Long-Term Projection of Highway System Condition

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A computer model is described that has been developed by the New York State Department of Transportation (NYSDOT) to predict long-term deterioration and investment impacts on the New York State highway system. The model, the Highway Condition Projection Model, is being used by NYSDOT management to assist in identifying pavement rehabilitation strategies. In the model each section of highway on the New York State system is treated as a separate entity. With a rehabilitation strategy provided by the analyst, the condition and financial requirement are projected for each section of highway for each year for up to 50 years into the future. Deterioration rates determined from empirical data from the New York State highway system and typical costs based on recent construction experiences are applied. The model output is summarized by system, region, and condition. A description is given of how this model may be used to identify sections in need of repair, test alternative rehabilitation strategies, and evaluate the implications of these strategies on long-term condition and funding requirements. The model is operational and is currently undergoing testing and refinement. Applications of the model to NYSDOT's analysis of Interstate funding proposals for highway repair and rehabilitation are described.

U.S. roads are deteriorating as high inflation and interest rates push construction costs up; at the national level, estimates of the repair bill for highways and bridges run as high as $100 billion (1). Evidence from the Highway Performance Monitoring Study (HPMS) (2, pp. 158-159) suggests that the condition of state and local roads is poorest, but these government units are now being called to bear the brunt of federal cutbacks in many programs. Significant attention must be paid to this problem soon, or the United States risks losing its vast investment in highway infrastructure. The recently passed Surface Transportation Assistance Act of 1982 provides additional funds for highway repair and rehabilitation.

To ensure that funds are spent wisely, state and local governments must be able to identify current problems and estimate repair needs, yet the tools available to undertake this task are weak or unavailable. Numerous procedures have been developed to evaluate alternative highway rehabilitation strategies, but their context has been limited to the study of a handful of sections (3) and they do not handle system-level analysis. Other simple optimization procedures exist for network problems (4). Detailed analysis methods of rehabilitation strategies for individual sections are well advanced, but only recently has the magnitude of the overall network problem begun to emerge. Even the federal HPMS (5) does not review all road categories; locally owned roads are not required for inclusion. The use of different highway rating procedures in different states has exacerbated the situation and clouded comparisons between system. Clearly the states and local governments need the capability to assess network highway conditions, and soon. The recently released HPMS Analytical Process helps in this regard (6).

Recognizing these issues, the New York State Department of Transportation (NYSDOT) has recently undertaken a strengthening of its pavement management activities. NYSDOT's Pavement Management Task Force has been formed to review current procedures and recommend improvements in pavement management. Methods for determining highway condition and reporting it in timely fashion are being improved and streamlined. Studies of deterioration have also been initiated. This work is expected to yield a better capability to manage pavement needs as funds are restricted. In this paper a model to project the long-term impact of alternative general rehabilitation strategies on network condition is summarized, and recent work by NYSDOT (7-9) on highway condition assessment is reviewed. A parallel paper (10) contains a summary of the data-collection methods used to obtain current condition data.

METHOD

The method described here is known as the Highway Condition Projection Model (HCPM) (8). This is a computerized procedure that projects the condition of each section of the New York State highway system, applies repairs as directed by the analyst, and keeps track of costs by location, federal-aid class, and so on. This is not an optimization model but rather a what-if tool that describes the implications of policies proposed by the analyst. Except for this feature, the model is similar to the Washington State model (4). Because the HCPM operates substantially on each section of highway and then sums up the entire system, its output can be summarized in a variety of ways not available in higher-level sample-based models [e.g., the federal HPMS model (11,12)]. In addition the model can be focused on section-level or route and county analysis, a capability not possible with sample-based techniques. The general operation of the model is shown in Figure 1, which is discussed in more detail in the following.

