Federal Role in Supporting Research and Development for Reducing Transportation Maintenance Costs

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The 1975 policy statement of the Secretary of Transportation reflects that, for the most part, the nation's transportation infrastructure is in place. What is needed now is the modernization, repair, and more effective use of existing capacity. The cost of maintaining the transportation system is of concern, and much is being done in all sectors to cope with the situation. Inefficient maintenance practices, the need for more reliable and maintainable equipment, the need to eliminate or reduce manual labor, and the need for better information systems are being addressed. Solutions take time to implement and are expensive in most cases. Although the findings in this report do not show that a crisis situation exists or is imminent, they do suggest opportunities for the U.S. Department of Transportation to expedite the changes needed to significantly reduce future maintenance costs. Four major areas have been identified in which common needs exist for all transportation modes, in government as well as the private sector. Only visible action in the form of federal leadership, coordination, and dissemination of technical knowledge can help achieve the needed changes more rapidly.

In 1975, the Secretary of Transportation issued a statement on national transportation policy (1). In this statement, he pointed out that, for the most part, the nation's required transportation infrastructure is in place. What is needed is modernization, repair, and more effective use of existing capacity.

Need for more effective maintenance has been expounded by Clary (2). Railroad track neglect, the need for upgrading resurfacing and bridge replacement of the highway system, needed dredging of waterways, and maintenance of air traffic control systems were described in terms of spiraling maintenance costs and the threat this presents to the country's transportation systems. The railroad's track problems are perhaps the most dramatic. Because of decreasing revenues and other reasons, needed upgrading and repairs were deferred year after year. The results of these actions (and, obviously, other factors) have led to the current situation of bankrupt corporations and an enormous capital investment requirement preceding any recovery efforts.

Highways, on the other hand, have enjoyed a period of stimulated growth with the building of the Interstate Highway System. Now that this effort is almost complete, the task of maintaining the massive network (in light of increased costs, inflation, and competition for available dollars) is most formidable. Fears of the aforementioned railroad dilemma are understandable.

While airlines are coping with maintenance burdens, the Federal Aviation Administration is contending with increased maintenance requirements resulting in the need for bigger budgets and more personnel—all this in a climate of fiscal restraint and competing national priorities. In light of this situation, it is natural for the U.S. Department of Transportation (DOT) to be concerned. The Office of the Assistant Secretary for Systems Development and Technology initiated a project in September 1975 to increase the overall perspective of maintenance problems and to determine what actions might be taken to minimize the probabilities of future crises.

OBJECTIVES

National transportation policy is established to serve the nation by helping to guide the development, financing, and maintenance of the transportation system (1). In addition, the policy sets precedents on the use of federal subsidies, regulation, maintaining diverse transportation modes, and ensuring fairness toward competition of the modes.

It was within this framework that a basic objective of this study—to determine the DOT's role in reducing the maintenance burden of transportation systems—was established. Two questions that underlie the basic objective were also addressed.

1. How significant are maintenance costs with respect to total system costs?
2. What research and development (R&D) opportunities exist to effectively reduce current and future maintenance costs?

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FINDINGS

Highways

The Federal Highway Administration (FHWA) estimates that the annual cost of highway maintenance is nearly $6 billion and is increasing at a rate of about $300 million/year. This represents about one-third of all current highway expenditures (3, pp. 1-30). If the trend shown in Figure 1 continues, maintenance could account for one-half of all highway expenditures by 1985 (4). Even with this expenditure, there are currently 1.127 million km (700 000 miles) of streets and highways in need of improvement of which 322 000 km (200 000 miles) are rated as critical. In addition, 90 000 bridges need replacement (5, 6). Road building, on the other hand, has decreased somewhat but obviously will not cease. Figure 2, which shows this, is based on FHWA data. Over the next 20 years, the amount of road building and upgrading that will be required is most formidable (7). There also exists a large backlog of secondary highway maintenance that has been estimated by FHWA to average about $2.25 billion/year over a 20-year period (1972 to 1992) (3). Figure 3 shows a more detailed examination of maintenance costs. Labor and traffic services each account for almost 50 percent of maintenance cost dollars. (Traffic maintenance includes snow and ice control and rest area and sign maintenance.) Physical maintenance, however, still consumes most of the volume of work performed (8).

