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The road improvement prioritizing system currently utilized by the Virginia Department of Transportation is similar to the method utilized by many states: it is a sufficiency rating system that evaluates proposed projects on the basis of points assigned for a number of variables. Although this type of system is commonly used, it has several limitations, including its lack of sensitivity to individual variables, the difficulty in assigning and interpreting a point total based on multiple heterogeneous variables, and the rigidity of the system after the point structure is established. In this report, an alternative method is introduced that consists of sorting projects in sequential ranking steps based on ranges of individual variables. The proposed method is simpler, more flexible, and requires less data manipulation than the present rating system. Individual variables have greater impact on the prioritizing process, and the resulting prioritizing ratings correlate well with results obtained from the previous rating method.

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FINAL REPORT

PROCEDURES FOR PRIORITIZING ROAD IMPROVEMENTS UNDER THE STATEWIDE HIGHWAY PLAN

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(A Cooperative Organization Sponsored Jointly by the Virginia Department of Transportation and the University of Virginia)

In Cooperation with the U.S. Department of Transportation
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ABSTRACT

The road improvement prioritizing system currently utilized by the Virginia Department of Transportation is similar to the method utilized by many states: it is a sufficiency rating system that evaluates proposed projects on the basis of points assigned for a number of variables. Although this type of system is commonly used, it has several limitations, including its lack of sensitivity to individual variables, the difficulty in assigning and interpreting a point total based on multiple heterogeneous variables, and the rigidity of the system after the point structure is established. In this report, an alternative method is introduced that consists of sorting projects in sequential ranking steps based on ranges of individual variables. The proposed method is simpler, more flexible, and requires less data manipulation than the present rating system. Individual variables have greater impact on the prioritizing process, and the resulting prioritizing ratings correlate well with results obtained from the previous rating method.

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INTRODUCTION

In 1978, a statewide transportation planning process was initiated for Virginia. The Transportation Planning Division (TPD) of the Virginia Department of Transportation (VDOT) was assigned the task of determining the types and sequence of road improvements to be funded in the statewide plan. The stages of the resultant planning program are shown in Figure 1. Initially, an inventory of Virginia roads was compiled including the termini, functional classification, length, number of lanes, pavement width, shoulder width, terrain type, traffic volume (existing and forecast), and service volume of all primary, secondary, interstate, and urban roads (Transportation Planning Division, 1983). A detailed deficiency analysis was performed to examine each road by multiple criteria (Table 1). Based upon the results of the deficiency analysis, recommendations were made for highway projects that included major new facilities, major construction and reconstruction, minor road widening, bridge replacement and rehabilitation, railroad crossing improvements, and the construction of commuter parking lots. Alternatives for roadway improvements were considered in the following order: (1) spot improvement, (2) minor widening, (3) major reconstruction, and (4) building a new facility at a different location to alleviate the deficiency. The number of recommended projects and the limitations of funding and manpower required that a prioritizing scheme be developed for the administration of the projects.

The TPD developed a prioritizing method based on 15 factors, which was implemented in March 1982. It was revised in June 1982 to the 9-variable system that is currently used (Figure 2). All major highway recommendations (major new facilities, major construction and reconstruction of roadways, and minor road widening) are included in the road prioritizing system to determine the order of funding under the statewide plan.

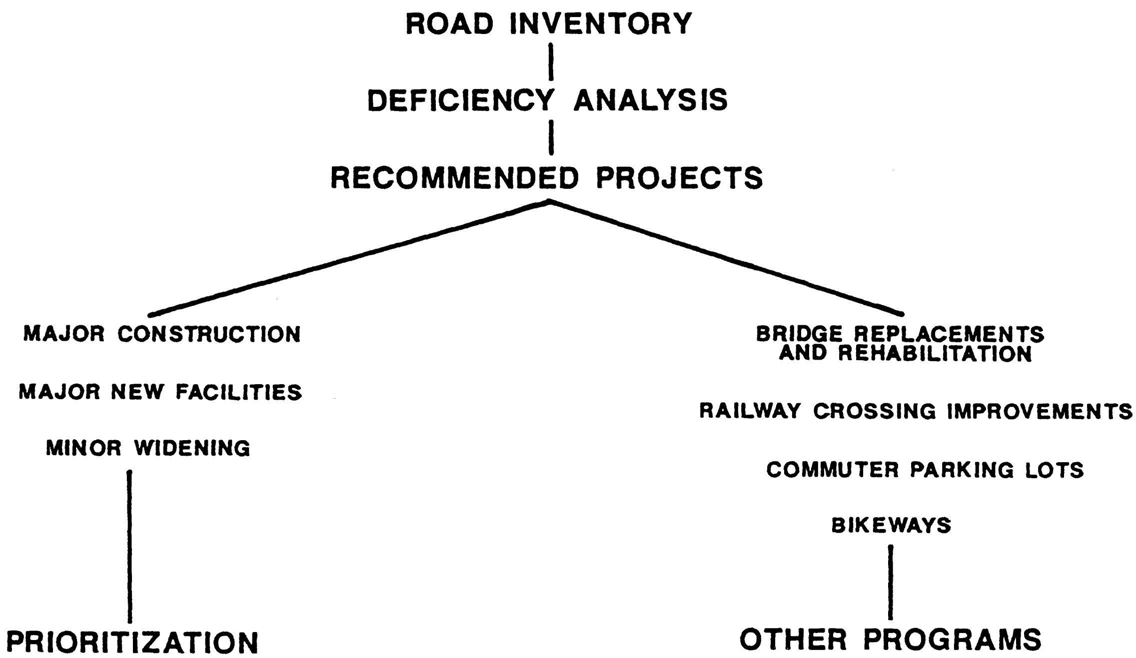

Figure 1. Statewide planning program.

Table 1

Parameters for Highway Deficiency Analysis

Urban (Interstate, Arterial, Collector)
Rural (Interstate, Arterial, Major Collector, Minor Collector)

1. Current volume/service flow ratio
2. Future volume/service flow ratio
3. Geometrics (acceptable or poor)
4. Minimum pavement width (16 ft)
5. Pavement condition (acceptable or unacceptable)
6. Drainage (good, fair, poor)
7. Safety improvements recommended
8. Bridge obsolescence
9. Railroad crossing deficiencies
10. Spot deficiencies (e.g. curves, intersections)

Rural (Local)

1. Less than minimum pavement width
2. Less than minimum pavement type (unpaved roads with 50 or more vehicles per day are deficient)
3. Geometrics (based on resident engineer's comments)

Existing V/SV	Pts.	Forecast V/SV	Pts.	Geometrics	Pts.	Functional Classification	Pts.	Existing VPD	Pts.	Forecast VPD	Pts.	Route Continuity	Pts.	Cost Future VMT	Pts.	Accidents	Pts.
0.0-0.25	0	0.0-0.25	0	Adequate	0	Local	0	0-1,000	0	0-1,000	0	No	0	> 400	0	Below Average	0
0.26-0.50	2	0.26-0.50	2	Unknown	2	Minor Collector	1	1,001-5,000	1	1,001-5,000	1	Yes	5	301-400	1	Above Average	5
0.51-0.65	4	0.51-0.65	4	Inadequate	5	Major or Urban Collector	2	5,001-10,000	2	5,001-10,000	2			201-300	2		
0.66-0.75	6	0.66-0.75	6			Minor Arterial	3	10,001-20,000	3	10,001-20,000	3			101-200	3		
0.76-0.90	8	0.76-0.90	8			Principal Arterial	4	20,001-40,000	4	20,001-40,000	4			51-100	4		
0.91-1.00	10	0.91-1.00	10			Interstate	5	40,001-60,000	5	40,001-60,000	5			0-50	5		
1.01-1.25	22	1.01-1.25	12				6	> 60,000	6	> 60,000	6						
1.26-1.50	24	1.26-1.50	14														
1.51-1.75	26	1.51-1.75	16														
1.76-2.00	28	1.76-2.00	18														
> 2.0	30	> 2.0	20														

Figure 2. Department prioritizing system variables and point scale.

The statewide program is reviewed and the procedure updated every five years. Since the current prioritizing scheme developed by the TPD was last used in 1984 for the statewide plan, the Virginia Transportation Research Council (VTRC) was requested to review it and to suggest alternatives. This report summarizes the study conducted to evaluate the current method and to develop an alternative one.

