Maintenance Skid Correction Program in Utah

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Deficiencies in resistance to skidding in sections of highways exist and sometimes contribute to elevated accident rates. A more efficient process for priority ranking projects for restorative treatment of these deficiencies given limited funding is presented. Projects for treatment of these deficiencies using the benefit-cost ratio are discussed. Surface treatments are recommended and the associated project costs are identified. Benefits are identified through expected accident reductions. The costs associated with accidents are computed and multiplied by an accident reduction factor (ARF) to find the expected benefits of the countermeasure. Two separate methods are used in calculating the benefits. The first method involves using a standard ARF that is applied to all projects regardless of functional class and traffic volume. The second method utilizes new expected ARFs specific to each project. These new factors are based on the assumption that the countermeasure will reduce accidents to the average accident rate of each project's particular functional class. Individual projects are then selected from the prioritized lists using a dynamic programming technique.

When the United States was established, much of its legal system was patterned after the British system. Among the concepts brought to the new country was the principle of sovereign immunity. The sovereign immunity concept came to have the following meaning as the result of U.S. Supreme Court rulings in the early 1800s: the government could not be sued unless it gave its express permission, and even when it allowed itself to be sued, it was not responsible for the acts of its employees. This defense was almost unbeatable, and as a result governmental units were rarely brought to court on tort issues. Sovereign immunity became the primary defense against torts for state governments for almost a century and a half.

LOSS OF SOVEREIGN IMMUNITY

Eventually the courts began to realize the unfairness in the sovereign immunity defense. Several states lost their sovereign immunity through court decisions, usually by their state supreme courts. Most states viewed these cases as flukes and continued business as usual. Then in the late 1960s and through the 1970s, most states lost their immunity status through not only court decisions but also individual state legislation. As a result, the number of suits against the states mushroomed. Especially ripe were the transportation departments in which endless maintenance defects on the older roads seemed to breed lawsuits. The number of tort claims against state transportation departments exploded from about 2,000 cases per year to more than 27,000 per year from 1976 to 1986 (*1*).

TORT ISSUES

The breach of a legal duty is the major issue in most tort liability cases involving skid accidents. This negligence is the failure to exercise such care as a reasonable and prudent person would under the circumstances. Neglecting a duty can be either wrongful performance or the omission of a required act (*2*).

If an agency can demonstrate that there is a systematic approach to treating deficiencies in resistance to skidding in the network and that the process has been followed in the case in question, it is easier to prove that the agency acted reasonably within the externally imposed constraints. This means that the agency needs to have in place a mechanism to

1. Routinely monitor the condition of the facilities,
2. Identify the deficient elements of the network,
3. Prioritize and program the deficient elements for treatment, and
4. Select appropriate warning or interim measures when deficiencies cannot be corrected immediately.

Two key factors limit the abilities of highway agencies to follow such a procedure. One is the lack of reliable and up-to-date information of every highway element. The other is the lack of resources. The first deficiency limits the ability to accurately and correctly detect the problem. Even when detected, the second deficiency sometimes prevents corrective measures from being implemented.

Agencies that overcome the first barrier and decide to invest in safety-related projects are faced with yet another responsibility, that is, to develop procedures for ranking improvement projects and allocating the limited funds in the most effective manner. Because one of the strongest types of evidence to demonstrate the standard of care or the plan used to correct safety problems is the agency's own guidelines and policies, it is important that logical project prioritization and programming are available.

The primary objective of this paper is to present a study that proposes changes to the approach currently taken by the Utah Department of Transportation (UDOT) to identify high-risk locations and schedule treatment in order of priority.

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So how does a state transportation agency proceed with a program to correct pavements that are deficient in their ability to resist skidding and protect itself from being sued? The following are requirements for a defendable program:

1. A periodic inventory of the skid index throughout the highway system,
2. Accident data and history on the system including possible contributing cause, and
3. A procedure to logically prioritize and program proposed improvements within the available funding on the basis of skid index and accident data.

CURRENT SKID CORRECTION PRACTICE IN UTAH

Skid Index Studies

UDOT's skid correction program has been in operation since the late 1960s. A locked-wheel skid trailer was purchased recently to enhance the frequency of monitoring and inventory updating. At present, one test is taken at least every 2 years at each milepost with the trailer traveling at the posted speed limit but not exceeding 55 mph. Each measured skid index is then adjusted to a standard speed of 40 mph using a computerized speed correction method. When the corrected skid indexes approach a specified critical value, the operators slow the testing speed to 40 mph and increase the number of tests to four per mile. Through a literature survey of skid studies and a poll of other western states, UDOT has established 35 as the critical skid index.

