vide greater sight distance or an advance warning arrowboard should be used at the site.

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Transit Bus Maintenance in Small and Medium-Sized Communities

GARY L. ROBERTS AND LESTER A. HOEL

The findings of a study of bus maintenance practices used by 13 small and medium-sized public transit systems in Virginia are presented. Bus maintenance activities are discussed according to two basic maintenance approaches: (a) municipal fleet, in which the buses in a fleet of all vehicles operated by a political jurisdiction are maintained, and (b) transit only, in which the transit buses of a publicly owned transit system are maintained. An overview of the current condition of bus maintenance is provided by comparing maintenance practices of the municipal-fleet and transit-only systems. The main factors that affect the performance of transit bus maintenance are identified and classified. These factors, such as inadequate personnel assignment and low maintenance priority for transit buses, serve as the basis for proposed guidelines to improve transit bus maintenance and to provide adequate protection of taxpayer investment statewide.

It is generally acknowledged that the maintenance of transit vehicles accounts for approximately 20 percent of total transit operating expenses (1) and, with the increasing complexity of the advanced-design buses (ADBs) currently being purchased, it is quite likely that this proportion will become even larger. The changing characteristics of the new buses were noted in a recent congressional report (2), which stated that "the ADB does not embody any serious attempt to simplify and make [buses] more durable, but rather may be another manifestation of our love affair with complex technology. Like new autos, new buses emphasize features related to style and comfort--often at the expense of durability, maintainability, and fuel economy."

In addition to facing the increased costs occasioned by the technical complexity of the ADB, transit bus systems are expected to lose the federal funds that they have come to rely heavily on for operating assistance. From its beginning in 1975, federal funding for operating assistance increased from $300 million to more than $1.1 billion in 1980. Because the costs of operating transit vehicles have increased significantly in the past two decades (1), this federal assistance is being used as a subsidy that enables transit fares to be kept artificially low (3,4). The loss of this subsidy will necessitate decreases in the operating budget, which will adversely affect bus maintenance.

When combined, this increasing technical complexity and decreasing federal operating assistance make a strong argument that the adequacy of transit bus maintenance in the future is uncertain. Thus, it is essential that the federal, state, and local agencies responsible for the administration and funding of public transit bus systems give high priority to efforts to assist the operating properties to increase the effectiveness and productivity of their vehicle maintenance.

The research reported here was undertaken to develop information that would be useful to state and local agencies in Virginia in developing and implementing the needed assistance programs.

OBJECTIVES AND SCOPE

The objectives of this research were (a) to document the current condition of transit bus maintenance and the maintenance practices used by the small and medium-sized transit systems in Virginia and (b) to propose guidelines for maintenance practices to improve transit bus maintenance statewide.

The small and medium-sized transit systems studied included all fixed-route transit bus systems except the Washington Metropolitan Area Transit Authority, which operates in Northern Virginia.

METHODOLOGY

The study comprised the following tasks:

1. A direct mail questionnaire survey of maintenance management personnel at 13 Virginia operating properties,
2. Site visits to each of these operating properties, and
3. An analysis of the information obtained from the survey and site visits.

QUESTIONNAIRE SURVEY

A questionnaire was mailed to maintenance management personnel at each of the 13 Virginia properties participating in the study to obtain information on

maintenance facilities, personnel, procedures, problems, bus purchases, and cooperative efforts. All of the questionnaires were completed and returned.

Responses by Subject Area

As in any survey, the completeness of the responses varied but, in general, the range was good to excellent. The main responses in the six subject areas covered are discussed and summarized below.

Maintenance Facilities and Equipment

One maintenance facility was used for the support of transit bus operations at each of the properties. Several properties had various maintenance activities housed in different buildings but, since these were all located at the same site, they were considered to be one facility. The facilities ranged in age from 1 to 80 years, and the mean age was approximately 35 years.

The amount of maintenance equipment available was considered adequate by seven respondents and inadequate by the remaining six. The type of maintenance equipment available was judged adequate by five respondents and inadequate by eight.

Maintenance Personnel

The main responses concerning maintenance personnel relate to turnover, employment, and training. It was indicated that the annual turnover rate for maintenance personnel ranged from 0 to 10 percent, the mean being 2.6 percent. The turnover rate for service personnel was between 0 and 17 percent, and the mean was 2.4 percent. Twelve of the respondents, about 92 percent, indicated that it was difficult to attract qualified bus maintenance personnel, whereas one system did not experience such difficulty.