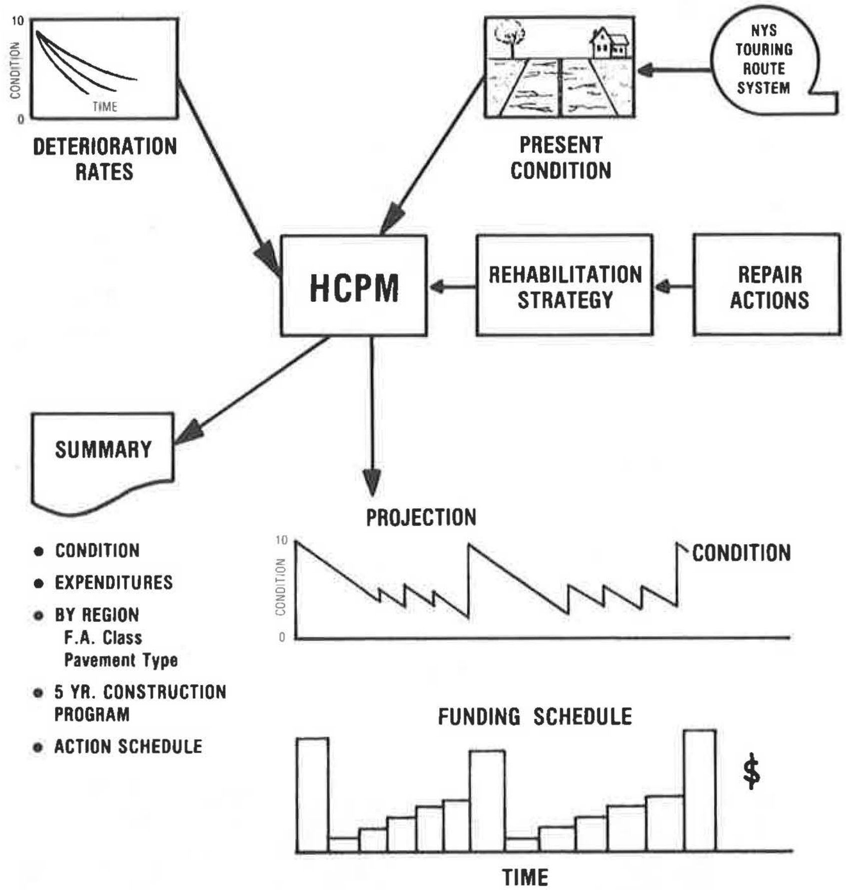
Highway Section Data

The HCPM uses the NYSDOT sufficiency file (13), which contains detailed characteristics, conditions, and traffic data for each section of the state touring route system. The 1982 file contains 19,803 records totaling 15,687 miles. Data items for each record include the following:

1. Characteristics
   a. Location and identity
   b. Length
   c. Number of lanes
   d. Direction: two-way or one-way
   e. Pavement width
   f. Surface, base, and subbase types
   g. Functional class
   h. Federal-aid class
2. Traffic
   a. Count year
   b. Annual average daily traffic
   c. Design-hour volume
   d. Capacity (level D)
   e. Volume/capacity (V/C) ratio
   f. Percentage of trucks
3. Condition
   a. Surface rating
   b. Base rating
   c. Maintenance index
   d. Structural rating
   e. Sufficiency rating
   f. Year of last repair

This detail permits extensive analysis of pavements by location and evaluation of unit costs, traffic loads, and so forth.

Figure 1. Highway condition projection model.



Condition

The condition of New York's highways is measured in several ways:

1. Surface score: A scale of 1 to 10 indicates the quality and condition of the roadway surface.
2. Base (rupture and displacement) score: A scale of 1 to 10 represents the condition of the base material underlying the surface.
3. Maintenance index: A scale of 1 to 10 indicates whether maintenance on that particular segment has been greater than normal, average, or less than normal.
4. V/C ratio: This ratio indicates the density of traffic and the degree of congestion.
5. Structural score: A weighted combination of the first three items on a scale of 0 to 100 is computed as follows: 3 times the surface score plus 4 times the base score plus 3 times the maintenance score.

Measurement of the first two items (surface and base) is easily related to visual characteristics. NYSDOT has recently developed visual scales showing pavements in various stages of condition. Two such scales have been prepared (7) for surface and base (rupture and displacement) and are shown in Figure 2. The visual scales provide a means that is straightforward, easily understood, and rapidly carried out of assessing highway condition in the field while also relating that assessment to perceptions of highway condition by public officials and citizens. Although the method of developing such scales need not be discussed in detail here, it should be noted that it was based on standard procedures involving the sorting and arranging of photographs by U.S. Department of Transportation experts. Once developed, the scales were retested to ensure validity.

