Objectives for a Transit Bus Fleet Management Data, Information, and Knowledge Exchange

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Exchanges for bus equipment and bus fleet performance data, equipment management information, and fleet management knowledge, following several different formats, have been proposed and attempted. However, the objectives and structure of the proposed exchanges are usually poorly defined. In this paper objectives for an exchange are recommended and data, information, and knowledge that should flow through an exchange are discussed. Highlighted in the paper is the partitioning of exchange flows into levels. Data flows represent the least processed level of exchange, information flows represent processed data, and knowledge flows are the most highly processed level of exchange. The more highly processed the exchange, the less interpretation is required before application. For the exchange to be of maximum value, it should provide information on all three levels.

The purpose of this paper is to provide guidance on an issue of current interest to transit bus fleet managers; bus equipment manufacturers; and mass transportation administrative agencies at the local, state, and federal levels: creation of an exchange for bus equipment and bus fleet performance data, equipment management information, and fleet management knowledge. Although the initiation of an exchange has been a topic of recent concern to bus fleet managers, the recommendations provided in this paper are equally applicable to managers of other public works fleets (transit agencies are considered members of the public works family of service agencies).

INTRODUCTION

The focal point of the paper is a series of recommended objectives for an exchange. The importance of the proposed objectives lies in the direction they provide for structuring an exchange. The exchange of bus equipment and bus fleet performance data, equipment management information, and fleet management knowledge is an attractive concept, and establishing such an exchange has been proposed on several occasions. However, the objectives that proposed exchanges are to achieve are usually poorly defined. In at least one case (and probably in others), a lack of clearly defined objectives caused an attempted exchange to founder during its demonstration. In this paper concepts of exchange level development are defined and specific objectives are recommended for future efforts to initiate an exchange.

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MOTIVATION FOR AN EXCHANGE

In 1982 the Transportation Research Board (TRB) organized a conference on bus maintenance (*1*). One of the charges of the conference was to recommend activities that offered the potential of improving the performance of bus maintenance. A highly recommended management tool was the creation of a "national information network for sharing data on major model-specific defects" (*1*, p. 36). A second bus maintenance conference was organized by the TRB in 1984 (*2*). During the second conference the attendees indicated that the single most important issue facing bus maintenance managers was the creation of an "improved information exchange."

Since the 1984 TRB conference there have been several efforts to improve the exchange of information on bus maintenance and bus performance. The American Public Transit Association (APTA) has taken a key role in the promotion of exchange and has organized biannual workshops on bus equipment and maintenance. Periodically APTA devotes a section of its weekly newspaper, *Passenger Transport*, to bus maintenance topics. The Urban Mass Transportation Administration (UMTA) and other organizations (i.e., state or regional transit associations) have also attempted to promote exchange in various fashions ranging from highly structured exchanges of computerized maintenance data to informal discussions of garage-level problems. Universities and research organizations have promoted exchange through formal presentations and classroom-style workshops (*3*). However, all of these efforts are clearly changing with time and they will evolve to different forms and improve in the future.

A discussion of these transitory exchange efforts is, however, outside of the scope of this paper. Many current forms of exchange are likely to shortly change. However, current efforts to promote exchange indicate the industry's recognition of the importance and value of exchange.

The creation of an exchange is an attractive notion, and it has been attempted by other industries. For example, in the early 1970s, the American Public Works Association (APWA) sponsored an attempt to create a national data base to identify the performance of public works equipment (e.g., garbage packer trucks, street maintenance equipment, pickup trucks) (*4*). At the time, pooling of data from several public works agencies appeared to be feasible because many of the agencies used the same service organization to process their equipment management information. Because several public works agencies were already using the same data coding structure and their data were processed by the same software package, the service organization believed it could process several agencies' data simultaneously and produce summary information. For example, the service group could compute the average cost per equipment operating hour or maintenance labor hours per piece of equipment using the combined data of all of its client public works agencies. The summary information would serve as a point of reference against which individual agencies could judge their own fleet's performance. Unfortunately, the APWA's attempts failed, mainly because of the lengthy computer processing time required to produce summary statistics using early 1970s computers. However, because of the increased computing speed of current computers (late 1980s), APWA is again interested in developing a similar data pool (private communication with Robert Bugher, Executive Director of the APWA, 1987).