Federal, state, and local highway departments are well aware of the challenge of maintaining roads and highways and have been for many years. The Transportation Research Board (TRB) and FHWA, together with the entire highway industry, are working to meet this challenge. Searches for better materials, equipment, and processes have been supported by both federal and state funds. More recently, causes for maintenance inefficiencies were identified, and improved maintenance management systems were encouraged. The following are the primary causes of highway maintenance inefficiencies:

1. Patronage system,
2. Lack of maintenance management research,
3. Inadequate maintenance data,
4. Lack of uniform standards,
5. Ineffective procedures for planning and scheduling, and
6. Overstaffing to meet emergencies.

Case studies have shown that maintenance planning, including performance standards and a good information system, can save significant amounts (11). For example, Crawford (10) found in 1971 that Louisiana maintenance costs were increasing by $4 million to $5 million/year. Through improved maintenance management practices, routine maintenance costs dropped $1.5 million. An attrition plan reduced the number of workers from 5150 to 3596 persons and increased total productivity. It has been estimated that 20 to 30 percent of current maintenance costs could be eliminated by efficiency improvements (5), especially those that reduce maintenance work force requirements. The 1974 National Transportation Report (20) stated that "there is no doubt that labor cost is the major cost factor, and the one that can have the greatest impact on total cost. This finding suggests that measures to control costs should focus primarily on labor costs."

Still the challenge is growing. As the Interstate Highway System was built, the primary and secondary roads were neglected (7). Demands on shipping produced heavier loads and greater traffic volumes, which tends to shorten the service life of pavements and structures (6). This suggests that the cost of maintaining roads could get worse, especially if antiquated maintenance practices continue (4). It is not surprising then that many states feel that increased labor efficiency is the first step in easing the budgetary and staffing strains (9; 21, p. 53).

After effort for improved efficiency, a stepped-up program of research is considered the most promising avenue for reducing maintenance costs. FHWA, in conjunction with TRB, has identified highway maintenance research needs and has estimated that an investment of $9 million could return $750 million over a 5-year period (4). Some areas suggested for more research and development include

1. Diagnostic and condition measurement equipment;
2. Standardization of equipment;
3. Better composite materials;
4. Improved criteria for design and use of highways and bridges;
5. Better cleaning and litter pickup equipment;
6. Improved bridge design;
7. Better methods and equipment for pavement removal, replacement, and patching;
8. Methods for recycling materials;
9. Compact tools;
10. Equipment and maintenance data systems;
11. Equipment management system; and
12. Life-cycle costing.

The overall objective is to eliminate or at least minimize the need for maintenance. This can be accomplished through the integration of maintenance needs and requirements into design procedures and construction practices to obtain maximum benefit. A large portion of the maintenance cost burden can be avoided with better initial construction (12). (To this end, DOT has initiated a program to improve construction methods; improved tunneling methods are being demonstrated.)

A need exists for more standardization. The standardization of basic highway maintenance equipment would reduce acquisition costs, provide assets for more spare parts, and simplify the maintenance tasks. A recurring criticism is that there are no industry design standards or solid research experience for effective design (3). Adequate field data are also not readily available to provide the necessary basis for this type of endeavor.

Much of the maintenance costs can be reduced only by the mechanization of heretofore basically human labor processes and by great improvement of the efficiency of current mechanical processes. In addition, new equipments and processes must also be designed for operation and maintenance by semiskilled persons (13). There is some doubt about whether these things will be done. There is, however, a large program directed to improve highway maintenance capabilities and reduce costs (3). This year, FHWA has established a new R&D category, improved technology for highway maintenance, with the following research programs (22):

1. Use of waste material in road repair,
2. Improved inspection techniques for bridges and drainage structures,
3. Development of new test procedures and improved testing programs,
4. Improved technology for highway maintenance, and
5. Rehabilitation of existing pavements and development of premium pavements requiring no maintenance.

In addition, much complementary work is being conducted under the direction of state highway departments and the industry associations.