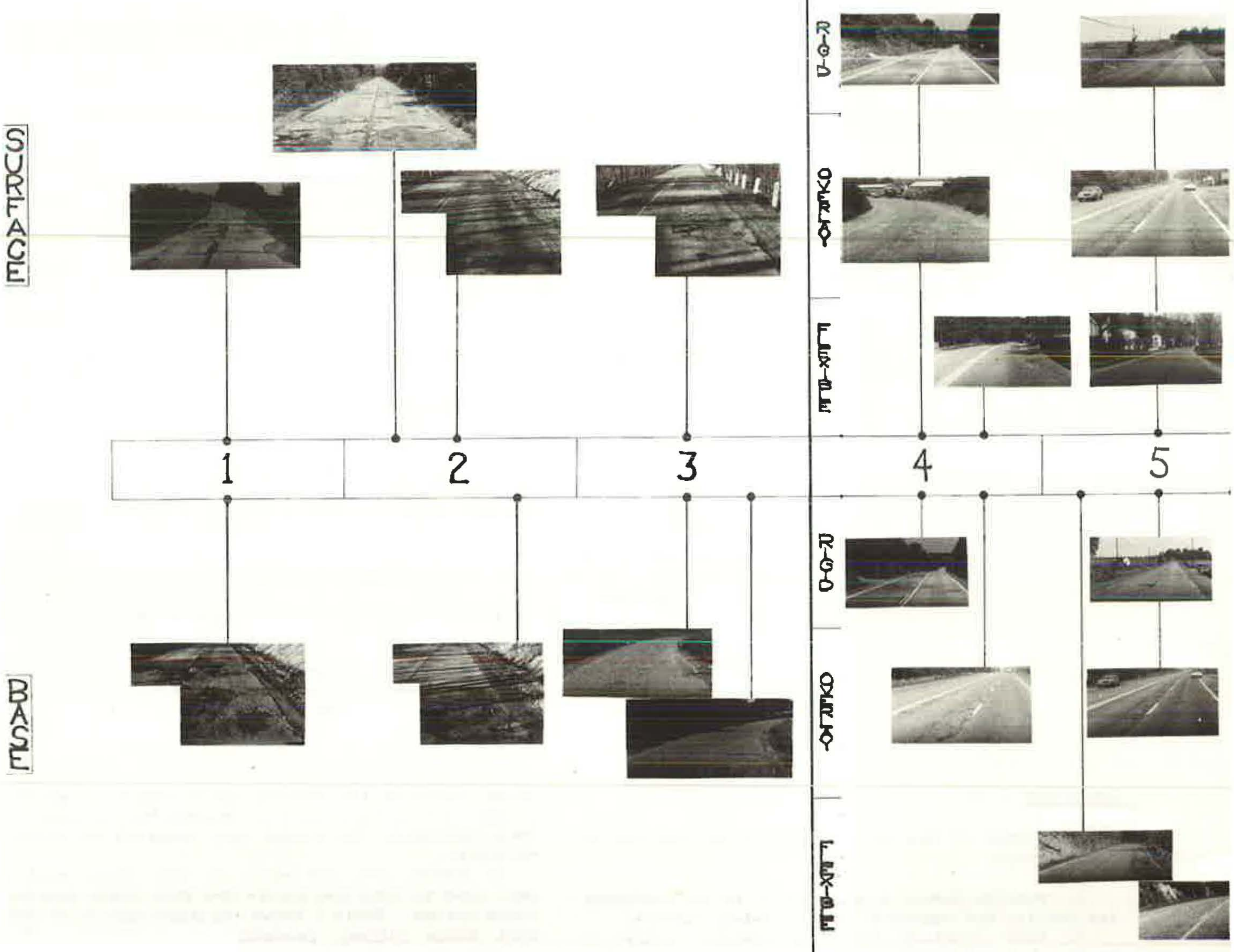
In summer 1981 and again in 1982 these scales were used to rate the entire New York State touring route system. Table 1 shows the distribution of New York State highway pavements by condition. The overall pavement condition of the state touring route system is generally quite good, and road surfaces are in better condition than road bases. Approximately 86 percent of road surfaces were in fair or better condition in 1982 compared with about 80 percent of road bases. About 14 percent of road surfaces and 20 percent of road bases were in poor condition.

The relationship between the NYSDOT condition scale and the present serviceability rating (PSR) used by AASHTO (14) and FHWA for evaluating HPMS sections (11) has been established. The PSR is a scale of 0 to 5 that considers surface, rideability, and structural condition. With data on 100 pavement sections scored by both methods, NYSDOT found that a simple average of its surface and base scores adequately represented the relationship. In other words, the PSR is about one-half the average of surface and base scores. This relationship has proved valuable in developing user cost routines, because most national data express the relationship between user costs and highway condition in terms of PSR and operating speed (15).

Deterioration Rates

Five basic factors influencing the deterioration of pavements are initial construction, traffic load,

Figure 2. Photographic scales of pavement condition.



Note: K is used to represent 10.

Table 1. Pavement condition, 1982, New York State touring route system.

Condition	Level	Surface Lane Miles	Surface Percent	Base Lane Miles	Base Percent
Excellent	10	1,021	9.9	1,044	9.5
	9	2,904		2,747	
Good to fair	8	7,656		6,461	
	7	11,858	76.1	11,039	70.4
	6	10,745		10,439	
Poor	5	4,249		5,763	
	4	1,041		1,763	
	3	234	14.0	403	20.1
	2	19		77	
	1	2		3	
Total		39,729		39,739	
Avg			6.82		6.64

maintenance, environment (primarily climate and weather), and time. In spite of much research to sort out these factors, the understanding of highway deterioration is weak at best. In a recent review (3), two analysts summed it up:

> The first point worthy of emphasis is the lack of published information on deterioration of road pavements. The available (separate) sources can vary nearly be counted on one hand. This lack of information is even more surprising when one considers the wide variations that exist between deterioration relations developed from available data.

To determine approximate deterioration rates for New York State pavements, two approaches were used:

1. The data for the entire 1978 state highway system were arrayed by condition versus number of years since last contract work and initial-year deterioration rates were computed for different pavement types, and
2. Pavement conditions from NYSDOT's 59 continuous-counter locations were analyzed to determine average deterioration rates for pavement types.

