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Sufficiency Ratings for Secondary Roads: Model Development

CLETUS R. MERCIER

ABSTRACT

Work has been done to develop numerical evaluation systems for priority planning use with secondary roads. However, the resulting systems are somewhat local in orientation and are not easily usable in other parts of the country because of differences in road networks, terrain, soil and weather conditions, and even political climate. Most state highway organizations use a form of numerical evaluation called sufficiency rating systems for priority planning. However, this practice is not prevalent in county highway organizations. County highway administrators have used a priority system that is commonly the composite of (a) knowledge of the local road network and its condition, (b) comparison of road conditions with a set of objectives (whether formally or informally adopted), and (c) political expediency. The research reported here was undertaken to develop a sufficiency rating system for secondary roads in Iowa. If a usable system that would yield reasonable results were available, county engineers would have an additional tool to assist them in arriving at a defensible road improvement program. The steps taken to develop the proposed model are recounted in this paper. Described are the instrument used to gather data to choose the rating criteria, the criteria chosen, their relative weights, and the final form of the model.

Work has been done to develop and improve numerical evaluation systems for priority planning use with secondary roads (1-7). However, the resulting systems are local in orientation and have limited application to planning needs of road systems in other parts of the country. Enough differences exist in road networks, terrain, soil conditions, weather conditions, and even political climate to preclude direct application.

There are elements of these systems that are reusable in other locations. Most rating systems are patterned after the sufficiency rating system originally developed by the Arizona Highway Department in 1946. Most systems even use much the same list of rating criteria and the maximum composite rating of 100, although there are some variations in the relative importance of the criteria.

The choice of rating criteria and the relative importance of each criterion compared with the others used make it possible to tailor the system to fit local needs. This is because sufficiency ratings are "descriptive": they use a mathematical expression as a measure of immediacy of need. The choice of criteria used and their relative importance (relative weight) is an empirical process based on an evaluation of past design practice and the resulting investment.

Although most state highway organizations use sufficiency rating scores for priority planning, the

Department of Engineering, 403 Marston Hall, Iowa State University, Ames, Iowa 50011.

practice is not prevalent in county highway organizations. County highway administrators have used a priority planning system that is commonly the composite of

1. Knowledge of the local road network and its condition,
2. Comparison of road conditions with a set of objectives (whether formally or informally adopted), and
3. Political expediency.

Job longevity is at least partly based on how well the administrator's perception of priorities matches that of the local population. A numerical evaluation system can help simplify the priority planning process and provide defensible results for the county highway administrator, but only to the extent that the results coincide with local perception of needs. This suggests that county highway administrators are the people best qualified to choose the rating criteria and their relative weights. In Iowa these people would be the county engineers.

The research reported here, sponsored by the Iowa Department of Transportation, was undertaken to develop a sufficiency rating system that could be used for secondary roads in Iowa. If a usable system that would yield reasonable results were available, county engineers would have an additional tool to assist them in arriving at a defensible road improvement program.

PROCEDURE

There were several assumptions made at the outset:

1. County engineers currently use at least a limited set of decision criteria in making decisions regarding project priorities.
2. Some degree of consensus exists among the county engineers about which are the most important criteria and their relative importance.

A questionnaire was developed to be used as a survey tool. Results of the survey were used to develop a final list of weighted rating elements that in turn were used as part of the proposed sufficiency rating system.

The purpose of the questionnaire was to determine whether any degree of consensus existed among the county engineers about preference for a set of rating criteria and the relative importance of each. If such a consensus existed, it could be used as a basis for choosing the rating criteria and their relative weights for use in a proposed sufficiency rating system for county roads.