Any pavement with an index below 35 is considered substandard, and steps are taken to correct the condition. Pavements having skid indexes measured between 35 and 45 are considered marginal and those pavements above 45 are classified as standard. In the 1990–1991 inventory, of the 4,713 mi tested, 203 mi (4 percent) were substandard and 747 mi (16 percent) were marginal. These data, along with information on the structural adequacy, ride index, and pavement distress, are compiled by the planning division.

Because most deficiencies in a pavement's ability to resist skidding are corrected by district maintenance forces or with maintenance construction contracts, the district directors are notified of the deficient or substandard sections in the network under their respective jurisdictions. The data supplied for each section are the skid index, accident rate, percentage of wet weather accidents, and annual average daily traffic (AADT). Locations where the accident rate is higher than expected are noted. Tables 1 and 2 are examples of the information provided to the district directors. The example provided is from District 6, one of the six districts in Utah and comprises Utah, Juab, Daggett, Uintah, Wasatch, and Duchesne counties. Of the 1,051 mi of highway in District 6, 95 (9 percent) were classified as substandard.

TABLE 1 Highway Sections Deficient in Skid Resistance Identified in District 6

DISTRICT 6					
PROJECT NUMBER	STATE ROUTE	MILEPOST	DESCRIPTION	FUNCTIONAL CLASS	AADT
1	6	166.0 - 166.8	Main St. to 1000 East	Ma.Col/M.Art Mi.Co./P.Art	7,968
2	28	23.5 - 29.0	South of Levan	Principal Arterial	2,051
3	40	16.0 - 19.5	Heber City Main Street	Principal Arterial	9,619
4	40	111.0 - 115.3	SR-87 to 400 So. Roosevelt	Principal Arterial	5,716
5	40	147.0 - 152.0	700 So. Vernal To Rd. Left	Principal Arterial	5,775
6	41	0 - 4.8	So Nephi Int. To I-15	Major Collector	3,047
7	115	3.0 - 3.7	Rd. Crossing to SR-147	Art/Maj. Col Urb Col/Min Col	1,598
8	121	0 - 1.5	SR-40 to Dry Gulch	Major Collector	1,441
9	121	36.0 - 39.0	Highline Canal to 1150 West	Maj. Col/ Min Art	1,715
10	208	0 - 2.0	SR-40 to M.P. 2	Major Collector	167
11	265	2.72 - 3.34	800 E. to Canterville Rd.	Major Collector	32,072

TABLE 2 Skid Index, Accident Rate, and Suggested Treatment of Identified Projects

DISTRICT 6				
PROJECT NUMBER	SKID INDEX AVG (MIN)	3 YEAR AVG ACC RATE *	% WET WEATHER ACCIDENTS	TREATMENT
1	37 (34)	3.868	3.70	PMSC
2	34 (20)	1.942	0.00	CHIP SEAL
3	39 (29)	3.608	13.53	PMSC
4	34 (29)	1.433	5.13	PMSC
5	34 (29)	1.328	9.52	PMSC
6	30 (24)	2.997	8.33	CHIP SEAL
7	26 (18)	3.266	0.00	CHIP SEAL
8	30 (27)	5.912	0.00	CHIP SEAL
9	38 (23)	7.986	2.22	CHIP SEAL
10	24 (19)	0.000	0.00	CHIP SEAL
11	23 (23)	2.159	6.38	PMSC
TOTAL	μ= 31 (25)	3.13	4.44	
STD. DEV.	σ= 5.1 (5)	2.25	4.61	

* RATE IN PER MILE PER MILLION VEHICLES

Programming Maintenance Skid Correction

The district director, together with the maintenance engineer and the district pavement management team, develops the maintenance program under which the skid deficiencies will be addressed. The maintenance program is integrated with the construction and rehabilitation programs. However, the fact that UDOT does not allocate specific funds to correct skid deficiencies means that not all sections will be treated immediately. Thus, the maintenance engineer is faced with the decision either to change or channel a certain amount of the funds from the regular maintenance budget or to postpone the corrective action until the deficient sections are part of the routine maintenance schedule.

Project Selection

Projects are selected on the perception of what projects are the worst candidates. The factors that are evaluated in determining these are the skid index, the accident rate, and the age and condition of the pavement surface. Funds required to address these are channeled from the maintenance budget, depending on the size of the maintenance budget and the maintenance engineer's gut feeling about its effect on the long-term implications on the regular maintenance program.

