Evaluation of RAMS-DO1 as a Tool for Project Programming

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The RAMS series of programs was developed to help the Texas State Department of Highways and Public Transportation with its Pavement Management System activities. The evaluation of the RAMS District Optimization Program in selecting projects to maximize network benefit is described in this paper. The trial involved using the system to analyze decisions made by a specific Texas District in 1985 to allocate its maintenance and rehabilitation funds. Decisions made by the district staff were compared with those recommended by the optimization scheme. The RAMS-DO1 program, the study indicated, has great potential to help the districts allocate their resources. However, only limited agreement was found between projects recommended by RAMS and those selected by the district staff. This was due to the following two reasons. First the district's needs greatly exceeded available funds. The overall district need for M&R work was estimated at \$35 million, but the district's allocation was only \$12.6 million. Therefore, the district had many miles of pavement in substandard condition and only 36 percent of the funds necessary to address that need. The second reason was that the district concentrated its M&R selections on the higher volume roads, whereas RAMS selected both high- and low-volume projects. This selection was based on its objective function which calculates benefit caused by improving pavement condition independent of the traffic served. This indicated the need to expand the RAMS objective function and a traffic factor was introduced in later runs.

In the early 1980s, the Texas State Department of Highways and Public Transportation (SDHPT) implemented its network-level Pavement Evaluation System (PES). Initially, only a small portion of the state's road segments were inspected. Since then, the sample size has increased considerably and in recent years, every mile of Interstate pavement has been inspected annually.

In general, the main user of PES data has been the Austin office to track network condition and estimate overall funding requirements. However, in an attempt to develop and implement applications at the district level, a project was initiated that had, as one of its objectives, the development of a user-friendly microcomputer package to assist districts with their maintenance and rehabilitation (M&R) operations. This microcomputer package is called MICRO-PES (Release 1.0). MICRO-PES currently contains four application programs:

1. A program to extract a user-selected set of road segments from the master PES data base called the create a subset file program (the file created by this program is used in the other three programs);
2. A program that uses a series of decision trees to help determine first-cut estimates of network M&R needs;
3. A program that selects the optimum set of M&R strategies for a given budget level; and
4. A program that estimates the amount and cost of routine maintenance required on any particular set of road segments.

More information on the MICRO-PES system can be found in the *MICRO-PES Release 1.0 User's Manual* (*1*).

To show how the third program mentioned above (RAMS District Optimization Program or RAMS-DO1) can be used to assist the district engineer in determining the "best" use of allocated M&R funds is the subject of this paper. RAMS, an acronym for Rehabilitation and Maintenance System, is a suite of computer programs developed to help the Texas SDHPT with its PES activities. The RAMS package operates at two distinct levels, the district level and the state level. One program for application at the district level is the RAMS District Optimization Program, referred to as RAMS-DO1. This program was developed to help districts select maintenance and rehabilitation activities that would make the best possible use of available resources for a particular fiscal year. Categories of resources considered include materials, equipment, manpower, and budget constraints.

Figure 1 provides an overview of RAMS-DO1. RAMS-DO1 provides a highway engineer with an analytical tool for evaluating the effects of different budget levels and drawing a budget-versus-benefit profile. The effects of changes in unit costs for manpower, equipment, and materials, or of different minimum rating requirements can also be evaluated.

The utility of RAMS-DO1 is illustrated here by performing a case study on decisions made in the Lufkin District (District 11) in 1985 relative to the selection of M&R projects. This particular district and time period were chosen because complete PES data for District 11 was available for 1985 and 1986. The 1986 data were needed to analyze the effect of decisions made in 1985 without the use of RAMS-DO1 and implemented in 1986. District 11 was also a good choice because most of its road segments are flexible pavements. RAMS-DO1 is currently set up to handle only flexible pavements.

Funds allocated to District 11 in 1985 were not sufficient to allow the proper M&R activity to be performed on each deficient road segment. Therefore, the problem for District 11 in 1985 was to find what M&R strategies should be applied to which road segments to make the best use of the allocated funds.

RAMS-DO1 is a 0-1 linear program that selects the "best" set of road segments and strategies based on a given budget

