value of these measures immediately available, know how these measurement values compare with those of similar transit systems, and have a program in place to change these values to reduce total operating costs.

Data generated by each bus in the system are required to determine the six fleet measures. Maintenance managers must have available the identity of buses by make, model, age, and mileage of the most efficient equipment and, conversely, which buses are the most costly to operate. These data permit intelligent decisions to be made in developing improvements in the maintenance system and in developing an effective bus replacement strategy.

The keystone of a highly efficient and effective maintenance service is an accurate system that provides relevant and timely information. The information system can be manual or computerized; purchased, rented, or custom-designed; and developed to suit a particular operation.

MAINTENANCE SERVICES

With a maintenance information system in place, critical evaluation of the maintenance services and revenue equipment can be undertaken. Minimum standards as well as goals should be established for all maintenance functions:

1. Preventive maintenance scope and intervals,
2. Road-call service and repairs,
3. Bad order repairs,
4. Vehicle appearance (cleaning, painting, and body repairs),
5. Fueling and daily service,
6. Overhauls,
7. Spare parts stocking and inventory controls, and
8. Warranty administration.

The effectiveness of the daily functional responsibilities can be evaluated by using the six fleet performance measures. Only by the use of detailed, hardware-type procurement specifications will transit operators be assured of receiving efficient and reliable buses and equipment. Only by carefully monitoring the performance, reliability, and operating costs of various equipment types and components can efficient and reliable products be identified for specification. This requires that limited quantities of new systems, components, and even complete buses be procured for test and evaluation in revenue service. This testing requires engineering capability with the responsibility for

1. Testing new equipment,
2. Developing hardware-type specifications for procurement of new equipment,
3. Monitoring development of relevant technologies,
4. Interfacing with other operators on equipment evaluations,
5. Developing production-quality inspection and acceptance test procedures,
6. Conducting in-plant inspections during production and acceptance tests of new vehicles,
7. Administering new-vehicle warranties, and
8. Developing retrofit improvements to existing equipment.

The increased competition among transit bus manufacturers will ultimately ensure that equipment desired by the operators is available on the market. Bus procurements to operator-developed hardware-type specifications worked well in the past for transit operators and continue to work well in the trucking industry.

In this new competitive environment, the manufacturers will assume a more traditional marketing posture to "sell" transit operators on the attributes of their products. They may also offer other benefits to purchasers, such as extended warranties, parts discounts, or special engineering assistance, which transit operators must factor into their procurement decisions.

ROLE OF UMTA

UMTA can contribute to operator success during this transition period in several ways. The Office of Capital and Formula Assistance can remove obstacles to procurement by those properties that have developed or can develop definitive hardware-type specifications. New precedents in procurement practices must be established for other operators to follow or to improve. The Office of Bus and Paratransit Assistance can provide funding assistance to individual transit properties for specific projects that will result in improved maintenance and/or engineering capabilities and will identify superior transit equipment. Sample projects could include

1. Development and implementation of maintenance information systems,
2. Development of improved periodic maintenance programs,
3. Development of standard operating procedures,
4. Development of work-quality standards,
5. Development of plans and improvements for shop facility use,
6. Improvement of engineering capabilities,
7. Development of specifications, and
8. Establishment of test projects for new systems and components.

As a result of the New Federalism, changes will occur within the transit industry during the next several years that will demand efficient management and maintenance techniques. Publicly owned transit operations will have unparalleled freedom to conduct their business in partnership with local authorities. However, many operators do not have the skills necessary to function effectively in this new environment. In this transition period, UMTA can assist operators in acquiring the expertise needed to function more independently as well as reduce its involvement in bus procurements as funding levels are reduced.

Workshop Report

Frank J. Cihak, Chairman
Ralph E. Malec, Recorder

During the past five years or more, changes in transit vehicle design have caused many serious maintenance problems. Costs have risen, breakdowns have become more frequent, and buses are out of service for longer periods of time. The problems faced by maintenance personnel have many causes. Some are related to the increased sophistication of transit vehicles, others are due to decreased component reliability, and still others are related to apparent design problems.

