How Good Is the Highway Performance Monitoring System? A Comparison with State Results

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ABSTRACT

Described in this paper is a comparison that was recently made by New York State of 1984 Highway Performance Monitoring System (HPMS) sample data with a 1984 inventory of data drawn from the same roads. The comparison is on condition and estimates of repair needs. The analysis shows that the 1984 HPMS data are, in aggregate, a good representative sample of the 1984 system's condition. Estimates of need show a similar pattern over time, but differ from those prepared by the state because the methods are not comparable. The paper concludes with a number of recommendations concerning the HPMS analytical package that, in the state's view, would increase its value to potential users that HPMS data are useful.

The purpose of pavement management is to increase the cost-effectiveness of public investment in highways, by improving the procedures by which highway condition and needs are estimated, projected, and evaluated. Pavement management cannot effectively be accomplished unless the state highway agencies can estimate future transportation needs, with sufficient accuracy to be credible as well as sufficient lead time to plan for needed repairs.

The Highway Performance Monitoring System (HPMS) established by the FHWA to describe system condition and estimate needs on a national basis, has been found to be an adequate tool for national estimates (1-3). However, because HPMS estimates are based on a small sample of road sections in each state, and are observed biennially, its representativeness and usefulness at subnational levels (such as the state level or areas or road groups within states) is considerably weak. In addition, each state's requirements for program-specific projects selected from all roads under its jurisdiction precludes the use of HPMS as a project identification tool, except in those few states that use a complete inventory of roads as input to the HPMS analytical process. Because of these problems, and because they have other tools available, the states generally rely on other techniques to forecast highway condition and prepare estimates of needs.

The availability of these other procedures provides the opportunity for comparison of the power of the HPMS system at the state level. Because most states conduct periodic inventories of condition and prepare periodic needs statements, these estimates can be compared with results from the HPMS. The analysis can show to what extent HPMS complements the state's procedures, and the degree to which it may be relied on to prepare future estimates of needs.

The purpose of this paper is to review one such comparison that was recently conducted in New York. In this comparison, the raw HPMS data and the results of needs projections in the HPMS Analytical Process were compared with the data from New York's own inventory of system condition, and the results of its own projections of needs.

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APPROACH

Of 109,800 mi in New York State, approximately 15,560 are under the jurisdiction of the state department of transportation (Figure 1). In addition, the New York State Thruway and other parkway authorities are responsible for approximately 830 more centerline miles. Most of this mileage is on the federal aid system. The remaining 93,490 mi are owned by localities and include an additional 9,720 mi on the federal aid system.

The approach taken into this study is to develop and compare 1984 estimates of highway condition, and projected needs for the 1990s, using two parallel methods. The study, Highway Financing for the '90's, is part of a broader investigation being undertaken by New York State to estimate highway repair needs in the next decade after completion of the current 5-year transportation program. Figure 2 shows the overview for the study, identifying particular tools to be used for each assessment. In this figure, HCPM refers to the New York State Department of Transportation (NYSDOT) Highway Condition Projection Model, discussed later. The comparison between HPMS and the New York methods includes data on (a) existing (1984) highway conditions, (b) projected pavement repair needs, and (c) projected capacity, safety, and other nonpavement highway needs.

EXISTING CONDITIONS

The New York State and HPMS condition measuring systems are different, and must be related mathematically. To measure condition, New York State uses two 10-point scales (surface and base) to rate each section of highway. On each scale, 1 represents the worst condition and 10 represents the best condition, with roads rated 5 or less generally representing poor conditions. Full-system inventories of condition are conducted annually from a moving vehicle using a visual photograph scale. This visual scale is the key difference between the New York State method and the federal method.

On the other hand, the HPMS condition rating system uses the 5-point Pavement Serviceability Rating (PSR), in which 0 represents the worst condition and 5 represents excellent conditions, with roads rated