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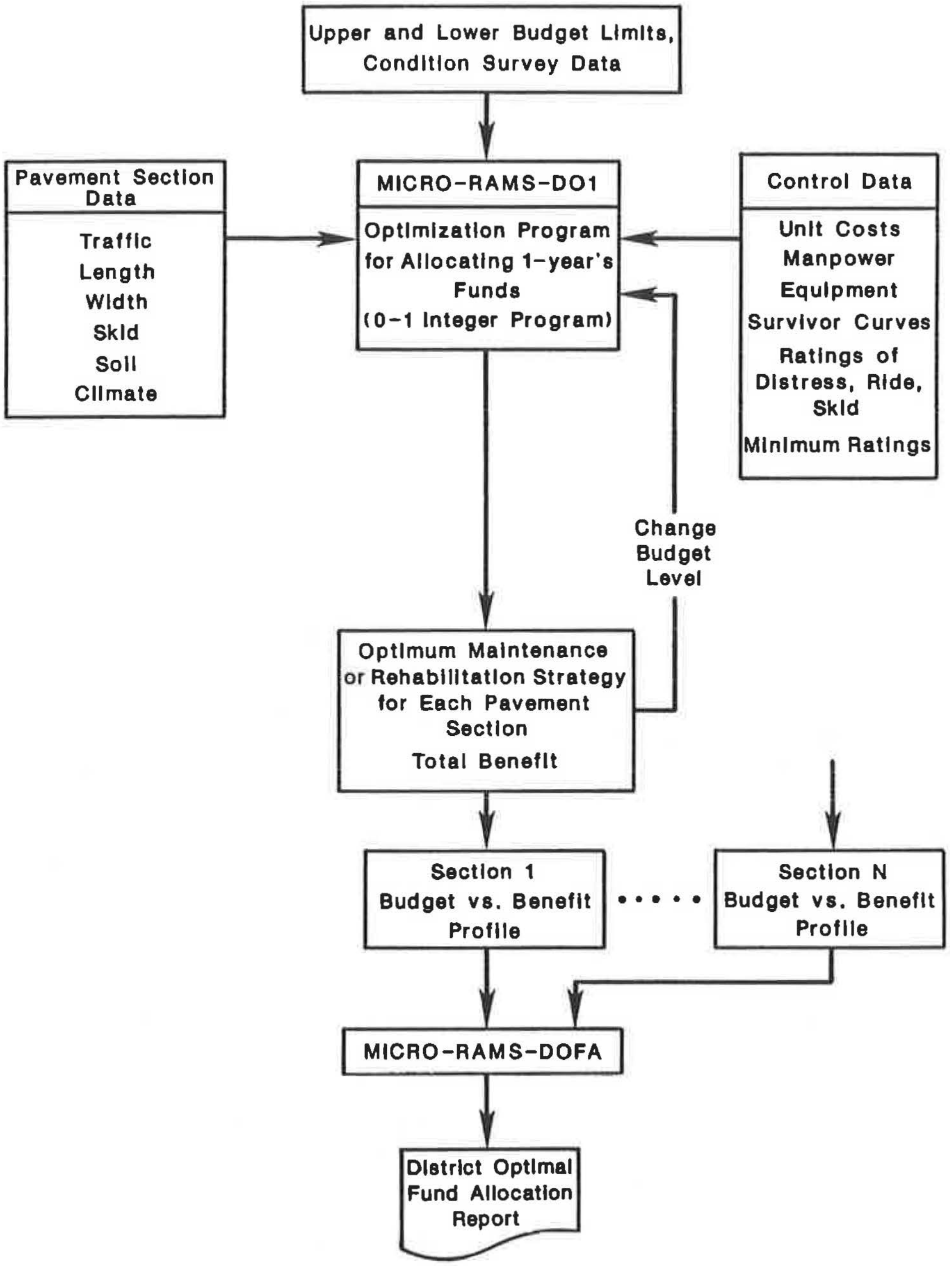

FIGURE 1 Overview of Micro-RAMS-DO1.

level. The best set is the one that maximizes the total "benefit" derived from the application of M&R strategies to road segments. The benefit for a combination of a particular road segment and M&R strategy is a function of the area of the road segment and a weighted measure of how the strategy performs in eliminating existing distresses over the next several years (the number of years is a user-supplied input—usually 10 years). Technical details concerning the program are presented elsewhere (*2–4*) and will not be repeated here. It is emphasized, however, that RAMS-DO1 is only a decision analysis tool. The purpose of the program is simply to assist in the decision-making process. There will always be factors affecting final decisions that are not incorporated into RAMS-DO1. The program, however, will give the district engineer a good idea of the road segments that should be seriously considered for M&R activities.

PRELIMINARY DATA ANALYSIS

This case study was based primarily on information derived from a list of pavement-related projects for fiscal year 1986 for District 11. The first step in analyzing this data was to determine for each project the RAMS-DO1 M&R strategy that most closely resembled the "Type of Work" as specified in the SDHPT projects list. Table 1 lists the M&R strategies currently available in RAMS-DO1.

A few of the project descriptions in the SDHPT list were identical to the names of the RAMS-DO1 strategies (e.g.,

TABLE 1 RAMS-DO1 M&R STRATEGIES

Strategy	Meaning
Fog Seal	As Stated
Seal Coat	As Stated
OGPMS	Open-Graded Plant Mix Seal
Thin Overlay	Less Than 2" Asphalt Concrete Overlay
Moderate Overlay	2"-3" Asphalt Concrete Overlay
Thick Overlay	3"-6" Asphalt Concrete Overlay
Light Duty Reconstruction	Strengthen Base & Surface Treatment
Heavy Duty Reconstruction	Full Reconstruction

seal coat). Most other descriptions differed somewhat from the RAMS-DO1 strategy names. For some of these, it was easy to determine which RAMS-DO1 strategy was most appropriate (e.g., rotomill, seal, and overlay in the SDHPT list was interpreted to be equivalent to a heavy overlay in RAMS-DO1). For others, it was not so easy and required some judgment by the researchers (e.g., resurface in the SDHPT list became a thin overlay in RAMS-DO1). Finally, some SDHPT descriptions differed substantially from any of the RAMS-DO1 strategies (e.g., clear trees and underbrush) and therefore were not included in the study. Of the 64 projects in the SDHPT list, 45 were classified into the eight different RAMS-DO1 M&R strategies and subsequently included in the analysis.