Railroads

The annual maintenance expenditure for railroads is currently more than $5 billion and is increasing at a rate of more than $280 million/year (Figure 4). This represents approximately 39 percent of all railroad expenditures (14, p. 16). These figures, however, do not take into account the amount of maintenance that is deferred as a matter of practice by the railroad industry. Deferred maintenance is more difficult to quantify. The most exhaustive study (16) estimated the total deferred maintenance of way and structure at approximately $6 billion for the nation's railroads. A special report on railroads concluded that the single largest deterrent to railroad profitability has been the result of a generation of deferred maintenance (17).

Harris (15) contends that "too much of the railroad's limited resources is required for maintenance." It can similarly be stated that, if the railroads are to increase their profitability, the cost of maintenance (39 percent) is a prime candidate for reduction. Examination of maintenance procedures indicates that there is considerable scope for reducing costs and increasing availability. [This has been confirmed also in foreign railroads (23).] Federal Railroad Administration personnel have related that, because of the downward trend of the railroad industry, maintenance policy, for the most part, is to repair as necessary. Preventive maintenance is practiced, however, on locomotives.

Improvements in maintenance management for some railroads could significantly reduce maintenance costs. It appears that systems management, operations research methods, and industrial management techniques are not being used to the extent that they should be in complex operations. Work standards, automated data systems, advanced operations, and optimization models are tools that are normally associated with modern management practices. In this regard, the American Association of Railroads and other associations are working on maintenance standards and minimum design standards. Lack of standardization in car components such as heating and cooling controls has led to many maintenance problems (25).

Government regulation may also be contributing to inefficient operations. Safety measures, for example, that result in maintenance actions such as inspection or immediate repair are based primarily on personal judgment or experience. Accurate data verifying these policies are believed rare. Better data are needed to correct these and other deficiencies.

In many operations, modern automated data systems have been installed because no maintenance policy can succeed without a continuous feedback of accurate field data. There are also emerging examples of expanded use of computer models that can assist in determining the best maintenance policies for various conditions (24, Appendix 4). Traditional ways of doing business and outmoded labor agreements are the biggest obstacles in introducing these changes.

Research and development in the railroad industry has been almost exclusively hardware oriented (15). Designs have been made to better accommodate specific services, such as trailers and containers as well as automobiles. Research and development is continuing on rails, trucks, controls, fire protection, and tunnel construction. Designs for track renewal machines and diagnostic and measurement equipment are also appearing for use. In addition, there is also some research, such as that on wheel-rail dynamics, that is evolving to improve the much needed base of technical knowledge. More of this type of research is believed necessary.

Urban Mass Transit

Data on buses, subways, and trolleys were found for the most part in Transit Operation Reports published by the American Public Transit Association (APTA). These data had to be extrapolated to estimate the national costs associated with maintenance. The annual maintenance expenditure for buses, subways, and trolleys is estimated to be $900 million/year at present. This is increasing primarily for trolley operations; bus and subways have remained somewhat constant. [Trolley maintenance costs are increasing primarily because of the aging fleet of vehicles. Only one trolley has been reported purchased since 1955 (26, p. 17, Table 13).] Maintenance expenditures account for 15 to 30 percent of operating expenses reported by the transit properties (Figure 5). These figures obviously do not include maintenance that is deferred for various reasons.

A closer look at available statistics shows that trolley and subway maintenance costs are higher than those for buses primarily because of the maintenance of way and structures expense. The following gives maintenance as a percentage of operating expense for trolleys, subways, and buses for 1973 and 1974:

Maintenance Expense Item	Trolleys	Subways	Buses
Way and structures	17.4	15.6	0
Equipment	9.9	13.4	15.7
Total	27.3	29.0	15.7

A large portion of the bus expense is the daily servicing required to keep equipment clean and operable. Figure 6 shows that servicing expenses approach those of actual repairs. Together, they account for 15 percent of the total operating expenses, which is second only to drivers' wages. The cost of maintenance is probably higher, for, although deferred maintenance cannot be quantified, it is known to exist. This policy is considered the lesser of many evils, which seems paradoxical in light of the fact that deferred maintenance is one of the suggested contributors to declining ridership.

The Urban Mass Transportation Administration (UMTA), together with industry groups such as APTA, is engaged in efforts to improve an industry that for the most part has been degrading since the late 1940s. Research and development expenditures for new buses, subways, and paratransit vehicles are increasing. Although bus engine performance has improved significantly since the 1930s, much needs to be done to improve components such as air conditioners, brakes, transmissions, and starters. Air conditioners for buses have caused the most significant maintenance problems. Regulations requiring procurement by the low bidder have caused an apparent setback in the improvement of these units as less reliable units have appeared in these buses.