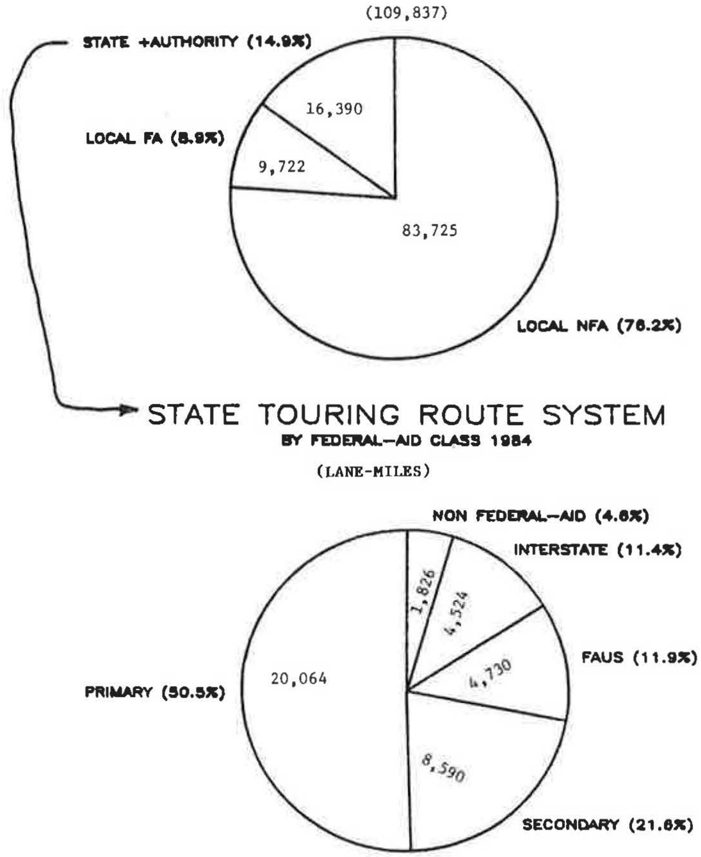

FIGURE 1 New York State Highways and State Touring Route System.

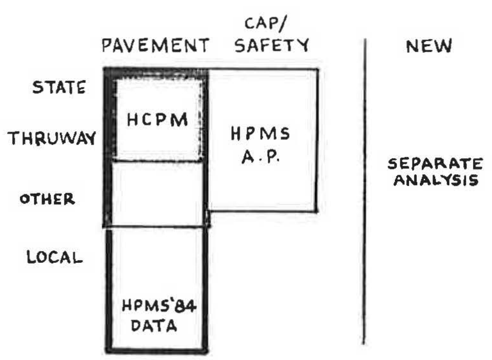

FIGURE 2 Overview of highway analysis methods including "Financing for the '90's" study.

2.5 (2.0 for Interstate) or less generally considered to be in poor shape. In New York, the HPMS condition ratings are made every 2 years for a sample of 2,700 sections. Before 1984, the state used this 5-point verbal rating system contained in the HPMS field manual. Beginning in 1984, New York State used its own 10-point rating procedure to estimate HPMS condition, then calculated the HPMS rating as follows:

PSR = (Surface Rating + Base Rating)/4

This relationship was developed from a statistical analysis of 100 sections rated by both methods (4). Because of changes in the procedure, "trend" statistics for HPMS for 1982 to 1984 are not strictly comparable. Although the rating systems are, therefore, not strictly comparable, they are relatable.

Table 1 gives the average 1984 condition of roads using the state and the HPMS rating processes. Because the rating methods for 1984 are identical, this comparison essentially tests the overall representativeness of sample distribution of HPMS. For the State Touring Routes, the HPMS sample data, based on a sample of 1,909 sections, produces an overall average condition and "percent poor," which is close to the full inventory results for the state system. This is also shown in Figure 3, which shows the distributions of each data set. Therefore, the condition of local roads is probably also good (within statistical limits). Figure 4 shows that in prior years, the distribution of condition in the HPMS sample appeared to be generally worse than that in the state touring system. Because the 1984 data agree and the sample locations were unchanged from 1982 to 1984, it is suggested that the 1982 HPMS data may have been scored too low.

Because the NYSDOT does not collect its own data on nonstate-owned roads, the only indication of the condition of these roads is taken from the HPMS. Table 1 gives the average condition of these local roads. In the worst shape of all is New York City, where the overall system mean is estimated at 5.04 (on a 10-point scale) with 56 percent rated as "poor" (5 or less). Even though this data may have considerable sampling error, it is clear that municipal, town, and county-owned roads in New York are in considerably worse condition than the state-owned roads. National HPMS data suggest a similar pattern for most states (5).

Another useful comparison, which is not often

TABLE 1 Average Condition by Jurisdiction and Measurement Method, 1984

	New York State Method		HPMS Method		
Jurisdiction	Total Measurements Where % ≤ 5	Average[a]	Total Measurements Where % ≤ 5	Average[a]	Sample Size
State touring route	14	6.82	6.80	12	1,909
Towns			6.62	16	166
Counties			6.44	16	354
Villages			6.24	24	66
Other cities			6.22	20	172
New York City			5.04	56	43
Total					2,710

[a]Surface rating + base rating/2.