The next step was to determine the average cost per mile-foot for each of the M&R strategies. This was done by dividing the cost for each project of a given strategy by the product of the length (in mi) and the pavement width (in ft) of the road segments in the project and then averaging these values. For all strategies, except for thin overlay, an increase of between 110 percent and 120 percent was calculated over the default cost values recommended in the original RAMS-DO1 package. The increase for thin overlay was higher, but it was believed that some of the projects classified as thin overlay might have been a moderate overlay or base rework and thin overlay. Therefore, to be consistent, the average cost per mile-foot for each strategy, including thin overlays, was set equal to the previous RAMS-DO1 value times 2.15 (i.e., a 115 percent increase). This increase is very close to the overall inflation increase in the years since the original RAMS-DO1 work was developed (1978). Obviously, additional work is needed to get more precise estimates of the unit costs for various strategies. Table 2 shows the unit cost values used in this case study.

The next step was to determine the amount of money used for the projects in each of the nine counties in District 11. These values became the budget levels used in the RAMS-DO1 runs. This was done so that decisions made by RAMS-DO1 could be compared to those made by the district. Table 3 gives the amounts determined for each county. It was nec-

TABLE 2 UNIT COSTS FOR RAMS-DO1 M&R STRATEGIES

Strategy	Cost Per Mile-Foot
Fog Seal	$ 120
Seal Coat	$ 460
OGPMS	$ 2,040
Thin Overlay	$ 1,990
Moderate Overlay	$ 4,300
Thick Overlay	$ 7,630
Light Duty Reconstruction	$ 4,000
Heavy Duty Reconstruction	$ 5,590

TABLE 3 COUNTY EXPENDITURES FOR PROJECTS

County Number	County Name	Expenditures (In Dollars)
3	Angelina	3,191,000
114	Houston	670,000
174	Nacogdoches	406,000
187	Polk	3,810,000
202	Sabine	181,000
203	San Augustine	202,000
204	San Jacinto	204,000
210	Shelby	1,147,000
228	Trinity	2,776,000
Total District Fiscal Year 1986 Allocation		$12,587,000

essary to run the program by county because of the limitation on the number of highway segments that can be accommodated in the microcomputer version of RAMS-DO1. Currently, the number of highway segments that can be analyzed in any given run is 125.

In order to estimate the funds needed by the counties for M&R activities, another program in the MICRO-PES system was run for District 11. It consists of a set of SDHPT decision tables relating pavement type, traffic level, and distress type to the appropriate rehabilitation strategy. Results of that run for flexible pavements are shown in Table 4. Note that the estimated costs in Table 4 are broken down into urban and rural categories. Therefore to determine a county's total requirements, the totals from both categories must be added together. Taking the district as a whole, it is clear that not enough funds were allocated to District 11 to solve all the problems with flexible pavements. In fact, the $12,587,000 is only about 36 percent of the $35,086,764 ($16,933,169 + $18,153,595) needed, as estimated by MICRO-PES.

A result of the inadequate funding for District 11 was a drop in pavement condition between 1985 and 1986. In fact, Table 5 indicates that the average pavement scores for four of the six distress types included in the PES data base were worse in 1986 than in 1985. In the next section, decisions made by the district are compared with decisions provided by RAMS-DO1. The 1986 average pavement condition scores in Table 5 are compared with the values that would have resulted from implementing the RAMS-DO1 decisions. As a final step in preparing to make the RAMS-DO1 runs, it was necessary to create a file of pavement sections to be included in the analysis. Sections with no distress were excluded from the analysis. It was decided to include only those road segments with a pavement score below 80 in this file. A pavement score is an aggregate rating that reflects the overall condition of a pavement section and is a function of the visual distress and roughness. It ranges from 0 to 100, with 100 representing a pavement section in excellent condition.

Only road segments with pavement scores below 80 were analyzed to reduce the size of the county PES files because of the limitation on the number of sections that can be handled by the microcomputer version of RAMS-DO1. A pavement score of 80 was selected as the cutoff score because, in the judgment of the researchers, it is unlikely that road segments with a pavement score of 80 or greater would require any M&R activity.

EVALUATION OF RAMS-DO1

Using the 1985 PES data for District 11, several runs of the RAMS-DO1 program were made to generate, for each county within the district, an alternative list of projects along with the recommended maintenance or rehabilitation treatments. The maintenance and rehabilitation projects selected by the program were subsequently compared to those from the district to evaluate the degree to which RAMS-DO1 matches 1985 district selections. It was found that the results did not agree very well with the district selections. Discrepancies appeared in the projects selected and in the maintenance or rehabilitation treatments to be made.