RESEARCH METHODOLOGY

The research methodology involved several steps: (1) a review of the literature and a determination of the qualities desirable in a prioritizing scheme, (2) a review of the Department's prioritizing system and an identification of its strengths and weaknesses, (3) the development of a new prioritizing scheme incorporating the recommended improvements, (4) a test of the newly developed system, (5) a comparison of the results of the original and proposed methods, and (6) the preparation of a report of the study with recommendations for a prioritizing program.

THE QUALITIES OF A PRIORITIZING SCHEME

Prioritizing, the process of arranging projects in rank order of importance to determine the sequence of their implementation, is an important component of a planning and construction program. Such a program should allow identification and prompt scheduling of needed projects to enable a department of transportation (DOT) to provide timely and efficient service to the public; it should be as simple as possible so that its mechanism, capabilities, and the criteria contributing to the priority rating of a particular project can be easily understood. A flexible system is preferable because it may need to be modified when data are unavailable, when road systems with different specifications are analyzed, when revised methods of road assessment become available, when the significance and ranges of variables already included in the system are refined, or when alterations occur in the legislative requirements for road systems.

Types of Prioritizing Methods

Numerous methods have been devised by state DOTs to assist in the setting of priorities for road improvements. The types of prioritizing systems include technical (sufficiency ratings, option-evaluation techniques), nontechnical (political commitments, emergencies, project readiness), and financial (appropriation, geographical, rate of return) (Transportation Research Board, 1978). Most transportation departments employ a combination of these methods in the final selection of projects for implementation.

In sufficiency ratings systems, a project is assessed by multiple criteria, and points are awarded for its conformance to standards. Projects are compared and ranked using point totals. Sufficiency rating systems are the most commonly used technical prioritizing method (General Analytics, 1973). Improvements have been made in sufficiency ratings in recent years by incorporating factors reflecting safety, capacity, and other issues in addition to the road condition assessments on which the original sufficiency ratings were based. A considerable amount of research has focused on the development of other technical prioritizing systems such as the complicated computer programs called option-evaluation techniques that simulate the total decision-making process including project construction alternatives (McFarland & Memmott, 1985).

Despite the emphasis on technical methods in the prioritizing of most departments of transportation systems, the final decision-making process is often subjectively based on engineering judgment, political concerns, the amount of work already put into a project, and project readiness (Transportation Research Board, 1978). These are considerations with recognized significance in the planning process; but they are difficult to incorporate into a standardized system. The increasing size and complexity of highway systems prevents individual consideration of each proposed project.

Financial prioritizing is concerned with the appropriation and allocation of transportation funds. Apportioning funds by functional classification of roads or geographical area is a form of financial prioritizing. Another aspect of financial prioritizing is cost-benefit analysis. The cost-benefit may be evaluated by two different approaches: (1) by determining the maximum number of projects that could be implemented within a budget or (2) by selecting projects that will improve service to the maximum number of highway users within a budget. Complicated formulas and computer programs to assess cost-effectiveness have been derived; they are often based on sufficiency ratings. These are limited by the fact that cost estimates are potentially among the most inaccurate of all prioritizing considerations since they are affected by inflation, changing construction materials and methods, contractor variables, etc. (Transportation Research Board, 1978).

The type of prioritizing method must be selected to meet the objectives of the planning process, for example, for the identification of needs or for budget allocation. The VDOT statewide planning process was intended to furnish technical considerations for recommended highway projects independent of budgetary restraints (Transportation Planning Division, 1985). Consequently, the VDOT prioritizing system serves primarily as a method of needs assessment; budget considerations are applied later in the process. As the statewide planning process is currently designed, a deficiency analysis identifies the projects for recommendation, the projects are prioritized by degree of need, and the results are presented for the allocation of funds.

Prioritizing Variables

Categories of variables that are commonly used in prioritizing schemes appear in Table 2, which includes only a few examples. There are over 80 highway prioritizing variables contained in the literature. Some of the variables represent social issues such as environment, energy, and budget, but most can be classified into the broad categories of road service, safety, and condition. The service variable is used as an estimate of the quality of service provided to the user. It is frequently evaluated by measurements of traffic delays, the amount of traffic relative to road capacity, etc. Safety considerations are an attempt to estimate the probability of traffic accidents and tend to focus attention on those projects that elicit particular citizen concern. The physical condition of the road pavement is a factor that affects the speed, safety, and comfort of vehicles on the road. Most condition data is subjectively determined by road crews.

Table 2

Categories Used in Prioritizing Schemes

Category	Variable
Environment	Wetlands encroached upon Habitats compromised Potential effect on endangered species
Economics	Population Income generated by roadway Business displaced
Service	Traffic Volume/Capacity Travel delays Pavement width Continuity of roadway Average Daily Traffic
Safety	Accident location Accident analysis data Accident surrogates Road, shoulder, and median widths Sight distance
Condition	Remaining life of structure Road roughness Pavement strength

In developing or evaluating prioritizing systems, scrutiny of the variables is of fundamental importance. The following guidelines were developed during this study for the evaluation of prioritizing variables.

- The criteria must accurately reflect the major issues in the prioritizing of projects.
- Accurate data should be obtainable with a reasonable amount of effort.
- A small number of categories are desirable to simplify the system and to maximize the impact of each variable.
- The criteria accepted need to be easily explainable.
- The variables should favor projects that benefit the greatest number of highway users within geographic or functional categories.
- Criteria should be incorporated that ensure safe travel.

These criteria are compatible with the needs of most prioritizing systems and were used to assess the Department's prioritizing system and to select the variables for the new prioritizing system.

A REVIEW OF THE EXISTING VDOT PRIORITIZING SCHEME

The VDOT prioritizing system is conceptually similar to the sufficiency rating systems used in many other states. Values are assigned to variables based on an estimate of the variable's significance in the prioritizing decision. Points for each variable are awarded to a project according to its level of deficiency by that criterion (Figure 2). The maximum number of points is assigned for the most serious condition. The sum of points awarded to a project yields a number for comparison with other projects in prioritizing. The maximum number of points obtainable is 92. After the projects are arranged in order by the total scores, priority levels of high, medium, and low are established by separating the list of projects into equal thirds by estimated cost.

The Department's Prioritizing Variables

In the VDOT system, nine variables are used to prioritize recommended projects (Figure 2). These are listed below.

Service:

1. the existing volume of traffic on a given road segment divided by the service volume for that road segment (V/SV)

2. the forecasted volume of traffic for a given road segment divided by the service volume for that segment (FV/SV)

3. the existing volume of traffic per day (VPD)

4. the forecasted volume of traffic per day (FVPD)

5. the functional classification of the road

6. the road geometrics

7. the route continuity

Safety:

8. accident rates (for rural sections only, not available for urban sections)

Other considerations:

9. the cost of a road improvement divided by the vehicle miles traveled (VMT).

Although these variables are similar to those used in other systems, the point distribution in the VDOT system differs from that used by most other states. In other state's systems, points are usually divided almost equally among variables representing the major considerations of road condition, service, and safety (General Analytics, 1973; Zegeer & Rizenbergs, 1979). In the VDOT system, 89 percent of the points are awarded to service variables and 5 percent to safety considerations. There are no condition variables.

Service

The primary criterion in the current prioritizing system is volume of traffic using the roadway. Four of the nine variables in the Department's scheme represent volume assessments: existing V/SV (30 pts.), forecast V/SV (20 pts.), existing VPD (6 pts.), and forecast VPD (6 pts.). The sum of the potential points assigned for volume is 67 percent (62 pts.) of the total; 54 percent of the points relate to existing or forecasted V/SV. Therefore, projects are primarily sorted on the basis of traffic volume. The remaining 33 percent of the available points are distributed among the other five factors, namely, geometrics, route continuity, accident rates, and cost/VMT.

Two of the volume variables, totaling 26 points, represent forecasted values obtained by extrapolating from current data. As a result, the values for existing V/SV and VPD are considered twice. In addition, forecasted values are obtained using formulas or line graphs based on predictions of population growth and are subject to considerable error (McFarland &

Memmott, 1985). They may be useful in a deficiency analysis to anticipate needs, but current information should be used in prioritizing to determine the most urgently needed projects.

