A Framework for Evaluating Transit Maintenance Resource Utilization

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ABSTRACT

In recent years improvement of maintenance performance has been the focus of significant concern in the transit industry. Many transit agencies have been plagued with deteriorating vehicle reliability and availability. Even more transit agencies are facing continual increases in maintenance expenditures at a time when total operating budgets are constrained or even diminishing. These trends have moved transit maintenance from the backroom to the executive suite where maintenance performance and expenditures are coming under increased management scrutiny. Maintenance managers need effective, yet straightforward methods for assessing and evaluating the extent to which scarce resources are expended in a productive manner. Resource utilization should be directed toward completion of specific tasks that result in achievement of established performance objectives. Although maintenance is recognized as a complex function, there are some relatively uncomplicated methods for determining the extent to which resources are expended productively. One such methodology is presented and its application at two transit properties is discussed.

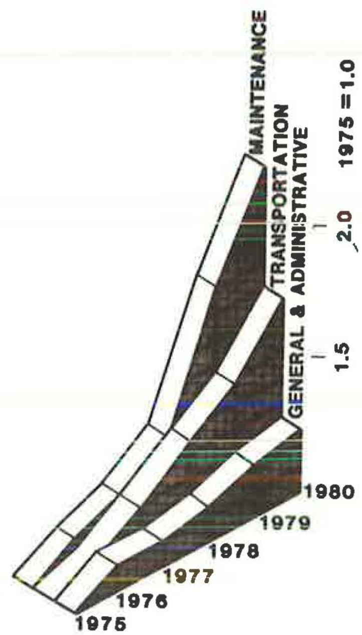

FIGURE 1 Transit operating cost increases.

Every day, the maintenance departments of the nation's public transit systems are expected to have more than 37,000 buses and 14,000 rail cars on the road and moving. Often these expectations are not met. This failure to achieve vehicle availability and reliability objectives in recent years has resulted in maintenance being moved from a backroom support function to the executive suite. The high public visibility of vehicle shortages and in-service breakdowns is only too obvious to transit managers and board members. A frequent response to deteriorating performance has been to increase the influx of dollars allocated to the maintenance function. Unfortunately, this strategy does not always work--many properties still experience declining maintenance performance, albeit at a higher cost.

It is important to note that not all transit agencies are experiencing a decline in maintenance performance; a few are enjoying steady improvements in revenue vehicle availability and reliability. However, most have done so at substantial cost. The transit industry, as a whole, has experienced unprecedented cost growth for maintenance activities in the past several years. In dollar terms, maintenance expenditures increased by 129 percent between 1975 and 1980, as shown in Figure 1 (1). This compares to an increase of 80 percent in transportation costs and 32 percent in general administration costs for the same period. Maintenance costs are now running at a rate of about 30 percent of total operating expenses and, unchecked, this escalating trend will cause these expenditures to claim an even greater percentage of diminishing operating budgets.

The financial needs of mass transit were recognized in the recent gasoline tax increase that was expected to raise $1 billion per year for repairing and upgrading (an amount approximately equal to the increase in maintenance costs over the last 5 years). Better equipment and more money, however, are not the sole mitigating strategies for today's maintenance problems. Better management of available resources, despite the emphasis to "keep them running at any cost," can provide substantial payoffs for transit managers. By improving the quality and performance of existing systems, transit managers can justify their higher cost. One framework for evaluating maintenance resource allocation and associated performance, which has been used to identify opportunities for realizing operational benefits, is discussed in this paper.

PROBLEM STATEMENT

In diagnosing the problems of numerous transit properties, several common themes have emerged:

1. Revenue equipment has become more sophisticated and technologically complex, but personnel training is often nonexistent or informal (i.e., on-the-job training).
2. Inadequate training is compounded by high labor turnover rates caused by increased competition for skilled labor, and excessive absenteeism.

3. Work scheduling and manpower planning are usually performed manually and are geared toward emergencies, not toward a production line type of operation.

4. Routine activities are frequently performed without adequate consideration of job content. Standards for activities that can be easily scheduled and monitored, notably preventive maintenance, are not adhered to rigorously.

5. The infrastructure of garages and terminals is by and large of turn-of-the-century vintage and has received little attention.

6. Maintenance shops also tend to overstock parts and supplies to avoid being caught short. Inventory systems generally do not monitor holding costs, material burn rates, or availability of supplies in a manner readily understood by management.

7. Management information systems, if they exist, often track the wrong performance measures and do not support resource allocation decision making.