A plausible explanation for these discrepancies can be obtained when one examines how projects are defined by the districts. In current practice, a project can be an agglomeration of more than one PES segment along a particular route or a subset of a PES segment. Many 1985 District 11 projects, for example, were more than two miles long (the usual PES segment length) and consisted of more than one PES segment. However, the current version of RAMS-DO1 works with the individual highway segments found in the PES data base and provides an optimized list of projects, which are really indi-

TABLE 4 FUNDS NEEDED FOR M&R ACTIVITIES

Summary Of Urban Flexible Pavement Rehabilitation Cost By County (in dollars) - District 11

County	3 in. Overlay	6 in. Overlay	Part. Reconstruct.	Reconstruct.	Total
Angelina	2,201,079.	1,002,376.	331,056.	256,714.	3,791,225.
Houston	579,090.	517,595.	182,952.	0.	1,279,637.
Nacogdoches	880,365.	814,779.	49,833.	197,472.	1,942,449.
Polk	2,673,266.	1,329,897.	284,360.	197,472.	4,484,995.
Sabine	180,966.	0.	69,696.	0.	250,662.
San Augustine	113,271.	0.	0.	0.	113,271.
San Jacinto	536,865.	968,324.	0.	0.	1,505,189.
Shelby	1,306,304.	1,472,917.	0.	0.	2,779,221.
Trinity	147,454.	321,949.	317,117.	0.	786,520.
SUB-TOTAL					
URBAN	8,618,660.	6,427,837.	1,235,014.	651,658.	16,933,169.
Angelina	1,026,433.	374,351.	988,986.	0.	2,389,770.
Houston	1,546,365.	693,243.	619,598.	0.	2,859,206.
Nacogdoches	654,248.	0.	453,953.	116,160.	1,224,361.
Polk	1,490,039.	684,577.	867,715.	1,403,213.	4,445,544.
Sabine	0.	0.	315,955.	0.	315,955.
San Augustine	86,655.	0.	297,370.	0.	384,025.
San Jacinto	866,554.	363,953.	1,209,923.	598,244.	3,038,654.
Shelby	853,555.	0.	785,242.	0.	1,638,797.
Trinity	996,537.	0.	413,530.	447,216.	1,857,283.
SUB-TOTAL					
RURAL	7,520,386.	2,116,124.	5,952,272.	2,564,813.	18,153,595.
TOTAL	16,139,046.	8,543,961.	7,187,286.	3,216,471.	35,086,764.
(URBAN AND RURAL)					

TABLE 5 AVERAGE PAVEMENT CONDITION SCORES BY DISTRESS TYPE

Year	Rutting	Alligator Cracking	Longitudinal Cracking	Transverse Cracking	Failures Per Mile	PSI
1985	11.50	22.97	23.36	18.40	38.29	2.68
1986	11.16	21.99	23.58	18.53	37.21	2.52
MAX*	15.00	25.00	25.00	20.20	40.00	5.00

* The MAX value represents no distress present; therefore decreases in values represent worsening conditions.

TABLE 6 COMPARISONS OF AVERAGE DISTRESS RATINGS FOR PROJECTS SELECTED BY RAMS-DO1 WITH PROJECTS SELECTED BY DISTRICT 11 (PRE-TREATMENT RATINGS)

County	Rutting (0-15)*	Alligator Cracking (0-25)	Longitudinal Cracking (0-25)	Transverse Cracking (0-20)	Failures (0-40)	PSI (0-5)	PES Pavement Score (0-100)
1. Angelina							
a. District 11	8.81	23.10	20.52	14.05	38.06	3.35	62.57
b. RAMS-DO1	11.03	17.97	17.38	13.50	34.69	3.08	43.25
2. Houston							
a. District 11	12.08	22.08	22.25	15.08	40.00	2.94	68.50
b. RAMS-DO1	11.43	18.57	18.29	11.57	40.00	2.77	51.71
3. Nacogdoches							
a. District 11	9.78	21.67	21.33	14.33	37.78	2.59	67.78
b. RAMS-DO1	13.33	21.67	16.67	12.17	36.67	3.15	54.00
4. Polk							
a. District 11	12.40	21.10	20.20	16.30	36.10	3.20	66.45
b. RAMS-DO1	7.75	13.04	17.14	14.75	27.50	2.26	29.54
5. Sabine							
a. District 11	10.27	21.36	25.00	20.00	40.00	2.45	75.91
b. RAMS-DO1	15.00	10.00	25.00	20.00	40.00	2.50	65.00
6. San Augustine							
a. District 11	14.29	25.00	24.00	18.57	40.00	2.94	81.29
b. RAMS-DO1	10.00	15.00	18.00	20.00	40.00	2.20	54.00
7. San Jacinto							
a. District 11	12.14	23.57	25.00	20.00	37.14	2.04	66.86
b. RAMS-DO1	12.00	16.25	13.00	12.25	40.00	3.53	52.25
8. Shelby							
a. District 11	10.00	25.00	22.00	17.57	40.00	3.06	80.43
b. RAMS-DO1	10.30	18.00	18.20	12.60	34.00	2.63	56.40
9. Trinity							
a. District 11	11.25	20.83	22.67	19.42	40.00	2.74	69.42
b. RAMS-DO1	9.64	20.20	20.60	16.44	36.00	2.30	51.16

* Numbers inside parentheses show the range in scores possible for each distress category.

vidual PES segments. These individual segments may not necessarily combine to form the projects selected by a particular county as was the case for this study. Consequently, one of the research needs identified concerns the improvement of RAMS-DO1 to enable the user to specify projects so that the optimization will be made based on a specified pool of projects rather than on two-mile road segments. These projects may be individual PES segments or a combination of such segments.