The functional classification of roads has a maximum value of 10 points. This variable further increases the emphasis on road volume in the system because roads with a higher functional classification, such as interstates, also have an elevated traffic volume. Since VDOT funding is separate for each different administrative classification, the roads in different categories need not compete in a prioritizing system.

The VDOT variables geometrics (5 pts.) and route continuity (5 pts.) are also included among the service criteria in many systems. The data for these variables are subjectively ascertained by field crews during the inventory. In the geometrics analysis, field crews evaluate a road's horizontal and vertical alignment, and the typical section of the highway (see Table 3). Manpower limitations do not permit the detailed analysis and measurements of grades, degrees of curvature, and sight distance (Transportation Planning Division, 1985). Geometrics is an issue in road design that is considered earlier in the deficiency analysis and may not contribute significantly at the prioritizing stage.

Safety

Accident rates (5 pts.) are the only direct indication of road safety in the current system. The total number of points is assigned to roads with a higher than average accident rate. Roads with average or below average rates receive no points for this variable.

Other Considerations

The cost of a proposed road improvement divided by the vehicle miles traveled (5 pts.) is an effort to estimate the return on an investment. However, economic variables are inappropriate in a prioritizing scheme to identify the most urgently needed projects. They are also inconsistent with the intent of the state highway plan to provide decision makers with technical data on proposed projects independent of economic constraints (Transportation Planning Division, 1985). Budget planning considerations can be applied following the prioritizing for needs.

Table 3

Criteria for Inadequate Geometrics

- o Vertical Alignment
  - -- Significant reduction in operating speed due to inadequate vertical sight distance.
  - -- Very poor rating according to FHWA Highway Performance Monitoring System criteria, i.e., frequent grades and vertical curves that impair sight distance and/or severely affect the speed of trucks with truck climbing lanes not provided.
- o Horizontal Alignment
  - -- Speed warnings on horizontal curves.
  - -- Significant reduction in operating speed because of inadequate horizontal sight distance.
  - -- Very poor rating by FHWA Highway Performance Monitoring System, i.e., several curves are uncomfortable and/or unsafe when traveled at the prevailing speed limit on the section, or the speed limit is severely restricted because of the design speed of the curves.
- o Typical Section
  - -- Inadequate shoulders that impair traffic operation.
  - -- Inconsistent roadway sections that impair traffic operation.

An Evaluation of the Department's Prioritizing System

Weighting systems can be very effective when the relative significance of each variable is known (or can be estimated) and the summation of the variables is readily interpreted. However, prioritization using point systems has important limitations. It assumes a multifactorial basis for ranking, but the combination of multiple variables may be less significant than critical values of individual variables (Harness & Sinha, 1983). For example, a road that was unremarkable by all criteria except for a very high accident rate would receive a low weighting number, even though it deserves more careful scrutiny. Weighting systems are most readily applied to homogeneous variables. A composite score of points for heterogeneous variables is very difficult to interpret (McFarland & Memmott, 1985). The Department's point total includes variables that are quite heterogeneous: they are dissimilar in type, time frame, method of assessment, and representation.

If the funding based on the prioritizing results is questioned, it would be desirable to be able to identify the variables that resulted in a project receiving a high or low rating. With a weighted scale, the factors contributing to the priority rating may not be readily identifiable because the result of the process is a total that does not identify individual high values.

After weights are assigned to the variables, alteration of the variables or absence of data would require restructuring of the weighting system. The reassignment of weights and point scales can be cumbersome. For this reason, two systems with either eight or nine variables are used by the TPD to compensate for the frequent lack of accident data. The validity of the total score depends on the availability of information for each variable.

The Department's weighting system provides a number for rating projects. However objective it appears, this number incorporates subjective information. The data used in the Department's prioritizing system are available through the inventory system that originated with the statewide highway plan. This information is reasonably accurate where it represents quantified observations. Some variables such as geometrics are based on the observations and judgment of individual road crews and are probably less accurate. The predicted values for V/SV, VPD, and cost/future VMT also provide the system with inaccurate information resulting from uncertainties in the prediction of population growth and distribution. For some variables an intermediate point value is assigned if the information is unknown, but attempting to compensate for unavailable information may further contribute to inaccuracy in the final results.

In addition, the point scale and weight of each of the system variables were subjectively assigned. Some variables have a detailed scale of up to 10 gradations. This implies a precision that is not possible for subjectively identified limits and is not necessary when the goal is to divide projects into three groups. Broader categories, such as the identification of a level that is alarmingly high or reassuringly low, have greater significance and less subjectivity. Although broad ranges result in a loss of sensitivity, they can sometimes compensate for minor inaccuracies in the data.

Once the recommended projects are ranked according to their rating in the deficiency analysis, they are separated into thirds by estimated cost. First, the estimated cost of all recommended projects in the list is totaled and divided by three. Beginning with the highest ranked project, the estimated cost of each project on the list is added until a value is reached that is approximately equal to one third of the total cost of all projects. The ranked projects included in the list to this point are assigned a high priority rating; the next third on the list are assigned a medium priority rating; and the final third are low priority projects. Therefore, rather than conforming to established criteria for priority levels, the assignment of a high priority rating to a project is arbitrarily based on the project's position in the ranked list and the expense of the projects above it. An expensive project high on the ranked list could dramatically affect the number of subsequent projects receiving a high priority rating. Failure to establish criteria that define a project's priority as represented by the point score impairs the use of the system to identify needed projects. Budget constraints should be imposed after needed projects are selected.

A NEW PRIORITIZING METHOD

In designing this new system, the objective was to accomplish the goals of the original system more reliably, consistently, and simply. This alternative method has fewer variables, each of which is divided into three data ranges representing values that are high (above threshold), medium (marginal), and low (adequate). All proposed projects are initially sorted into three groups of high, medium, and low as defined by the ranges of a primary variable (Figure 3). The grouped projects are then evaluated using the ranges of each secondary variable. Projects in the high range of a secondary variable may be elevated to the next highest group. The sorting sequence is easily performed by computer and requires less data manipulation than a weighted system. The projects are ranked within the high, medium, and low classifications by the ranges of the individual variables as well. In the final prioritized list, the first project in each group would be the most deficient as assessed by all variables.

A similar ranking approach was proposed by Harness and Sinha (1985). In their system, projects were divided into progressively smaller subsets using various criteria, but there was no provision for projects to change priority categories after assignment by the initial variable.

Tremendous flexibility is possible with the proposed method because each variable is applied independently of the others. A particular variable, depending on its assigned role, can be used to rank projects within a priority category or to raise or lower projects to other priority groups (see Figure 4). Although the initial grouping should be based on an important variable, subsequent assessment using the other variables should still result in appropriate prioritization. The system can even be designed with additional primary variables that cause a project to automatically shift to a high priority rating if above a certain threshold value. If the data for one or several of the variables are lacking, the project can still be evaluated on the available information. Additional variables can be added to the process, or ranges can be changed to reflect new information without restructuring the system.

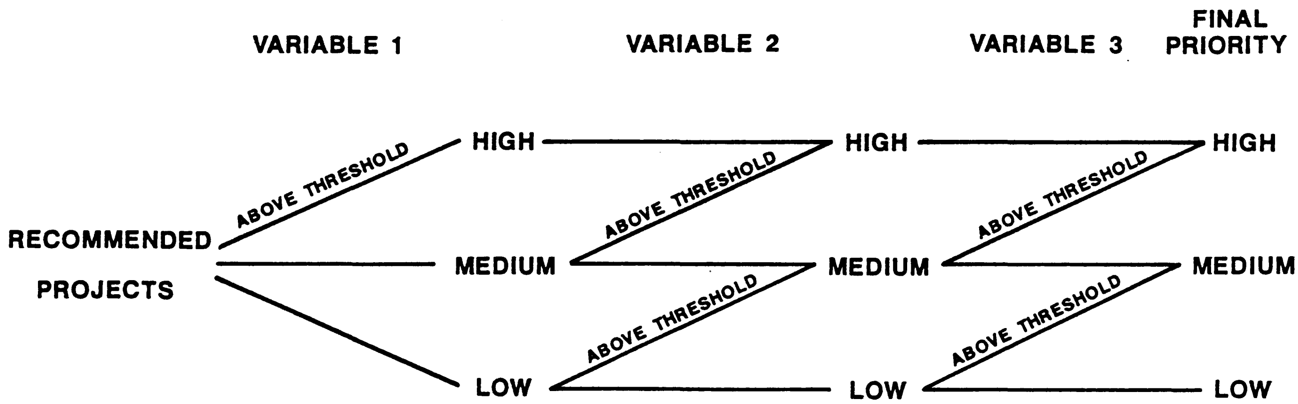

Figure 3. Research prioritizing scheme.