Table 2 gives the results from this comparison. The rates are comparable for flexible and rigid pave-

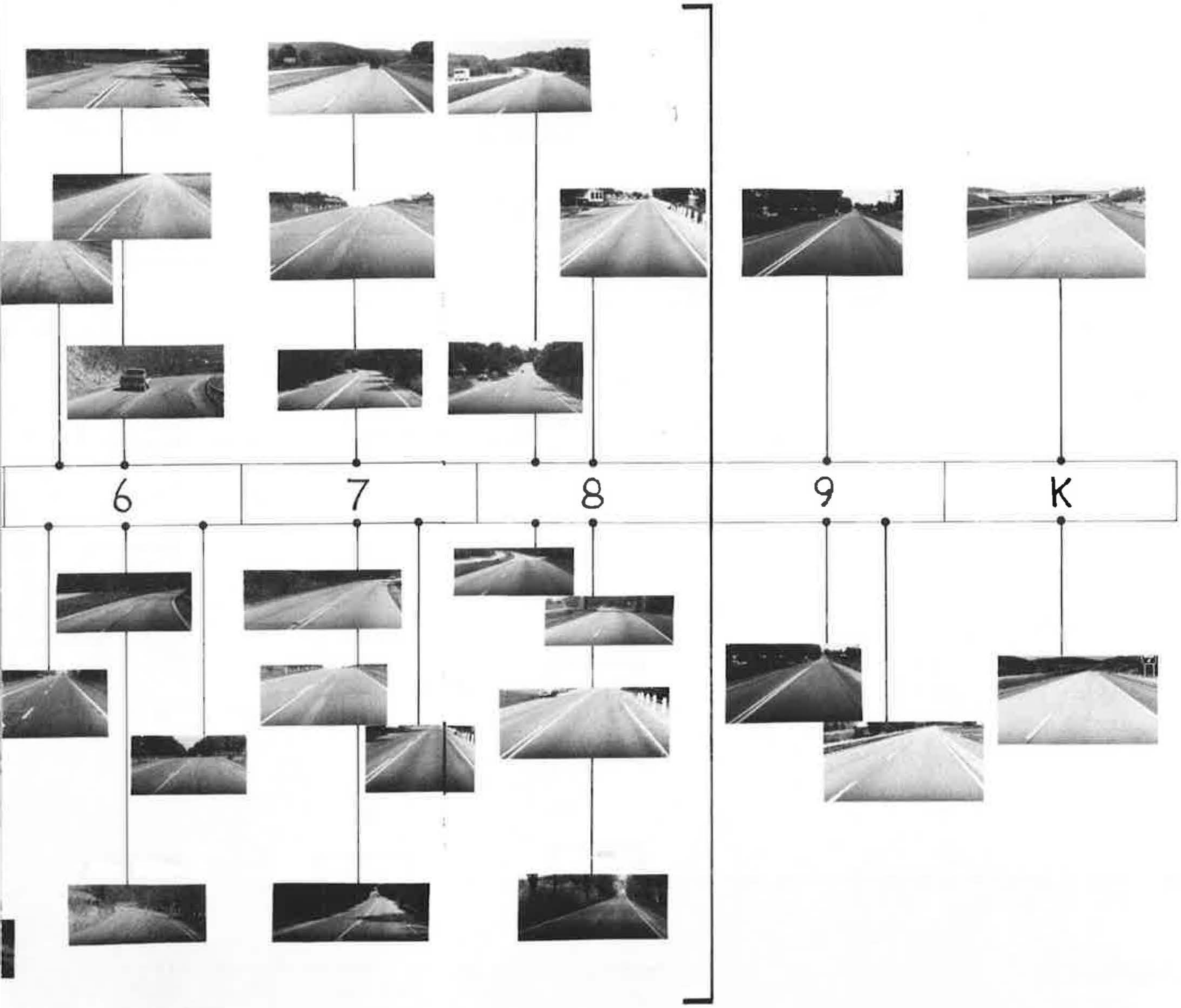


Table 2. Average deterioration rates.

	Avg Deterioration Rate (points/yr)[a]			
	1978 New York State Highway System		Continuous-Counter Sites	
Pavement Type	Surface	Base	Surface	Base
Flexible	-0.33	-0.36	-0.32	-0.32
Rigid	-0.18	-0.19	-0.21	-0.21
Overlaid	-0.45	-0.53	-0.40	-0.35

[a]On the 10-point scale shown in Figure 2.

ments; for overlays, system-based rates are a bit higher.

Repair Actions

Literally hundreds of different treatments and actions are used in rehabilitating and repairing roads, and it is not possible to review them here. The HCPM permits the analyst to identify up to 50 such actions; not all, of course, might be tested in a given analysis. Recent tests of the HCPM have been made with the generic-type repair actions shown in Figure 3. These actions cover the range of work typically undertaken to repair pavements.