In addition to evaluating the agreement between the RAMS-DO1 and District 11 lists of projects, a comparison of pavement condition ratings for projects selected by RAMS-DO1, with the ratings for projects selected by the district, was also made. Table 6 provides a comparison of average distress ratings for RAMS-DO1 and 1985 District 11 projects. In most instances, the average distress ratings for projects selected by RAMS-DO1 were lower than those for the district selections. This indicates that the sections selected by the program were, on the average, in a poorer condition than those selected by the district. This is evident in Figure 2 showing the cumulative distributions of pavement scores for each group of projects (i.e., RAMS-DO1 and District 11). From this figure, it is readily apparent that the pavement scores for the RAMS-DO1 group of projects were generally lower than those for the district.

It is of interest to estimate what the average pavement condition scores would have been in 1986 had the RAMS-DO1 selections been implemented. Table 7 compares the 1985 average pavement condition scores with the 1986 averages, after implementation of the District 11 group of projects, and also with estimates of the averages that would have been obtained had the RAMS-DO1 group of projects been implemented. In the latter case, average pavement condition scores were estimated assuming that the distress ratings for projects selected by the district remained at 1985 levels. In addition, for projects selected by RAMS-DO1, the after-treatment scores predicted by the program were used to calculate the average pavement condition scores.

Table 7 indicates that, even if in 1986 the RAMS-DO1 selections had been implemented, the average pavement con-

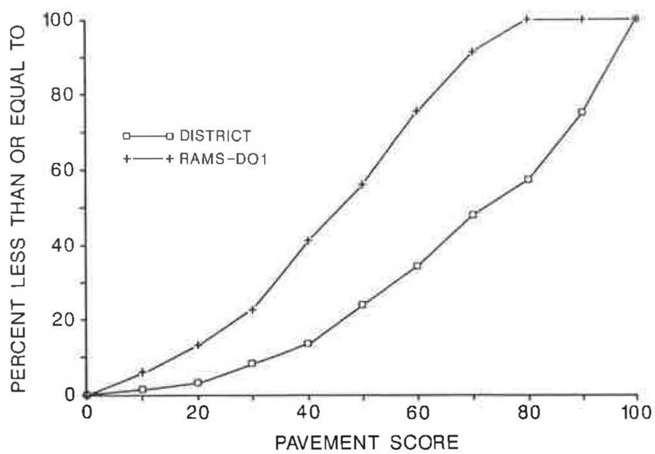

FIGURE 2 Cumulative distributions of pavement scores for District 11 projects and RAMS-DO1 projects (1985 scores).

dition scores for four of the six distress types (i.e., rutting, alligator cracking, failures/mile, and PSI) would have been predicted to decline from the 1985 values. This is evident in Figures 3 to 6 showing cumulative distributions for these distress types. Results shown in the figures are consistent with what occurred in the district in 1986, and indicate that probably not enough money was allocated to District 11 to improve the overall condition of its highways. As presented previously, the district only received about 36 percent of the $35,086,764 it needed for M&R projects. However, Table 7 also indicates that the reductions in average pavement condition scores are predicted to be less had the RAMS-DO1 group of projects been implemented. This may be due to the fact that projects selected by RAMS-DO1 were generally in a poorer condition than those selected by the district. One would consequently expect, that had such projects been repaired, the average pavement condition scores would have been higher than in 1986.

A number of reasons can explain why some roads in poorer condition than those on the 1985 district list of projects were

TABLE 7 COMPARISON OF AVERAGE PAVEMENT CONDITION SCORES

Distress	Average Ratings		
	1985 (Before)	1986 - District 11 (After)	1986 - RAMS-DO1 (Projected)
Rutting	11.50	11.16	11.43
Alligator Cracking	22.97	21.99	22.37
Longitudinal Cracking	23.36	23.58	23.84
Transverse Cracking	18.40	18.53	18.75
Failures/Mile	38.29	37.21	37.69
PSI	2.68	2.52	2.55

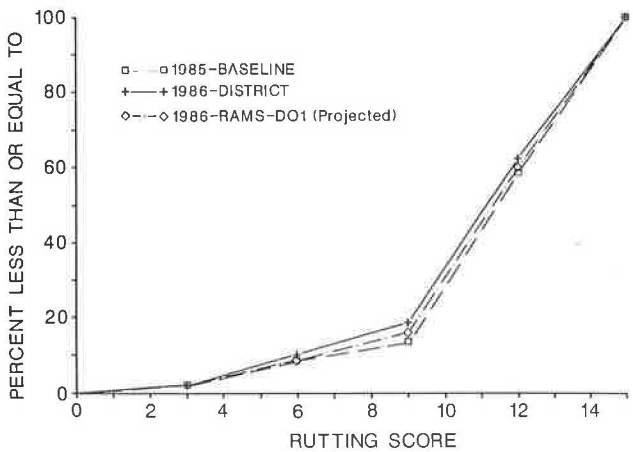

FIGURE 3 Cumulative distributions of rut depth scores.

