# Pavement Management System To Maximize Pavement Investment and Minimize Cost

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Pavement management is a process by which decision makers rationalize management decisions regarding a wide spectrum of activities: planning and programming of investments, design, construction, maintenance and rehabilitation, periodic evaluation of performance, and pavement research. In this context, management is defined as efficient coordination of the above activities in order to reach a systematic decision. The system reported herein is the result of the development and implementation of a third-generation pavement management system for the Ohio Department of Transportation that has required slightly less than 4 years to complete. The pavement management system described is characterized as a network-level system that provides optimal actions for candidate pavements, long-range budget allocations, present assessment, and future forecasting of the network conditions and rehabilitation need. Various modules and submodules are manipulated to achieve optimal solutions over a 6-year planning period by maximizing pavement performance for a given budget or by minimizing cost for a given network performance level.

The pavement management system (PMS-III) developed and implemented for the Ohio Department of Transportation (ODOT), is a network-level system that can prescribe optimal maintenance and rehabilitation actions and the required budget for each roadway segment for each year of a 6-year planning period. On the basis of present network condition and a deterministic prediction model, PMS-III forecasts future network condition and rehabilitation needs and an associated budget. The optimal maintenance policies recommended by this pavement management system are based on maximizing the preservation of pavement investment for a given annual budget or on minimizing the cost of maintaining the network condition at a given performance level.

Generally, pavement management systems developed and implemented in the United States are quite diverse in scope, concept, and analytic approach in order to address various management and engineering decisions (*1–5*). The ODOT PMS-III described herein, however, is characterized as a system that provides optimal actions for candidate pavements, long-range budget allocations, present assessment, and future forecasting of the network condition and rehabilitation needs.

The ODOT PMS-III, shown in Figure 1, incorporates the following components:

- Pavement condition module,
- Maintenance and repair (M&R) action module,
- Cost module,
- Performance-prediction module,
- Optimization module, and
- Report generation module.

The operational aspects of these modules are discussed in the following section.

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## DESCRIPTION OF PMS-III MODULES

### Pavement Condition Module

The pavement condition module includes attributes for pavement distresses, riding quality, and user safety. These attributes are

1. Pavement condition rating (PCR),
2. Present serviceability index (PSI), and
3. Skid resistance–frictional characteristics (SN).

The use of these attributes in various pavement management systems has been extensively reviewed in the literature (*1–5*). PMS-III utilizes a PCR that was developed by the ODOT in the 1970s and reported in numerous publications (*4–6*). The PCR form used by the ODOT for composite pavement is shown in Table 1. Inputs from PCR ratings are used to activate the M&R selection process, which provides the optimization of M&R plans for pavement segments. PSI is currently not used in PMS, and SN is used only on the project level to correct pavements with low friction values.

### M&R Action Module

The M&R module is concerned with selection of the most feasible M&R strategies in view of given roadway information. Roadway information includes distress type, severity and extent of distress, pavement type, and roadway functional class (or traffic level). Components of the M&R submodule are described below.

- *M&R master list*: The master list (table) contains about 50 coded work items grouped under several different categories: do nothing, surface treatments, resurfacing, pavement repair, reconstruction, and traffic control.

- *M&R feasible action table*: This list, which is cross-referenced to the M&R master table, contains combinations of work items (termed actions) required for M&R projects. Combinations are different for the different pavement types.
- *M&R selection table*: These tables associate each pavement condition with one or more M&R action codes. There are separate tables for each pavement type that have been further subdivided into three highway classes: Interstate, multilane divided, and other. Based on distress type, severity, and extent, one or more rehabilitation maintenance actions will be recommended. The pavement distresses are categorized as surface or joint (structured) type. Figure 2 shows the generation of appropriate maintenance actions based on overall pavement group and distress severity and extent.

### Cost Module

The cost module determines cost for every given strategy selected by the M&R action module. Because the PMS described herein is a network system, the cost is an average of many projects performed on a roadway segment. The maintenance action is assembled from many rehabilitation activi-