The historical approach to transit maintenance (i.e., keep the vehicles running at any cost) has contributed to today's problems. More often than not, maintenance managers are rewarded for and are pressured to get equipment on the road to meet peak demand. This immediate charge overshadows the need to develop what in the long run are more effective quality control activities.

The magnitude of current maintenance cost and performance problems warrants a shift in maintenance philosophy toward effective resource management. Costs and performance can be improved through better management planning, monitoring, and control. Although the only solution to serious deterioration of facilities is capital expenditure for rehabilitation and repair, better management systems and productivity improvements require relatively small investments with respect to the possible payoffs. Thus, it is in these categories that immediate maintenance improvement opportunities are most abundant.

Although maintenance is recognized as a complex function, managers need a relatively straightforward means for identification and assessment of potential maintenance problems. The authors offer one approach to maintenance problem resolution, which has proven successful on several recent assignments, that involves four steps:

1. Complete a quick diagnostic review to identify substantive issues;
2. Evaluate the issues to identify resources influencing performance;
3. Define the organizational-procedural-systems changes to correct existing deficiencies; and
4. Put in place the organization and systems to prevent a recurrence. This approach is further addressed in the following paragraphs.

ISSUE IDENTIFICATION

A given condition in almost any maintenance analysis is that every division of the organization is a candidate for improvement. The universe of issues that could be investigated almost always exceeds the resources available for the task. Therefore, a screening mechanism is needed to separate substantive issues from those of lesser consequence. Substantive issues are those that currently or potentially could have a significant effect on performance and cost, or both. In order to define and isolate substantive issues, it is necessary to assess how effectively maintenance resources are being managed. Only after the issues have been defined is it possible to develop effective strategies for resolving problems.

Issues can be identified by applying quantitative tools to measure performance and qualitative tools to measure organizational effectiveness. In this approach, performance is interpreted as how efficiently the maintenance department uses resources to meet vehicle availability and reliability requirements. Organizational effectiveness is interpreted as how supportive the management structure is in directing and controlling the activities comprising the maintenance function. It is important to recognize that diagnostic tools aid in assessing what is happening with regard to performance, and not why a particular trend occurs. The four major diagnostic tools that the authors have applied in issue identification are described in the following paragraphs.

External Peer Group Analysis

This technique is used to compare a transit agency's maintenance performance indicators with those from a set of peer transit systems (i.e., those of similar size and characteristics). The purpose of the external peer group comparison is to flag those aspects of an authority's performance that appear substantially different from what could be expected. This is done in two ways. The first step is to compare the subject transit agency's performance for specific measures (e.g., mean miles between mechanical failures) to mean, maximum, and minimum values from the peer group (excluding the subject agency). When the property's performance falls into the upper range, one can conclude that performance is satisfactory to good. Conversely, a lower range of performance identifies a potential issue and suggests the need for improvement.

The second step in the external peer group analysis is to consider all the measures in a collective sense. This can be done by examining the subject property's rank in the peer group for each maintenance performance indicator and then determining the overall rank for the entire functional area. It must be stressed that although a peer group comparison is generally not conclusive enough to develop recommendations, it does assist in separating substantive issues from perceived issues.

Internal Peer Group Analysis

This technique compares performance among cost centers within the subject agency's maintenance function. Cost centers are organizational units that conduct similar operations but in different locations. Thus, this type of analysis is most applicable to larger transit systems with multiple maintenance facilities. As with the external peer group, these comparisons are based on performance indicators that are descriptive of maintenance resource utilization and are used to flag inadequate performance. Because internal data bases are generally consistent, the analyst may have greater flexibility in comparing indicators than was the case with the external peer group. Because cost centers operate under theoretically consistent cost and labor structures, each center's performance could be compared against the best rather than the average performance of the group. If there is only a 10 percent difference between best and worst, substantial improvement would probably be inconsequential in a cost sense. Greater differences, however, may indicate the potential for a good return on time and resources invested in correcting the disparity.

Trend Analysis

This technique is used to compare maintenance performance over time. A 4- to 5-year time period is desirable, although this time frame may vary in accordance with local occurrences (e.g., change in work rules, large service change). Trend analysis is very helpful in isolating positive and negative performance in both financial and nonfinancial measures. Financial measures, such as maintenance cost per mile, can be expressed both graphically and in terms of annual rate of growth. Annual rate of growth is a derivation of the standard compound interest formula, which describes percentage growth from year to year. The merit of this approach is that once established, the rate can be compared with the average annual inflation growth rate to discern how closely costs correlate with inflation.