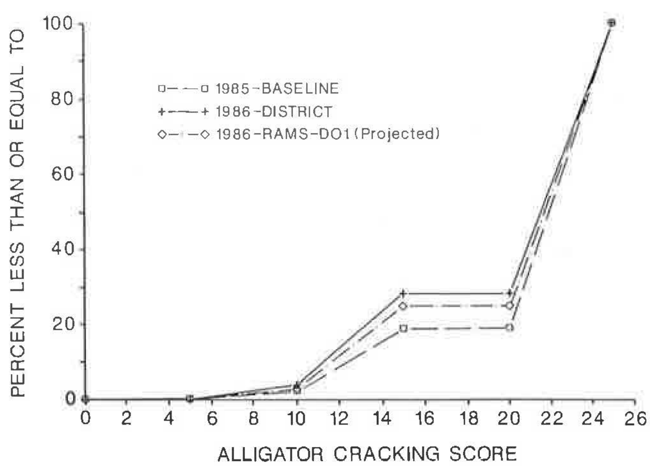

FIGURE 4 Cumulative distributions of ratings for alligator cracking.

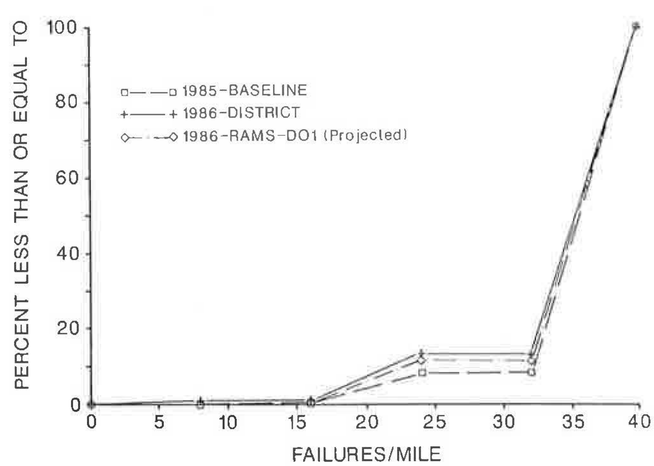

FIGURE 5 Cumulative distributions for failures per mile.

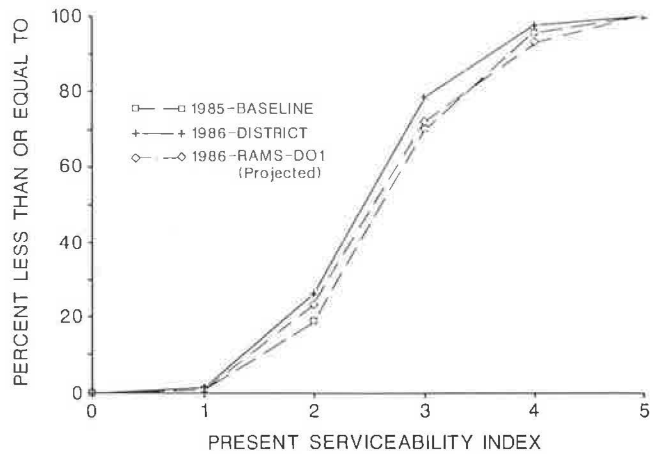

FIGURE 6 Cumulative distributions for Present Serviceability Index.

not selected. One possible reason is inadvertent omission. This can easily occur when one is faced with the situation of allocating a limited amount of resources among a host of different alternatives. In these situations, of course, a program like RAMS-DO1 can be most useful. By having the capability to consider a significant number of pavement sections in the development of a work schedule for a particular fiscal year, a highway engineer can have a more cost-effective allocation of the limited funds available.

It should be emphasized, however, that RAMS-DO1 is only a decision analysis tool and was never intended to dictate decisions to the highway engineer. Other considerations can play a significant role in the selection of projects that RAMS-DO1 cannot presently account for, including political considerations, project readiness, and the effects of traffic and the environment. In an effort to determine if traffic played an important role in selecting projects within the district, Figures 7 and 8 were prepared to show the distributions of Average Daily Traffic (ADT) and 18-kip equivalent single axle loads (ESALs) for the RAMS-DO1 and District 11 groups of proj-

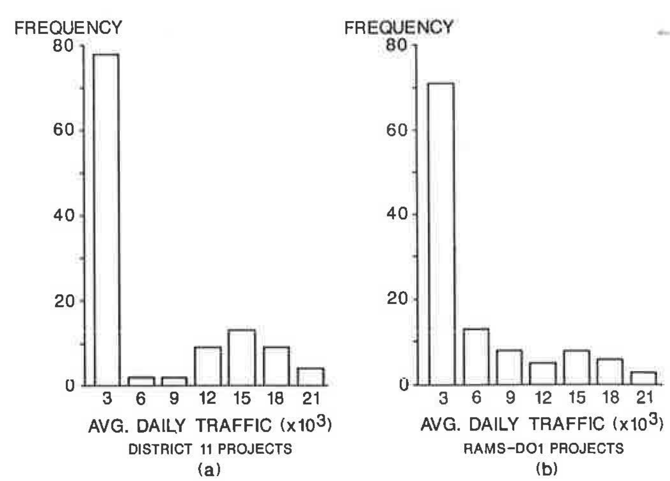

FIGURE 7 Distributions of Average Daily Traffic for: (a) District 11 projects; and (b) RAMS-DO1 projects.