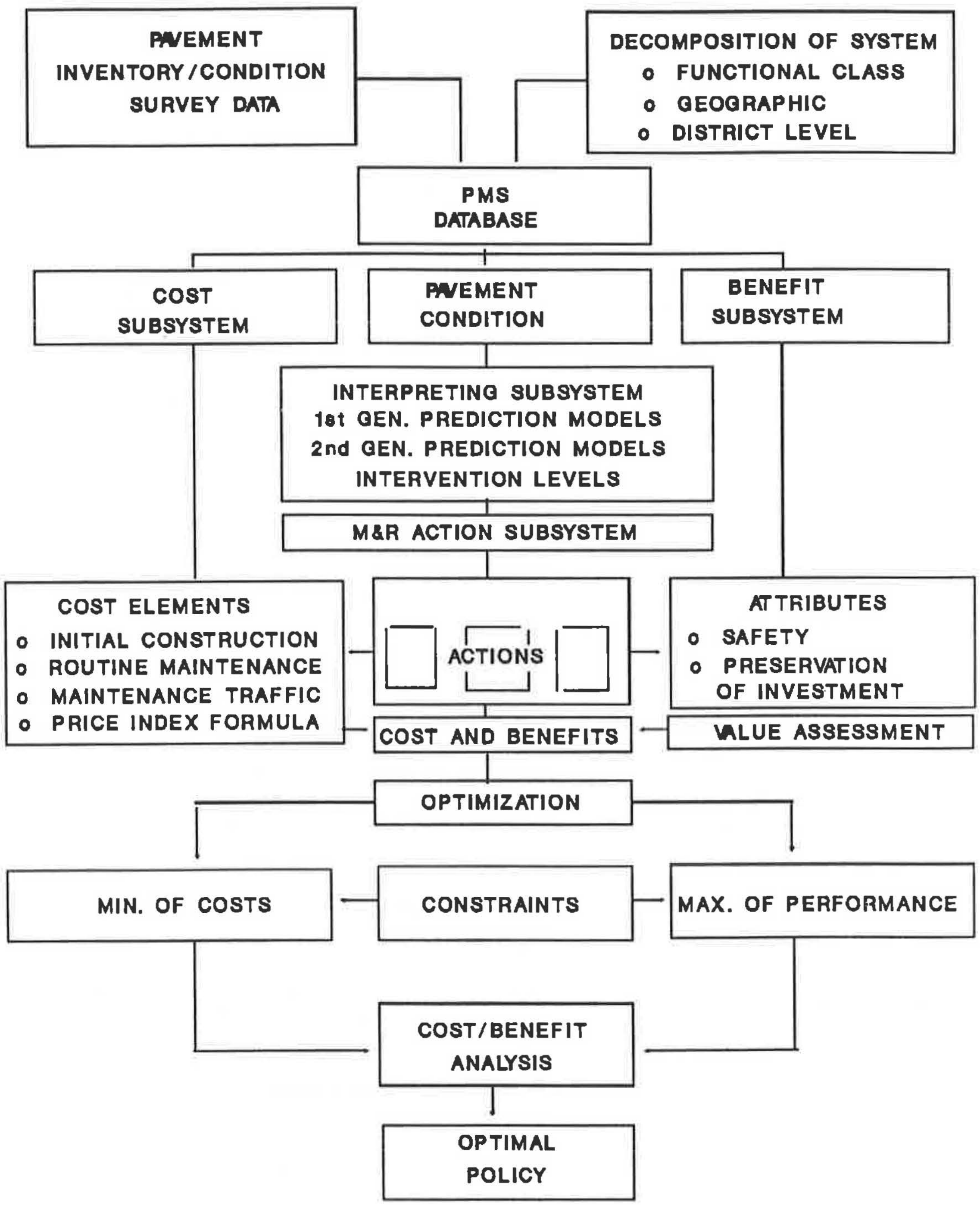


**FIGURE 1 Conceptual framework for Ohio PMS-III.**

ties in which the cost of each activity can be used for estimating the cost of a new maintenance action. All action costs can be updated or changed in the planning horizon on the basis of interest or discount rate, or the budget can be corrected on the overall network system with interest or discount rate.

**Performance-Prediction Module**

The performance-prediction module in PMS-III includes the prediction models required for forecasting deterioration of pavement attributes with time. The performance-prediction equation for each M&R action is dependent on traffic, pavement structure, and soil characteristics. Performance, as used herein, is measured by PCR. Because the M&R action selection plan is considered under various distresses, the PCR distresses are grouped accordingly and are contained in a damage (or loss) function. The general form of the performance or damage equation is exponential and S-shaped; that is,

$$\text{Damage function} = g = g[\exp(\text{traffic, pavement structure, soil characteristics})] \qquad (1)$$

The damage functions were developed from historic performance data and had considerable scatter, which was at least partially the result of limited data. However, updating techniques have been incorporated so that performance prediction models can be updated annually as new performance (PCR) data become available.

When the performance of grouped distresses is known, the future pavement condition can be calculated from the damage function for each selected M&R action. Figures 3 and 4 show the loss of serviceability of a given road segment for two