Structured Interviews

This qualitative technique assists in identifying past decisions or events that have affected performance. The structured interviews provide a medium for further investigation of specific performance questions arising from the previous analyses. In addition, this technique is used to identify potential problems relative to span of control, clarity of role, duplication of effort, and communication of objectives.

The application of one or more of the preceding tools serves as a first screen in defining what activities should be pursued to improve overall resource management. The issues identified as offering potential savings and performance improvements are then evaluated using a resource utilization approach.

EVALUATION FRAMEWORK

The authors have found, on numerous assignments in the past 3 years, that a great number of transit properties are experiencing a decline in maintenance performance despite an increase in actual expenditure. The trend of deteriorating performance requires an analytical approach that seeks to isolate those primary factors that influence maintenance performance. Accordingly, the authors have used a resource evaluation framework for analyzing the maintenance function. The approach recognizes that maintenance is a complicated function that embraces several interrelated tasks including: (a) service and cleaning, (b) inspections and preventive maintenance, (c) unit overhauls, and (d) repair.

The evaluation framework, which is shown in Figure 2, acknowledges that performance, as reflected by equipment availability, road calls, and vehicle appearance, is influenced by three key resources: (a) labor availability and skills; (b) equipment and facilities; and (c) information availability.

The manner and extent to which these resources are managed and productively used to fulfill the primary maintenance functions have a significant impact on performance and cost.

Under this framework, evaluation of an issue (i.e., a deteriorating performance trend) begins with examination of the functions and corresponding resources that contribute to performance and cost in the issue area. The function is examined in terms of the specific tasks to be performed and the anticipated level of resource expenditure (or range of resource expenditure) deemed necessary to complete the tasks. The expected level, or standard, for resource expenditure is then compared with actual resource availability and expenditure. Issue areas exhibiting substantial variation between anticipated and actual resource utilization warrant more rigorous analysis to determine the cause of the deviation.

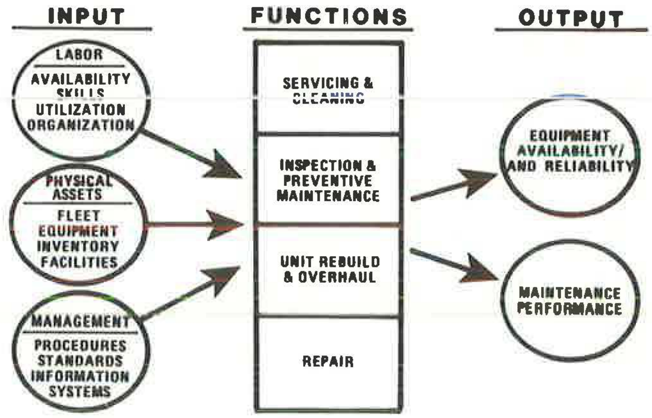

FIGURE 2 Maintenance evaluation framework.

The deviation may be the result of one or more of three problems: (a) the standard for resource requirements may be inappropriate, (b) the utilization of resources may be inefficient, and (c) extenuating circumstances may account for the deviation. The resource allocation analyst must review each possibility to isolate the source of the problem before corrective actions can be developed and applied. Application of this evaluation framework to actual issue areas is discussed in the following section.

EMPIRICAL APPLICATIONS

This evaluation framework has been applied by the authors at several U.S. transit agencies in the past year. Empirical results from two of these assignments are discussed in the following paragraphs.

In an assignment for a southern transit agency, significant cost efficiency and productivity problems were identified in the issue identification phase. The subject property was experiencing a serious decline in maintenance performance, although expenditures were increasing at a rate that exceeded inflation. The subject system was identified as having significantly higher labor costs per vehicle mile, a greater number of maintenance personnel per active vehicle, and fewer vehicle miles per mechanical failure than a group of its peers. Labor productivity, identified as a primary issue, was subsequently examined using the evaluation framework presented earlier.

The productivity analysis was conducted for three major maintenance functions: cleaning and service, inspections, and unit overhauls. Each of these functions is characterized by routine or repetitive activities that are relatively easy to standardize and schedule. The objective of the analysis was to determine how efficiently labor resources were being used to perform these functions. The analysis was conducted by comparing total available labor hours with the time needed to perform the specified tasks. The results of the analysis are presented in the following sections.