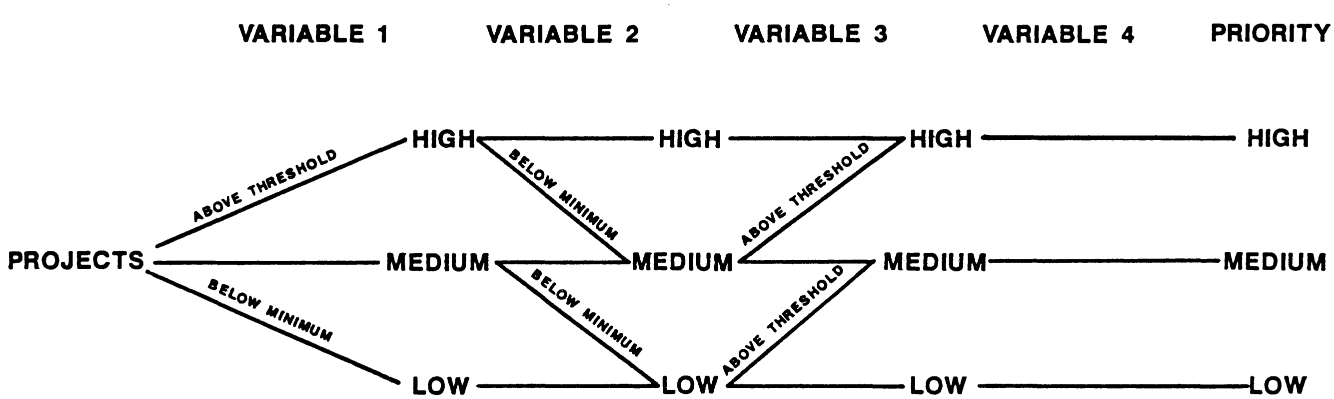

Figure 4. Research prioritizing scheme flexibility.

The Prioritizing Variables

The proposed system can be used for many prioritizing decisions. The variables and ranges chosen can be tailored to serve specific requirements. The variables selected for illustrative purposes are consistent with the guidelines recommended for road prioritizing systems listed earlier in this report and are largely drawn from those used in the Department's prioritizing system.

Service

The variable V/SV, traffic volume divided by service volume, is the primary determinate of a road's volume status in the proposed system. This variable is considered the most important in differentiating between projects because it assesses the adequacy of road design to serve current needs and because of the broad consequences when the V/SV is elevated. As traffic volume increases beyond the road's capacity, the resulting traffic congestion causes a decrease in service to the public, an increase in the probability of accidents, and an acceleration in the deterioration of the roadway.

High-use roads are usually emphasized in a prioritizing system to ensure that improvements benefit the maximum number of users. For this purpose, the variable V/SV is supplemented by a criterion for distinguishing between high- and low-volume roads and the average daily traffic volume (ADT). The two volume parameters are complimentary since the ADT indicates the size of the population using the road, and the V/SV assesses the adequacy of the road's design to accommodate its traffic volume. In a weighting system, two related variables would result in double counting. In a ranking system, however, they supplement each other as two check points in a screening process.

Safety

The most quantitative indication of the safety of a road is its accident rate. This figure, which is available for most roads in all administrative categories except urban, is based on the number of accidents by road segment. The accident rate is predictive at spot locations with a correlation around 0.5 (Calspan, 1986) and is the standard for safety evaluation. Criticisms of the usefulness of accident data are based on the infrequency of accidents, which necessitates long-term data collection for the accumulation of reliable information. The problem is greatest at rural locations where traffic volumes are low and accidents are least frequent. In addition, accidents are site specific and usually are not entirely engineering related. However, efforts to identify variables that can be used as accident surrogates have yielded few alternatives. Road volume is one variable that has a high correlation with accident data on rural and urban roads (Calspan, 1986). In the proposed prioritizing system accident data used in conjunction with the volume criteria should provide effective consideration of road safety.

Condition

The pavement condition rating that has been in use by the VDOT for about six years is included for several reasons. It identifies roadways with deficient pavement conditions as assessed by multiple criteria and is currently used for the establishment of maintenance priorities. Although the funding for maintenance and major reconstruction is separate, a savings to the Department could be obtained if the resurfacing and the reconstruction of a road prioritized for major rehabilitation were coordinated. The data necessary for this is available for most roadways in the state. Condition ratings are updated semiannually for primary and interstate roads, and they have been routinely determined for all secondary roads since 1988. Hypothetically, a road with a pavement in poor repair could artificially lower the V/SV by causing traffic to take better maintained routes. The condition rating system has been well studied, and threshold values for pavements in poor condition have been established (McGhee, 1987). These values are incorporated into the proposed ranking system.

To assess road conditions, field teams inspect sections of roadway for longitudinal or alligator cracking, rutting (wheel path depression), pushing (isolated displacement of the pavement usually occurring at intersections), raveling (loss of surface material from spalling), or patching (VDOT, 1988). Based on the frequency of these evidences of pavement distress, a rating factor is assigned for each distress type (see Table 4). These values are multiplied by individual weighting factors, totaled, and subtracted from 100 to obtain the condition rating, which is a type of sufficiency rating. The deterioration identified by condition ratings is generally related to traffic in terms of load and design variables (McGhee, 1987). Studies have shown that pavements initially deteriorate slowly after resurfacing and then enter a period of more rapid deterioration. The rate of deterioration is influenced by many factors and cannot presently be predicted for individual roadways.

Thresholds and Ranges

Three ranges are established for each variable. The ranges are derived from the point scales of the Department's prioritizing scheme and serve to evaluate the projects as adequate, marginal, or inadequate by each variable. The highest range in each sorting pathway is defined by a threshold value to identify roads in critical need of repair as assessed by that criterion.

The threshold level for V/SV is 1.50; thus, roadways carrying a traffic volume 50 percent or greater than their designed service volume will be assigned a high priority for improvements to alleviate a predisposition to accidents, travel delays, and deterioration of the roadways. The low range includes projects with a V/SV less than 1.00, indicating roadways at or below the traffic volume for which they were designed. The medium range is intermediate between the other two categories, comprising projects with a V/SV of 1.01 to 1.49.

1204

Table 4

Pavement Condition Rating Criteria
Condition Rating = 100 - Sum of all rating factors times weight

Distress Type	Weighting (Multiply by rating factor obtained from table below)
Longitudinal or Alligator Cracking	2.4
Rutting	1.0
Pushing	1.0
Ravelling	0.9
Patching	2.3

Rating Factor

Frequency of Distress	Not Severe	Severe	Very Severe
None	0	0	0
Rare (less than 10%)	1	2	3
Occasional (10% - 40%)	2	4	6
Frequent (over 40%)	3	6	9

The highest range of ADT is above 30,000 vehicles per day, and the low range is below 10,000 vehicles per day. These values offer a reasonable estimate of high and low traffic volumes for a particular roadway. If the same ranges are employed for each administrative classification of roads, the priority levels will be elevated for high volume roads such as interstates. This type of standardization may be desirable in the statewide planning process, or specific ADT ranges can be established for each administrative classification in the computer program.

Accident rates vary among road classifications. The threshold level is twice the average accident rate. The threshold levels shown below in Table 5 were calculated from the Summary of Accident Data (VDOT Traffic Engineering Division, 1986). The lowest range includes rates below average, and the median range includes rates intermediate between the high and low ranges.

Table 5

Accident Rate Thresholds

Road Type	Low	Medium	High
Interstate	<81	81-162	>162
Primary	<207	207-414	>414
Secondary	<391	391-782	>782

The prioritizing computer program should be set for accident rate ranges specific to each administrative classification. Similarly, threshold condition ratings vary among road types as indicated in Table 6 (McGhee, 1987).