Surface Treatment Alternatives

Before scheduling a maintenance activity to correct the skid index, a review is made to determine whether the segment under consideration is programmed for rehabilitation or reconstruction. If the section needs rehabilitation and is programmed, it is determined whether the treatment can be deferred until the project begins. If the rehabilitation is scheduled too far in the future, a temporary treatment is considered or the rehabilitation project is moved forward to correct the problem earlier.

The common treatments on asphalt pavements in Utah are a chip seal, a slurry seal, and a plant mix seal coat. On concrete pavements the best option is grinding. Many defects such as rutting, minor cracking, and early raveling can be corrected for little additional cost while correcting the skidding problem. Treatment selection for sections deficient in their ability to resist skidding is based on two factors: (a) pavement type and (b) traffic counts. UDOT has written guidelines for specific treatments for specified AADTs. The deficient sections are addressed as dictated by these written strategies. The costs and locations of applicable treatments are shown in Table 3.

Proposed Modifications to Program

To improve the practice of addressing pavement sections deficient in their ability to resist skidding in Utah, the authors would like to propose some modifications to the current program. If a more systematic strategy were adopted, it may be able to direct a specific amount from the maintenance budget and invest it in a set of sections deficient in their ability to resist skidding that would reap the maximum benefit. For this purpose, it is suggested that the following programming process be adopted.

Step 1. All substandard and marginal projects would be ranked on the basis of expected benefit-cost (B/C) ratio. In the present case the benefits were estimated on the basis of expected reductions in accidents of different severities. To demonstrate the importance of employing appropriate acci-

TABLE 3 Treatment Costs and Criteria for Surfaces Deficient in Skid Resistance

TREATMENT	COST PER LANE MILE	APPLICATION
PMSC	$14,800	Asphalt Pavements Where AADT > 4,000
CHIP SEAL	$4,500	Asphalt Pavements Where AADT < 4,000
SLURRY SEAL	$5,100	Asphalt Pavements In Shade Areas, Mountains, Or Intersections
CONCRETE GRINDING	$21,100	Concrete Pavements Surface Texturing

dent reduction factors, different project prioritization schemes were compared. One uses the standard factor currently in use by UDOT. The other uses a factor derived using the accident rates of functionally similar road sections and the expectation that a treatment would cause accident rates to trend toward the average.

Step 2. Step 2 involves defining what the funding constraints are for this program. It is recognized that UDOT will not have sufficient funds to address all projects at one given time. It was therefore decided to pursue this program on the basis of the estimated cost of correcting all of the known skid index deficiency problem areas over 4 years. In this way one-fourth of the problem areas in any given year would be addressed.

Step 3. Step 3 involves the dynamic programming process. This process involves simply going down the list of projects and their costs and including as many projects under the given funding level so as to optimize the funding.

Dynamic Programming

Dynamic programming is a process used to maximize funds. In this process, prioritized projects are included in the program so that all of the available funds are utilized. The process looks at possible combinations of projects to program the available funds. Projects are included or deferred on the basis of their being able to fit within the program. In this way funds that expire on the basis of the fiscal year are maximized.

CASE STUDY

To illustrate the proposed procedure and some of its pros and cons, data from District 6 of the Utah DOT are used in this paper. Table 4 gives the project costs for the 11 segments determined to be deficient in their ability to prevent skidding. It is assumed that these segments are not currently programmed for reconstruction or rehabilitation and need to be addressed. The objective of the exercise now is to determine the projects that could be corrected with funds transferred from the maintenance budget. Often this amount does not cover all projects. Thus, it should be assigned to the optimal set of projects.

The B/C ratio method was used to initially rank the identified projects. To do this the number and severity of each

TABLE 4 Total Project Costs for Required Treatment

DISTRICT 6				
PROJECT NUMBER	STATE ROUTE	LANE MILES	COST PER LANE MILE	TOTAL PROJECT COST
1	6	1.6	$14,800	$23,680
2	28	11.0	$4,500	$49,500
3	40	17.5	$14,800	$259,000
4	40	8.6	$14,800	$127,280
5	40	20.0	$14,800	$296,000
6	41	19.2	$4,500	$86,400
7	115	1.4	$4,500	$6,300
8	121	3.0	$4,500	$13,500
9	121	6.0	$4,500	$27,000
10	208	4.0	$4,500	$18,000
11	265	2.48	$14,800	$36,704
TOTAL		94.78		$943,364

type of accident, with a dollar value for each accident type, must be known. The Accidents Record Division of UDOT provided the data given in Table 5.