Cleaning and Service

The first step in the resource utilization analysis was to identify available labor hours. Total available hours were calculated as follows:

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Total available
  labor hours = Number of line employees
                x [(Base hours - deductions)
                x (Scheduled breaktime factor)
                + (Overtime)]
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The cleaning and service section at one garage had 15 line employees dedicated to revenue vehicle service and cleaning (supervisors and vaultpullers were excluded). The standard number of employee base hours is 2,080, predicated on a 40-hour work week. Deductions including vacations, holidays, illness, injury, absence without leave, and requested leave reduced base hours by 13 percent at the subject property. Scheduled break time, consisting of two 15-min breaks per day per employee, further reduced total hours by 6.25 percent. Overtime averaged about 17 percent of scheduled man-hours (i.e., base hours less holidays and vacations) and increased available man-hours accordingly. In the aggregate, the cleaning and service section at the bus garage had 30,269 labor hours available to perform this maintenance function.

The next step in the analysis was to calculate the total time required to clean and service revenue vehicles at the garage on an annual basis. Using monthly bus assignment sheets, it was estimated that 70,563 vehicles are deployed annually and therefore cleaned and serviced at the garage. The agency had an established standard of 12 min per bus for cleaning and servicing. Thus, 14,113 labor hours are needed if the standard is adhered to at the division.

A comparison of total labor hours available (30,269) to hours required (14,113) suggests that excess manpower was available for this function. According to these calculations, there are 16,156 excess hours, or 53 percent of total available labor hours, that are not expended productively. One mitigating factor in this productivity assessment is that the influx of vehicles to be cleaned and serviced is not constant. Although some of the potentially unproductive time is attributable to lulls between peak surges, overall vehicles were not being cleaned and serviced in accordance with the 12-min standard. Instead, the vehicles were being cleaned and serviced at a rate of more than twice the standard.

In an effort to assess the validity of the established standards, work activities and facilities were examined. The time standard appeared sufficient to cover work activities under reasonable conditions. However, the job was not conducted under reasonable conditions. The facility where this function was performed required that buses move through three different buildings, exiting onto a public street several times--the 12-min standard was unrealistic. It was subsequently recommended that management reevaluate the standard it was using to schedule work and manpower.

Inspections

A similar analysis was conducted for the section dedicated to preventive maintenance. The agency's formal policy was to inspect each revenue vehicle at 6,000-mile intervals; actual practice resulted in inspections at 13,500-mile intervals. Available labor hours were estimated at 30,269 hr annually, as compared to labor requirements of 11,760 (based on the established standard of 8 hr per inspection with inspections occurring at 6,000-mile intervals). These estimates indicate that the unit was more than adequately staffed to perform the desired number of inspections at the 6,000-mile interval. In fact, 18,509 hr, or 61 percent of the total available hours, exceed the amount needed to conduct inspections in accordance with the standard. Because inspections were actually performed at more than 13,000-mile intervals, the staff appeared to be productively deployed only a small percentage (i.e., 20 percent) of the total labor hours available.

Investigation of the standard of 8 hr per inspection revealed that it includes time for inspection and some on-the-spot repair. Examination of actual practices indicated that the majority of the time intended for inspection was actually spent on running repair, and thus was impeding the ability of mechanics to conduct scheduled inspections. The dearth of timely inspections was, in turn, resulting in poor vehicle reliability and excessive in-service breakdowns. Therefore, it was recommended that greater supervision be imposed on this section to enforce compliance with formal inspection objectives. It was also recommended that management develop guidelines suggesting the maximum amount of time to be spent on running repair during inspection to promote greater productivity in this unit. The guidelines should be supplemented with a mechanic training program to ensure that procedures are understood and followed responsibly. Major running repair needs uncovered during inspection were to be scheduled for completion by inspectors after primary duties are completed, or by the repair section.

Unit Overhaul

In general, components are rebuilt on a failure basis. The subject property did not maintain component life records that would indicate the expected longevity of the rebuilt unit. The dearth of information pertaining to useful component life impedes management's ability to project work requirements and schedule production. No formal job standards were in-place for unit overhaul--foremen responsible for ensuring productive deployment of mechanics kept informal records on anticipated and actual job completion times. These anticipated job times correspond closely with actual job completion times at an aggregate level and were used to determine resource requirements.

The resource needs were estimated at 25,455 labor hours for major rebuild projects, with total available labor hours projected at 38,341. Approximately 34 percent of available time cannot be accounted for by major unit rebuilds. The foremen estimated that 20 percent of total time was spent on small unpredictable jobs such as rebuilding valves and relays, and degreasing components, although no verifying records were maintained. The remaining 14 percent of available hours was assumed to be devoted to unreported rebuilds and unproductive time.