Table 6

Condition Rating Ranges

Road Type	Low	Medium	High
Interstate	90-100	83-89	<83
Primary	90-100	78-89	<78
Secondary	90-100	75-89	<75

The condition threshold rating values originated with the pavement management system when the worst 10 percent of the road system for each category was identified for maintenance. The values shown in this report represent revised and lowered threshold values. Roads are assigned a value of 100 immediately after resurfacing. Therefore, the low priority range for the condition variable is 90 to 100.

Application of the Proposed Prioritizing System

In the proposed prioritizing system, projects are separated into administrative classifications before prioritizing so that roads with the same funding source are compared (Figure 5). Similarly, roads may be separated by district to correspond to funding allotments. However, this prioritizing system lends itself very well to a statewide planning program in which projects from all districts are considered together.

V/SV is the primary variable in the system and is used for initial sorting into categories of high, medium, and low priority. It is the initial ranking criterion because of its importance in assessing design deficiency, a critical consideration in a needs assessment prioritizing program. V/SV will also reflect high values for other variables including ADT, accident rate, and condition (Figure 6). Furthermore, it emphasizes road improvements that benefit a large number of road users. Following the initial separation into prioritized categories using V/SV, the groups are "fine-tuned" using variables specific for service, safety, and condition (Figure 7). Projects initially sorted into medium and low priority groups are promoted to the next highest category if they exceed the threshold values of subsequent ranking criteria. For example, a road in the medium priority category with an ADT rating indicating a high volume of use (greater than 30,000) is promoted to the high priority group.

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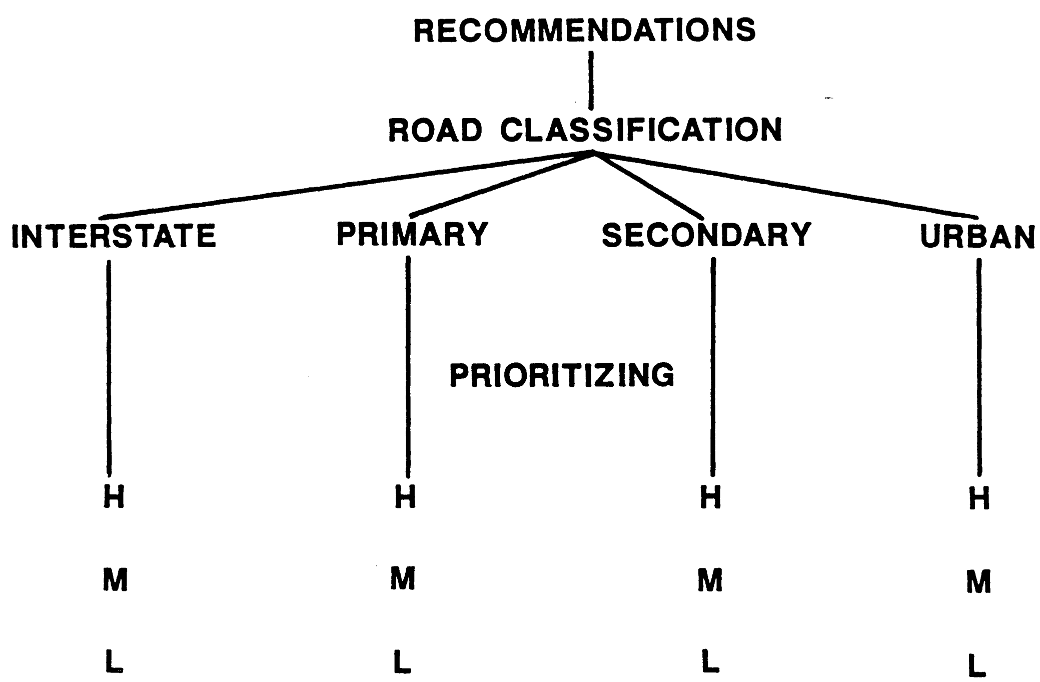

Figure 5. Proposed prioritizing sequences.

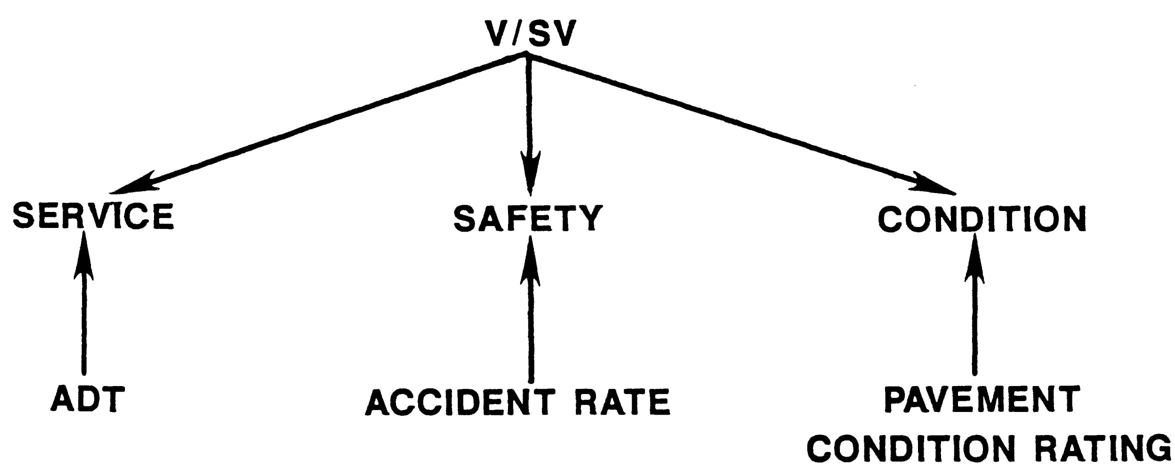

Figure 6. Interrelationships between variables.

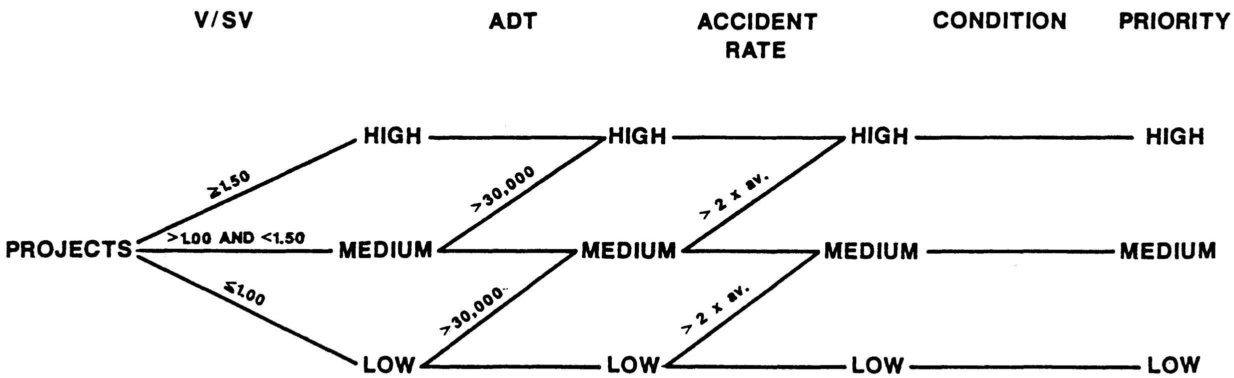

Figure 7. Proposed prioritizing scheme.

Generally, a road with a high V/SV will also have a high ADT, but ADT is used as a check to identify high volume roads that are below the V/SV threshold. In the primary roads on which the system was tested, this variable did not change the ranking of projects, since all roads with a high ADT also had a high V/SV.

Accident rate is an example of an independently sorting variable that produces a shift in priority category for a number of projects. Projects with a high accident rate in the lower priority categories are consequently promoted to the next highest priority group to emphasize road safety.

Condition is the most dynamic variable because a road can be converted from the high to the low condition range following resurfacing. Consequently, it is not used to change the priority level of projects. It is useful for sorting within a priority group, and it can be employed as a planning tool to identify projects scheduled for both routine maintenance and major construction.

Projects are ranked in relationship to each other within the prioritized groups. For example, the highest entry on the high priority list would be the proposed project with a V/SV greater than 1.50, daily traffic volume greater than 30,000, condition rating beyond the threshold, and an accident rate greater than twice the average. If the budget permits funding of projects of medium and low priority, the most urgent projects in these categories can be readily identified on the ranked list.