Much effort is being directed toward improved maintenance management. Maintenance philosophies vary greatly from company to company. The key problems, however, appear to be the lack of good, readily available maintenance data; inadequate maintenance consideration during design; and the need to employ modern systems management methods, including ones for equipment and work standards, life-cycle costing, and modeling for systems optimization. The recognition of these needs is the basis for UMTA's current transit management program. In the research and development programs, TRANSBUS appears to contain many of the activities

Figure 1. Maintenance cost as a percentage of total highway expenditures.

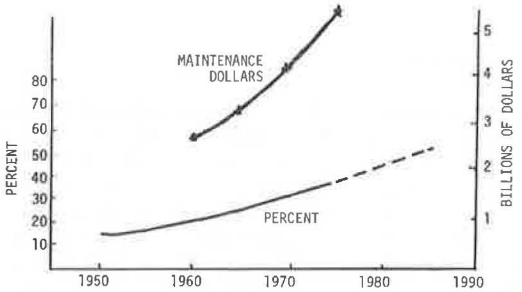


Figure 2. Highway building trend, 1964 to 1973.

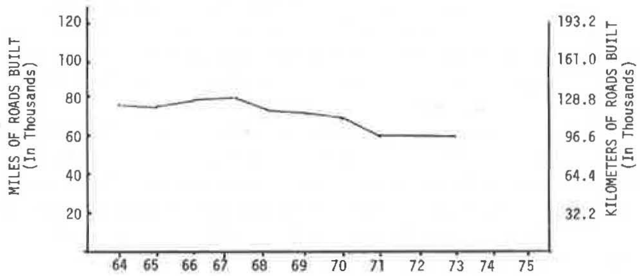
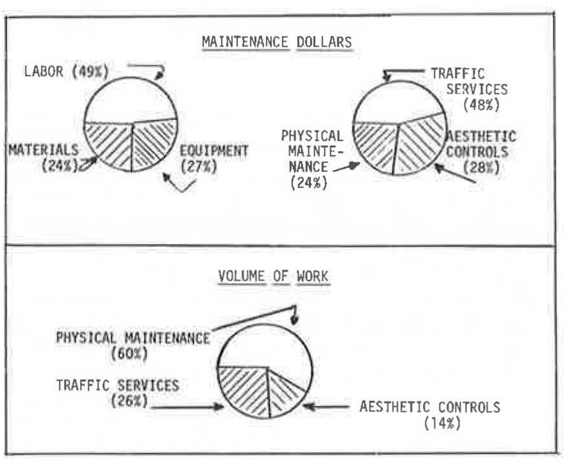
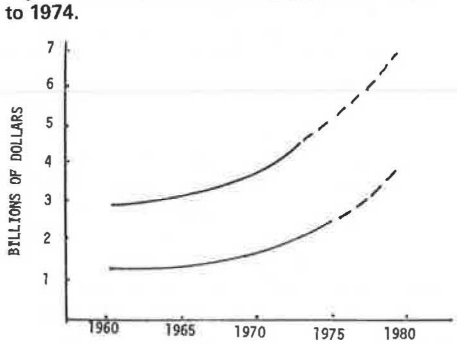


Figure 3. Distribution of maintenance dollars and volume.



NOTE: Traffic services include snow and ice control, rest areas and sign maintenance. Aesthetic controls include litter, mowing, vegetation, etc. Physical maintenance includes repairs to surface and base, structures, shoulders, etc.

Figure 4. Railroad maintenance costs from 1960 to 1974.



needed to overcome the aforementioned deficiencies. Test and evaluation programs for light rail transit continue this trend by including assessments of maintenance costs early in the life cycle. Some development work has also been done toward effective measurement and automatic diagnostic equipment.

Federal Aviation Administration

The cost of maintaining the nation's airway facilities is now approaching $350 million/year and is increasing at a significant rate as shown in Figure 7, which is based on data obtained from the Office of Budget of the Federal Aviation Administration (FAA). This is primarily due to recent inflation, expansion of the national airways system, and the obsolescence of a large portion of field equipment.