The increased sophistication of transit vehicles has many implications for maintenance. At a very basic level, today's systems require higher levels of preventive maintenance. Their technologies make diagnosis of failures more complicated and repair more difficult and/or time consuming. This is especially apparent in air conditioning, electrical systems, turbocharged engines, wheelchair lifts, and door control systems. Changes in vehicle design have also had a negative impact on fuel economy.

Operators are noting a number of difficulties related to vehicle design, including inadequate coolant systems, increased suspension system failures, and body and chassis problems. Decreased life mileages have been noted for transmissions and brakes. Some of these problems are the subject of current UMTA-industry research projects, and others would benefit from new retrofit programs designed to improve existing coaches. All of these problems are compounded by the short supply of trained mechanics and continued reliance on the White Book specifications.

The workshop group attempted to identify solutions for the above problems. The suggested solutions are summarized below.

IMPROVE RELIABILITY AND MAINTAINABILITY THROUGH SPECIFICATIONS AND DESIGN

To assure maintainability, specifications should list the total service hours required to remove and replace major components. All such times would be verified on the coach after it was delivered through a series of demonstrations. Bus builders should be encouraged to simplify vehicle subsystems to make them easier to maintain and trouble-shoot. Builders should develop all test and repair equipment required to service their vehicles. Builders should also be encouraged to prepare wiring diagrams and maintenance manuals that are easy to read and understand.

Research into on-board diagnostic systems should be continued. Interest in these systems is high; however, the concept remains to be proved. The New York City Transit Authority test program should be followed closely. Care should be taken to analyze the reliability and complexity of the sensing equipment.

The possibility of specifying vehicle availability by having manufacturers guarantee the number of hours a coach is to be ready for service should be investigated. A similar practice is currently used in the heavy equipment industry.

Specifications should list all reliability requirements, and these requirements should be clearly defined and specified by subsystems. The methods for measuring reliability should also be defined. Manufacturers should be required to provide a plan of corrective action for subsystems that fail to meet requirements.

CREATE GUIDELINES FOR WRITING SPECIFICATIONS

Sections 1, 3, and 4 of the White Book can be applied partly or fully to all specifications. Basic technical specifications are available to any interested transit authority through the APTA Bus Specification Information Exchange.

DEVELOP PREQUALIFICATION TESTS FOR COMPONENTS

There is a definite need to develop a set of prequalification procedures for new components. New components should be more reliable than those units they are replacing. The possibility of developing a "Service Evaluated Products List" should be investigated. Such a list has been developed by the rail transit industry. This list evaluates the performance of units based on actual service.

IDENTIFY AND UPGRADE PROBLEM COMPONENTS

The bus manufacturer is responsible for tracking and upgrading problem components. Manufacturers should be able to use their parts usage and warranty claim information to identify problem components. Users are also responsible for keeping manufacturers informed of problem areas. An industrywide information-gathering and distribution system must be set up, perhaps through APTA.

PURSUE LATENT DEFECTS

Transit systems should use the fleet defect section of their specification to pursue latent defects during the warranty period. After the warranty has expired, the transit operator should resort to a negotiated settlement to solve the problem. If the negotiations fail, legal action may be taken.

IMPROVE QUALITY-CONTROL FUNCTIONS

Good predelivery inspections are important to ensure quality coach construction. In-house inspectors should be used if possible. The guidelines being developed in the APTA Regional Inspection Workshops should be used. Postdelivery inspection should detect the defects that develop during the delivery process. The White Book acceptance criteria are satisfactory. Design factors have greater effects on long-term maintenance costs than new-bus quality-control measures.

INCREASE MANUFACTURER TECHNICAL SUPPORT

Transit properties should specify sufficient training and technical support to ensure that, once new coaches are placed in service, they operate successfully. Manufacturers should be encouraged to develop new and innovative training programs. UMTA grants should be made available to cover the costs of warranty administration and data collection on failures.