The respondents were unanimous in their expressed need for some sort of formal, in-state training programs for transit bus mechanics. Although the response to the relative need for training was unanimous, only 2 systems had an organized in-house training effort and 4 indicated that they had an in-house apprentice program.

Maintenance Procedures

Maintenance capability, contract work, vehicle records, maintenance schedules, and the levels of maintenance are the main categories included in maintenance procedures.

A total of 6 properties indicated that they had complete in-house maintenance capability, and 7 felt that their capability was less than complete. The need for more in-house capability was expressed by 8 of the respondents, whereas the other 5 felt that they did not need more capability.

A total of 4 of the respondents contracted out service work, and 5 contracted out maintenance. Component and subassembly rebuild work was the largest type of activity put out to contract. A total of 10 properties indicated that they did contract out rebuild work and only 3 did not.

All of the respondents indicated that they had a system of vehicle maintenance records of some kind; 3 of the systems responded that their records were computerized.

A preventive maintenance program was being used by 12 of the 13 properties and was based on vehicle use in miles. The indicated mileage interval used for the basic preventive maintenance schedule ranged from 1500 to 6000 miles; the mean for the 12 properties was approximately 3770 miles. In addition, 1 respondent indicated that certain maintenance procedures were scheduled on a seasonal basis.

The percentages of total maintenance reported to be preventive maintenance ranged from 20 to 80 percent, and the mean was 46.9 percent. The same figures also appeared for the percentages of maintenance work reported to be remedial: The range and the mean, 45.5 percent, were almost identical. The distribution, however, was quite different. In addition, routine component change-out and subassembly replacement were practiced by 3 properties.

Of the 10 maintenance tasks listed in the questionnaire, 5 were commonly done by all respondents. The scheduled inspection of vehicles and the repair of major components were being done by 12 properties. Of the 5 most common tasks--minor repairs and replacement, replacement of parts, and replacement of major components--3 were being done by all respondents.

The 5 remaining tasks were being performed by a smaller number of the respondents. The rebuilding of major components and the repair of subassemblies were being done by 7 properties. A total of 9 properties reported that they replaced subassemblies, and only 5 rebuilt subassemblies for stock. The final maintenance task, body and chassis structural work, was being done by 8 properties.

The reporting of defects was the last subject covered in the questions on maintenance procedures. A total of 10 respondents indicated that vehicle operators reported vehicle defects to maintenance personnel on a written form, 2 indicated that they used verbal reporting, and 1 had no set procedure. Vehicle service personnel in 8 properties used a written form to report defects to maintenance personnel, 3 properties reported these verbally, and 2 had no set procedure.

Maintenance Problems

Most of the maintenance problems cited by the respondents related to the kind of operation and the type of vehicle. Of the responding properties, 6 indicated that they experienced maintenance problems peculiar to their operations. These included a very short service life for brake linings and tires caused by hilly terrain. Transmission failures, and the attendant road calls, were also attributed to the terrain over which the properties' vehicles operated. Various problems resulting from inadequate maintenance facilities and equipment were cited. Several properties cited problems with limited manpower and mechanical ability as being related to their kind of operation.

A much larger group, 10 respondents, noted problems experienced as a direct result of the type of transit vehicle they were operating. These responses indicated substantial problems with vehicles that were no longer being marketed in the United States and vehicles for which major components and subassemblies were no longer available from the manufacturer. Certain foreign-manufactured buses were singled out as a major source of problems, along with small-sized domestic vehicles that were not holding up very well in daily revenue service.

An additional major source of problems was the high rate of component and system failures experienced in the operation of ADBs, irrespective of the bus manufacturer. Specifically cited were failures of air-conditioning equipment, electrical components, brake systems, wiring, engine accessories, and automatic transmissions. It appears that failures were found in all of the major systems necessary for the operation of the bus. These failures were noted to have led to numerous running repairs and in-service breakdowns, which had resulted in costly road calls.

Bus Purchases

A total of 10 properties said that they expected to purchase new buses within 3 years. The numbers of buses to be purchased ranged from 1 to 47 and totaled 118.