The rating criteria list included in the questionnaire represented a composite list of criteria employed by 12 states currently using sufficiency rating systems. They were arranged by the categories of condition, safety, and service. (These were the categories first used in the Arizona rating system and they have also been used in most rating systems developed since that time.) Two lists of criteria were provided in the questionnaire, one for roads with the functional classification of either trunk or trunk collector and one for roads classified as area service. [Most of the paved secondary roads in Iowa are classified as trunk or trunk collector, and little of the mileage of area service roads is paved (8).] It was anticipated that county engineers would show different preferences for rating criteria for the different functional classes.

One additional element was included in the questionnaire. Most systems developed to date have grouped the rating criteria into the categories of condition, safety, and service. Respondents were asked to place the categories in rank order first and then to designate how they perceived their relative importance by inclusion of a weighting factor. (Respondents were asked to rank the categories as 1, 2, or 3, designating the most important a 1, followed by the other two in rank order. Relative importance was to be indicated by assigning the relative weight of 10 to the most important category and smaller relative weights, ranging from 9 to as low as 1, to the other two categories.)

This portion of the questionnaire was included in case there was no consensus on the ranking and weighting of the rating criteria. A measure of agreement about the ranking or weighting, or both, of the rating categories might prove to be useful in identifying the most appropriate criteria to use. A brief description of each of the rating elements was enclosed with the questionnaire to aid the respondents.

DATA ANALYSIS

Response to Questionnaire

A total of 108 questionnaires were mailed to county engineers and engineers from the Iowa DOT. Of these 108, 71 were completed and returned, providing a return rate of 67 percent. The 71 received included 66 from county engineers (67 percent return rate) and 5 from Iowa DOT engineers (56 percent return). Figure 1 is a map of the state of Iowa that shows the political boundaries of the 99 counties. Responses were received from engineers in the shaded counties. Most of the counties with larger urban areas returned completed questionnaires. Rural sections of the state are well represented.

Identification of Preferred Rating Elements

The initial step in processing the raw data was to place them in a computer file, using a data processing format.

Frequency distributions were then computed for each rating criterion listed in the questionnaire by category, rank, and weighted rank. The form shown in Figure 2 is the same as the one provided in the questionnaire.

Mean and median scores plus the standard deviation from the mean were also computed for each criterion. Although the mean, median, and standard deviation were of value, frequency distributions were the most useful in isolating those rating elements deemed most important by the respondents. As expected, the weighted rank of the rating elements identified the preferred rating elements most clearly.

The frequency distributions were carefully examined to identify a set of rating elements that consistently ranked high in comparison with all of those suggested. Although provision was made on the questionnaire to write in additional rating elements, only one respondent did so. Therefore only those elements listed on the questionnaire were considered.

Examination of the frequency distributions produced some fairly conclusive findings in terms of selection of a set of preferred rating elements. The results are described next.

Selection of Preferred Rating Elements

A total of 15 rating elements were consistently ranked high by respondents. These elements were regarded as important in evaluating trunk and trunk