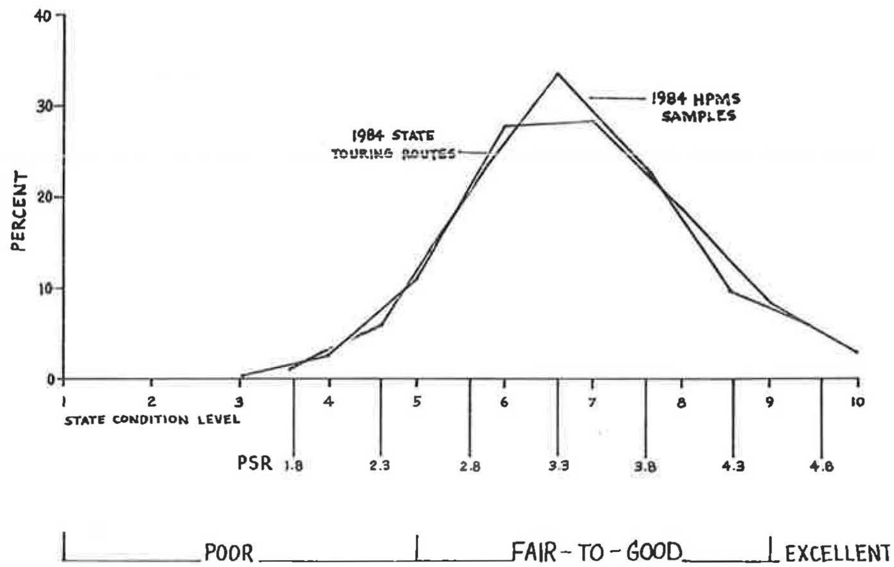

FIGURE 3 Condition distribution comparison—state touring routes versus HPMS samples, 1984.

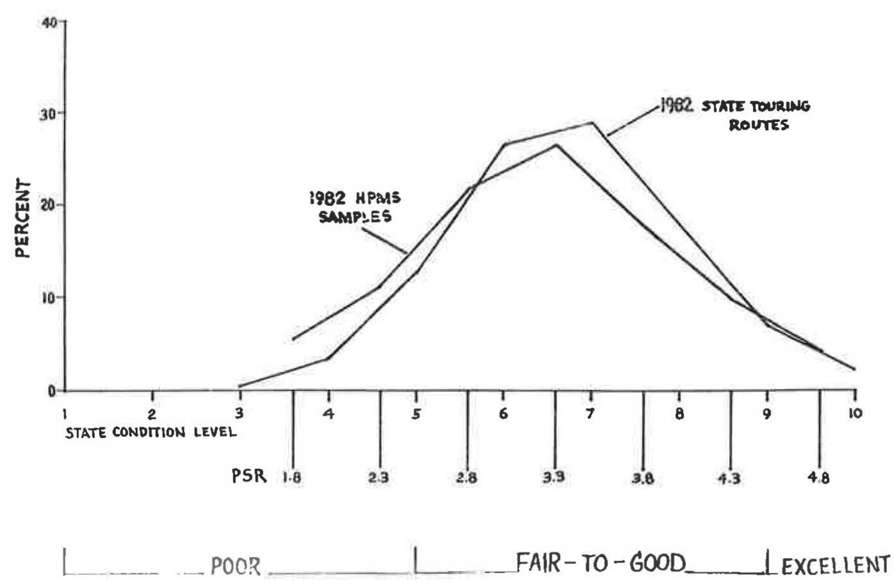

FIGURE 4 Condition distribution comparison—state touring routes versus HPMS samples, 1982.

TABLE 2 Changes in Condition (10 pt. Scale), 1982-1984

Measurement Method	−5 to −1 Declined	0 (No Change)	+1 (Rescored Upward)	2+ (Improved)
New York State				
Matched sections	6,059	6,637	1,761	1,728
Percent of sections	37	41	11	11
Average change	−.59/yr	–	–	+3.05
HPMS				
Matched sections	886	394	345	380
Percent of sections	44	20	17	19
Average change	−.58/yr	–	–	+3.13

made, is to track the trend of individual highway sections over time. Table 2 and Figure 5 show the results of comparing 2,005 HPMS sections (state-owned system only) that were evaluated between 1982 and 1984 with 16,159 similarly compared sections from the state's inventory. Results show similar average deterioration rates and average gains, but different percentages of sections estimated to have been improved or rescored upward. Essentially, the HPMS data appear to overstate the number of miles improved. This also suggests that the 1982 HPMS sections were rated too low, a conclusion reached previously by comparing the distributions. This comparison leads to two conclusions: (a) HPMS data are solid, and (b) the 1982 HPMS data probably understated condition.