Of the respondents, 11 felt that the buses available were compatible with present maintenance operations. A smaller number, 7 respondents, felt that the bus manufacturers were providing adequate technical assistance.

Questions relating to spare buses were also included in this section of the questionnaire. The percentages of total bus fleets indicated as spares by the respondents ranged from 9 to 40 percent, and the mean value was approximately 20 percent. A total of 9 respondents felt that a certain percentage of the fleet should be spares; their figures ranged from 15 to 40 percent, and the mean was approximately 25 percent. The other 4 properties related the number of spares to the size and type of operation, maintenance capability, etc., and not to some percentage of the fleet alone.

In responding to a related question in this area, seven of the operations said that they leased their tires and the others said they purchased them.

Cooperative Effort

The questions under the heading "cooperative effort" contained the term "statewide cooperative". The definition of this term in the questionnaire was open-ended in order to gain information concerning the concept of these cooperative approaches rather than information on any particular program.

The cooperative purchase of parts and supplies for bus maintenance was believed to be a possible asset by 6 of the properties, and the cooperative rebuilding of components and subassemblies was seen as an asset by 7. The greatest positive response was registered for the idea of cooperative bus purchase: 8 properties felt that this would be an asset.

The aggregate results presented in this section contained responses for both small and medium-sized public transit systems. Small systems were those with fewer than 20 buses, and medium-sized systems were those with more than 20 buses but fewer than 250. Taking part in the study were 7 small systems and 6 medium-sized systems. These two groups were separated by their own distinctive approaches to bus maintenance. The only exception to this was a small system that used the maintenance approach associated with the medium-sized systems.

Thus far, no attempt has been made to separate the results by group; however, that will be done on the basis of maintenance approach in the next section of this paper. When this is done, the differences and the common problems shared by both the small and medium-sized transit systems are illustrated. The results for individual systems are not indicated or discussed so that there can be no attempt to compare one system with another.

Summary of Responses

The analysis of the questionnaire results produced a comparative interpretation of the two basic maintenance approaches used in Virginia: (a) the maintenance of transit buses as a part of the fleet of all vehicles owned by a political jurisdiction and (b) the maintenance of transit buses only, in the case of a publicly owned transit system. These two approaches are referred to in this paper as "municipal fleet" and "transit only". It must be stressed that the interpretation represents the groups as a whole and that comparisons of individual transit systems were not appropriate. The lists presented below characterize the conditions of each group separately and those that were generic to both groups.

Municipal Fleet

The municipal-fleet approach had the following characteristics:

1. The systems had inadequate amounts and types of maintenance equipment.
2. The turnover rate for service personnel was higher than the rate for maintenance personnel.
3. Written maintenance procedures were not in common use.
4. The average preventive maintenance inspection interval was approximately 2900 bus miles.
5. Major component rebuilding in-house was not a common practice.
6. The replacement of subassemblies in-house was not a common practice.
7. Subassemblies were not rebuilt in-house.
8. Body and chassis structural repairs generally were not done in-house.
9. Written operator reports of bus defects were not in common use.
10. Written service personnel reports of bus defects were not in common use.
11. The type of transit operation caused maintenance problems.
12. Spare buses, on the average, constituted 30 percent of the fleet.
13. Bus tires were purchased.
14. Interest in all the cooperative approaches was common.

Transit Only

The characteristics of the transit-only approach were as follows:

1. The turnover rate for maintenance personnel was higher than the rate for service personnel.
2. Written maintenance procedures were in common use.
3. The average preventive maintenance inspection interval was approximately 4800 bus miles.
4. Major component rebuilding in-house was a common practice.
5. The replacement of subassemblies in-house was a common practice.
6. Subassembly rebuilding in-house was a common practice.
7. Body and chassis structural repairs were generally done in-house.
8. Operator reports of bus defects were in written form.
9. Written service-personnel reports of bus defects were in common use.
10. Spare buses, on the average, made up 18 percent of the fleet.
11. Bus tires were leased.
12. Interest in possible cooperative approaches was not common.