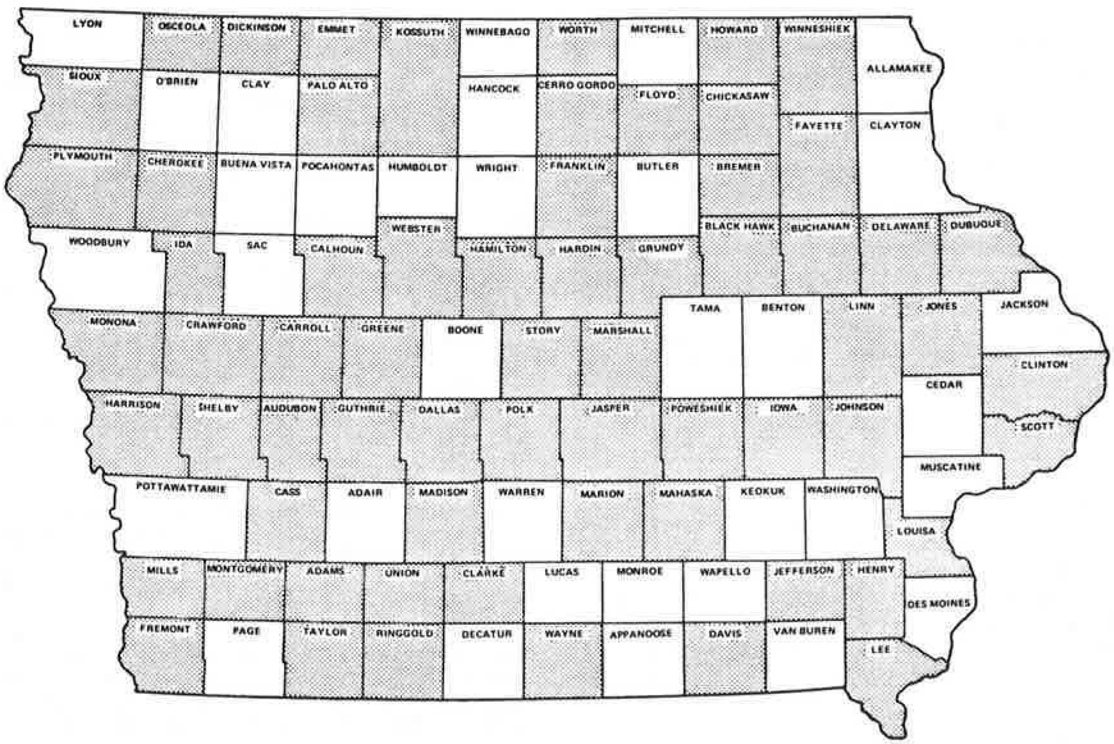

FIGURE 1 Counties responding.

	RANK BY CATEGORY	OVERALL RANK	WEIGHTED RANK
CONDITION			
Foundation	___	___	___
Wearing surface	___	___	___
Shoulder	___	___	___
Drainage	___	___	___
Remaining life	___	___	___
Maintenance economy	___	___	___
SAFETY			
Pavement width (surface)	___	___	___
Shoulder width	___	___	___
Right-of-way width	___	___	___
Stopping sight distance	___	___	___
Passing sight distance	___	___	___
Hazards (safety)	___	___	___
Alignment consistency	___	___	___
Traffic control	___	___	___
Accident rate	___	___	___
SERVICE			
Alignment (horizontal)	___	___	___
Alignment (vertical)	___	___	___
Pavement width (surface)	___	___	___
Improvement continuity	___	___	___
Ride quality	___	___	___
Surface type	___	___	___
Shoulder width	___	___	___
Snow problems	___	___	___

FIGURE 2 Form for rating element weights for trunk and trunk collector roads.

collector roads as well as area service roads, although there was some variation in ranking for the different road classifications.

Table 1 gives a brief summary of the survey results. A decision was made to include only those criteria that were consistently ranked high by the respondents. A weighted rank of 80 was chosen as the lower limit. Table 1 gives the cumulative percentage of the frequency of responses that ranked the criteria at a weight of 80 or higher.

TABLE 1 Survey Responses (cumulative percentage, weighted rank = 80+)

	Trunk and Trunk Collector	Area Service	Average
Condition			
Foundation	54	64	60
Wearing surface	60	60	60
Shoulder	14	13	12
Drainage	38	60	49
Remaining life	34.7	24.5	29.6
Maintenance economy	57.1	63.3	60.2
Safety			
Pavement width (surface)	38	30	34
Shoulder width	18	16	17
Right-of-way width	4	10.2	7.1
Stopping sight distance	58	52	55
Passing sight distance	40	34	37
Hazards (safety)	70	64	67
Alignment consistency	44	36	40
Traffic control	48	46	47
Accident rate	56.3	50	53.2
Service			
Alignment (horizontal)	42	48	45
Alignment (vertical)	38	42	40
Pavement width (surface)	26	22	24
Improvement continuity	24	20	22
Ride quality	44	44	44
Surface type	20	32	26
Shoulder width	8	10	9
Snow problems	36.7	48	42.3

Six of the most preferred rating elements received consistently high weighted rankings from respondents for all secondary roads:

1. Maintenance economy,
2. Foundation,
3. Wearing surface,
4. Drainage,
5. Hazards, and
6. Stopping sight distance.

Though not equal, they consistently ranked high in comparison with all other rating elements.