The Department of Defense (DOD) and the National Aeronautics and Space Administration (NASA) have successfully developed an extensive exchange that is operated by the Navy (*5*). Since the early 1970s, many DOD-NASA organizations and contractors have been required to submit data and reports from technical studies that document the costs, reliability, and maintainability of equipment to the Government-Industry Data Exchange Program. Although the Navy does not have an exact mechanism for estimating the benefits of their data exchange system, users are surveyed annually and asked to estimate the costs they avoided as a result of the exchange. In 1985 more than $61 million in savings were reported by the system's users; the operating cost of the exchange was roughly $3 million (*5*). These results have led the Navy to conclude that the savings and cost avoidance accrued through the use of the exchange far exceed the exchange's operating costs and the exchange members' costs for use of the system.

Levels of Exchange

Clearly, exchange can be at many levels ranging from informal discussions of garage floor problems to structured exchange of computerized data. To classify exchange levels, flows are divided into three levels: exchanges of (a) data, (b) information, and (c) knowledge. There are significant differences in the attributes of data, information, and knowledge. These terms are defined [the definitions are adapted from those of Horton (*6*)] as follows:

1. Data: A datum is simply the relationship between some measurable attribute and a specific event. For example, data on failures of a specific bus component (e.g., transmissions) will consist of miles traveled or hours of use (a measurable attribute) until each component failure (the event). Such failure data may be derived by reviewing maintenance work orders or vehicle maintenance history logs. Data are the lowest level of maintenance and vehicle performance flow.
2. Information: Information is processed data and it reduces the uncertainty of future events. For example, if statistical analysis is performed on component failure data, the statistics (i.e., the mean miles between failures, the standard deviation of miles between failure, and other statistical parameters) can help to determine when to expect future failures of the same component. Statistical information reduces uncertainty because it aids in the making of forecasts of future failures.
3. Knowledge: Knowledge is highly processed data, and the creation of knowledge from data requires independent judgment and interpretation of data analysis. For example, if failure data and repair cost data were analyzed, it might be possible to specify a component's minimum cost replacement or overhaul interval (e.g., overhaul engines every 250,000 mi or at failure). Procedures for determining the optimal interval between component overhauls are knowledge. Procedures are one form of knowledge. Other forms involve factual and judgmental knowledge. Factual knowledge requires the study of data sets to derive facts. For example, Duffy et al. (*7*) compared the use of prerun inspections by transit systems and found that transit systems with more thorough prerun inspection procedures tended to enjoy better maintenance system performance as indicated by mechanic labor hours per mile. Judgmental knowledge is derived from observing data without the use of formal data analysis. For example, during their study of prerun inspections, Duffy et al. found that, in the judgment of most maintenance managers, the use of prerun inspections improves maintenance performance (*7*).

The distinctions among data, information, and knowledge are quite important. The value of an exchange will be largely a function of the format, structure, and level of exchange (i.e., data, information, or knowledge). For example, if only raw data are exchanged, then, for the exchange to be valuable to the participants, each participant must have the capability of processing raw data into either information or knowledge. Some sophisticated transit agencies may find a raw data exchange beneficial. However, many others without complex data processing skills are not likely to find raw data worthwhile. Thus it is apparent that the utility and success of an exchange will be dependent on the data, information, and knowledge that flow into and through the exchange and on matching the level of exchange (i.e., data, information, or knowledge) to the requirements of exchange users.