The FAA is aware of and has been attacking the problem of increasing maintenance costs. Existing equipment is being upgraded with the replacement of electronic tubes with solid state components. Current research and development is on automatic remote control and

Figure 5. Mass transit maintenance costs as a percentage of total operating expenses.

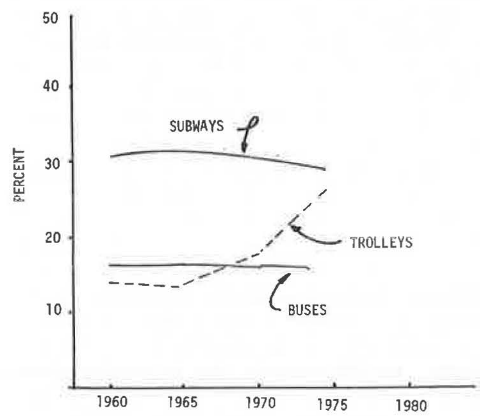


Figure 6. 1973 average bus operating expenses.

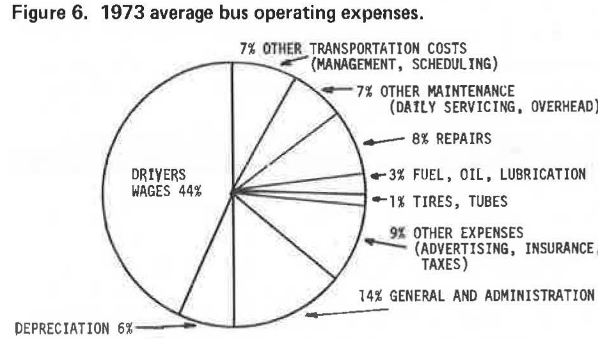
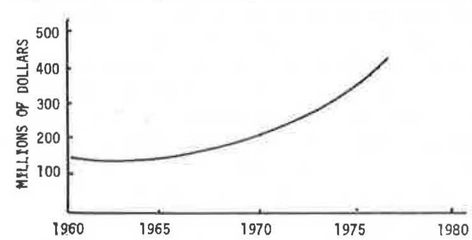


Figure 7. Airway facility systems maintenance costs.



monitoring systems (diagnostics) for newer equipment. In addition, a program called "zero maintenance" has been initiated to pull together the various activities engaged in reducing maintenance costs. This program includes the development of a new staffing (work) standard that will be used as a basis for updating the maintenance instruction manuals. A maintenance data system (MARS-1) is being implemented; information relating operation requirements to maintenance costs has been compiled; and systems modeling has been initiated to review maintenance concepts.

A significant deficiency appears to be in the current procedure to determine the maintenance concept after the procurement of equipment. This should be analyzed fully before purchasing decisions; that is, life-cycle costing should be done. Improvements in equipment specifications on maintainability, maintenance analysis, and test requirements should also be investigated more thoroughly.

U.S. Coast Guard

The maintenance expenses required to keep the U.S. Coast Guard (USCG) operational are as varied as the equipment used: buoys, rescue boats, larger ships, aircraft, traffic systems, bases, piers, communications and surveillance electronics, and the like. For this reason in particular, meaningful cost information could not be obtained without a level of effort inconsistent with the scope of the overall study.

The USCG is very much aware of the increasing costs of operations and maintenance and, although there is no overall program directed at reducing maintenance costs, specific efforts are always going on. In electronics, preventive maintenance is on the way out with the elimination of vacuum tube equipments. Computerized maintenance systems (diagnostics) are being developed to help optimize maintenance planning. New failure and maintenance data collection systems are being implemented and trend analyses are being performed.

New maintenance concepts are being tried. For example, experiments with downgraded equipment have been conducted in which a series of power sources are allowed to operate in a degraded mode with acknowledged failure modes. No preventive maintenance is performed and redundant equipment is used. Current R&D efforts include development of self-maintaining buoys.