Using these dollar values and the number of each severity type of accidents, a total value of accident costs for 1991 was found for the projects in District 6 (Table 6).

The expected benefit of investing in each project was considered to be the savings in the present value of the expected accident (PVAC). Two methods were explored to arrive at these expected savings. In one method a standard accident reduction factor (ARF) of 42 percent was used. In the other the expected accidents were expected to decrease to the average accident rate for the functional class of road to which each project belongs. The assumption that the treatment will reduce all—not just wet weather accidents—was arrived at because any skid correction project also will include other measures, such as new striping and shoulder dressing, that enhance safety.

Method 1

The ARF of 42 percent for resurfacing was arrived at using the data provided to UDOT by the Texas Highway Department. A discount rate of 4 percent and an 8-year design life was used for estimating the PVAC. (UDOT's Division of Safety currently uses an interest rate of 8 percent and a 20-year design life in computing the PVAC of accidents.) It may be expressed numerically as

$$\text{PVAC} = \text{ARF}[(\text{NS1} \times 4{,}500) + (\text{NS2} \times 25{,}200) + (\text{NS3} \times 48{,}300) + (\text{NS4} \times 228{,}600) + (\text{NS5} \times 2{,}722{,}500)] \times (\text{P/A } 4\,\%\, 8)$$

where

ARF = accident reduction factor,
NS# = number of accidents of each severity type, and
(P/A 4 % 8) = present worth factor of annual costs using 4 percent interest rate and 8 years of treatment life.

The B/C ratios are found by simply dividing the PVACs by the project costs. Table 7 shows the respective B/C ratios for the projects in District 6. The projects can now be ranked according to either B/C ratios or benefits only. The rankings under the two criteria are shown in Tables 8 and 9.

TABLE 5 Associated Costs of Each Accident Severity Type

SEVERITY NUMBER	DESCRIPTION	DOLLAR VALUE
1	Property Damage Only	$4,500
2	Minor Injury	$25,200
3	Possible Incapacitating Injury	$48,300
4	Incapacitating Injury	$228,600
5	Fatal Injury	$2,722,500

TABLE 6 Number of Accidents and Associated Costs for Each Project

DISTRICT 6						
PROJECT NUMBER	NUMBER OF ACCIDENTS 1989 - 1991					TOTAL DOLLAR VALUE
	SEVERITY TYPE 1	SEVERITY TYPE 2	SEVERITY TYPE 3	SEVERITY TYPE 4	SEVERITY TYPE 5	
1	18	3	4	2	0	$807,000
2	20	1	2	1	0	$440,400
3	95	14	19	5	0	$2,841,000
4	22	4	6	7	0	$2,089,800
5	24	6	8	4	0	$1,560,000
6	28	8	6	6	0	$1,989,000
7	2	1	1	0	0	$82,500
8	12	1	1	0	0	$127,500
9	28	4	6	1	1	$3,467,700
10	0	0	0	0	0	$0
11	32	5	5	5	0	$1,654,500

TABLE 7 B/C Ratio of Identified Projects Using Texas ARF

DISTRICT 6				
PROJECT NUMBER	ACCIDENT REDUCTION FACTOR *	PVAC **	PROJECT COSTS	BENEFIT - COST RATIO
1	0.42	$760,660	$23,680	32.12
2	0.42	$415,111	$49,500	8.39
3	0.42	$2,667,864	$259,000	10.34
4	0.42	$1,969,800	$127,280	15.48
5	0.42	$1,470,422	$296,000	4.97
6	0.42	$1,874,788	$86,400	21.70
7	0.42	$77,763	$6,300	12.34
8	0.42	$120,179	$13,500	8.90
9	0.42	$3,268,578	$27,000	121.06
10	0.42	$0	$18,000	0.00
11	0.42	$1,559,495	$36,704	42.49

* USING TEXAS REDUCTION FACTORS PROVIDED BY UDOT SAFETY DIVISION

** PRESENT WORTH OF ACCIDENTS USING 8 YEARS & 4% INTEREST

Method 2

The basic assumption in Method 2 is that the existing accident rate will be lowered to the accident rate for similar sections in the network. The logic is that it is unreasonable to expect surface treatments to have the same effect at all sites but that the accident rates would return to the average accident rate for similar roads. The observed accident rate and the mean accident rate for that class of roads can then be used to compute an expected ARF (EARF) for each project. EARF is expressed as a ratio of the difference between observed and expected accident rate to observed accident rate.