PAVEMENT REPAIR NEEDS

Figure 6 shows schematically how estimates of repair needs are made for the "Highway Financing for the '90's" study. For state-owned roads, needs estimates are based on the distribution of condition from the state's 1984 inventory of condition. This information is then fed into the Highway Condition Projection Model (HCPM), which produces an estimate of needs by year. HPMS information corresponding to the state highway system can also be inputted through the HPMS Analytical Process, and a needs estimate computed. For local roads, the HPMS Analytical Process can also be used to estimate needs or, alternately, needs may be estimated by multiplying the distribution of condition (from HPMS), times approximate unit cost-to-repair. In a sense, therefore, the HPMS Analytical Process serves as a shadow methodology that checks the state system projections based on the state's model, and checks the local road projections based on the distribution of condition.

Some comment is necessary concerning the procedures used by these two processes. The HCPM used by New York State is shown schematically in Figure 7.

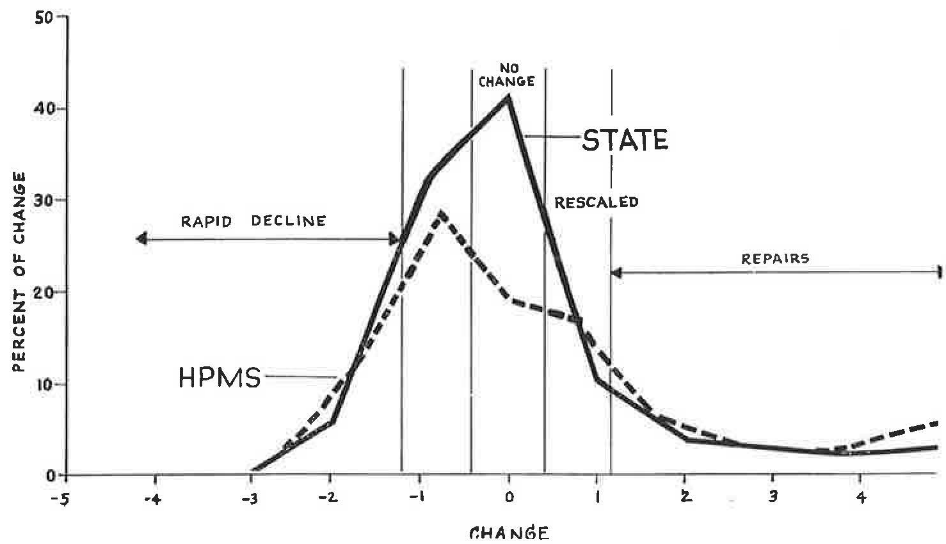

FIGURE 5 Changes in condition—New York State touring routes, 1982-1984.

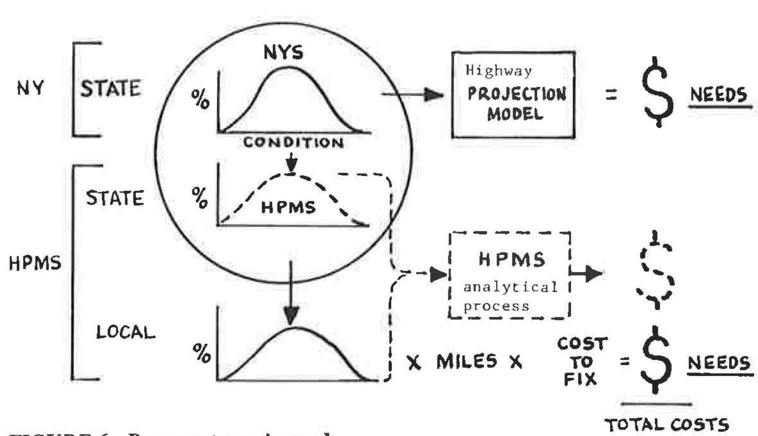

FIGURE 6 Pavement repair needs.