DISCUSSION OF RESULTS

Significance of Maintenance Costs for the Various Transportation Modes

The cost of performing maintenance is of such magnitude that it should not be ignored. Highways, railroads, and mass transit are consuming almost $12 billion/year, and the burden is increasing at more than $600 million/year, which is somewhat consistent with the rate of inflation. More elusive is the cost of not performing maintenance. Estimates in both the highway and railroad industries indicate that deferred maintenance currently accumulated is greater than expenditure for maintenance of the current year. Although it cannot be proved conclusively, deferred maintenance is strongly believed to be a primary contributor to the degrading market share of both the railroads and mass transit. Some alarm was detected in the possibility that a similar degradation could occur with the national highway and road system.

The data compiled do not depict an existing crisis, nor is there any indication of an imminent catastrophe. Maintenance is still an operational option. However, in the current dollar competition situation, not to recognize the opportunity to reduce costs that will make available resources for more choices is unwise. The potential for reducing maintenance costs is considered very high and should be pursued more vigorously.

A Role for the Federal Government

It is the policy of DOT (through cooperative efforts with industry) to improve the efficiency and productivity of transportation systems (1). The information obtained in the course of this study shows that maintenance costs can be reduced both through improved maintenance management and through an expanded research and development program.

With respect to other opportunities, such as improved designs for new equipment or construction, an investment to reduce maintenance cost offers an attractive alternative characterized by a lower investment, a shorter implementation time, and a wider area of application. Where the unit rate of return might appear smaller when compared to the development of new equipment, the range of application of improved maintenance methods could more than offset the unit difference. In other words, improved maintenance techniques and methods would have more universal application in that they could be applied to old equipment as well as new equipment.

At an aggregate level, maintenance (regardless of application) has common principles, functions, needs, problems, and shortcomings. Some selected cases have shown a real savings of 20 to 30 percent to be possible. If a 10 percent savings were more likely, the savings on $13 billion/year is $1.3 billion/year (obviously an oversimplification but believed useful for sizing the opportunity).

The variation found between and even within the modes indicates that a need exists to accumulate the latest knowledge concerning maintenance, to organize it in the context of overall objectives, demonstrate selective aspects, disseminate the information, and assist in implementation. To date, research activities in maintenance-related areas have been somewhat fragmented and, perhaps with the exception of highways, lack a well-organized national program. It is also more than likely that these activities have been underfunded.

There evidently exists in some sectors a reluctance to consider maintenance as a bona fide candidate for R&D especially in light of "high risk" or "high technology" criteria. However, it must be seriously considered consistent with the stated DOT R&D goal to find less expensive ways to maintain the existing infrastructure and reduce capital costs and maintenance for new infrastructure. In addition, R&D by the federal government is warranted as a means to obtain factual data for making sound regulatory and other policies (19, pp. 4-8).

Not only the opportunity but also the role of the federal government should be made more clear. At the federal level, one can see into many areas of maintenance activity in the various departments and administrations, industry, and foreign nations. One also can see more easily the results of billions of dollars spent in research and development. The federal government has shown greater competence as a developer than perhaps in any other role as demonstrated by its participation in the highway program.

A more active role by the Department of Transportation, particularly in the area of R&D, is suggested by the foregoing. The extent of this activity will have to be determined after more in-depth studies, including cost-benefit analysis, are made and are compared with other R&D candidate projects.

Targets of Opportunity

This study revealed areas where common needs exist in efforts to reduce maintenance costs. These areas should be examined in more detail to determine the specific actions that should be taken (programs), the needed funds (investment), the time to implement, and the potential monetary payoff.

Maintenance Data Systems

The most important need in all areas is that of reliable and comparable data. The data needed falls into three major categories: (a) reliability (or failure) data, (b) availability (or time) data, and (c) cost data. There are numerous efforts going on in this general area. However, there is a need for better guidance (perhaps from more experienced sectors such as the airline and aerospace industries) on collection, storage, real-time access, usage, and standardization for higher level aggregation. (Because this is a costly area and requires 5 years or more to reach payoff proportions, government support will be needed.) Discussion of the value of good data is academic; the front end costs are the deterrent.

Related to the subject of data systems, one of the most important and often forgotten aspects is use. When one reviews the maintenance problems of the various transportation modes, one notices that not enough is known about the equipment and systems in operation. This is particularly critical with respect to technical characteristics, such as time to wear out, maximum stresses, aging, and the like. Centers of knowledge are not apparent. DOT should explore the potential of establishing this function in existing organizations such as the Transportation Systems Center of DOT. This activity could then be directly integrated into the ongoing efforts of technology transfer.