Two additional rating elements were also ranked high for all secondary roads, though at a lower level:

1. Traffic control and
2. Pavement width.

However, pavement width was double-listed on the questionnaire; it was included under both Safety and Service. An evaluation of the responses showed that (when both listings were considered) pavement width (roadbed width) should be considered one of the most important of the rating elements.

A third cluster of rating elements on the preferred list was ranked differently for area service roads than for trunk and trunk collector:

1. Passing sight distance,
2. Accident rate,
3. Ride quality,
4. Horizontal alignment,
5. Vertical alignment,
6. Alignment consistency, and
7. Snow problems.

The responses suggested that there should be some differences between the sufficiency rating system proposed for trunk and trunk collector roads and the system for area service roads. These differences were considered when the suggested scales for the rating elements were developed.

The list of criteria, together with a first draft of the proposed model, was presented to an advisory committee composed primarily of county engineers. The committee concurred with the findings with minor exceptions. They suggested deleting alignment consistency and adding surface type (for unpaved roads) and shoulder width (for paved roads).

The final list of criteria chosen includes 14 for paved secondary roads and 14 for unpaved. The survey results did not suggest, however, that each criterion should be given equal weight. Instead results suggested that the criteria should be scaled to provide for differences in emphasis. Before proceeding, a determination was made of the logical rating category for each element to simplify the weighting procedure.

The first four rating elements--maintenance economy, foundation, wearing surface, and drainage--all relate quite well to the Condition category. They all are strongly associated with the condition of the roadbed. Logically, all four should be included in that rating category.

Most of the rest of the preferred rating elements represent some characteristic of safety, and it would be consistent to include them in that category. Rating elements of that type are enumerated next, and a brief explanation of the rationale for inclusion is presented.

1. Accident rate and hazards are obvious choices for inclusion under Safety. By definition, a hazard represents an accident risk.

2. Stopping sight distance represents a potential for accident in that, at design speed, a driver cannot see far enough ahead to make an emergency stop. Traffic control covers stop signs and other traffic control devices and indicates the existence of any problem traffic control sites, which also present potential safety problems.

On the other hand, restricted passing sight distance could present two different problems--one related to Service, in its constraint of traffic capacity, and the other to Safety, in that a driver could take an unnecessary risk in attempting to pass a slower vehicle. Because traffic is usually light on secondary roads, the threat to safety represents the greatest problem, so this criterion has been included under Safety.

3. Pavement width or roadbed width has an effect on both safety and service. Being too narrow can make driving somewhat hazardous, but it also affects driving comfort and traffic capacity. A decision to place this rating element in either category is arbitrary, but including it under Service appeared to be more appropriate. Ride quality and surface type were also placed under Service because they relate mostly to that category.

4. Horizontal alignment is another rating element that can affect both a road segment's relative safety (by reducing visibility or forcing a reduction in speed to safely negotiate a curve or both) and service (by affecting driver comfort and road capacity). As was the case with pavement width, placement is somewhat arbitrary, but the decision in this instance was to include it in the Safety category.

However, the inclusion of vertical alignment in the system model presents a dilemma. Poor vertical alignment can result in portions of a road segment with safe stopping sight distance or safe passing sight distance problems, or both, but these are elements already included in the proposed rating system. Even though vertical alignment can affect service (lowered capacity, higher operating costs, and lessened driver comfort), these factors are less important for secondary roads. For these reasons, this rating element was not included in the proposed model.