Costs of rehabilitation actions were estimated by reviewing current contract prices and discussing with department experts the steps involved in various jobs. The column Percent of Cost Capitalized refers to the proportion of such work that would normally be let out for contract as opposed to that undertaken by NYSDOT. The columns Improvement in Surface and Improvement in Base refer to the incremental improvements in pavement condition (on the scale of 1 to 10 in Figure 2) resulting from the action. As an example, if a multilayered overlay (action 5) were placed on a pavement surface at condition level 5 (Figure 2), the resulting surface condition level would be 9.5 (5 + 4.5). These values were obtained by reviewing construction jobs and determining the improvement they made on pavement condition.

Figure 3. HCPM sample input.

H I G H W A Y C O N D I T I O N P R O J E C T I O N M O D E L

NYS DEPARTMENT OF TRANSPORTATION
TRANSPORTATION STATISTICS AND ANALYSIS SECTION

TEST DESCRIPTION: 1982 S-1; INTER-RIGID; 60-72 HIGH TK-VOL; FAULTING/SPALLING; VOL = 0

PARAMETER INPUT DESCRIPTION

NUMBER OF YEARS PROJECTED	25			
REPORT TYPE REQUESTED	SYSTEM SUMMARY ONLY			
CURRENT YEAR INPUT	1982			
INFLATION RATES	10.9%	8.7%	7.6%	7.4%
INTEREST RATES	12.9%	14.9%	13.7%	12.0%

DETERIORATION RATES

RIGID		OVERLAY		BITUMINOUS	
SURFACE	BASE	SURFACE	BASE	SURFACE	BASE
.30	.30	.45	.25	.32	.32

DESCRIPTION OF REPAIR ACTIONS ******************

ACTION NUMBER	DESCRIPTION	IMPROVEMENT IN: SURFACE	BASE	COST TO REPAIR MIL $/2LA MILE	PERCENT OF COST CAPITALIZED	ECONOMIC SERVICE LIFE	ENDING PVMT TYPE
3	MED. RECONST-PCC	7.0	7.0	1.000	100	25	RIGID
4	RECON RESURF PCC-OV	6.0	6.0	.500	80	20	OVERLAY
5	ML OVERLAY PCC -> OV	4.5	4.5	.200	80	15	OVERLAY
6	CM RESURFACE PCC-OV-OV	3.0	3.0	.120	80	07	OVERLAY
7	GRIND DR. LA/RESEAL PCC	0.4	2.5	.070	80	05	RIGID
8	PATCH SPL/RESEAL-PCC	0.5	1.0	.016	80	05	RIGID
13	MED. RECONST-BITUM	7.0	7.0	1.000	100	25	BITUM
15	ML OVERLAY PCC-OV POST 72	4.5	3.0	.200	80	12	OVERLAY
16	CM RESURF-AC-AC-AC	2.0	2.0	.120	80	07	BITUM
17	GRIND DR. LA/PATCH SPL/RESEAL	0.8	2.5	.100	80	07	RIGID
25	ML OVERLAY AC-AC	4.5	3.5	200	80	10	BITUM

STRATEGY MATRIX (ACTION X AT CONDITION X,X) ******************

SURFACE CONDITION

BASE CONDITION	1	2	3	4	5	6	7	8	9	10
1	3	3	3			3				
2	3	3	3			3				
3	3	3	3			3				
4				5	5	5				
5				5	5	5	7	7		
6	5	5	5	5	5		7	7		
7										
8						6				
9					6					
10										

ACTIONS ARE APPLIED IF: SURFACE <= 3.50 AND BASE <= 3.50 O R LANEVOLUME > 0

Repair Strategy

The HCPM uses a repair-strategy matrix that directs the model to undertake road repair at specified condition levels. Essentially, the matrix tells the model when (at what pavement condition level) to undertake repairs to a particular section and what work to do. Figure 3 shows an example of the strategy matrix for one group of sections (rigid Interstate highways built between 1960 and 1972 that have high truck volumes). Numbers in this matrix refer to the repair actions above the matrix; for example, the matrix directs the model to apply action 5, a multilayered overlay, to a road section on which the surface and base are at condition level 5. Two additional important features are the lane-volume cutoff, which directs the model to take the specified action only if the traffic volume is greater than the cutoff, and the condition cutoff, which directs that action be taken regardless of volume if the condition is below the specified levels. These features together with the range of actions permit examination of a wide variety of policies and strategies.

Operation and Output

The model reads the input data shown in Figure 3, specified by the analyst, including detailed data on the repair actions, the strategy matrix, the volume cutoff and condition cutoff (minimum levels), and the deterioration rates. The model then begins by reading the data on a highway section from the Highway Sufficiency File. Beginning with the current year, the model checks to see whether the condition of the section is in a cell of the strategy matrix that identifies repair. If not, the model causes the condition of the highway section to deteriorate to the next year's condition by applying the deterioration rates specified by the user. This continues until work is required according to the strategy matrix. The model then checks to see whether the section has enough traffic (whether the section is above the volume cutoff) and whether the condition is below the condition cutoff. If either of those cases applies, the model applies the prescriptive action from the strategy matrix to the section of the highway. It adds the increment in condition (improvement in surface and improvement in base) to the condition scores to determine the resulting condition scores for surface and base, calculates the cost of the work by multiplying the length of the section times cost per mile, and adds these data to all of its summary counters. The model then goes on to the next year and continues the cycle until the ending-year horizon is reached for this particular section. It then goes back to the beginning of the program, reads data for another section, and begins the process again.