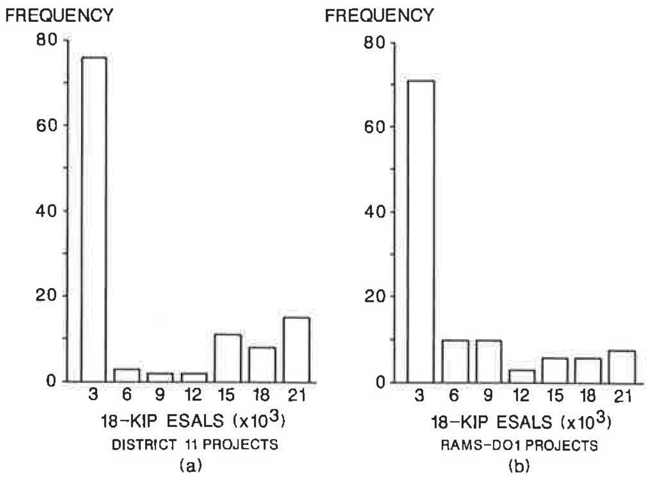

FIGURE 8 Distributions of 18-kip ESALS for: (a) District 11 projects; and (b) RAMS-DO1 projects.

ects. Figures 7 and 8 indicate that the district selections had somewhat higher traffic levels. There are more observations at higher ADTs and 18-kip ESALs for the district selections than for the RAMS-DO1 group of projects. In fact, the means of the ADTs and 18-kip ESALs for the district projects were 6,046 and 6,802 respectively, compared with 3,396 and 3,607 for the RAMS-DO1 selections. This would indicate that traffic was an important factor in the district selection of projects.

The results obtained therefore point to the need for considering traffic in the RAMS-DO1 optimization algorithm. This task would involve generating survivor curves for different traffic levels and developing a scheme for weighting the RAMS-DO1 objective function depending on traffic. Currently, a scheme exists by which a user can specify adjustment factors to account for the influence of traffic level on the survivor curves. Adjustment factors greater than 1.0 can be used to shift the survivor curves to reflect the influence of heavier traffic loadings. However, this feature of the program is not used at the present time. The relationship between level of traffic loading and traffic adjustment factor needs to be further evaluated.

In order to illustrate the effect of this factor on the optimal list of projects generated by RAMS-DO1, a series of runs was made in which a traffic weighting factor equal to log (ADT) was applied to the objective function. This evaluation was conducted using the PES data for Angelina, Polk, and Trinity counties. The results are presented in Table 8. As may be expected, the effect of a traffic weighting factor is to favor the selection of projects with higher traffic levels as reflected in the upward shift of the means for ADT and 18-kip ESALs. In addition, application of a weighting factor can lead to selection of projects with higher condition ratings over projects with lower ratings but with much less traffic. This is evident in the upward shift of the mean pavement scores for Angelina and Polk counties as the objective function is weighted for traffic level. The effect of traffic as illustrated in Table 8 can also help to explain why the district group of projects had higher mean condition ratings than those for the RAMS-DO1 group. Consequently, consideration of traffic in the optimization process is a research item that needs to be addressed in order to more realistically simulate how decisions are made on maintenance and rehabilitation projects.

Another exercise evaluated the effect of budget level on the optimal list of projects generated by RAMS-DO1. One of the useful applications of this program is the development of a budget-versus-benefit profile. This capability for evaluating different budget levels should facilitate budget preparation and help justify funding requests by districts in the state. In order to demonstrate this capability, a series of runs was made in which the optimal list of projects for Angelina, Polk, and Trinity counties was evaluated assuming a budget for each county twice that available in 1985. The benefits of a bigger budget are indicated in Table 9 comparing mean distress ratings predicted under two different budget levels. The mean distress ratings shown represent those that can be obtained immediately after implementation of the RAMS M&R strategy. As may be expected, a higher budget level would enable resident engineers to repair more miles of roadway and thus increase the average condition ratings or further improve overall highway conditions. Table 9 therefore shows the kinds of information that highway engineers can obtain from RAMS-DO1 to justify increased funding requests.

CONCLUSIONS AND DIRECTIONS FOR FURTHER RESEARCH

MICRO-PES is a decision analysis tool with promising potential. RAMS-DO1, an integral part of this package, is not

TABLE 8 COMPARISON OF MEAN TRAFFIC LEVELS AND PAVEMENT SCORES ON PROJECTS SELECTED TO SHOW EFFECT OF APPLYING A TRAFFIC WEIGHTING FACTOR ON THE RAMS-DO1 OBJECTIVE FUNCTION

	No Traffic Weighting Factor Applied			Traffic Weighting Factor Applied		
County	ADT	18-KIP ESALS	Pavement Score	ADT	18-kip ESALS	Pavement Score
Angelina	8147	8904	43.25	9371	10,313	48.05
Polk	5638	6043	29.54	7039	7598	36.65
Trinity	1704	1733	51.16	2217	2143	49.09