5. Shoulder width is associated with both safety and service. However, because it applies only to paved roads, it was placed under Service because it then balances surface type. (Shoulder width is included under roadbed width for unpaved roads.) Snow problems are more obviously associated with service in that they can restrict access to a road.

If the rating elements were placed in rating categories as previously suggested, there would be four under Condition, six under Safety, and four under Service. The following table gives the suggested breakdown by rating category.

Rating Category	Item Rated
Condition and maintenance experience	Foundation
	Wearing surface
	Drainage
	Maintenance economy
Safety	Accident rate
	Hazards
	Stopping sight distance
	Passing sight distance
	Traffic control
	Horizontal alignment
Service	Pavement (roadbed) width
	Ride quality
	Snow problems
	Surface type (unpaved roads)
	Shoulder width (paved roads)

Proposed Relative Weights--Rating Categories

As noted earlier, most rating organizations use a maximum composite rating of 100, with each rated criterion assigned a maximum value. Each of the three rating categories is assigned a share of the 100 points, with the rating elements allocated a fraction of that share.

The proposed rating system is also based on a maximum value of 100 because it is familiar to most highway engineers. What remains is to determine the relative share that should be assigned to each category.

The completed questionnaires contained sufficient information to approach this problem from three directions. An evaluation of the three approaches yielded a reasonable range of values. They are described briefly next.

1. An analysis of the category rank suggested by respondents. Respondents were asked to rank the three rating categories in order of perceived importance.
2. An analysis of the category weights suggested by respondents. After the respondents ranked the rating categories, they were asked to weight each category relative to the other two.
3. A weighted average that used the preferred rating elements and their relative weights. Some of the rating elements were considered more important to the rating system than others. An evaluation of these differences in relative weights of the rating elements, combined with others in the most logical rating category, could serve as a guide to the appropriate weights of the three rating categories.

The following range of values was suggested:

1. Condition--30 to 38 points,
2. Safety--32 to 47 points, and
3. Service--20 to 32 points.

An analysis of the simple ranking of categories suggested a breakdown of 38 points for the Condition category, 37 points for Safety, and 25 points for Service (for trunk and trunk collector roads) and 37-32-31 (for area service roads). An evaluation using weighted category ranking results in a proposed breakdown of 35-35-30 (trunk and trunk collector) and 36-32-32 (area service). The third approach used the weighted preferred rating criteria, with the rating criterion of horizontal alignment shifted from Service to Safety. This results in a suggested scale of 30-47-23 (trunk and trunk collector) and 30-44-26 (area service).

The method used in Approach 2 best reflects the opinion of the respondents to the questionnaire, in that they were able to weight the rating categories as well as rank them. Moving horizontal alignment from Service to Safety and the deletion of vertical alignment from Service would change the proportions of Safety and Service from 35-30 to 40-25, which comes close to that suggested by the third approach. Therefore the proposed scale was

1. Condition--35 points,
2. Safety--40 points, and
3. Service--25 points.

Analysis of the completed questionnaires did suggest a slightly different breakdown of points for the model between trunk and trunk collector roads and area service roads. This resulted in a slightly higher total for the Service category than for Safety. This variance was reflected in the use of the model and forms for the first trial run, but its effect on the resulting ratings was negligible. Therefore the same breakdown of points has been proposed for all secondary roads to be rated.

Proposed Relative Weights--Rating Elements

The final step in the formation of the proposed model was to ascertain the appropriate maximum point value for each included rating element. The list of preferred rating elements and their relative weights, referred to earlier, were used to resolve this last problem. All that remained was to make such adjustments as were necessary to the individual weights to match the category weights in the proposed models.