The lack of pertinent production and performance information in this section was determined to undermine managerial efforts in unit rebuild planning and control. It was recommended that procedures be formalized for recording production data and that an information system be developed to provide management with accurate longevity, resource requirement, cost, and productivity information. Management could then establish standards for routine rebuilds based on sound production information. Such information would also aid in work and manpower scheduling and control.

The authors used this evaluation framework in a slightly different manner at a large eastern transit property. In the issue identification phase, maintenance cost efficiency, labor productivity, and vehicle availability were identified as substantial problem areas. The property was experiencing a severe decline in vehicle availability although the vehicle repair staff was increasing in size.

In an effort to determine the reason for these seemingly conflicting trends, a review of revenue vehicle availability and maintenance worker availability was performed at each garage. The results, shown in Figure 3, indicated that most mechanics were generally scheduled to work when the majority of vehicles were in revenue service. During the morning peak, the number of mechanics available actually exceeded the total number of vehicles at the garage. Conversely, relatively few mechanics were scheduled for work during the periods when the greatest number of vehicles were available to be worked on.

In this case, it was recommended that some maintenance staff be rescheduled to offer more productive use of labor resources. The problem was resolved by rescheduling some day shift staff to the evening and night shifts. The change was carefully planned to ensure that adequate staff was available to respond to vehicle breakdowns and other availability problems during the day.

In addition to scheduling of mechanics, labor productivity in the repair function exhibited some significant shortcomings. Although engineering standards (i.e., time and motion standards) had been formally established for a wide variety of routine repairs, the automated work order system showed significant discrepancies between the standard and reported times for specific repairs.

Further investigation revealed that the primary reason for the disparity was that mechanics were not reporting their time accurately. On the automated work order system, a mechanic might log on for a single repair job (e.g., replacement of a lower radius rod) and in the course of that repair, the mechanic may discover other required work (e.g., air bag replacement).

After notifying the foreman, the mechanic would complete all repair work while recording his time on the original assignment. Some foremen were not instructing mechanics to record time accurately because they knew the time was spent productively. However, in doing so those foremen were detracting from the usefulness of the automated work order system as a management tool.

It was recommended that training programs be altered to emphasize the importance of accurate time reporting and that supervisors promote mechanic responsibility for accurate information reporting. Foremen and mechanics should be held accountable for proper use of the system to promote compliance. Management's ability to plan and control maintenance activities is significantly affected by the quality of information available.

CONCLUSIONS

Although the resource evaluation framework described in this paper is theoretically sound, some problems must be anticipated in its application. First, many transit agencies do not really know what the optimal level of resource expenditure (e.g., labor hours, materials) is for the conduct of specific maintenance functions. Although several properties have conducted extensive industrial engineering studies to determine resource requirements and time standards for specific tasks (e.g., preventive maintenance, inspection, service and cleaning, routine repair, and unit overhaul), more work is needed in the industry as a whole to allow maintenance managers to anticipate, plan, schedule, and deploy resources in an effective and efficient manner. Second, some transit properties with established standards for activities that can be easily scheduled and monitored, notably preventive maintenance, do not adhere to the established resource requirements. A third problem in the field is that most information systems do not track resource utilization in a manner supporting efficiency and productivity analyses. In this respect, the cost of existing performance levels is not always visible to