On completion of the analysis for the entire system, the model summarizes the results, showing average condition and cost of rehabilitation for each year for the state highway system and various subsystems. Figures 4-6 show typical system output. The model is currently programmed to output a summary of data by region and federal-aid class, a 5-year construction program, and an action schedule. Other options are also possible. One of the most useful current outputs is the 5-year construction

Figure 4. HCPM system summary.

H I G H W A Y C O N D I T I O N P R O J E C T I O N M O D E L

NYS DEPARTMENT OF TRANSPORTATION
TRANSPORTATION STATISTICS AND ANALYSIS SECTION

TEST DESCRIPTION: 1982 S-1; INTER-RIGID; 60-72 HIGH TK-VOL; FAULTING/SPALLING: VOL = 0

SYSTEM SUMMARY TOTAL SYSTEM MILEAGE = 231.37

YEAR	SURF MEAN	COND %<6	BASE MEAN	COND %<6	COST TO REPAIR ($M) CAP-I	MAINT	TOT-COSTS	R O A D U S E R C O S T S FUEL	ACCDT	OP-EX	TIME
1982	6.86	6	6.80	11	13.5	3.3	16.8				
1983	7.13	24	7.23	19							
1984	6.81	24	6.94	19	24.6	6.1	30.7				
1985	7.57		7.79								
1986	7.22	30	7.51	25							
1987	6.86	30	7.22	25							
1988	6.51	36	6.94	25	28.4	7.1	35.5				
1989	7.52	28	7.97	23	1.2	.3	1.5				
1990	7.19	28	7.74	23	11.4	2.8	14.2				
1991	7.40	22	7.89	21	20.4	5.1	25.5				
1992	7.94	7	8.58	1	14.4	3.6	18.0				
1993	8.36	7	8.83	2	1.3	.3	1.6				
1994	7.98	6	8.63		5.4	1.3	6.8				
1995	7.80		8.59								
1996	7.35		8.34		17.0	4.2	21.2				
1997	7.92		8.68		1.2	.3	1.5				
1998	7.54		8.47		9.0	2.2	11.3				
1999	7.63		8.53		12.5	3.1	15.7				
2000	7.93		8.72		13.8	3.4	17.2				
2001	8.31		8.95		.7	.1	.9				
2002	7.90		8.72		3.3	.8	4.1				
2003	7.65		8.59								
2004	7.20		8.34		18.2	4.5	22.8				
2005	7.84		8.72								
2006	7.40		8.47		9.0	2.2	11.2				

P E R C E N T D I S T R I B U T I O N

SURFACE SCORE

	1	2	3	4	5	6	7	8	9	10
CURRENT YEAR: 1982				.56	5.30	30.16	35.70	27.87	.36	.02
HORIZON YEAR: 2006						21.80	25.24	35.20	17.75	

BASE SCORE

	1	2	3	4	5	6	7	8	9	10
CURRENT YEAR: 1982				.73	10.41	25.32	35.14	27.98	.37	.02
HORIZON YEAR: 2006								47.04	37.32	15.63

Figure 5. Action schedule.

M I L E A G E A N D C O S T F O R R E P A I R S D I S T R I B U T E D B Y A C T I O N

STATEWIDE SYSTEM SUMMARY

	ACTION 3 MILES	COSTS	ACTION 5 MILES	COSTS	ACTION 6 MILES	COSTS	ACTION 7 MILES	COSTS
1982			20.25	12.16	4.25	1.53	18.95	3.19
1983								
1984			51.84	28.53	.02		16.27	2.22
1985								
1986								
1987								
1988			68.10	35.56				
1989					4.25	1.53		
1990			14.88	7.50	18.77	6.76		
1991			50.55	25.54				
1992			1.48	.88	51.86	17.13		
1993			4.07	1.62				
1994			17.33	6.80				
1995								
1996					67.84	21.27		
1997					4.25	1.53		
1998			.08	.03	33.65	11.27		
1999					51.68	15.73		
2000					52.21	17.25		
2001					4.07	.97		
2002			.26	.10	17.33	4.08		
2003								
2004					72.09	22.80		
2005					.26	.06		
2006					33.73	11.29		

Figure 6. HCPM 5-year construction program.