Evaluation of the Proposed System

This novel approach offers several advantages over traditional weighting systems and eliminates specific problems identified in the Department's prioritizing system. Fewer variables are included, but they represent the major issues in VDOT's needs analysis and are consistent with the priority considerations of other states. Subjectivity is minimized in the research scheme by selecting variables that are based on objective, readily available information. The sequential ranking system allows maximal consideration to be given to each variable independently. The potential for multiple variables to contribute to a project's priority level provides a flexibility in reclassification that is not possible with other systems. This is particularly important if factors affecting safety are under consideration; critical thresholds identify problems that could be lost in a point total.

The system is amenable to modifications should other variables need to be incorporated. Ranges of variables can be altered for roads in different administrative classes. The prioritizing is performed by a computer program with minimal manual data manipulation, yet the results and criteria for ranking remain quickly discernible in the final ranked list. Should the rationale behind the ranking of a particular project be questioned, the ranges used in prioritizing easily identify the basis for its classification.

A COMPARISON OF THE ORIGINAL AND THE PROPOSED PRIORITIZING METHODS

Many of the elements of the Department's prioritizing scheme are retained in the design of the proposed method. The primary differences include utilization of the most significant and objective of the original variables, and the sequential sorting technique using broad ranges of variables to replace the weighting approach. Four variables are utilized in the proposed system as opposed to nine in the Department's current system (Table 7). The original emphasis on volume variables is retained in the proposed scheme. Accident rate is again incorporated as an indication of safety but given a greater contribution to prioritizing classification. The proposed system introduces a condition variable. The modifications result in a method that is conceptually simpler than the original system, yet capable of achieving the same goals in the final ranking results.

The two systems can be evaluated by comparing priority ratings obtained using both methods for the same group of projects. Primary road projects already prioritized using the original scheme and for which the necessary data were available were selected from the inventory lists provided by the TPD. The priority ratings resulting from each system were carefully compared for their similarities, differences, and the factors underlying any disparity.

Table 7

Comparison of Department and Proposed Variables

Prioritizing Categories	Department Priority System Variables		Proposed Priority System Variables
Service	Existing V/SV	30 pts	V/SV
	Forecast V/SV	20 pts	
	Existing VPD	6 pts	ADT
	Forecast VPD	6 pts	
	Route Continuity	5 pts	
	Geometrics	5 pts	
Safety	Accident Rate	5 pts	Accident Rate
Condition			Pavement Condition
Other	Cost/Future VMT	5 pts	
	Functional Classification	10 pts	

Correlation and Regression Analyses

The two methods were analyzed using the Statistical Package for Social Sciences (SPSS) program. The major variables in the Department's system for which data were available (existing and forecast V/SV, functional classification, existing and forecast ADT) were assessed for their contribution to the ratings assigned by the Department and their correlation with the Department's and the proposed system's priority ratings. Sufficient data were not available for geometrics, route continuity, and accident rate to permit statistical evaluation, but these categories only contribute 5 points each to the total score.

A correlation analysis was performed between the ratings resulting from the proposed and the Department's prioritizing systems. The statistical evaluation revealed a high correlation of 0.71 ($p < .001$) between the ratings obtained from the two prioritizing systems, indicating that the proposed and the Department's systems result in similar priority ratings for most of the projects analyzed. Although yielding similar results, the proposed system is much simpler to comprehend and requires less data.

Correlations among the individual variables in the Department's system were also analyzed; they revealed high multi-colinearity among the Department's variables. In other words, a number of the variables contributing to the Department's rating are strongly interrelated, resulting in repeated consideration of similar criteria. The statistical correlations between the variables are shown in Table 8. Roads with a high V/SV also have a high functional classification, ADT, and future ADT. This has the effect of imposing another weighting system on the data because interrelated variables involve counting an underlying factor twice; thus, they contribute more to the final ranking than independent ones. Although variables should independently contribute to the final rating results, points in the VDOT system are separately awarded for variables most of which are based on volume. The correlations between the individual variables and the ratings awarded by each system are shown in Table 9. The highest correlation for ratings in each system is with the variable V/SV. Surprisingly, despite the strong influence of volume in both systems, all of the major volume variables have a higher correlation with the proposed system's ratings.

A series of regression analyses was done examining the variables and the rating results. The Department's variables were used to predict the Department's rating results, and the proposed system's variables were similarly evaluated for its rating results. Then a regression analysis was performed to evaluate the ability of the proposed system's ratings to predict the ratings obtained with the Department's method.

Table 8

Correlation Matrix of Prioritizing Variables

	Functional Classification	ADT	Forecast ADT	V/SV
ADT	.4719			
Forecast ADT	.4465	.8659		
V/SV	.5186	.7598	.6972	
Forecast V/SV	.0837*	.0590*	.0884*	-.0590*

* Not significant

Table 9

Correlation of Variables with Prioritizing Results

	Functional Classification	ADT	Forecast ADT	V/SV	Forecast V/SV
Proposed	.4555	.6400	.5400	.8381	-.1157*
Department	.4212	.5094	.4478	.6300	-.1262*

* Not signficant

Forty-two percent of the variance in the Department's rating results was attributable to the system variables. V/SV was the variable that best predicted the Department's system ratings. Its predictive value was the highest of the variables (39% percent). Only one variable, forecast V/SV, lacked any correlation with the ratings. This may actually indicate that there is no relationship between the future V/SV variable and the rating results, or it may have been the result of inconsistencies in the data provided to the researchers.

The regression analysis of the proposed system and its primary variable indicated that 0.70 of the variance in the research prioritizing results was attributable to V/SV. This close relationship should be anticipated since the ratings were based primarily on the V/SV volume consideration, with provision to elevate some project ratings on the basis of ADT and accident rate.

From another regression analysis, 50 percent of the variance was obtained using the proposed system's ratings to predict the Department's ratings. This value was appreciably higher than the 42 percent of the variance that was attributable to the Department's own system variables. In other words, the proposed prioritizing system was statistically more predictive of the Department's priority rating than any of the Department's system variables considered individually or collectively. This peculiar result may be partially the result of assigning priority ratings for some projects independently of the prioritizing system results on a nontechnical basis.

The use of nontechnical prioritizing methods is common among highway administrators and is frequently based on relevant considerations that are difficult to include in a prioritizing system (Transportation Research Board, 1978). However, the failure of the Department's system variables to predict the final priority ratings as accurately as the proposed system's results suggests that the current method does not reflect the Department's criteria for project prioritizing as effectively as the proposed system does.

Analysis by V/SV

V/SV is a fundamental variable in both prioritizing systems. Therefore, a comparison of the ranges and averages of V/SV values between the priority groups obtained by each method should assess the consistency of the two systems and indicate whether the simplified V/SV ranges in the proposed system accurately reflect the Department's priority group ranges.

The Department's system yields prioritized categories with an average V/SV similar to those obtained using the proposed method (Table 10). This indicates that the high, medium, and low ranges selected for the volume variable in the proposed system categorize projects for this important variable similarly to the weighting system. The V/SV values of the medium priority projects are consistently above those in the low priority categories, suggesting an effective separation of the projects into distinct and homogeneous groups, although some overlap of V/SV would be anticipated because of the influence of other variables (Figures 8 and 9). A comparison of graphs of the V/SV values of the projects in each prioritizing category in the research and Department systems also demonstrates that the distribution of the fundamental variable V/SV for low and medium priority projects is very similar between the two methods (Figures 10 and 11). In contrast, the graphs of the proposed system's and the Department's high priority groups are markedly dissimilar (Figure 12). The Department system's high priority projects span the entire range of V/SV, with almost two-thirds of the projects having a V/SV below 1.50 and one-third having a V/SV less than 1.20. Projects with V/SV values as low as 0.23 are found in the Department's high priority group, whereas the proposed system's high priority group consistently includes a homogeneous subset of projects distinct from those in the medium and low categories (Figure 8).