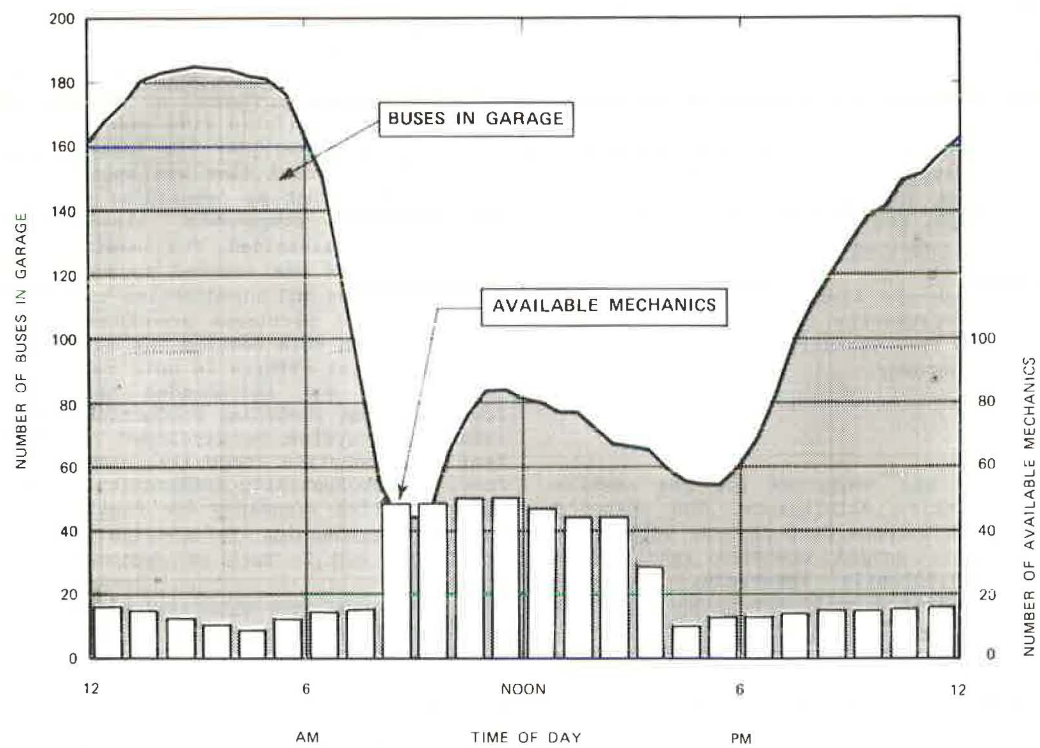

FIGURE 3 Relationship between manpower and equipment availability.

managers responsible for resource planning, allocation, and control.

Each of these problems can be resolved with relatively small investments with respect to the potential benefits in management monitoring, planning, and control systems. Appropriate information support systems are elements essential to effective resource management and performance quality control in transit maintenance. Utilization of basic industrial engineering tools will help maintenance managers change work scheduling from an ad hoc process to a more efficient production line procedure.

The resource evaluation framework presented here is one straightforward means for analyzing productive utilization of resources in transit maintenance. It can be applied in a variety of operating environments, and it offers some flexibility in data requirements for use. The technique has proven successful in identification of substantive issues, as well as the extent and cause of specific resource utilization problems. Armed with this information, maintenance managers are in a better position to implement improvement strategies and realize potential benefits (i.e., cost savings and better equipment performance) from improved resource utilization.

Again, it must be stressed that one relatively uncomplicated approach to evaluating maintenance resource utilization is presented in this paper. Additional research in maintenance resource management is necessary to help identify break-even or optimization points for the conduct of specific maintenance tasks. The magnitude of the problems in transit maintenance, and therefore of the opportunities for improvement, implies that the additional research will not be long in coming.

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Publication of this paper sponsored by Committee on Manpower Management and Productivity.

Restructuring the DOT Research Organization: Washington State Case Study

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ABSTRACT

The Washington State Department of Transportation has operated a successful research program for many years, producing findings that have supported the operating divisions of the department. Because of personnel changes, an increased research budget, and a desire for closer ties to state universities, the secretary of transportation requested that a major review of the research organization be carried out. This review included interviews with key department employees, universities, other departments of transportation, and transportation center contacts. Also included was a national survey of 51 departments of transportation on their practices (100 percent response). On the basis of this information and careful study, a new research organization was recommended that included a new committee structure and stronger ties to operating divisions and state universities. The study also recommends a joint director for the department of transportation research office and state transportation center, which includes the department of transportation and two universities. The secretary accepted the recommendations now under implementation.

For some years, the Washington State Department of Transportation (WSDOT) has operated a successful research and development program. A large number of projects have been undertaken, often through contract research with different universities, and the results have been satisfactory.

The research completed has produced significant cost-effectiveness advances in several areas. Most of these have been quantified and made available to the top management of the department, and many of the recommendations emerging from the research efforts have been put into practice. Associated with the overall research program has been a developing technology transfer activity, which has translated research findings into effective use and also brought to key department personnel a large amount of information from sources outside the state. In general, the research effort has been satisfactory and has produced good results for the department.

This was accomplished through consistent attention to research needs, supported by a stable organization in which staff turnover was kept to a minimum. Because of the stable relationship that had been developed over the years, it was possible to look forward to a regular output of effective research results, most of which were implemented by the department. Commencing in early 1981, however, this pattern was broken and several staff changes at WSDOT, plus new persons at the University of Washington, saw changes to the stable, basic research