Types of Exchange

Current methods of exchanging bus equipment and bus fleet performance data, equipment management information, and fleet management knowledge are relatively diffused and require quite different development approaches. For example, the APTA conferences on Bus Equipment and Maintenance are largely devoted to the exchange of judgmental knowledge (informal analysis derived from experience). UMTA has promoted, through a demonstration project, the exchange of statistical information through a centralized computer data base that contains maintenance data records from several transit agencies. Each of these represents an exchange of maintenance data processed to different levels (processed to become information or highly processed to become knowledge). The usefulness of each level depends on the user's ability to interpret the materials being exchanged. For example, knowledge requires little interpretation before it can be applied whereas pure data require a good deal of analysis and interpretation. The relative popularity of APTA's conferences, as witnessed by their increasing attendance, leads to the conclusion that many bus maintenance managers find exchange at the knowledge level (particularly judgmental knowledge) quite useful (*8*, p. 6).

Contrasting the various methods of exchange illustrates that no one single means of exchange is appropriate for all users all of the time. Sophisticated users often may only require access to a data bank; they can perform their own analysis to develop information or knowledge. Others may find data processed to the information level, or even data that are highly processed to the knowledge level, more useful. Further, some topics may be appropriately exchanged at only one of the three levels. For an exchange to be of universal utility to all potential users it should contain all three levels.

EXCHANGE RECOMMENDATIONS

The first step in the development of any activity is to establish a management plan. A management plan should include fundamental planning components; objectives to be achieved by the operation of the activity; rules, procedures, and programs; and a budget to govern the activity's operation. Clearly, it is premature to propose operating rules, procedures, programs, and a budget for an exchange. However, it is reasonable to recommend general objectives for an exchange of bus equipment and bus fleet performance data, equipment management information, and fleet management knowledge.

PROPOSED OBJECTIVES

Proposed objectives for an exchange are categorized by their time frame. Some are continuing objectives to be accomplished throughout the life of the exchange. Some objectives can be accomplished with a relatively small amount of historical data; these are short-term objectives (within 1 year). Some can only be accomplished with several years of historical data; these are midterm objectives (1 to 3 years). Other objectives can be accomplished when historical data are available for a long enough period to gain a maintenance profile over a bus's life; these are long-term objectives (5 years or more).

Proposed Continuing Objectives

Clearly there are nontechnical, fundamental goals that should be common to any system, such as deriving the greatest cost savings for the system's users, attracting a large number of regular users, and other standard goals. However, continuous technical objectives for an exchange should include the following items.

Development of Standards

Most transit systems have institutional and environmental differences that, to some extent, make maintenance and operating data from different agencies inconsistent. For example, a transit agency may have mechanics who are more qualified than mechanics at other transit agencies, which, in turn, makes the performance of the agency's maintenance system superior. Differences in mechanic performance may be due to factors that are under the maintenance manager's control (such as mechanic recruitment and training programs). Differences may also be due to institutional factors outside the fleet manager's control. For example, the fleet manager may be unable to offer wages that will attract competent mechanics, or there may be local socioeconomic factors such as a lack of competent diesel mechanics in the local labor pool. The extent of inconsistencies grows even more serious when a comparison is made of local data collection methods, definitions, and data accuracy. Uniformity is further diminished by differences in maintenance procedures, policies, rules, and practices. Comparability is also made even more difficult by variations in environmental and route service factors such as duty cycles, fleet age, the terrain covered by routes, weather, and ridership levels.

Because of the variations among agencies, an exchange should strive to develop standard procedures for data definitions and collection. By minimizing the institutional variations in data definitions and data collection, the exchange can increase the comparability of the maintenance operations of individual users. Thus a continuous objective of the exchange should be to strive for standard definitions and data collection procedures. A first step toward uniformity would be the adoption of a standard job coding system for maintenance and servicing of transit buses. If a standard code were adopted, maintenance and servicing jobs could be recorded by transit agencies using the same alphanumeric codes for job and cost categories. The code could be developed and kept up to date in a manner similar to that used for the American Trucking Associations' *Vehicle Maintenance Reporting Standards* (*9*).

Comprehensive Coverage of Levels of Exchange

UMTA's experimentation with a national computerized bus maintenance data base and information exchange provides an illustration of the need for comprehensive coverage of all levels of exchange (*10*). The primary purpose of UMTA's system was to take data from individual transit systems, merge the data, and derive summary statistics on a national basis (e.g., cost per repair, labor per repair, total maintenance costs) and possibly even identify specific model defects that exist in contributors' bus fleets. An individual system could then use the summary statistics to make comparisons with its own performance.