Table 10

Averages and Ranges of V/SV by Rating Group

Department's Prioritizing Scheme -- District 1		V/SV	
Rating	Average	Maximum	Minimum
High	1.46	3.18	0.23
Standard Deviation	0.54		
Medium	0.95	1.44	0.58
Standard Deviation	0.16		
Low	0.73	0.99	0.21
Standard Deviation	0.17		
Proposed Prioritizing Scheme -- District 1			
High	1.95	3.18	1.04
Standard Deviation	0.46		
Medium	1.15	1.44	0.50
Standard Deviation	0.17		
Low	0.78	1.00	0.21
Standard Deviation	0.18		
Range of District 1			
All Projects	1.11	3.18	0.21
Standard Deviation	0.49		

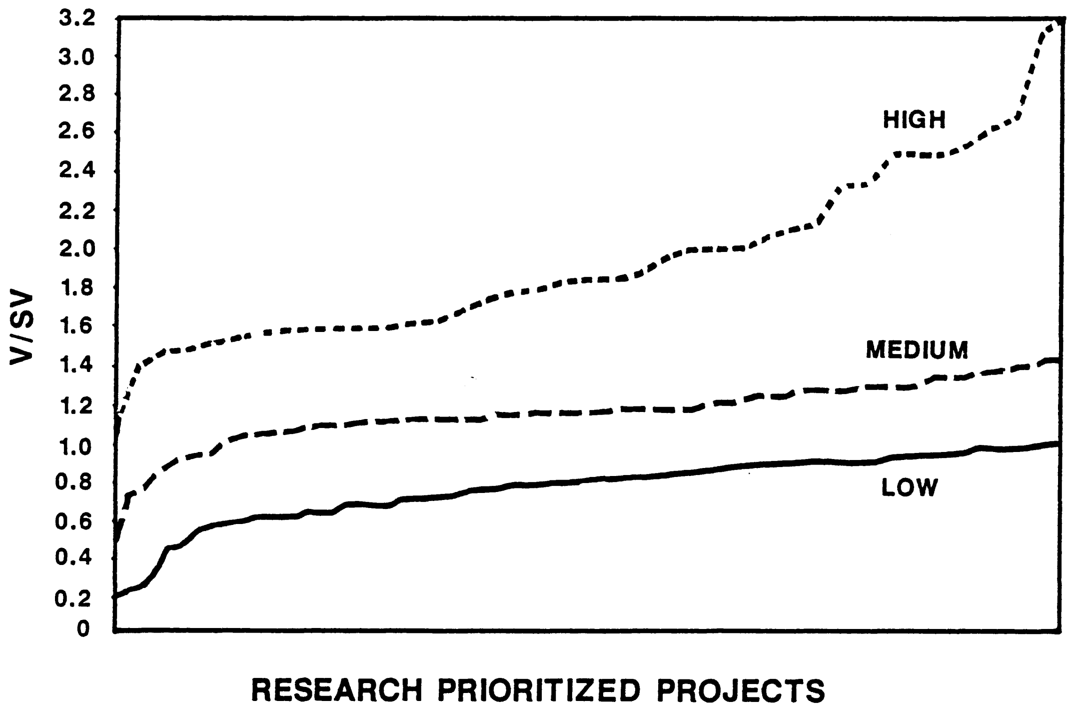

Figure 8. V/SV of research system prioritized projects.

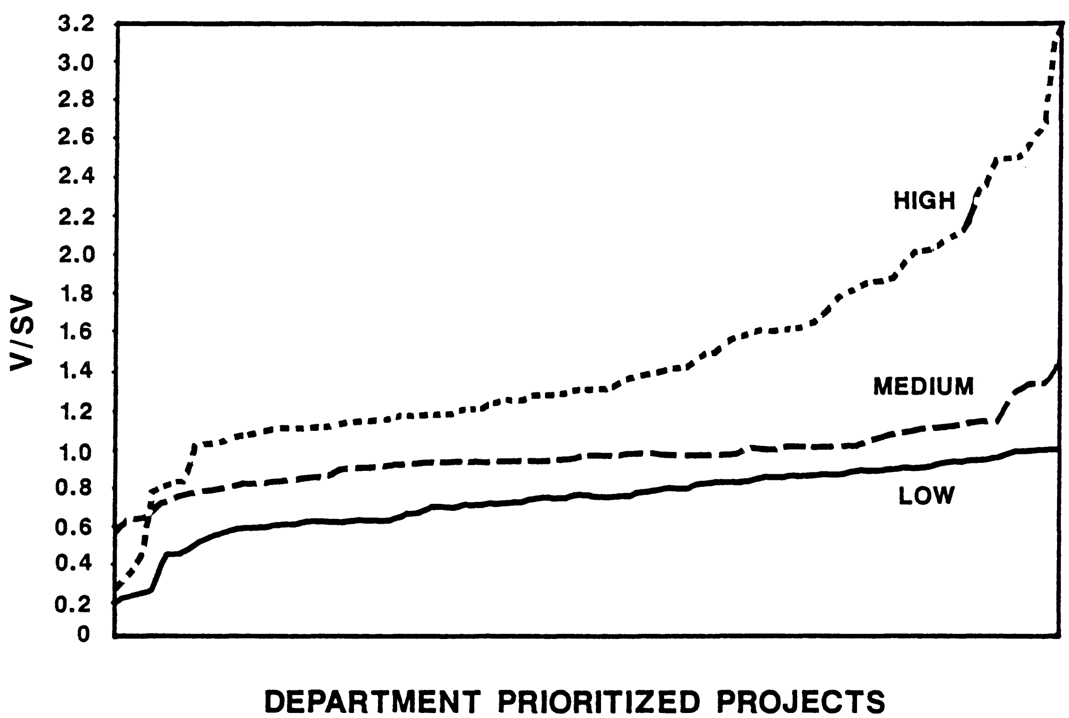

Figure 9. V/SV of Department system prioritized projects.

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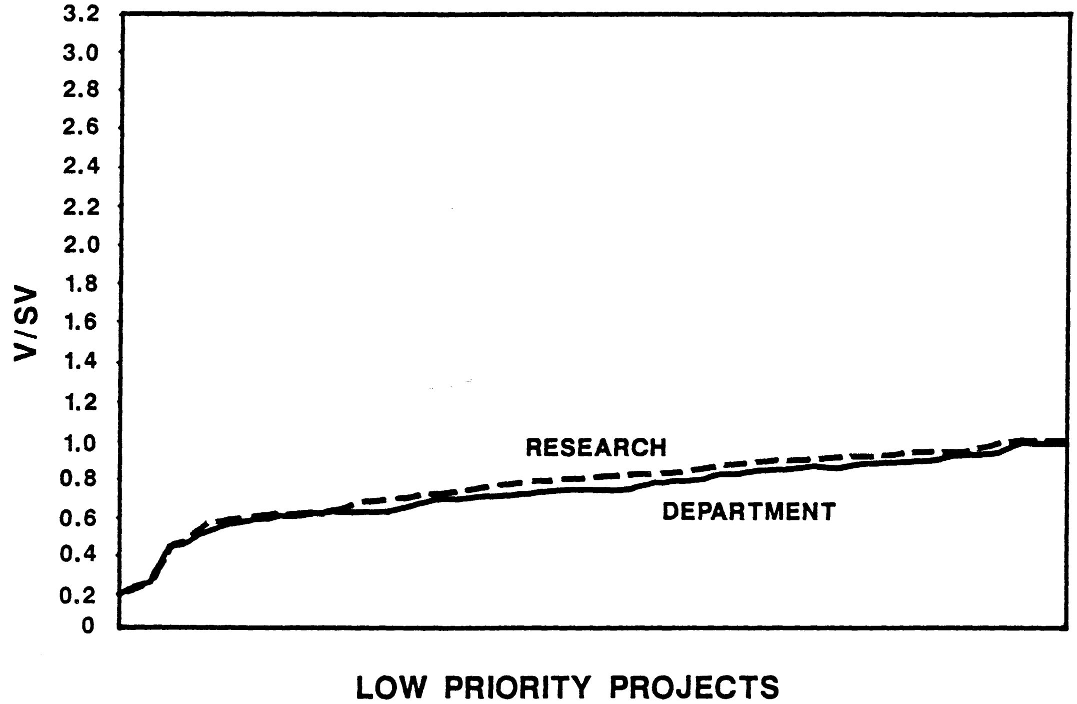

Figure 10. V/SV of low priority projects.