TABLE 1 COMPOSITE PAVEMENT CONDITION RATING FORM

| DISTRESS | DISTRESS WEIGHT | SEVERITY WEIGHT | | | EXTENT WEIGHT | | |
|---|---|---|---|---|---|---|---|
| | | LOW | MEDIUM | HIGH | OCCASIONAL | FREQUENT | EXTENSIVE |
| Ravelling | 10 | Slight loss of sand | Open Texture | Rough or Pitted | < 20% | 20-50% | > 50% |
| Bleeding | 5 | - | Bitumen & Agg. Visible | Black Surface | < 10% | 10-30% | > 3 % |
| Patching (Deterioration of Patch) | 5 | Slight Deterioration | Moderate Det. Affect Ride | Needs Replaced | < 10% | 10-30% | > 30% |
| Surface Disintegration or Debonding | 5 | < 1" < 1/sy | < 1" >1/sy > 1" <1/sy | > 1" > 1/sy | < 20% | 20-50% | > 50% |
| Rutting | 10 | < 1/4 | 1/4" -1" | > 1" | < 20% | 20-50% | > 50% |
| Corrugations | 5 | Noticeable | Some Discomfort | Poor Ride | < 10% | 10-30% | > 30% |
| Pumping | 10 | Staining 1/8" | Staining 1/8" | Faulting | < 10% | 10-25% | > 25% |
| Shattered Slab | 10 | Little Spal. No Faults | Some Spal. Mod. Faults | Severe Distortio | < 2/mi | 2-5mi | > 5/m |
| Settlement | 5 | Noticeable (ride) | Some Discomfort | Poor Ride | < 1/mi | 2-4mi | > 4/m |
| Transverse Cracking Unjointed Base | 20 | < 1/8" No Spalls | 1/8 - 1" > 5 length) Spalls | > 1" (.5 length Spalls | > 15' | 10-15' | < 10' |
| Jointed Base (1) Joint Reflectio (2) Other | 12<br>8 | 1/8" No Spalls | > 1/8" Spalled (.5 length) | > 1" Spalled (.5 lengt) | < 20%<br>< 15% | 20-50%<br>10-15' | > 50%<br>< 10' |
| Longitudinal Cracking | 5 | < 1/8" No Spalls | 1/8" - 1" (Spalled. 5) | > 1" (Spalled.5) | < 50 Per 100' | 50-100' Per 100' | > 150' Per 100' |
| Pressure Damage/ Upheaval (Bump Height | 5 | < 1/2" Good Ride | 1/2" - 1" Fair Ride | > 1" Poor Ride | < 20% | 20-50% | > 50% |
| Crack Sealing Def. | 5 | | NOT CONSIDERED | | < 20% | 20-50% | > 50% |

different 6-year planning-horizon maintenance alternatives. The two plans have the same action in each planning year except the second year. It is clear that the rate of deterioration is higher for action 50 (no more than 2 in. overlay with no repair) compared with action 80 (at least 3 in. overlay with repair). In addition, the pavement using the alternative plan in Figure 4 will be in service for a longer time (25 years versus 11 years at the same PCR level) compared with the alternative plan in Figure 3 if no additional action is taken after the planning years.

On the project level, the recommended performance prediction models have been selected from among empirical and mechanistic-empirical prediction models that are consistent with the availability of input data on a routine basis. Throughout the development of PMS-III, emphasis has been placed on utilizing submodules that are consistent with available input data and thus require no additional tests and evaluations.

### Optimization Module

In the ODOT PMS-III, the highway system consists of approximately 19,000 mi and is divided into segments that are based on maintenance history, road inventory, design information, and pavement condition. The master file identifies each "segment" of the highway (generally between 0.2 and 10 mi long), and the present condition state and other pertinent information are also recorded. Based on historical data, a forecast is made of the future-condition state of each segment, depending on what M&R action has been taken. A $T$-year M&R plan associated with a given segment is defined by specifying the action to be taken in year $t$, $t = 1, \ldots, T$ (the plan is an ordered set of $T$ actions). Only a limited number of applicable plans can be associated with each segment for maintaining the entire highway system in satisfactory condition.

The optimization system used in PMS-III is a network optimization system with a network-to-project structure. The initial M&R alternative strategies are selected on the basis of inputs from the pavement condition module. For each initial M&R strategy, the performance prediction module is used to obtain the end-of-the-year condition of the pavement in terms of severity and extent. The M&R action table is used again to select several appropriate actions. This process continues until all planning-horizon plans are selected for $T$ years.

In order to compare the $T$-year planning-horizon alternative M&R action, one has to consider the performance of a roadway segment after the planning years ($T$). Therefore it

| Description | M/R Action Codes |
|---|---|
| Do nothing | 000 |
| Routine Maint. | 010 |
| Seal Coat | 020 |
| Joint Repair, Seal, Underseal | 030 |
| CPR | 040 |
| Nonstructural Overlay with Minimum Repair | 050 |
| Nonstructural Overlay with Repairs | 060 |
| AC Structural Overlay with Minimum Repair | 070 |
| AC Structural Overlay with Repairs | 080 |
| Crack&Seal (R&R) | 090 |
| PCC Structural Overlay | 100 |
| Reconstruction with Flexible | 110 |
| Reconstruction with Rigid | 120 |
| Reconstruction with Composite | 130 |