During the demonstration of UMTA's computerized data base and information exchange system, a liaison board of knowledgeable transit professionals was asked to evaluate the exchange. Members of the liaison board from large transit systems with sophisticated maintenance management information systems and detailed data bases failed to see the value of having access to a national data base because they already had their own detailed performance statistics. In general, a data base with more detail will have a greater number of maintenance job codes, which permits greater accuracy in identifying specific maintenance jobs. When detailed data sets are merged with less detailed data sets, the detailed data sets are condensed and job codes are aggregated; information is lost in the aggregation process. Liaison board members from large transit systems thought that their own sophisticated information systems were likely to provide them with more detail than would a national data base because of aggregation problems.

The specific reason for larger systems being unattracted to UMTA's exchange is probably that the system only exchanged information at one level. The UMTA system provided only summary statistics, using a national data base, that are similar to those commonly produced by individual maintenance management information systems. Further, the data would have to be aggregated into the least common denominator of job codes and classifications used by transit agencies contributing data to make the data from each agency compatible.

The UMTA project foundered during its demonstration because of a lack of clearly defined objectives. After the demonstration phase, UMTA's proposed exchange was shelved. Even at the final liaison board meeting, the board did not fully understand the objective of the exchange system (*10*).

A comprehensive exchange should provide data, information, and knowledge that an individual system could not derive on its own. For example, a national exchange should be able to provide transfer of knowledge through (a) research conducted using a national data base; (b) dissemination of one transit agency's technological innovation; (c) exchange of technological innovations from related industries; and (d) technical, engineering, and management training. Thus the exchange should strive to comprehensively exchange data, information, and knowledge.

Proposed Short-Term Objectives

Short-term objectives are generally those that can be achieved with a modest amount of data on maintenance performance from individual data contributors. Proposed short-term objectives include the following items.

Identifying Model-Specific Defects

The identification of model-specific defects was identified as a primary purpose for the development of a national data base in the 1982 TRB Conference on Bus Maintenance (*1*). A defect is usually identified by premature failures and possibly other performance attributes (e.g., high fuel consumption) that indicate a flaw in design or manufacture. Equipment flaws, or even equipment that performs below expectations, can be brought to the attention of manufacturers so that they may rectify the problem. Also, agencies that own the equipment could be made aware of the defect, its special conditions, and possible ways to design out the defect (e.g., retrofits).

An exchange could identify specific defects with modest amounts of data. As an example, studies could be conducted that are similar to the Transportation Systems Center's (TSC's) reliability study of V730 transmissions in 1982 (*11*). The TSC study successfully identified the poor reliability of early models of the V730 transmission with transmission life data from only a few large transit systems. As one equipment manufacturer pointed out, such field-collected data can be quite valuable to the manufacturer in product improvement because "laboratory and proving ground tests are conducted on a relatively small number of samples due to the great cost involved. . . . Quite often preventive maintenance and service practices tend to be more idealized in proving ground tests. . . ." (*12*). A national data base provides the opportunity to examine a large number of pieces of equipment under actual operating conditions.

Tools, Diagnostic Equipment, and Tests

Methods of conducting maintenance are constantly being improved by the use of special tools, diagnostic equipment, and test procedures. Sessions at APTA's Bus Equipment and Maintenance conference are often devoted to improved methods. Knowledge of these methods should be reported and disseminated through an exchange. The exchange should stress the importance of reporting improvements in standard formats with data that provide evidence of the method's effectiveness and cost savings.

Training

The exchange should seek to facilitate training at all levels: maintenance labor, front-line supervisors, and fleet management. Training can be facilitated through exchange of existing materials, organization of workshops, and preparation of training materials.

Performance Data

In the short term, data on performance measures could be collected from transit properties. The performance measures could serve as a basis for comparing the productivity of individual transit systems with national averages. Of course, individual transit agencies must realize that performance measure averages may not be comparable to their own system.