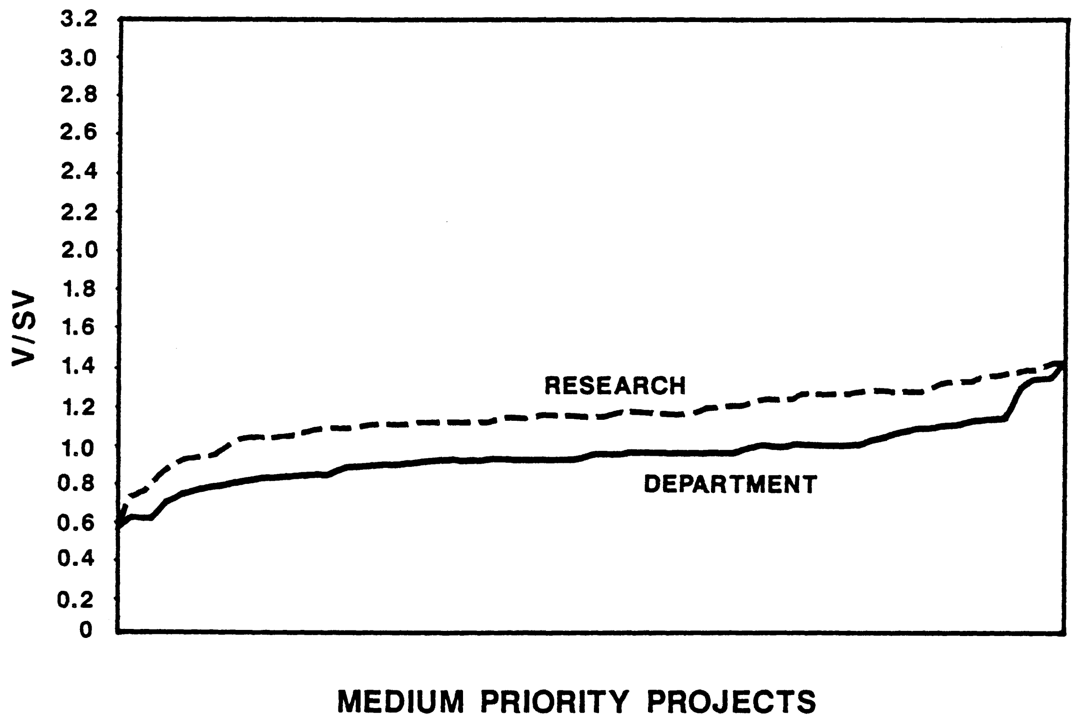

Figure 11. V/SV of medium priority projects.

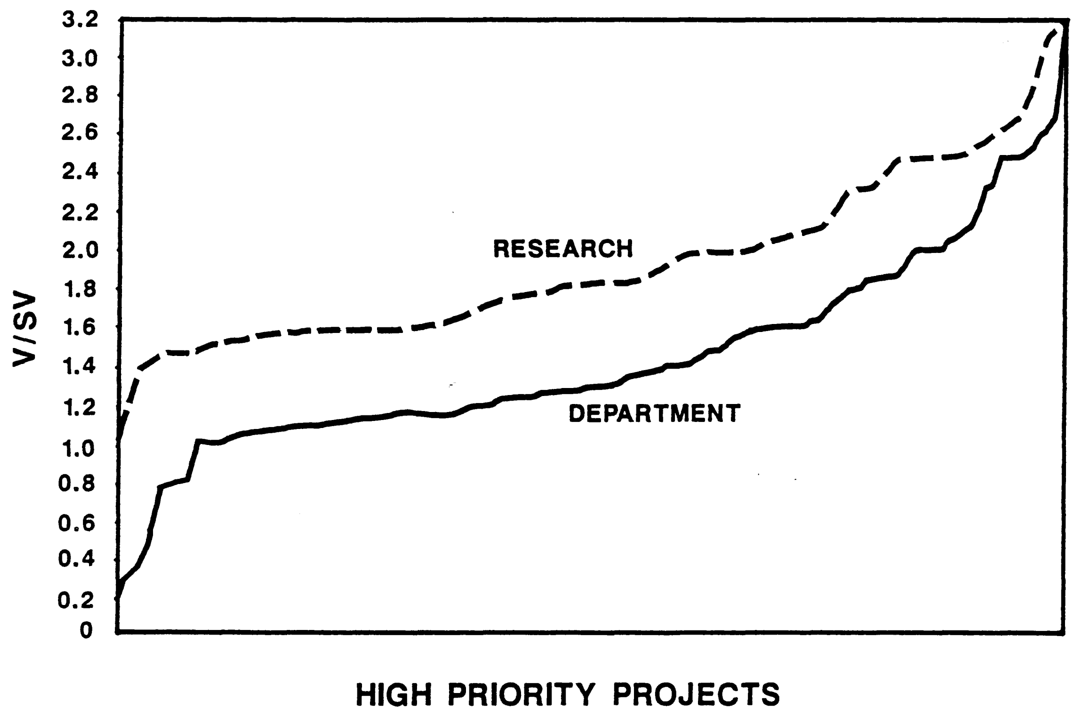

Figure 12. V/SV of high priority projects.

SUMMARY OF FINDINGS AND CONCLUSIONS

The original prioritizing system has several flaws that impair its reliability, consistency, and effectiveness as a tool to select the most needed projects.

- Multiple interrelated variables result in repeated consideration of a single prioritizing factor--volume.
- The extensive use of theoretical future variables introduces considerable error and contributes little to the identification of current urgent highway needs.
- Several of the variables have essentially no effect on the final priority ratings because of a disproportional allotment of weights.
- The assignment of priority levels relative to other projects by dividing the ranked list into thirds by cost rather than by using criteria to define needs limits the number of projects to be presented for funding and makes the justification of projects selected for implementation difficult.
- Inconsistencies were found in the ratings, especially in the high priority categories.

Although weighting systems are the most commonly used method of prioritizing in state departments of transportation, they have several limitations, namely an insensitivity to individual variables, an inflexibility to modifications without a restructuring of the point system, and difficulty in designing an optimum weight and point system.

In consideration of these limitations, a nonweighting system was designed for prioritizing. The new prioritizing method uses a sequence of ranking steps. Fewer variables are employed than in the original scheme, and broad ranges identify a project as adequate, marginal, or inadequate by each criterion. Each variable has an effect independent of the other variables and can contribute to the final priority ratings. Consequently, the system is more sensitive to each variable. The strong consideration of volume is retained in the new system, but the system was structured to allow the contribution of many considerations to the final classification. It can be amended by adding variables and changing ranges more easily than a weighting method. Criteria for ranking a project are defined by ranges and threshold values to justify the final rating and to produce homogeneous classifications.

The original and proposed systems were compared statistically. The analysis revealed a high correlation between the ratings achieved by the two systems. The average ranges of V/SV within the high, medium, and low priority groups were also similar, indicating that the three broad ranges chosen for the proposed system closely approximate the results achieved with the more complicated, finely graduated point system currently used by the Department. The most surprising result was obtained using regression analyses of the Department's variables and the proposed system's ratings to predict the Department's system's ratings. The proposed system's ratings were appreciably higher (0.50) than the Department's system's own variables (0.42) in predicting the Department's system's rating. Regarding the lower predictive value of the variables, this may represent the effect of nontechnically based decisions on ratings that did not entirely result from the prioritizing system. If so, the proposed system's ratings more closely reflect the goals of the Department in setting priorities.

SUGGESTIONS FOR FUTURE RESEARCH

An area for future research would be a condition rating that incorporates more information than current pavement condition. For example, studies of pavement distress ratings have indicated that some roadways are more sensitive to traffic load and deteriorate more rapidly. Projected ratings have indicated a period of decline to threshold value ranging from less than three to greater than seven years for different roadways (McGhee, 1987). Assessment of the rate of roadway deterioration would be useful to incorporate into a prioritizing system.

RECOMMENDATIONS

A computer model was developed in the implementation phase of this project that will enable the Planning Division to implement this system. It is recommended that the Planning Division work with the Research Council to test, modify, and if results are favorable, implement this system.

The benefit of using the program developed for applying this system in each Construction District should be studied. The districts may be able to benefit by categorizing projects into short-, medium-, and long-range according to cost (e.g., under $10,000 as short-range, $100,000 and greater as long-range, etc.) and evaluating each category separately instead of evaluating all projects concurrently.

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