| | Other | | | Multi-Lane | | | Interstate | | |
|---|---|---|---|---|---|---|---|---|---|
| | L | M | H | L | M | H | L | M | H |
| | 000 | 000 | 010 | 000 | 010 | 010 | 000 | 000 | 010 |
| | 010 | 020 | 000 | 010 | 020 | 000 | 000 | 010 | 020 |
| | | 020 | 030 | 020 | 020 | 050 | | 020 | 050 |
| Surface 1 | 000 | 000 | 010 | 000 | 000 | 010 | 000 | 000 | 010 |
| -raveling | 010 | 110 | 050 | 010 | 110 | 050 | 010 | 110 | 050 |
| -bleeding | 020 | 020 | | 020 | 020 | | 020 | 020 | |
| -longitudinal | 000 | 010 | 010 | 000 | 010 | 010 | 000 | 010 | 010 |
| cracking | 010 | 020 | 030 | 010 | 020 | 030 | 010 | 010 | 030 |
| -crack scale | 020 | 030 | | 020 | 030 | | 020 | 030 | |
| deficiency | 000 | 010 | 020 | 000 | 010 | 020 | 000 | 010 | 020 |
| | 010 | 020 | 030 | 010 | 020 | 030 | 010 | 020 | 030 |
| Surface 2 | | 030 | | | 080 | | | 050 | |
| -rutting | 010 | 010 | | 010 | 010 | | 010 | 010 | |
| -debonding | 020 | 020 | | 020 | 120 | | 020 | 120 | 070 |
| -settlement | 050 | 050 | 050 | 050 | 050 | 050 | 050 | 050 | 050 |
| -corrugations | 010 | | | 010 | | | 010 | | |
| | 020 | 020 | | 020 | 020 | | 020 | 020 | 020 |
| | 050 | 050 | 050 | 050 | 050 | 080 | 050 | 050 | 080 |
| | 000 | 010 | 020 | 010 | 020 | 020 | 010 | 020 | 030 |
| | 010 | 020 | 030 | 020 | 030 | 060 | 020 | 030 | 060 |
| | 030 | 030 | 060 | 030 | 060 | 070 | 030 | 060 | 070 |
| | 000 | 010 | 020 | 010 | 020 | 030 | 010 | 020 | 020 |
| Joint 1 | 010 | 020 | 030 | 020 | 020 | 060 | 020 | 020 | 060 |
| -pressure | 030 | 030 | 060 | 030 | 060 | 080 | 030 | 060 | 080 |
| damage | 010 | 010 | 030 | 020 | 020 | 060 | 010 | 030 | 060 |
| -patching | 030 | 030 | 060 | 030 | 060 | 080 | 030 | 060 | 080 |
| -pumping | | 030 | 080 | 030 | 090 | 090 | 030 | 090 | 090 |
| -shattered | 010 | 020 | 030 | 020 | 060 | 090 | 020 | 060 | 090 |
| slabs | 020 | 030 | 060 | 030 | 080 | 110 | 010 | 070 | 110 |
| | 030 | 060 | 090 | 060 | 090 | 130 | 060 | 090 | 130 |
| | 000 | 010 | | 000 | 010 | | 000 | 010 | 020 |
| Joint 2 | 010 | 020 | 020 | 010 | 020 | 030 | 010 | 020 | 050 |
| -transverse | | | | | | | | | 020 |
| crack | 000 | 010 | 050 | 000 | 010 | 050 | 000 | 010 | 050 |
| -(unjointed) | 010 | 020 | 020 | 010 | 020 | 070 | 010 | 020 | 020 |
| -jointed base | | 070 | | | 070 | | | | 080 |
| -other | 000 | 010 | 050 | 000 | 010 | 050 | 000 | 010 | 050 |
| | 010 | 020 | 070 | 010 | 050 | 070 | 010 | 050 | 070 |
| | | 070 | | | 070 | | | 070 | 080 |

**FIGURE 2 M&R selection chart—composite.**

is important to consider the serviceability of the roadway segment during its useful life. Here serviceability is measured by PCR. In Figures 3 and 4, loss of serviceability of the roadway segment is estimated as the complement to the area under the performance curve. The best plan should have the smallest complementary area for all feasible alternative plans. Consequently, the optimization is based on minimization of loss of serviceability.

The remaining useful life of a segment is normally considered to be that period of time for which no major rehabilitation has been performed for that segment beyond the planning period. The remaining useful life of a segment is dependent on the sequence of actions taken over the planning period and is unique for a given set of actions. Minimization of loss of serviceability and enhancement of remaining service life are accommodated through a term called "annual present worth of deduct value." Obviously, if the deduct value is minimized, the serviceability and remaining life will be maximized. Minimization of the present worth of deduct value is accomplished through manipulation of a term called the objective function, $C_{k,i,j}$. The objective function is defined as the sum over the planning years of the product of terms that include the capital recovery of the segment, the deduct value, the length of the segment, traffic, and traffic growth. In the objective function $C_{k,i,j}$, $k$ is the district, $i$ is the segment, and $j$ is the specific plan.