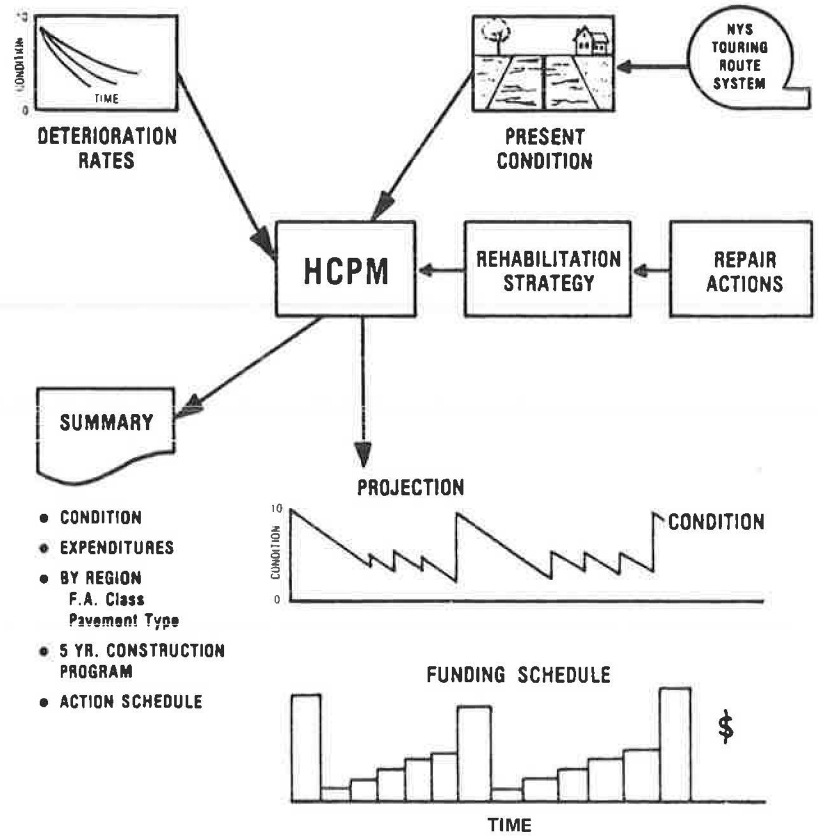

FIGURE 7 Highway condition projection model.

Basically, the model operates on an inventory of existing condition and applies typical deterioration rates and repairs prespecified by the analyst. In this model, time (years) is used to deteriorate pavements; traffic is not used. The output is estimates of highway pavement needs, and resulting condition by year. The model is discussed in greater detail in a number of technical reports (6,7).

The HPMS Analytical Process, on the other hand, operates on a sample of highway sections representative of the higher functional classes. Deterioration is predicted by the AASHTO PSR curves, which relate pavement condition for accumulated axle load equivalents. In this model, time (years) is used only as an increment to move the model forward, but the basic deterioration is incorporated through projected traffic estimates.

Pavements are deteriorated until they reach a prespecified cutoff level, at which time work is undertaken according to a set of rules that are internal to the model. Costs of repair are also internal to the model, and may not easily be changed. The output of the HPMS Analytical Process is a projection of repair needs, resulting system quality ("composite index"), and miles repaired for each year, and for 5 years. So, conceptually, the models are similar; yet, in detail, they are different.

HPMS analytical tests were run on New York State's 1982 HPMS data; four tests were prepared, as shown in Figure 8. These correspond to tests that would assess pavement needs only, versus pavement and capacity-safety needs. For each of these, two repair strategies are tested, one termed "defensive" (in which repairs are undertaken at PSR Level 2.5), and the other termed "offensive" (in which repairs are undertaken at Level 3).

Results of these tests are shown in Figures 9-11.

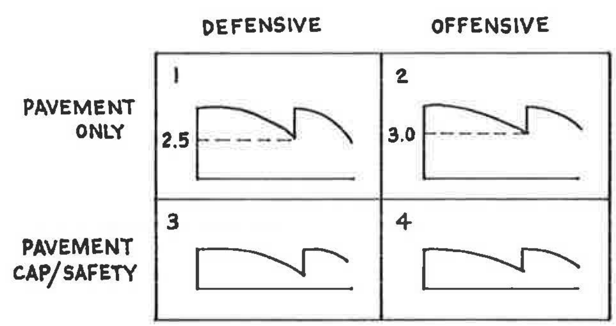

FIGURE 8 New York State tests with HPMS analytical process.

All of these tests are unrestrained needs tests, meaning that no cap is placed on dollars available. Each test shows a familiar pattern in which existing backlog of repair needs is improved in the first 5-year period, resulting in a substantial improvement in composite index. Then, additional repairs in the remaining 5-year periods are able to sustain the improvements over time. Interestingly, the offensive repair strategy (Test 2), in which pavements would be repaired at a higher level of condition but would presumably be treated more lightly (a) produced higher overall 5-year costs compared with the defensive strategy (Test 1) in the first 5 years ($9.0 versus $7.4 billion), (b) required more mileage to be repaired (17,600 mi versus 24,900 mi), and (c) produced a slightly higher composite index, approximately 1 percent higher.