Standards and Standardization

Labor is by far the most expensive maintenance cost item (20). For maintenance management to be efficient, there must be some baseline from which to plan and determine efficiency. Case studies of state highway departments have shown 20 to 30 percent savings from employing these fundamentals. Development of work standards is one of the basic tools. All modes are in some stage of developing work standards independently. The potential of joint efforts should be explored. For example, taking advantage of what has been done in highways could speed the process of implementation in other areas.

The need for better design specifications and standards is almost universal. In some sectors, where performance specifications are considered as more desirable because of the flexibility allowed in response to the requirements, effective requirements for reliability, maintainability, and adequate testing have eroded because of their inherent cost. Lack of effective requirements and programs in these areas is the cause of many operating problems and maintenance costs being experienced today. Better methods for achieving higher reliability, better maintainability, and more effective testing at reasonable cost must be developed. The challenge is too large for any one sector. A joint effort under the leadership of the federal government should be evaluated.

In the private sector where no company commands the market place or where no strong common association has developed, the advent of nonstandard components adds significantly to maintenance and operating costs. In some modes of transportation (mass transit and railroads) this situation is openly acknowledged. A more in-depth study in the area should provide specific steps that the federal government might take in conjunction with the operators and trade associations to improve this aspect.

Verified Maintenance Requirements

There is a strong indication that many unnecessary maintenance policies and tasks are the result of regulations. [The maintenance task performed to satisfy the regulation and not the regulation itself is being challenged.] These maintenance requirements, in many cases, are formulated from individual judgment, perception of cause, or expected result. All too often, there is no verification of the effectiveness of the maintenance action. Causal data are also rare. It is believed that many of the maintenance requirements are overly costly in terms of person-hours, nonavailability of equipment, or noneffectiveness from a safety viewpoint.

Too often, the penalties associated with lowest cost procurement have hurt operations. Life-cycle costing is believed to be much better. Government regulations should be brought up to date on this issue. One major problem that is evident with life-cycle costing is that of good data, and better data would doubtlessly improve the situation.

Major questions on the effect of maintenance on transportation operations cannot be answered because of the difficulty in describing the operational environment that currently exists. Operations research, or more specifically simulation modeling, offers a tool to better cope with this problem. Where these models are limited in providing discrete answers, they have been proved most valuable in understanding "sensitivities" of changes. Changes in maintenance investment (up or down), efficiency (up or down), or policy could be better understood by using these tools. Operational policies would also be better served. A major problem here, once again, is the need for good data. The cost is also prohibitive for small operations. Federal leadership is needed to hasten widespread use of these capabilities.

Monitoring and Testing

The need to determine when maintenance must be performed, what level of performance is desired, or what the existing conditions were was found in all transportation modes. The basic problem appeared to be the inability to accurately describe conditions and what they mean in terms of imminent consequences.

Most inspections are made to identify hazardous conditions or impending failure. It is suspected that most inspection criteria are based on individual experience. A significant void is believed to exist in terms of data that accurately describe what conditions precede certain failures and by how long. If this is true, a large investment of maintenance dollars is wasted. (The airlines have recently imposed a design requirement that insists that these characteristics be known or that redundancy be built into the equipment.) A more detailed study into inspection costs, criteria, and effectiveness will provide insight into those areas (such as bridges, tunnels, and tires) where better inspection criteria might best be developed.

Much information is needed on the condition of equipment and structures. The decisions on when to repair or replace are becoming more critical because of the increasing dollar competition. The entire area of nondestructive testing promises enormous payoffs. An organized effort in this area will hasten the development of needed techniques and information. The front-end cost of this endeavor and the associated risks suggest that federal government support is needed.

A relatively new technology is making its way into the transportation field—automated diagnostics and monitoring. Electronics and computers and applications in the aerospace and aviation industries have provided the impetus. The cost and complexity of equipment and the increasing value of time (availability) are making this expensive alternative more attractive. Much has to be done in this area to make it more acceptable to the other transportation modes. Government support in this area has already demonstrated its effectiveness with track monitoring equipment and automated transit systems.

An in-depth evaluation of the potential cost and benefits will help determine its proper place in the R&D hierarchy.

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