The idea of creating national averages (standards) for performance is attractive, and efforts to create national fleet performance standards have been made in the past. In 1951 the American Transit Association established a panel of operating executives to establish a set of "transit pars" for transit industry performance (including maintenance) (*13*). The pars were standards for performance measurements, and they were designed to help management test the efficiency of their transit system.

Proposed Midterm Objectives

Midterm objectives are generally those that can be achieved within 1 to 3 years. Midterm objectives may involve the analysis of maintenance system performance of individual contributors of data to derive information and knowledge about the desirability of management practices of individual agencies.

Management Procedures

Maintenance management practices tend to vary dramatically from one transit system to the next. For example, the preventive maintenance activities that are conducted and the frequency of preventive inspections vary greatly even among transit agencies with similar duty cycles and equipment. The frequency of preventive inspections has been commonly observed to vary from 2,000 mi between inspections (2,000-mi inspections are largely for safety reasons) to 8,000 mi between inspections. Presumably there must be significant differences in the cost of preventive and corrective maintenance, and the reliability of equipment, when inspections frequencies vary so widely. However, there exists little information that, through empirical data analysis, identifies the trade-offs and advantages of various preventive maintenance strategies.

A midterm study (between 1 and 3 years) of maintenance performance data and the corresponding practices of individual contributors of maintenance data could identify the trade-offs and advantages of management strategies and policies. Studies could also cover (a) management control systems used by transit maintenance departments to better control labor time allocation, material dispersal, and consumable dispersal (e.g., fuel and oil); (b) maintenance staffing levels and skill distribution and the effectiveness of training programs to update and improve skill levels; (c) the effectiveness of conducting maintenance functions in house versus contracting them out for fleets of various sizes, maintenance labor skill levels, and maintenance facility and maintenance equipment resources; and (d) studies of other maintenance management practices that tend to vary from one system to the next or of practices that appear innovative and timely.

Equipment Innovation

Bus equipment innovation and equipment design issues are being researched by individual transit systems. For example, a summer 1987 "Bus Tech" in *Passenger Transport* reported that 13 transit systems were experimenting with alternative fuel systems (i.e., methanol fuel, compressed natural gas, and propane gas) (*14*, p. 6). Other areas of equipment innovation include the use of new nonasbestos brake blocks, drive line retarders, and emission control equipment. The exchange could set standards for the reporting of experimental results and provide engineering analysis of experimentation that appears to provide a high level of equipment improvement.

Proposed Long-Term Objectives

Long-term objectives are those that may not be achievable without several years of data (5 years or more). Long-term objectives may involve the analysis of maintenance and cost data that cover the entire life of a bus. A proposed long-term objective involves the collection of data to permit life-cycle cost analysis to be conducted.

Because buses have minimum lives that span several years, it is difficult to gain information on life-cycle costs and life performance data (i.e., reliability, maintainability, and availability) over a bus's entire life without a long-term data collection effort. The long-term collection of life costs and life performance data would be of tremendous assistance in the selection and specification of equipment, replacement and bus rehabilitation decision making, and budgeting for future maintenance and capital costs. Knowledge of equipment performance over its life is essential for setting the most cost-effective spare ratio policies. Of course, all cost data must be tempered by the data contributor's unique operating environmental conditions and duty cycle.

CONCLUSIONS

For an exchange to be of the greatest value it should strive to provide exchange at all levels: data, information, and knowledge. This is not an easy task and requires a significant effort and a long-term funding commitment. The performance of the Navy's Government-Industry Data Exchange Program illustrates the benefits of an exchange (*4*). However, its roughly 15-year existence and its approximately $3 million per year operating budget illustrate the significance of the support required to achieve the benefits that are possible through an exchange.

ACKNOWLEDGMENTS

The development of this paper was supported in part through a grant to the University of Oklahoma from the Urban Mass Transportation Administration, U.S. Department of Transportation. The author was a member of the faculty of the School of Civil Engineering and Environmental Science at the Unversity of Oklahoma during the course of the research project. The assistance of Edward J. Kannel, Professor of Civil Engineering at Iowa State University, in the preparation of this paper is also gratefully acknowledged.

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