Generic

Characteristics shared by both municipal-fleet and transit-only maintenance approaches were as follows:

1. The overall turnover rate for personnel was low.
2. It was difficult to hire qualified maintenance personnel.

3. The maintenance personnel needed additional training.
4. An increase of in-house maintenance capability was needed.
5. Contracting out maintenance tasks was a common practice.
6. The use of computer technology to support the maintenance function was very limited.
7. Preventive maintenance was a common practice.
8. Preventive maintenance schedules were based on bus mileage.
9. Periodic maintenance was not a common practice.
10. The type of bus used caused maintenance problems.
11. There were plans to purchase new buses within 3 years.
12. The maintenance operation was compatible with current buses.
13. The systems were unhappy with bus manufacturers' approach to technical support for the customer.

SITE VISITS

Site visits were made after the questionnaires had been returned so that survey responses could be discussed and clarified, if necessary, during the visits. Information was obtained on maintenance facilities, equipment, practices and contracted functions, personnel, organization, information systems, and planning.

The information obtained during the site visits is summarized below in two parts corresponding to the two basic approaches to vehicle maintenance--municipal fleet and transit only--discussed above.

Municipal Fleet

Transit systems in the municipal-fleet category ranged in size from 3 to 11 buses, and all operated fixed-route and scheduled service. The general findings from the visits to the municipal-fleet systems are reflected in the list below. Not all of these characteristics apply to all of the municipal-fleet operations; however, all are negative factors that diminish maintenance productivity.

1. The facility was undersized.
2. The facility was improperly equipped.
3. The maintenance operation was incorrectly staffed.
4. The employees were in need of initial or additional training.
5. Maintenance priority practices did not favor transit vehicles.
6. Breakdown maintenance was given priority over preventive maintenance.
7. There was a lack of goals and objectives for maintenance operations.
8. There was a lack of locally developed and implemented performance indicators.
9. Data collection and analysis were not sufficient for monitoring performance and increasing productivity.
10. There was a lack of maintenance planning.

Transit Only

Transit systems in the transit-only category ranged in size from 11 to 212 buses, and all operated fixed-route and scheduled service. The general information gathered during site visits to the transit-only systems is the basis for the descriptive list presented below. As in the case of the municipal fleets, not all of these characteristics apply to all of the transit-only operations.

1. The maintenance employees were in need of initial or additional training.
2. There was a general lack of goals and objectives for maintenance operations.
3. There was a general lack of locally developed and implemented performance indicators.
4. Data collection and analysis were insufficient for monitoring the performance of maintenance and increasing productivity.
5. There was insufficient planning of maintenance.

Summary

Compared with the maintenance facilities of the municipal fleets, those of the transit-only systems were much better organized and laid out, had more room for access to all areas of the vehicle, and were much better equipped.

The maintenance practices used by the municipal fleets were fewer in number and approached at a lower level than those used by the transit-only systems. Neither group engaged in periodic maintenance to any appreciable degree.

Systems in the transit-only group had a cadre of transit bus maintenance personnel whereas the municipal fleets had only vehicle maintenance personnel. Maintenance training and retraining were needed in all systems, and their importance was increasing daily.

Bus maintenance had a low priority in the municipal fleets, established by both formal design and informal practice. In the transit-only systems there was no problem with maintenance priority since only buses were maintained.

There was very limited use of modern methods of data collection and analysis in the maintenance operations of the municipal fleets. In addition, these systems had no goals and objectives, either written or verbally expressed. The collection and analysis of data for use in the maintenance operation were more common practices in the transit-only systems; however, there was comparatively little use of modern methods such as computer support. There was also a general lack of goals and objectives for maintenance functions in the transit-only systems.

Maintenance planning depends on proper data collection and analysis. As previously discussed, these practices were not well organized or used to any appreciable degree. The result was that maintenance planning was virtually nonexistent in the municipal fleets and only crudely practiced in most of the transit-only systems.

CONCLUSIONS AND RECOMMENDATIONS

When combined, the questionnaire responses and the information from the site visits provided a picture of transit bus maintenance at small and medium-sized systems in Virginia.

In the municipal fleets, maintenance practices were unorganized and informal. Maintenance was provided for the transit buses as an adjunct function and was perceived as carrying a lower priority than the other maintenance activities. There was no formulation of policy for maintenance operations, and complete control was vested in some unit of the local government.

The commitment to proper bus maintenance was much stronger in the transit-only systems. Overall, these systems were better organized and administered and were staffed by personnel who were knowledgeable about transit buses and the complications of proper maintenance. It is evident from the information

Table 1. Type and number of transit systems affected by various maintenance factors.