The New York State HCPM was also used to test need under a variety of strategies. (Note that be-

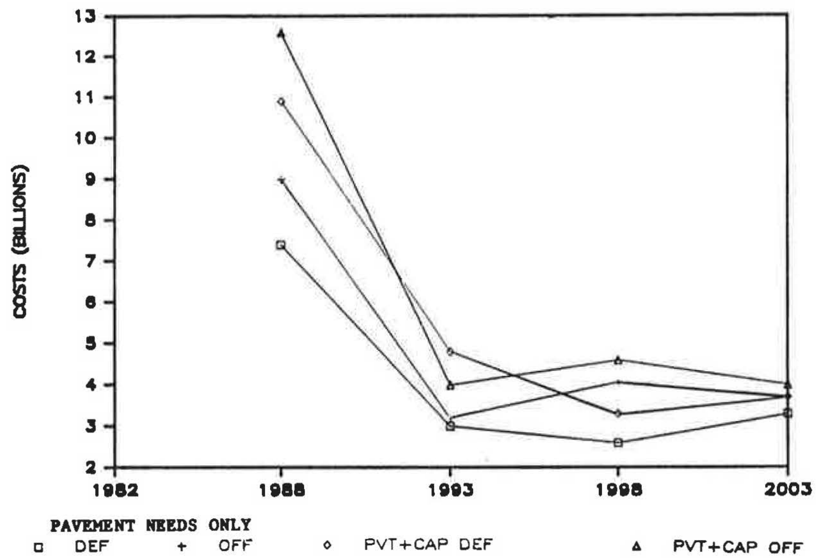

FIGURE 9 Projected New York State highway needs based on HPMS 1982 data.

cause the Highway Financing for the '90's study is ongoing, these numbers should be treated as illustrative only, and not as official estimates of need.) One particular strategy, termed "Test 2," simulates a "big-push" approach in which repairs would be made now to all sections requiring work, and, once repaired, highway sections would be retained in good condition by a substantial increase in heavy maintenance on (what by then would be) good roads.

The comparison between New York State and HPMS (Test 2) data are given in Tables 3 and 4. Because the systems are of different size, the analysis must be converted to a per-mile basis. The basic conclusions are as follows:

1. The New York State tests, focusing on 16,300 mi, suggest a total 12-year need of $4.4 billion, resulting in a 5 percent improvement in condition. The HPMS test (Test 2), focusing on a 36,000-mi system over 10 years, identifies $12.2 billion worth of needs, and a projected improvement of 5 percent in performance.

2. On the basis of cost per system mile per year, the HPMS model estimates approximately twice the repair costs as does the New York model, particularly in the first 5 years.

3. For "percent of system improved," the HPMS models propose that a smaller portion of the system would be repaired.

Thus, it appears that while the general shape of the needs profile is similar from both tools, the HPMS analytical process estimates a higher and also a higher per-unit cost than the New York model, although the New York model identifies a greater need for lighter and less costly treatments.

Details on construction costs are given in Table 5. Because the HPMS model uses a large number of costs for different circumstances and situations, and these costs are not easily accessible to the

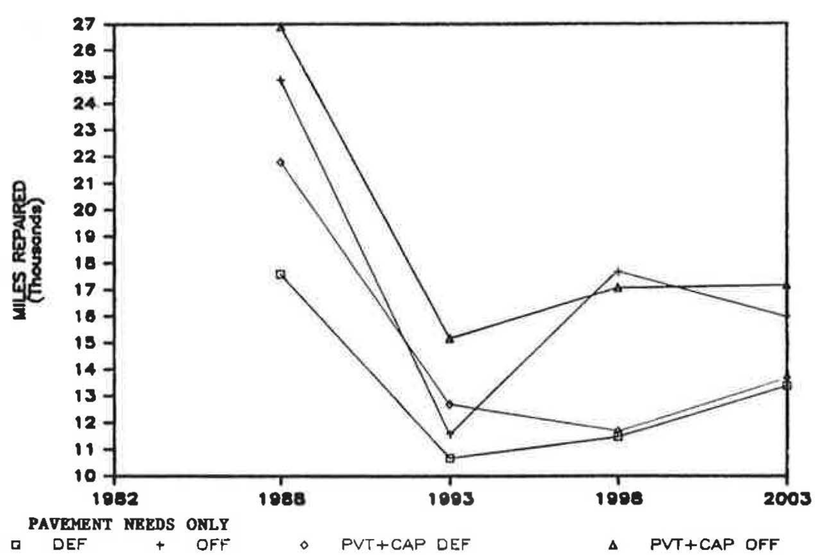

FIGURE 10 Projected New York State miles repaired based on HPMS 1982 data.