For example, the proposed weight to be applied to the Condition category is 35 points (of a possible 100). Four rating elements were included in that category: foundation, wearing surface, drainage, and maintenance economy. Respondents ranked foundation, wearing surface, and maintenance economy about equally, and drainage was ranked slightly lower. Dividing the 35 points that were allocated to that rating category among the four rating elements resulted in the following breakdown:

1. Foundation--9 points,
2. Wearing surface--9 points,
3. Drainage--8 points, and
4. Maintenance economy--9 points.

A similar procedure was used for the rest of the model. Respondents weighted snow problems slightly heavier for area service roads than for trunk and trunk collector roads, and there was a corresponding decrease of the rating element ride quality. This one minor adjustment was made in relative weights in the model for the first trial run. However, as noted earlier, its effect on the resulting ratings was negligible. Therefore, except for variations relating to surface type, the same basic model is proposed for all secondary roads.

It should be noted, however, that some minor variations in its use are applicable, depending on the road's surface. These variations are described next.

1. If the road is paved, pavement (roadbed) width refers to hard-surface pavement width. If the road is unpaved, this rating element refers to the width of the traveled way. This width is the distance between the top of the foreslope on one side of the roadway and the top of the foreslope on the other side. For sufficiency ratings, this distance will be compared with the design standard for that particular functional classification expressed as the sum of all lane widths and shoulder widths.
2. If the road is unpaved, shoulder width becomes part of the roadbed width. Therefore it is not rated separately but becomes part of the traveled way and is rated as part of the pavement (roadbed) width.
3. If the road is unpaved, its surface type will be rated. A paved road will receive the maximum rating (in terms of surface type) no matter what design standard applies. Therefore inclusion of this rating element will not result in any loss of points and this element need not be included. Any existing road surface of a lesser quality on the rated road segment will result in the inclusion of the surface type rating element, so it can be compared with the design standard.

Table 2 gives the resulting model with the maximum weight of each criterion listed.

TABLE 2 Final Proposed Sufficiency Rating System Model

Rating Category	Item Rated	Maximum Points
Condition and maintenance experience (35 points)	Foundation	9
	Wearing surface	9
	Drainage	8
	Maintenance economy	9
Safety (40 points)	Accident rate	6
	Hazards	9
	Stopping sight distance	8
	Passing sight distance	5
	Traffic control	6
	Horizontal alignment	6
Service (25 points)	Pavement (roadbed) width	9
	Ride quality	5
	Snow problems	6
	Surface type (unpaved)	5
	Shoulder width (paved)	(5)

Trial Run of Model

A limited number of road segments were evaluated to provide an abbreviated trial run of the initial form of the model. The roads evaluated were located in central Iowa and ranged from a heavily traveled trunk road to lightly used area service roads. The sample was chosen with the expectation that the sufficiency ratings for these roads would encompass scores ranging from excellent to scores that would suggest critical needs.

Minor changes were made in the model on the basis of the first trial run. The revised model was then used in a more extensive test in another Iowa county. A sample of about 20 percent of the county's secondary roads was rated and the results were used to derive the final form of the model and rating forms recommended in the project report.

Questionnaire responses had suggested that there be slight differences in the point breakdown of the model for trunk and trunk collector roads and for area service roads. However, as noted earlier, the first trial run indicated that the same model could be used for all secondary roads for the second trial because differences in results were negligible. This also makes the model easier to use. The first trial run did not suggest any other changes, except for some revisions in record keeping.

Because the second trial run used a much larger sample of roads, it was possible to make some comparisons of the ratings. Use of the rating system yielded what appeared to be reasonable results. For example, scores on the trunk roads in the sample ranged from 73 to 96. The 96 score was for a nearly new, straight road in excellent condition. The road with the 73 score is much older and has narrow pavement and a number of curves. By most measures, it would be considered tolerable and the score indicates that. However, it is the most heavily used road in the county's secondary system, and the high accident rate would appear to reflect this combination of heavy use and road deficiencies. The score also suggests that this road should receive a high priority for improvement.

Choice of design standard also affected the ratings. One trunk road received a score of 80, but it was scored this high only because its traffic count was less than 200 vehicles per day (vpd). Had it been more heavily used (more than 400 vpd), it would have received a score of 71. It would appear that use of the design standard would help the county engineer to maximize the effect of tax funds spent by better meeting consumer needs.