USE LIFE-CYCLE COSTING PROCEDURES

UMTA now requires that life-cycle costing be used to evaluate new-bus bids. Phoenix Transit has successfully demonstrated the use of life-cycle costing in a recent bus purchase. Grantees decide which cost elements they want to use in their analysis procedures.

There are several sources of guidelines for establishing life-cycle costing procedures. A special APTA task force is currently establishing guidelines for life-cycle costing. Grantees can use the APTA Specification Information Exchange to get ideas on how other systems are specifying life-cycle costing procedures. In addition, the APTA Compendium of Life-Cycle Cost Information is available to any interested property.

PERFORM FUEL ECONOMY TEST MEASUREMENT

The SAE fuel economy test procedure (SAE J-1321) was validated on the test track in 1980. This procedure still needs to be demonstrated on a transit property to verify that transit systems can use it for their own evaluation programs. The test procedure could be used to evaluate demonstrator coaches. It could also be used in testing fuel-saving devices and additives. The initial demonstration would be moderate in cost and could be funded by an UMTA grant.

Part 4:

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Appendix

Appendix

Discussion

Gil M. Pegg
General Motors Corporation

The following viewpoints differ from those of the conference participants identified and are intended to add to the reader's perspective of the subjects addressed.

Specific reference is made to the resource paper by H. H. Buckel in Workshop 5. Buckel worked on the UMTA Transbus Program (to which he refers). His paper makes a strong defense of the program and at the same time casts General Motors in a rather negative light, particularly our role in the Transbus program. The facts clearly show, however, that GM met or exceeded all of the requirements of the Transbus program and that in no way did we try to undermine its purpose.

More important, however, Buckel's conclusions fly in the face of two prestigious studies on the Transbus project, both of which took a dim view of the program. One was completed by the congressional Office of Technology Assessment and the other by the National Research Council. The NRC report concluded that bus manufacturers were justified in not bidding on low-floor Transbus purchases. (No bids were submitted by the prescribed UMTA deadline.)

In sum, much of the Buckel paper actually has no relevancy to the subject it was intended to address and includes subjective, controversial views and sensitive issues that have long been refuted and put to rest. Furthermore, his paper appears to have been almost entirely overlooked in the related workshop discussions.

Our second concern relates to comments on technical information and training made by A. B. Hallman in the Charge to the Workshop and by participants in Workshop 3.

We fail to recognize the decrease in technical information and training referred to by these participants. In 1963, the GMC coach maintenance manual covered 12 coach models and consisted of 510 pages; this increased to 663 pages for the last "New Look" coaches produced by GMC in 1975. Today, the current 04 Series RTS coach maintenance manual exceeds 1100 pages. The artwork has been converted to a line-drawing format, the number of schematics has increased, and the manual has been organized to isolate standard and optional equipment, which makes it possible for individual properties to closely match the maintenance manual to their vehicles.

The general wiring diagrams supplied with the New Look coach and early RTS coaches have been replaced with computer-generated individualized wiring diagrams applicable to each specific coach order (even small orders of one or two coaches).

To the best of our knowledge, an acceptable job performance aid (JPA) covering all major coach systems is still nonexistent. The JPA concept is not new but merely represents a different method of presenting technical information.

If the JPA system is still being developed and tested, how can Hallman be so certain it is better than the manuals currently being supplied? In addition, he has not addressed the problem of who will be responsible for updating the JPAs. At GMC, we consider these continuing obligations from both a legal standpoint and a moral standpoint every single day. We seriously question the motivation of hired outside firms or consultants to do any further updating or correctional work after they have been paid for the original documents and JPAs. It is obvious that no provisions whatsoever have been worked out for handling product recalls or safety-related changes once the original JPAs are printed.