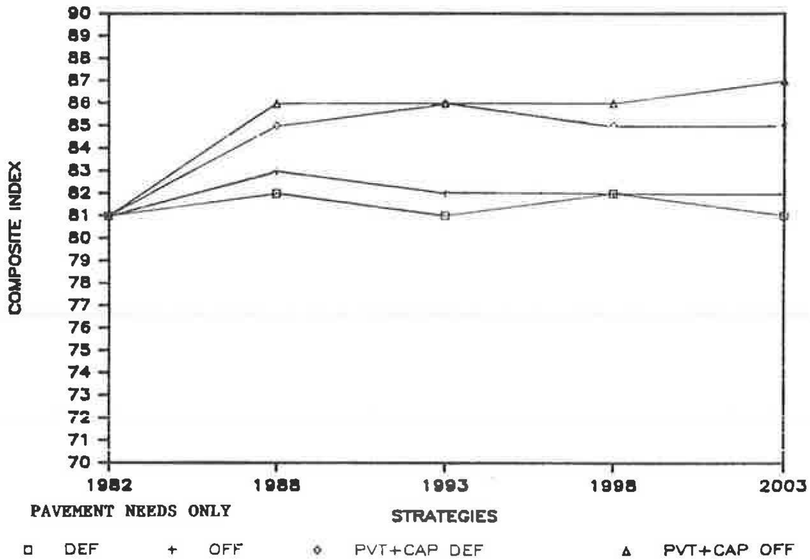

FIGURE 11 Projected composite index for rural and other principal arterial.

TABLE 3 Comparison of Tests by Measurement Method—Pavement Needs Only

Test Characteristics	Measurement Method: New York State	HPMS
System	16,300	36,000
Model	HCPM (Alt 2)	HPMS Analytical Process (Test 2)
Data	1984	1982
Initial performance	6.97	34.3 (private portion of composite index)

TABLE 4 Comparison of Tests by Time Span—Pavement Needs Only

	Time Span			
	New York State		HPMS	
Test Characteristics	1-7 yr	8-12 yr	1-5 yr	6-10 yr
Results				
Needs ($ billion)	3.25	1.2	9.0	3.2
Miles repaired	17,900	12,100	25,000	11,600
End performance	7.72	7.35	36.6	36.0
Comparison miles				
Cost per system mile per year ($ thousand)	28	15	50	18
Cost per repair mile ($ thousand)	182	99	360	275
Repair miles per system (%)	110	74	70	32
Percent change in performance	11	5	7	5

test designer, it is difficult to determine the overall average cost of actions undertaken. The models use different classifications of costs and the New York model classifies by pavement type (rigid, flexible, and overlay), while the HPMS model classifies by location (urban, rural). The major discrepancies appear to be in the estimated costs of resurfacing, which are assumed to be higher in the HPMS model than in the New York model. Reconstruction costs are roughly comparable. The state would normally continue to use its own estimates of these needs because it feels it has a better understanding of repair costs.

TABLE 5 Unit Construction Costs

Construction	Costs ($ million/2-lane mi)
HCPM	
Rigid	
Reconstruction	1.5
Portland cement concrete overlay	.25
Joint repair	.075
Flexible/overlay	
Reconstruction	1.5
Medium reconstruction	.75
Regular R + P[a]	.30
TIMS and special	.075
HPMS	
Urban 2-lane undivided	
Reconstruction	1.58
Resurface with shoulder	.57
Resurface	.51
Rural-OPA[b]	
Reconstruction	1.04
Isolated reconstruction	.64
Resurface with shoulder	.21
Resurface	.11

[a]R + P = reconditioning and preservation.
[b]OPA = other principal arterial.

CAPACITY AND SAFETY NEEDS

Two estimates of capacity and safety needs were made as follows (Figure 12). In the first, using the HPMS methodology, results of the HPMS tests were compared to estimate the total capacity and safety needs for the 36,000 HPMS mile system, and for a reduced state approximation totaling 15,015 miles. Secondly, New York State's inventories were stratified mileage with narrow lanes and high volume capacity ratios, and typical costs to repair were multiplied by each cell to produce an estimate of the total needs. Results of this analysis are given in the following table.

Measurement Method	System Length (mi)	1983-1988 ($ billion)	1989-1993 ($ billion)	Total ($ billion)
HPMS	15,015	2.14	.58	2.72
New York State	15,649	1.47	1.0	2.47

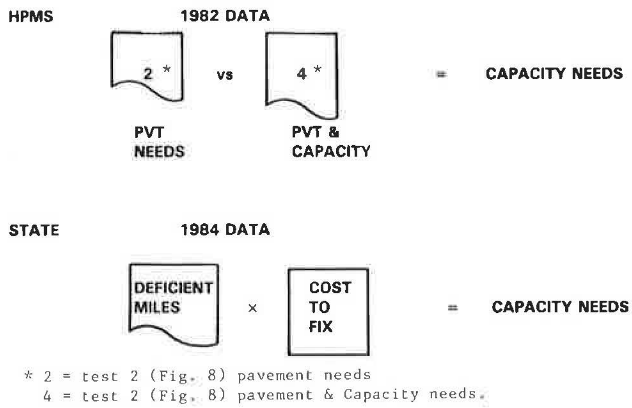

FIGURE 12 Capacity and safety needs.