Factor	No. of Systems Affected		
	Municipal Fleet	Transit Only	Generic
Lack of goals and objectives	6	6	12
Inadequate maintenance personnel assignment	4		
Inability to hire qualified personnel	6	7	13
Lack of maintenance personnel training	6	6	12
Low maintenance priority for transit buses	4		
Inadequate maintenance facility capability	3	2	5
High incidence of running repairs and road calls	3	4	7
Lack of data collection and analysis	6	6	12
Lack of maintenance system planning	6	7	13
Lack of periodic maintenance programs	6	5	11
Inadequate preventive maintenance programs	6	6	12
Need to educate local political bodies	6	7	13
Present conditions of buses	3	4	7
Use of inadequate buses	3	1	4
Use of obsolete buses	4	1	5
Complex design of ADBs		3	
Skill level to maintain ADBs		3	
Lack of bus maintenance operational expertise	6		
Inadequate number of spare buses	2	3	5

presented here that transit bus maintenance is complex and in need of improvement at all the systems reviewed. This complexity is the result of relations among the many factors that have an influence on the maintenance function. These factors are identified in the next section of this paper.

Factors That Affect Maintenance Performance

The questionnaire results, when combined with the observations and information obtained during the site visits, provided a data base that was analyzed to identify and classify factors that affect the productivity of transit bus maintenance. Numerous factors affect the maintenance of transit buses, and they vary enormously from system to system. It would have been a monumental undertaking to identify, categorize, and discuss all of the probable factors that were affecting the maintenance operations in each of the 13 Virginia systems reviewed. What were identified were the main factors, within which a multitude of smaller factors are found.

The identified factors were further classified by group as municipal fleet, transit only, or generic to both groups. Classification of a factor as generic or otherwise does not mean that the factor affects all the systems of that group. The factors, the system category to which they apply, and the number of systems they affect are given in Table 1.

A majority of these main factors (14) were classified as generic, and these as a whole tend to be more complex and consequential than the others, which is to be expected. The 5 remaining factors identified were specific to the municipal-fleet or transit-only systems.

Proposed Maintenance Guidelines

Until the present time, there has been no attempt by federal or state government to review the maintenance of transit equipment purchased with grant funds. There is no accountability for these funds that ensures that the equipment will receive the best possible maintenance and thus provide maximum service to the public.

The various factors that affect the performance of transit vehicle maintenance have been presented. It is evident from the material discussed in this paper that the operating properties cannot be held entirely responsible for the current situation in transit vehicle maintenance. The proposed federal approach to the problem is a program of mandatory maintenance for transit vehicles purchased with capital grant funds (5). A federal mandate for vehicle maintenance will not upgrade the performance of maintenance unless the factors that affect maintenance are addressed and relief in those areas is provided to transit maintenance operations.

The maintenance guidelines proposed here are meant to be applied at the state level to all operating properties that receive state funds. They will provide the necessary protection for the already considerable capital investment in transit in Virginia and continuing insurance for future investments.

This approach places the burden of compliance on the operators, but at the same time it provides them with the tools necessary to meet that responsibility in such a way as to allow the guidelines to be fashioned to local conditions. The enormous variations in local operating conditions in Virginia make this type of approach essential.

The proposed guidelines do not dictate the type of maintenance activities to be carried out. A total of 13 transit operations were reviewed in this study, and all operated under different geographic conditions, used different types of equipment, and had that equipment maintained by mechanics of varying skills. For these reasons, it is impossible to propose a maintenance approach for inspection schedules or component replacements that would be correct for more than one operation.

The proposed guidelines are stated in general terms and deal with the organizational and administrative approaches to maintenance, not with the particular maintenance procedures or the activities they encompass. The wording is general to provide the flexibility necessary for implementation of the guidelines. The goal of the proposed guidelines is not standard vehicle maintenance but a standard approach that will become familiar to each of the transit properties. These guidelines will promote an exchange of information and a mutual understanding of the operational aspects of transit vehicle maintenance as practiced by properties in Virginia.