Certain concepts proposed by the JPA system may have some foundation, and we are always open to new ideas. However, we still believe that the implementation of changes in the existing maintenance manuals, training programs, and service bulletins is best left to each vehicle manufacturer.

If an operator truly believes that manufacturer A has better maintenance manuals, better training programs, or better service engineering help available than manufacturer B, the operator should factor these elements into bid specifications and life-cycle costing programs to recognize better performance during the procurement process.

Closure

Kay Inaba
Xyzyx Information Corporation

I totally agree with Pegg that the manufacturer is the most logical source of technical information. In fact, we would like to see all manufacturers provide usable and effective maintenance manuals with all their equipment. Using outside firms or consultants to develop such manuals is a compromise necessitated by the manufacturers' failure to provide such usable manuals.

I also agree wholeheartedly with Pegg that usable maintenance manuals as well as other life-cycle cost (LCC) items should be factored into the procurement process. Obviously, proponents of the LCC purchasing concept also agree. I wish them well.

Also, I commend GMC for its efforts to improve its maintenance manuals. These efforts seem to represent a considerable cost. Thus, cost does not appear to be a major barrier (for the manufacturer) to improving maintenance manuals.

The only major area of disagreement seems to be on what constitutes improvement. We do not agree that more means better. Simply providing more pages or more schematics will not make the individual page more usable.

The basic purpose of the UMTA program to improve maintenance manuals (more commonly known as the JPA project) is to improve the usability of maintenance manuals. The aiding technology is a human factors technology that has been thoroughly tested in the military services. There is considerable evidence to indicate that the technology is directly applicable to the mass transit community.

According to Pegg, GMC is (and has been) willing and ready to help improve maintenance manuals. Thus, it would appear logical for GMC (as well as other coach manufacturers) to adopt the aiding technology. Yet, the comments by Pegg appear to indicate that GMC is reluctant to accept it.

If Pegg is questioning whether the aiding technology applies to bus maintenance, I refer him to all the aiding studies conducted by the U.S. Department of Defense in the past 20 years. Perhaps the reluctance is due to a concern that accepting aiding as a technology might imply that GMC is admitting that its maintenance manuals have usability problems. It would appear that the position of GMC in the industry is such that such a criticism would not damage its reputation in any way.

Given the many areas of agreement, it would appear that the next logical step is to help the manufacturers apply the aiding technology. Our experience to date indicates that a significant number of bus agencies would welcome such an event.

Closure

A. B. Hallman
Urban Mass Transportation Administration

Pegg is correct in his contention that the equipment supplier should be the source for any JPA-like maintenance manuals that may be procured in the future. He is also correct in pointing out that the utility of improved maintenance manuals should become a factor in life-cycle costing programs. General Motors is also to be commended for recent improvements in computer-generated wiring diagrams to support the maintenance of New Look and RTS coaches.

It is not necessarily true, however, that more pages in a maintenance manual produce a better or improved document. There was never a contention during the workshop that the quantity of technical information had diminished. The preliminary results from the Detroit DOT demonstration show that novice mechanics with modest training in the use of JPAs for the heating and air-conditioning system performed as well as experienced mechanics using conventional maintenance techniques.

The intent of the UMTA demonstration project in Detroit was to determine what improvements in maintenance performance might be achieved by using a human-factors technology that had shown improvements in the U.S. Air Force and the nuclear power community.

The **Transportation Research Board** is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 270 committees, task forces, and panels composed of more than 3300 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, the Association of American Railroads, the National Highway Traffic Safety Administration, and other organizations and individuals interested in the development of transportation.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purpose of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its Congressional charter, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has been the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine.

The National Academy of Sciences was established in 1863 by Act of Congress as a private, nonprofit, self-governing membership corporation for the furtherance of science and technology, required to advise the federal government upon request within its fields of competence. Under its corporate charter, the Academy established the National Research Council in 1916, the National Academy of Engineering in 1964, and the Institute of Medicine in 1970.