The functional class volume group and the 5-year average accident rate for each project's functional group are presented in Table 10. The information on accident rates for each functional class was furnished by UDOT's Traffic and Safety Division, and these rates were used to compute the EARFs given in Table 11; the expected PVAC for each of the projects is presented in Table 12.

Despite the low skid indexes, the accident rates on Projects 2, 4, 5, 10, and 11 are less than the averages for the respective groups. Method 2 produces zero benefits for the above projects, and if the B/C ratios as shown in Table 13 or pure benefits shown in Table 14 are used, they will not be programmed but

TABLE 8 B/C Ratio Ranking of Projects Using Texas ARF

DISTRICT 6	
PROJECT NUMBER	COST (1000'S DOLLARS)
9	27.0
11	36.7
1	23.7
6	86.4
4	127.3
7	6.3
3	259.0
8	13.5
2	49.5
5	296.0
10	18.0

TABLE 9 Benefit-Only Ranking of Projects Using Texas ARF

DISTRICT 6	
PROJECT NUMBER	COST (1000'S DOLLARS)
9	27.0
3	259.0
4	127.3
6	86.4
11	36.7
5	296.0
1	23.7
2	49.5
8	13.5
7	6.3
10	18.0

TABLE 10 Average Accident Rates for Each Project's Functional Class

DISTRICT 6				
PROJECT NUMBER	URBAN OR RURAL	FUNCTIONAL CLASS	VOLUME GROUP (x1000)	5 YEAR AVG ACC RATE *
1	SU	16	5 - 10	3.74
2	R	O2	0 - 5	3.08
3	R	O2	5 - 10	2.00
4	R	O2	5 - 10	2.00
5	R	O7	5 - 10	2.27
6	R	O7	2.5 - 5	1.96
7	R	O8	1 - 2	2.76
8	R	O7	0 - 2.5	2.54
9	SU	16	0 - 2.5	4.38
10	R	O7	0 - 2.5	2.54
11	U	14	25 - 35	6.04

* RATE IS PER MILE PER MILLION VEHICLES

still should be scheduled for treatment. Those projects displaying zero benefits will be prioritized on the basis of the associated costs of the accidents, with those having the highest accident costs being the higher priority.

Allocation of Funds to Feasible Projects Using Dynamic Programming

With the imposed funding limitations, suppose it will be possible to fund $235,000 worth of projects each year for the next 4 years. According to the current practice, funds will be allocated to projects each year, starting with the one showing the highest B/C ratio. This practice does not result in global optimization. Thus, although the projects funded will have the highest B/C ratios, the total return on the investment may not be a maximum. In this paper, a dynamic programming approach will be applied to allocate funding during the next 4 years. This practice permits the selection of the set of projects that will maximize the benefits. Effectively, all the projects on the list will be considered and the available funds will be allocated sequentially so that all the funds are depleted or the remaining funds are insufficient to fund a complete project. The following is an example of the process by which

TABLE 11 Expected Accident Reduction Factors

DISTRICT 6			
PROJECT NUMBER	OBSERVED ACCIDENT RATE	AVERAGE ACCIDENT RATE	EXPECTED ARF
1	3.868	3.74	0.03
2	1.942	3.08	-
3	3.608	2.00	0.45
4	1.433	2.00	-
5	1.328	2.27	-
6	2.997	1.96	0.35
7	3.266	2.76	0.15
8	5.912	2.54	0.57
9	7.986	4.38	0.45
10	0	2.54	-
11	2.159	6.04	-

TABLE 12 Present Value of Accident Costs Using New ARF

DISTRICT 6		
PROJECT NUMBER	ACCIDENT REDUCTION FACTOR *	PVAC **
1	0.03	$59,933
2	-	$0
3	0.45	$2,841,573
4	-	$0
5	-	$0
6	0.35	$1,544,525
7	0.15	$28,685
8	0.57	$163,204
9	0.45	$3,514,034
10	-	$0
11	-	$0

* USING FACTORS ESTIMATED FOR FUNCTIONAL TYPE

** PRESENT WORTH OF ACCIDENTS USING 8 YEARS & 4% INTEREST dynamic programming would allocate funds in Year 1 to projects ranked on the basis of B/C ratios in Table 13.

Project Number	*Cost ($ thousands)*	*Remaining Amount*
9	27.0	235 − 27 = 208.0
6	86.4	121.6
8	13.5	108.1
7	6.3	101.8
1	23.7	78.1

Up to this point both the current approach and the dynamic programming approach give similar results. However, a dilemma occurs when a project shows a negative or zero return.