The objective function is further defined as

$$\sum_{k,i,j} C_{k,i,j} * x_{k,i,j} \tag{2}$$

where $x_{k,i,j} = 1$ or 0 and

$$C_{k,i,j} = A * \sum_{t=1}^{f_{k,i,j}} \frac{d_{k,i,j,t} * L_{k,i} * T_{k,t}}{(1 + R)^t (1 + R)^{f_{k,i,j}}} \tag{3}$$

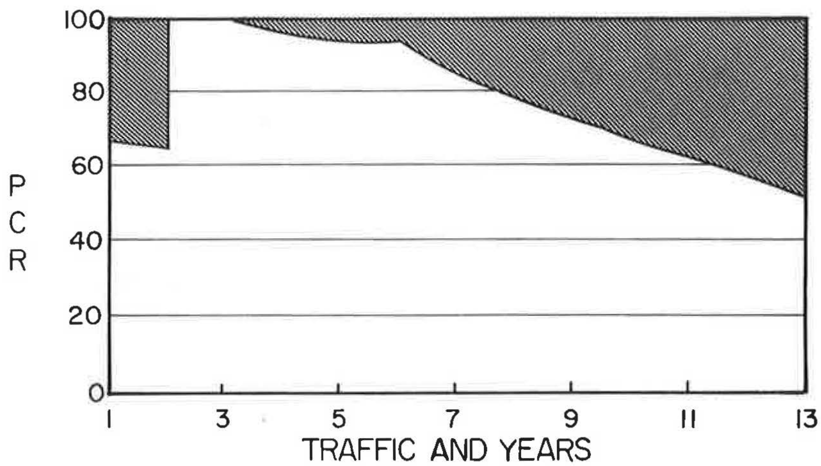


**FIGURE 3 PCR versus time and traffic for a specific M&R plan over the 6-year period. Actions 10,50,00,00,10,00.**

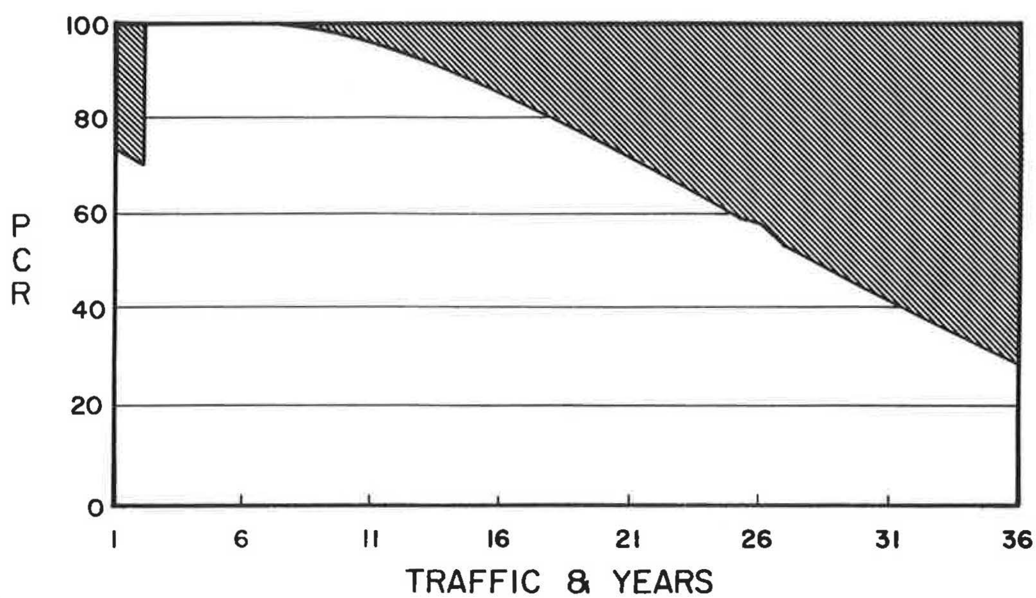


**FIGURE 4 PCR versus time and traffic for a second specific M&R plan over the 6-year period. Actions 10,80,00,00,10,00.**

where $A$ is the capital recovery factor, defined as

$$A = \frac{r * (1 + x)^{f_{k,i,j}}}{(1 + r)^{f_{k,i,j}} - 1} \tag{4}$$

and

$L_{k,i}$ = length of a segment $i$ in district $k$,
$f_{k,i,j}$ = life (in years) of action $j$ in district $k$ for segment $i$,
$d_{k,i,j,t}$ = deduct value of action $j$ in district $k$ for segment $i$ during year $t$,
$T_{k,i}$ = traffic (in equivalent single-axle loads) on segment $i$ in district $k$ at the beginning of the planning period,
$R$ = annual rate of traffic growth, and
$r$ = discount interest rate of performance.

There are two distinct constraints to this optimization formulation—budget and plan constraints. These constraints are appropriate for the type of model; that is, most minimization or benefit maximization is applied to each year in the planning horizon.