The following maintenance guidelines are proposed:

1. Formulation of specific goals and objectives targeted at the vehicle maintenance function and based on local operating conditions;
2. Implementation of an organized and systematic preventive maintenance program to include operator inspection, daily service inspections, and scheduled maintenance inspections;
3. Use of maintenance information forms that include, as a minimum, (a) operator inspection (vehicle defect) forms, (b) detailed maintenance inspection forms designed for the transit vehicle being inspected, (c) road call and emergency maintenance forms, (d) detailed daily fuel, oil, and fluid use form, and (e) maintenance work order (repair order) form;
4. Systematic data collection and analysis to support the formulation and implementation of appropriate maintenance performance indicators and measures, including, as a minimum, data on (a) maintenance performed (type, mileage, and description), (b) actual labor time for inspection, repair, and rebuilding, (c) parts used and cost for inspection, repair, and rebuilding, (d) component and subassembly replacements (new, rebuilt, or used replacements), (e) road calls (cause, action taken, labor time, time out of service, parts, and resolution), (f) number of missed or late runs due to maintenance problems, (g) materials and supplies consumed per vehicle, (h) number of buses out of service, for

what reason, and how long, and (i) other data necessary due to local operating conditions;

5. Systematic maintenance planning for preventive and periodic maintenance based on the data collection and analysis proposed in guideline 4;
6. Specific maintenance personnel assigned to inspection and repair of transit vehicles; and
7. Minimum training requirements and competency qualification for maintenance personnel.

Clearly, in light of the present economic conditions in public transit, the proposed guidelines must be accompanied by the proper direction and level of assistance from the appropriate local and state agencies. Guidelines 2, 3, 4, and 6 can be implemented by the operating properties with minimal disruption and outside assistance. The remaining three guidelines--1, 5, and 7--will require a certain amount of assistance for implementation. Such an effort is now being undertaken as an extension of this research by the Public Transportation Division (PTD) of the Virginia Department of Highways and Transportation. The implementation of guideline 1 will be assisted by the current actions of PTD, in conjunction with the Virginia Association of Public Transportation Officials, to develop a transit information exchange program and management seminar series at the state level to deal with maintenance. Guideline 5 is being supported by the efforts of PTD to initiate a vehicle maintenance management information system study effort and demonstration program at a medium-sized property. Once developed and implemented, this system will be made available to the other transit operations within the state. Finally, guideline 7 is being supported by the ongoing efforts PTD is sponsoring to define and refine the possible alternatives for providing training assistance programs in transit bus maintenance to all Virginia operating properties. These actions will give the transit operators the assistance they need to combat external factors that affect maintenance performance and provide accountability for capital funding grants.

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Louisiana's Equipment Replacement Dilemma

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The Louisiana Department of Transportation and Development is currently in the second year of a three-year equipment improvement program. The Legislature approved the program based on an economic analysis that indicated that a 20 percent annual savings was possible. Net savings will accrue after a four-year period as a result of increasing capital investment to reduce the cost of equipment operations, assuming the economic predictions are used. An accumulated unit cost curve is maintained on each individual machine and, along with repair limits, is used to identify the critical repair that makes an equipment unit uneconomical. This critical repair concept is the basis for identifying the optimum time to replace each unit. The method has accurately predicted the optimum replacement point in 96 percent of the cases and allows for ranking of replacement needs in priority order so that available funds can be used most effectively. Although this concept is economically sound, there are many obstacles in the path to implementation. Implementation has been difficult at the field level because of the dilemma surrounding replacement decisions. Since an average one-year lead time is required to obtain new equipment, replacement equipment is not normally available at the time of failure. Managers are rarely able to retire a unit and await replacement. This dilemma is compounded by the buildup of a replacement backlog over a period of many years. Of a 7500-unit equipment fleet, almost 3500 units are beyond the economic replacement point, which further complicates the manager's dilemma. For this program to succeed, the field manager must thoroughly understand the dilemma posed by the replacement decision and be willing to support the computer-assisted projections based on faith in the statistical accuracy of the system.

In Louisiana, management control of the equipment fleet of the Louisiana Department of Transportation and Development is exercised by the Division of Maintenance and Field Operations. Central control of the statewide fleet is the responsibility of the director of maintenance and field operations, who delegates routine decisionmaking authority to the chief maintenance and operations engineer. Service facilities are located in nine Department of Transportation and Development districts under the direction of a district administrator. Planning, budgeting, systems development, experimental programs, and other centralized functions are directed by the