TABLE 13 B/C Ratio Ranking of Projects Using New ARF

DISTRICT 6			
RANKING	PROJECT NUMBER	COST (1000'S DOLLARS)	B/C RATIO
1	9	27.0	130.15
2	6	86.4	17.88
3	8	13.5	12.09
4	3	259.0	10.97
5	7	6.3	4.55
6	1	23.7	2.53
7	4	127.3	0.00
8	11	36.7	0.00
9	5	296.0	0.00
10	2	49.5	0.00
11	10	18.0	0.00

TABLE 14 Benefits-Only Ranking of Projects Using New ARF

DISTRICT 6			
RANKING	PROJECT NUMBER	COST (1000'S DOLLARS)	BENEFITS
1	9	27.0	$3,514,034
2	3	259.0	$2,841,573
3	6	86.4	$1,544,525
4	8	13.5	$163,204
5	1	23.7	$59,933
6	7	6.3	$28,685
7	4	127.3	$0
8	11	36.7	$0
9	5	296.0	$0
10	2	49.5	$0
11	10	18.0	$0

There are two options at this point. One is to carry the $78,100 over to the next year and allocate the new $235,000 + $78,100 to Project 3 that will yield an approximately $1,500,000 return or to proceed to treat the maximum number of sections having B/C ratios equal to 0. For instance, the $78,100 is not enough to fund Project 4 but is enough to fund Project 11 and still have sufficient funds remaining for Project 10.

The benefits of investing in Projects 11 and 10 may be simply related to the pavement life. Because such benefits are uncertain, it may be worthwhile to adopt the option of carrying the money over and then investing in Project 3 in the following year. On the other hand, from a risk minimization (loss control) point of view, it may pay to treat as many deficient sections as possible, starting with the section with the highest accident costs. Even with this approach, dynamic programming permits the selection of the maximum number of projects as opposed to the traditional approach that will allocate the funding to projects only according to the B/C ratios.

Using the risk minimization criterion, Projects 11 and 10 will be funded in Year 1 with the $78,100 remaining after the first iteration shown above. This will leave $23,400 to be carried over to Year 2. This still does not provide enough funding to complete Project 3 in Year 2, which has the highest remaining B/C ratio. Continuing the risk minimization approach, the funds would be allocated in Year 2 as follows:

Project Number	*Cost ($ thousands)*	*Remaining Amount*
4	127.3	(235 + 23.4) − 127.3 = 131.1
2	49.5	81.6

The remaining amount would again be carried over to Year 3:

Project Number	*Cost ($ thousands)*	*Remaining Amount*
3	259.0	(235 + 81.6) − 259 = 57.6
5	296.0	0.

This example of dynamic programming does not completely illustrate the advantages of the method. Because the costs of some projects exceed the entire budget for 1 year, the amount of flexibility is limited. This still is better than the current practice. The current practice would split the larger projects into smaller ones to fit into the budget. This practice results in higher construction costs because two or more contractors would have to mobilize to complete the smaller projects. Another common practice is transferring unused funds elsewhere, leaving insufficient future funding to complete the required work.

One way to maximize the advantages of this programming technique in this situation would be to award Project 3 at the end of the Fiscal Year 2. This way the carryover amount from Year 1 could be spent on the project until Year 3 funds become available. Doing this would allocate the funds at the earliest possible time; therefore they would not be lost elsewhere.

As deficient sections are treated and new ones located, this programming procedure should be performed again to ensure that the projects with the highest benefits are completed. A time frame of every 2 or 3 years would be sufficient to serve this purpose.

CONCLUSIONS AND RECOMMENDATIONS

Currently UDOT has the necessary manpower and equipment to survey the state highway system for the necessary data. The data, including skid index, pavement distress, structural adequacy, accident data, and ride index, are collected at acceptable intervals. By evaluating these data, UDOT can be aware of the condition of its facilities. There are still two major decisions to be made: the first is to decide whether to correct the deficiencies at the expense of a disrupted maintenance program; the second is to determine the optimal allocation of those funds among the various projects, assuming that the decision was made to allocate a portion of the maintenance budget.

There is no policy at present on the transfer of funds from regular maintenance to skid correction. However, it was shown that if funds are appropriated to skid correction, dynamic programming could be used to optimally allocate the funds first on the basis of B/C ratio and after that on the basis of the number of accidents. These two criteria can be viewed as efforts by the agency to utilize tax dollars to maximize public safety.

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