### *Budget Constraint*

The budget constraint includes the following ingredients:

1. The expenditures of all actions taken on all segments in the $k$th district in year $t$ is equal to the budget that will be allocated to that district in year $t$.

$$\sum_{i,j} a_{k,i,j,t} * x_{k,i,j} - y_{k,t} < 0 \tag{5}$$

where $a_{k,i,j,t}$ is the expenditure of actions taken in year $t$ in the $j$th plan of the $i$th segment of the $k$th district.

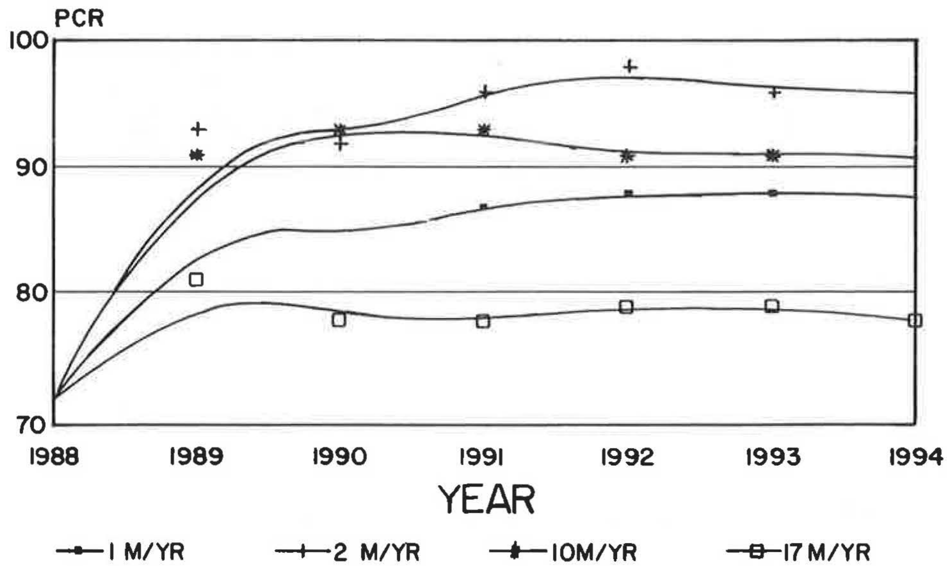


**FIGURE 5 PCR over the planning period for various budget levels per year.**

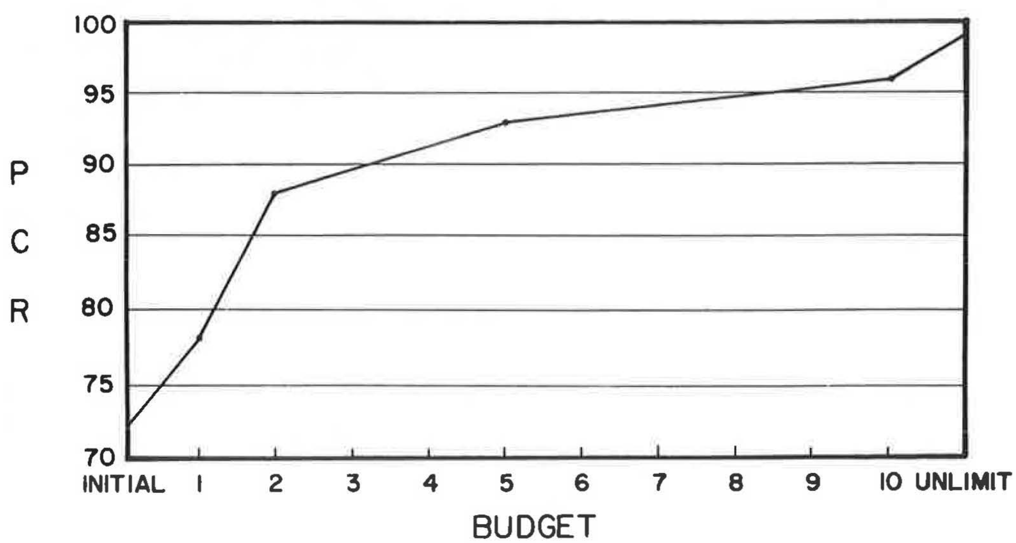


**FIGURE 6 Average network PCR for the 6-year planning period versus yearly budget.**

2. The sum of the budgets that will be allocated to the $k$th district in year $t$ is equal to or less than the entire budget for the highway system in year $t$.

$$\sum_{k} y_{k,t} < b_t \qquad (6)$$

Stated policy usually provides for use of only one plan for each segment. Thus the sum of $x_{k,i,j}$ over all applicable plans of the $i$th segment of the $k$th district must be 1. That is,

$$\sum_{j} x_{k,i,j} = 1 \qquad (7)$$

The above formulation has been installed in PMS-III and additionally provides the capability to specify a different budget level for each year over the 6-year planning horizon. The performance of the pavement is estimated over the planning horizon and also at the end. This procedure requires that once the budget levels have been selected, they remain unchanged over the 6-year period. Figure 5 shows pavement condition per year for different budget levels.

