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.

REFERENCES

1. Transit Fact Book. APTA, Washington, DC, 1980.
2. Management Information Systems Applications Within the Transit Industry. APTA, Washington, DC, 1980.
3. Chicago Transit Authority's Vehicle Maintenance System. Chicago Transit Authority and International Business Machines, Inc., n.d.
4. M. Couture and G. Paules. Automation in Public Transit Operation and Management. TRB, Transportation Research Record 761, 1979, pp. 51-53.
5. U.S. Transit Properties Bus Maintenance Reporting Systems. Dynamics Research Corp., Wilmington, MA, 1980.
6. Preliminary Design Maintenance/Inventory System. Arthur Andersen and Co., San Francisco, Feb. 1981.
7. G.J. Fielding, R.E. Glauthier, and C.A. Lave. Performance Indicators for Transit Management. Transportation, Vol. 7, 1978, pp. 365-379.
8. L.C. Sinha, A. Bhandari, and D. Dobry. A Comprehensive Analysis of Urban Bus Transit Efficiency and Productivity. Purdue Univ., West Lafayette, IN, Dec. 1978.
9. W.G. Allen, Jr., and L.G. Grimm. Development and Applications of Performance Measures for a Medium-Sized Transit System. TRB, Transportation Research Record 746, 1980, pp. 8-12.
10. S. Mundle and W. Cherwony. Diagnostic Tools in Transit Management. Booz-Allen and Hamilton, Inc., Philadelphia, Jan. 1980.

Workshop Report

William Van Lieshout, Chairman
Maria Kosinski, Recorder

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.