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

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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.

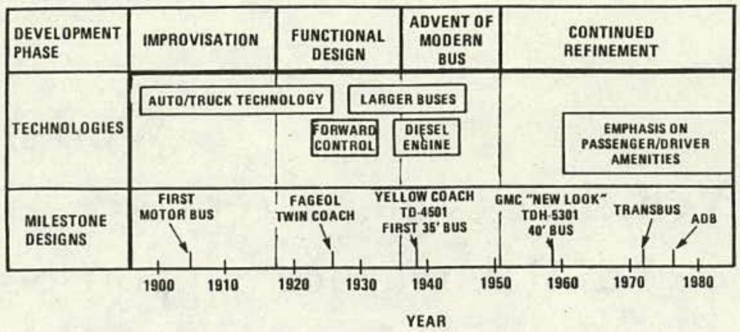

Figure 2. GMC 5100 series bus.

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