In contrast, Figure 6 shows the change in PCR achieved as a function of budget committed to the network in millions of dollars per year. Specifically in Figure 6, the initial PCR at the start of the planning period is approximately 72.5. Then if $3 million is spent per year for the 6-year period, the PCR will increase from 72.5 to 90 at the end of the sixth year. Figure 6 can also be used to infer what change in budget level per year results in the greatest change in PCR or, stated otherwise, "the best bang for the buck." In the example of Figure 6, if the budget level is changed from $1 million per year for 6 years to $2 million per year for 6 years, the PCR will change by 10 points (from 77.5 at $1 million per year to 87.5 at $2 million per year). A quick look at this type of information (output from PMS-III) can be beneficial in planning for the best use of resources to maintain an acceptably serviceable highway network.

Also available in PMS-III is what has been termed the "complementary" solution. In the foregoing discussion, the solution effectively minimized the deduct value under the constraint of prescribed budget level per year over the planning period. The complementary solution solves the system for the case of minimization of cost for a prescribed PCR level for the network. In the complementary solution the objective function is prescribed by the budget over the planning period and the influence of inflation and discount rates is included; the performance constraint is enforced by requiring that the performance level for every year of the planning period not be less than the specified value.

### *Comments on the Optimization Module*

The following comments are included to explain some of the other features that have been included in the optimization module.

1. The optimal solution identifies the optimal policy and the optimal budget to be allocated to each district.

2. The integer requirements on the decision planning variables, $x_{k,i,j} = 0$ or 1, are relaxed to accommodate more than one plan for a few segments. Allowing $x_{k,i,j}$ to obtain the values 0 or 1 is termed an integer programming problem in the computational world. In contrast, if the $x_{k,i,j}$ are allowed to obtain fractional values, the problem is termed a linear programming problem. The linear programming problem is included in the array of admissible solutions because at optimality, fractional values for the $x_{k,i,j}$ can occur in a very few segments. This means that for a segment one plan may be suggested for the first fraction of the segment, whereas a second plan may be suggested for the second fraction of the segment. The decision maker then has the opportunity to choose whatever combination of the two plans is most practical to implement considering the interface with other adjoining segments.

### Report Generation Module

The main-frame version of PMS-III was developed to provide the most useful sets of information to ODOT administrators and engineers and at the same time to be compatible with current and foreseeable resident computer hardware and software requirements at ODOT. Potential users of the PMS-III were canvassed to determine the most favorable format and number and type of outputs (reports). As a result, the reporting module provides a total of 12 reports for use by administrators and engineers in the central and district offices.

Three of these reports are shown in Figures 7–9. Figure 7 shows the optimized M&R action (PM306) for all roadway segments sorted by the district. Figure 8 shows the detail optimized M&R strategy plan (PMS-325) sorted by actions taken. Figure 9 is the optimized M&R strategy cost summary, showing the total miles of the roadway segment under various maintenance actions and the associated cost. In addition, the overall network pavement condition is shown for each planning horizon.

## CONCLUSIONS

The network PMS-III will select an optimized M&R action plan for 6 years and predict the remaining useful life of a plan. The optimal solution is obtained, and either pavement performance is maximized or the design condition of the pavement is satisfied to give the minimum cost required. The network PMS-III

1. Determines which M&R action should be used for a given segment to minimize the budget for a prescribed performance level,
2. Determines which projects should be funded and how much each project should cost,
3. Determines how much budget is required to maintain a given pavement condition,
4. Suggests the change in budget level per year over the 6-year period for which the greatest change in performance is achieved,
5. Generates reports to aid all levels of ODOT management and engineers in making cost-effective decisions on pavement M&R actions, and
6. Prescribes a 6-year planning horizon and predicts the useful remaining life of the roadway pavement for a significant period after the planning horizon.

Report PM306
Ohio Department of Transportation
District 12
Selection Criteria: District 12
Counties............................................
All Roads
Routes
PSI Limit: PCR Limit: Skid Limit:

District Six Year M&R Strategy Plan Detail
Sequenced by County, Functional Class, Road Number

Budget Constraints (in thousands): 1990 $200,000
1991 $200,000
1992 $200,000
1993 $200,000