The trial runs indicate that the proposed sufficiency rating system is feasible. However, the first time a sufficiency rating system is used for a given county, some extra effort will be required to gather data, especially data related to road geometrics. Once this has been done, however, much of the data gathered will be easily reusable; only those elements that change from year to year will need to be evaluated.

SUMMARY AND CONCLUSIONS

The objective of this study was to produce a sufficiency rating system that could be used to evaluate the adequacy of secondary roads in Iowa. The system developed should be reasonably easy to use yet yield results that are compatible with processes currently used in priority programming.

The model that is proposed uses the same format as that used by the Arizona Highway Department for the first sufficiency rating system developed in 1946. This format was adopted because it is well known, widely accepted, and comparatively easy to use. It is also considered to yield reasonable, reproducible results.

Models currently being used for primary roads are empirical in nature; they are numerical ratings that relate well to experience-based adequacy ratings. It follows that the experience of local engineering practitioners should figure heavily in determining the form of the proposed model. To that end, a questionnaire was developed that could be used to survey local engineering practitioners--mostly county engineers. A statistical analysis of the responses provided the basis for the formation of the model proposed in this paper.

Selection of rating criteria (and their relative weights) was based on the responses to the questionnaire. Scaling factors were based on the relative weights suggested by the responses and the model used by the Iowa DOT for primary roads. Maximum scores were established using a set of design standards adopted for the model.

To refine the model, some additional effort is needed to more easily access available data and more input is needed from potential and actual users. The comparative results produced by the trial runs suggest that the model is usable and should prove to be compatible with other processes used to form priority lists for project programming. It should provide results that are reproducible and defensible.

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A System for Forecasting and Monitoring Cash Flow as an Aid to Rational Financial Planning

GARY R. ALLEN

ABSTRACT

The research on which this paper is based was performed as part of a study to develop an improved system for generating a 2-year forecast of monthly cash flows for the Virginia Department of Highways and Transportation. It revealed that current techniques used by the department to forecast right-of-way payments; salaries and wages; and allocations to cities, counties, other state agencies, and transit properties require no change. On the other hand, it showed that forecasts of expenditures on materials, supplies and equipment, and maintenance contracts have overestimated actual cash outlays by significant margins. In addition, this research revealed that success in forecasting federal revenue reimbursements is, at best, likely to be spotty and that forecasts typically will be overly optimistic. For state revenues, official forecasts approved by the Office of the Secretary of Transportation of Virginia serve as the basis of the official cash forecast; nevertheless a technique is proposed for early identification of significant changes in state revenue collections. The use of techniques derived from this research in a December 1983 forecast of cash flows for January through July 1984 showed that the estimated cash balance for the end of the period was within $4 million of the actual balance. As of August 1985 the forecast was within $11 million of the actual balance. Among the major recommendations is that it may be reasonable to establish cash balances at contingency levels consistent with the expected excess of expenditures over revenues for the months of July through October.

Methods for forecasting and managing cash flow are well established in the private sector where inadequate cash balances can mean bankruptcy and excessive balances can result in forgone business opportunities. In the public sector, until fairly recently there was less perceived need for close forecasting and monitoring of cash flow. However, during the past several years, revenues for most transportation departments have become volatile and unpredictable, and construction expenditures have been subject to unprecedented rates of inflation. During such periods, a public works agency such as the Virginia Department of Highways and Transportation (VDHT) runs a serious risk of encountering inappropriate cash balance levels in carrying out its construction and maintenance program.

This risk can be minimized by (a) maintaining large cash balances that divert funds from current needs or (b) developing and using reliable management tools for short-term forecasting and monitoring

Virginia Highway and Transportation Research Council, Box 3817 University Station, Charlottesville, Va. 22903-0817.