TABLE 9 PREDICTED AVERAGE DISTRESS RATINGS AT TWO BUDGET LEVELS AFTER APPLICATION OF RAMS-DO1 MAINTENANCE AND REHABILITATION STRATEGIES

Distress	Angelina		Polk		Trinity	
	At 1985 Budget	At Twice 1985 Budget	At 1985 Budget	At Twice 1985 Budget	At 1985 Budget	At Twice 1985 Budget
Rutting	10.94	11.49	11.29	12.16	11.26	12.24
Alligator Cracking	22.32	23.29	21.51	22.63	22.32	23.48
Longitudinal Cracking	23.31	23.82	23.50	23.80	24.36	24.51
Transverse Cracking	17.88	18.50	18.80	18.96	19.51	19.51
Failures/mile	39.33	39.38	34.09	35.63	36.36	37.98
PSI	2.74	2.79	2.48	2.49	2.32	2.36
Number Of Miles Repaired	63.80	128.50	57.10	105.90	51.90	88.30

meant to replace the decision maker, but rather to assist him or her in determining the "best" combination of M&R activities and road segments.

The program provides three major benefits to the decision maker. First, it can be used early in the decision-making process to identify road segments obviously needing work and suitable candidates for maintenance or rehabilitation. Second, it can be used in the decision-making process to help determine the appropriate M&R treatment for each of the road segments in a group subject to a given funding level. Third, it can help the decision maker prepare a budget-versus-benefit profile for justifying requests for increased funding from the state. All these benefits are likely to save the decision maker time and improve the decisions made.

While RAMS-DO1 is a powerful tool as it is, several areas should be researched in order to improve existing capabilities. Directions for further research include the following:

1. Survivor curves should be developed for the different environmental regions in Texas. Within RAMS-DO1, these survivor curves are used for predicting pavement performance. A survivor curve shows the probability that a given pavement will not require additional maintenance or rehabilitation at a particular time. Survivor curves for various pavement distress types, and maintenance and rehabilitation activities, were determined from the collective judgment and experience of various Texas SDHPT engineers. The curves were subsequently built into the RAMS-DO1 program. It is recognized, however, that the current set of survivor curves may not apply to all districts because of variations in environmental conditions around the state. Consequently, the development of survivor curves for different environmental regions in Texas is appropriate.

2. Results from the case study reported here indicate that traffic was an important factor influencing decisions made by District 11 engineers. Consequently, this factor needs to be considered in the optimization process. It seems logical to give highly travelled road segments more consideration because fixing one of these roads gives more "benefit" to more people in certain circumstances. There are several ways to accomplish this. One possibility is by applying a weighting factor to the RAMS-DO1 objective function as was done in this case study. Another approach is to apply a weighting factor to the survivor curve because pavement performance is influenced by the level of traffic loading. All other conditions being the same, a pavement section subjected to a greater number of 18-kip ESALs per day will deteriorate faster than one subjected to a lower number of 18-kip ESALs. As mentioned previously, the program can accept a user-supplied adjustment factor to shift the survivor curves to account for the influence of traffic loading. However, a procedure for selecting the appropriate adjustment factor for a given level of traffic loading needs to be developed. Still another approach is to use weighting factors in both the survivor curve and the objective function. This would account for both the effect of traffic loading on the service life of the pavement section and the effect of traffic volume on user benefits that can be obtained.

3. The capability to specify projects that are either subsets of existing PES segments or combinations of individual segments is an improvement that will tailor the program more closely to existing practices within individual districts. Currently, RAMS-DO1 will only deal with individual PES data records, most of which are for two-mile road segments. Often, however, the district engineer is considering a project composed of several of these two-mile segments or a project that is a subset of a two-mile segment. Consequently, there is a need to allow the specification of individual projects. This will involve developing rules for assigning distress ratings to projects based on the ratings of the associated PES segments.

4. There is also a need for an interface that will allow the user to specify additional M&R treatments outside of those already included within the RAMS-DO1 program. Through

this interface, the user will be able to specify survivor curves and unit cost data associated with new M&R treatments. This task will also require enlarging the number of M&R strategies that the program can accommodate.

5. Versions of the RAMS-DO1 program should be created that will run on a multi-tasking operating system for a micro-computer. Multi-tasking operating systems already available will address memory above 640K. These versions of the program will allow larger groups of potential projects to be evaluated.

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REFERENCES

1. T. Scullion, M. Paredes, J. Fowler, and E. Fernando. *The Micro-PES Release 1.0 User's Manual.* Research Report 930-1, The Texas Transportation Institute, Texas A&M University, College Station, Tex., 1989.
2. N. Ahmed, D. Lu, R. Lytton, J. Mahoney, and D. Phillips. *The Texas Rehabilitation and Maintenance District Optimization System.* Research Report 207-3. Texas Transportation Institute, Texas A&M University, College Station, Tex., 1978.
3. D. Lu and R. Lytton. Strategic Planning for Pavement Rehabilitation and Maintenance Management System. In *Transportation Research Record 598*, TRB, National Research Council, Washington, D.C. 1976, pp. 29–35.
4. S. Senju and Y. Toyoda. An Approach to Linear Programming with 0–1 Variables. *Management Science*, Vol. 15, No. 4, Dec. 1968, pp. B-196–207.

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