Basically, the methods produced comparable results in terms of total needs estimates, and reasonable results with respect to short-term versus longer-term capacity needs.

By comparing the curves in Figures 9-11, it may be seen that the total gap between "capacity + pavement" and "pavement only" needs is approximately $3.6 billion in the first 5-year period. If improvements were made, the composite index (rural, other principal arterial) would be approximately 5 percentage points higher. The capacity needs add approximately 30-35 percent to overall pavement needs for most scenarios tested.

Because the New York State highway system is generally in good shape with a 1982 composite index of 79 (rural, other principal arterial), the addressing of all unrestrained needs does not produce a large increase in the condition of the system. Figure 11 shows that, even with all capacity and pavement needs undertaken, the composite index would rise to only 85 or 86 in the first 5-year period, and would remain at that level for the foreseeable future. Thus, even with unlimited funds, it is unlikely that an improvement of more than 5 or 6 percent in overall quality of performance could be achieved on a system-wide basis. Obviously, this index could be made higher if the criteria and standards for pavement condition, capacity, safety, and so forth, were increased.

CONCLUSIONS

The preceding assessment suggests the following general points:

1. The HPMS data and the Analytical Process models produced assessments of existing (1984) conditions and projections of future needs that generally showed the same overall patterns as did the more detailed analysis undertaken for the state's highway system. Although some differences do exist, these are largely based on the scale of system size and/or assumptions concerning costs. Also, the 1982 HPMS data appear to understate condition.
2. The HPMS urban cost assumptions, particularly for repair and resurfacing strategies, are probably too high for New York State.
3. The findings were reasonable and served as a useful bracketing tool for the overall financing project results. Although the HPMS analytical process does not produce project-level results, it does provide a useful overall framework for studies of system needs.

The author's experience in working with the HPMS model and its outputs suggests that a number of minor improvements could be made to the system that would substantially increase its usefulness. The following suggestions are therefore made:

1. User access to cost data. The basic problem in the model is that some of the assumptions in it are difficult to identify and change. This is particularly true for repair costs. Individual states and cities should have the flexibility to input their own cost information easily. The cost numbers are too detailed.
2. Flexible action assignments. The model now internally handles the decisions as to when various actions should be undertaken. Because most states have their own rules for project selection, users should be able to identify either points in time or condition, at which various actions are undertaken, and easily specify the nature (what is to be done, its costs, and its effect on condition).
3. User-oriented. At present, the model is difficult to operate, and requires considerable skill to interpret. A user-oriented version would be of great assistance.
4. Pyramid-style printouts. Statewide summaries from a sample of roads are generally policy reports. Policy-oriented individuals need clear concise summaries. The author found that the HPMS printouts are difficult to understand and organize. Although the first several pages contain a summary of the results, key items such as summaries for the system; a summary by federal aid class; a listing of the input data and percent changes, and so forth, are not shown and must be calculated or obtained from other sources. Basically, conclusions from the printouts cannot be drawn directly, but must be extracted by pulling together numbers from different parts of the printout or other printouts. A pyramid-style format, in which the most important numbers were provided first, then other numbers later, would be of great assistance. If possible, the information should be squeezed onto one simple page, and a short form of the output made available.
5. Time string. The data are not shown in terms of year sequences. There are inconsistencies in the naming of years and in the ways in which the model treats various years.
6. System composite index. No overall composite index is provided for system condition, either at the initial stage or in future years; thus, percent changes in condition cannot be computed for the system as a whole. The calculations should include an overall composite index for the system.
7. Federal-aid breakouts. Most of the analysis is conducted not on the basis of functional class, but rather on a basis of federal aid category. There should be a breakout for the higher federal aid classes. Even though the HPMS data was not expanded in that fashion, it can be summarized in that fashion.
8. Baseline comparison. Key baseline statistics (for instance, composite indices) from the raw file should be included in the output right up front, so that comparison of changes can be made directly.
9. History of condition at each site. The HPMS system now operates only on the most current HPMS file, not utilizing the data available from previous years at each location. This information could be used as a background for model enhancements to improve pavement performance prediction, identify work actions, and so forth.
10. Tie to PR-37 or other project data. The key action sequence in HPMS is the work that is conducted on each sample section. These data should be used more effectively in the model, and should be tied to the state's project data bases. In particu-

lar, the HPMS analytical model should allow for the subtraction of an existing project list or proposal from the background file before modeling is performed.

11. Graphic outputs. The analytical package is now provided entirely in numbers output. In this modern era of graphic output, the data should be shown in time series form.

12. Micro version. A simple micro version should be developed, allowing for the reading in of blocks of mileage at different condition levels and projection of condition for systems in a general fashion. (Note that particular emphasis should be placed on keeping it simple.)

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