Section Identification: RC ET GY	RTE	CO TRC YDS	BEGIN M-PT	END M-PT	MILES	LANES	AADT HUND	1982 COND S	1982 COND B	1982 ACT NUM	1982 COST	1982 COND S	1982 COND B	1983 ACT NUM	1983 COST	1983 COND S	1983 COND B	1984 ACT NUM	1984 COST	1984 COND S	1984 COND B	1985 ACT NUM	1985 COST	1985 COND S	1985 COND B	1986 ACT NUM	1986 COST	1986 COND S	1986 COND B
83	84I	014	00.73	00.88	00.15	4	265	8	8			8	8			7	7			7	7			7	7			7	7
82	84I	022	00.32	03.47	03.15	4	287	8	8			8	8			7	7			7	7			7	7			7	7
82	84I	022	03.47	03.71	00.24	4	266	8	8			8	8			7	7			7	7			7	7			7	7
82	84I	022	03.71	04.95	01.24	4	266	8	8			8	8			7	7			7	7			7	7			7	7
82	84I	022	11.51	11.71	00.20	4	238	8	7			8	7			7	6	7	.028	8	9			8	9			7	8
82	84I	022	11.71	13.64	01.93	4	238	8	7			8	7			7	6	7	.270	8	9			8	9			7	8
82	84I	022	13.64	13.70	00.06	4	238	10	10			10	10			9	9			9	9			9	9			9	9
82	84I	022	13.70	17.35	03.65	4	238	8	7			8	7			7	6	7	.511	8	9			8	9			7	8
84	84I	031	00.00	00.33	00.33	4	238	8	8			8	8			7	7			7	7			7	7			7	7
84	84I	031	00.37	00.61	00.24	4	238	8	8			8	8			7	7			7	7			7	7			7	7
84	84I	031	00.61	01.41	00.80	4	238	8	8			8	8			7	7			7	7			7	7			7	7
84	84I	031	01.41	03.37	01.96	4	238	8	8			8	8			7	7			7	7			7	7			7	7
84	84I	031	03.39	03.56	00.17	4	254	8	8			8	8			7	7			7	7			7	7			7	7
84	84I	031	03.56	03.98	00.42	4	254	8	7			8	7			7	6	7	.059	8	9			8	9			7	8
84	84I	031	03.98	04.00	00.02	6	254	6	8	6	.007	9	10			9	9			8	9			8	9			7	9
84	84I	031	04.00	05.00	01.00	4	254	8	8			8	8			7	7			7	7			7	7			7	7
84	84I	031	05.00	05.02	00.02	6	254	9	9			9	9			8	8			8	8			8	8			8	8
84	84I	031	05.02	06.94	01.92	4	254	8	8			8	8			7	7			7	7			7	7			7	7
84	84I	031	06.94	07.35	00.41	4	270	8	8			8	8			7	7			7	7			7	7			7	7
84	84I	031	07.40	07.90	00.50	4	270	8	8			8	8			7	7			7	7			7	7			7	7
84	84I	031	07.90	07.93	00.03	6	270	9	9			9	9			8	8			8	8			8	8			8	8
84	84I	031	07.93	08.12	00.19	4	270	7	7			7	7			6	6			6	6			6	6			6	6
84	84I	031	08.12	08.14	00.02	6	270	7	9			7	9			6	8	6	.007	9	10			9	9			9	9
84	84I	031	08.14	09.10	00.96	4	270	8	8			8	8			7	7			7	7			7	7			7	7
84	84I	031	09.10	09.33	00.23	4	270	5	8			5	8			4	7			4	7			4	7			4	7
84	84I	031	09.79	10.75	00.96	4	340	7	8			7	8			6	7			6	7			6	7			6	7
84	84I	031	10.75	10.78	00.03	4	340	5	8			5	8			4	7			4	7			4	7			4	7
84	84I	031	10.78	10.79	00.01	4	401	6	7*			6	7			5	6	5	.004	10	10			9	9			9	9
84	84I	031	10.79	13.01	02.22	4	401	7	8			7	8			6	7			6	7			6	7			6	7
15	87I	081	05.63	12.79	07.16	6	273	6	6			6	6			5	5	5	4.296	10	10			9	9			9	9
15	87I	081	12.79	13.03	00.24	6	172	6	6			6	6			5	5	5	.144	10	10			9	9			9	9
15	87I	081	13.03	16.47	03.44	6	172	6	6			6	6			5	5	5	2.064	10	10			9	9			9	9
15	87I	081	16.47	18.15	01.68	6	244	7	7			7	7			6	6			6	6			6	6			6	6

program (Figure 6), which shows the condition of each section and the funds required to sustain it for each year of the 5-year period.

Some other features are being added to the model at this time. These include the following:

1. A routine that calculates user costs for each section, including travel-time cost, operating cost, fuel cost, and accident cost, the availability of which will permit the analyses of benefits and costs of rehabilitation alternatives;
2. Amortization and interest routines; and
3. An option so the user may focus the analyses on one specific route or county combination or on a particular section of highway.

Table 3. Interstate pavement groups.

Pavement Group	Typical Problem	Miles[a]
Rigid, before 1960	Spalling and rutting, cracking, roughness	24.63
Rigid, 1960-1972, high truck volume (>3,000)	Faulting >0.25 in., spalling, cracking	231.37
Rigid, 1960-1972, low truck volume (<3,000)	Faulting (less), slight spalling	104.95
Rigid, after 1972	Slight spalling, surface and joints	209.12
Flexible	Cracking and rutting, some potholes	196.46
Overlaid		95.13
Total		861.66

[a]Excludes mileage on the N.Y. State Thruway.

AN EXAMPLE: INTERSTATE REPAIR AND REHABILITATION NEEDS

The following example illustrates the operation of the HCPM. The tests involve an assessment of recommended repair strategies and actions for New York's Interstate system.

The New York State Interstate system was constructed over a fairly long period of time and consequently exhibits different distress symptoms. In particular, rigid Interstates built between 1960 and 1972 that have a high truck volume (Table 3, second group) are beginning to show joint failure and severe faulting problems. Rehabilitation strategies for these sections are more complex than strategies for older sections or flexible pavement sections.

Suggested repair strategies for each group of Interstates shown in Table 3 were developed by the NYSDOT Pavement Management Task Force. These strategies consisted of actions necessary to correct identified problems and to repair and maintain the pavement for as long as possible. Examples of such repair actions are shown in Figure 3. The HCPM was then used to determine the overall cost of these strategies and the resulting system condition and to prepare a possible 5-year construction program. Examples of these documents, again for the second group in Table 3, are shown in Figures 4-6.

The analysis shows that repair needs for this group of sections (231.37 miles total) would total $16.8 million in the first year, $47.5 million over 5 years, and $142.2 million over 10 years (Figure 4); however, after this initial period, repair costs will be less. The average condition of this group of pavements will be substantially better in 1992 than at present (1992 surface condition, 7.94; 1992 base condition, 8.58) if these strategies are followed; this good condition can then be maintained for the next 15 years for about $132.3 million, or $8.8 million per year. The action summary (Figure 5) shows that the initial focus needs to be on joint repair and base protection actions, followed later by 2.5-in. overlays, then still later by cold milling and resurfacing of these overlays. Figure 6 shows a page from the 5-year construction program for this group of sections; it lists each section by location and shows the work required in each year.

The results of the Interstate highway repair and rehabilitation analysis for all six pavement groups are shown in Table 4. Overall, such repair needs total $55.6 million in the first year and $31.7 million over 10 years. The system would be substantially better at that time if these repair strategies were followed.

These data are being used by NYSDOT in a variety of ways:

Table 4. Effect of pavement improvements on condition: New York State Interstate system.

Pavement Group	Miles	1982 Condition Level		1983 Condition Level		1992 Condition Level		Repair Costs ($000,000s)	
		Surface	Base	Surface	Base	Surface	Base	1983	1992
Rigid, before 1960	24.63	6.1	6.2	7.9[a]	8.0[a]	7.3[a]	7.3[a]	5.1	1.1
Rigid, 1960-1972, high truck volume (>3,000)	231.37	6.9	6.8	7.1[a]	7.2[a]	7.4[a]	7.9[a]	16.8	12.4
Rigid, 1960-1972, low truck volume (<3,000)	104.95	7.0	6.4	7.4[a]	7.3[a]	7.6[a]	7.9[a]	9.1	3.4
Rigid, after 1972	209.12	8.6	8.4	8.5	8.3	7.8	7.9	2.1	1.4
Flexible	196.46	7.7	7.8	7.9[a]	8.1[a]	9.0[a]	9.0[a]	12.4	9.5
Overlaid	95.13	7.4	7.3	7.8[a]	7.8[a]	7.4	7.7[a]	10.1	3.9
Total	861.66	7.5	7.4	7.8[a]	7.9[a]	7.9[a]	8.1[a]	55.6	31.7

[a]Improved condition.

1. Overall system repair needs: The tests permit assessment of total system needs and resulting condition over the long term.
2. Repair strategies: The procedure permits analysts to determine the wisdom of various repair strategies.
3. Allocations: The data can be used to assist in allocation of funds to regions of the state; for the 1983 construction program, for instance, funds were allocated by lane miles, vehicle miles of travel, and repair needs.
4. Early alert: The model identifies sections in need of attention or likely to need attention in the future.
5. Suggested repairs: The model suggests, but does not prescribe, repair actions for each section of road. The department's decision making on specific actions is decentralized to its regional offices; the model can be used to assist in these decisions, but the recommendation of the regional director on specific actions is usually followed.

CONCLUSIONS

A new tool, the HCPM is one of several procedural improvements under development by NYSDOT to predict and evaluate the long-term implications of alternative rehabilitation strategies on the condition and the repair costs of the New York highway system. The model operates sequentially on data for each section of state highway and summarizes repair costs and condition by region and federal-aid class. Preliminary tests of the model suggest that it is beneficial in quantifying the implications of different repair strategies.

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