County: Cuyahoga Functional Class 41 **Cost Values are Printed in thousands/($)**

| Rd. | <--Location--> | | | CRNT | <--1990--> | | | <--1991--> | | | <--1992--> | | | <--1992--> | | | <--1994--> | | | <--1995--> | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NBR | BEG. | END | LEN | PCR | ACT | COST | PCR | ACT | COST | PCR | ACT | COST | PCR | ACT | COST | PCR | ACT | COST | PCR | ACT | COST | PCR |
| 071R | 0.00 | 3.30 | 3.3 | 61 | 120 | 5,445 | 100 | 000 | 0 | 100 | 000 | 0 | 100 | 000 | 0 | 100 | 000 | 0 | 100 | 010 | 43 | 100 |
| | 3.30 | 9.90 | 6.1 | 74 | 050 | 1,316 | 99 | 010 | 93 | 97 | 000 | 0 | 89 | 010 | 93 | 84 | 080 | 4,470 | 100 | 000 | 0 | 100 |
| | 9.90 | 15.0 | 4.6 | 76 | 050 | 1,636 | 97 | 010 | 116 | 94 | 000 | 0 | 85 | 020 | 311 | 77 | 080 | 5,556 | 100 | 000 | 0 | 100 |
| | 15.00 | 18.7 | 3.3 | 80 | 050 | 968 | 98 | 010 | 68 | 95 | 000 | 0 | 86 | 010 | 68 | 81 | 020 | 184 | 73 | 080 | 3,290 | 100 |
| | 18.70 | 19.10 | 0.3 | 60 | 080 | 281 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 000 | 0 | 99 | 010 | 6 | 98 | 010 | 6 | 98 |
| 077R | 0.00 | 4.10 | 4.1 | 71 | 080 | 2,563 | 100 | 000 | 0 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 010 | 53 | 99 | 010 | 53 | 100 |
| | 4.10 | 10.40 | 5.3 | 70 | 060 | 1,519 | 100 | 010 | 94 | 100 | 000 | 0 | 96 | 010 | 94 | 89 | 010 | 94 | 81 | 080 | 4,522 | 100 |
| | 10.40 | 13.80 | 3.4 | 49 | 020 | 179 | 42 | 060 | 1,071 | 99 | 010 | 66 | 97 | 000 | 0 | 91 | 010 | 66 | 89 | 080 | 3,188 | 100 |
| | 13.80 | 16.00 | 1.5 | 68 | 120 | 2,896 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 000 | 0 | 99 | 000 | 0 | 98 | 010 | 23 | 98 |
| 090R | 0.00 | 2.80 | 2.7 | 70 | 100 | 3,105 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 000 | 0 | 99 | 000 | 0 | 98 | 000 | 0 | 98 |
| | 2.80 | 6.70 | 3.8 | 60 | 100 | 5,910 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 000 | 0 | 99 | 000 | 0 | 98 | 000 | 0 | 97 |
| | 6.70 | 9.40 | 2.5 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 000 | 0 | 99 | 000 | 0 | 98 | 000 | 0 | 98 | 000 | 0 | 98 |
| | 9.40 | 9.70 | 0.3 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 000 | 0 | 98 | 000 | 0 | 98 | 000 | 0 | 97 | 000 | 0 | 97 |
| | 9.70 | 10.40 | 0.6 | 70 | 100 | 1,380 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 000 | 0 | 99 | 000 | 0 | 98 | 000 | 0 | 97 |
| | 10.40 | 11.70 | 1.2 | 55 | 010 | 84 | 49 | 010 | 84 | 45 | 100 | 2,760 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 000 | 0 | 99 |
| | 11.70 | 13.40 | 1.6 | 57 | 100 | 3,823 | 100 | 000 | 0 | 100 | 000 | 0 | 100 | 000 | 0 | 100 | 000 | 0 | 100 | 000 | 0 | 99 |
| | 13.40 | 14.60 | 1.1 | 57 | 100 | 2,530 | 100 | 000 | 0 | 99 | 000 | 0 | 99 | 000 | 0 | 98 | 000 | 0 | 97 | 000 | 0 | 96 |
| | 14.60 | 15.20 | 0.5 | 76 | 060 | 196 | 100 | 000 | 0 | 97 | 000 | 0 | 83 | 000 | 0 | 67 | 050 | 171 | 97 | 010 | 12 | 81 |
| | 16.30 | 18.00 | 1.6 | 66 | 100 | 3,570 | 100 | 000 | 0 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 000 | 0 | 99 | 010 | 40 | 99 |
| | 18.00 | 18.70 | 0.7 | 51 | 050 | 265 | 95 | 010 | 19 | 87 | 000 | 0 | 74 | 020 | 50 | 66 | 080 | 900 | 100 | 000 | 0 | 99 |
| | 18.70 | 21.30 | 2.5 | 64 | 100 | 5,872 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 000 | 0 | 99 | 000 | 0 | 99 | 010 | 66 | 98 |
| | 21.30 | 30.20 | 8.1 | 62 | 120 | 23,088 | 100 | 000 | 0 | 100 | 000 | 0 | 100 | 000 | 0 | 99 | 000 | 0 | 99 | 010 | 182 | 98 |

**FIGURE 7 Output from Report PM306: optimized M&R actions.**

Report PMS-325
Ohio Department of Transportation
Project Selection Criteria: District: 12
Counties:
Interstates/Multilanes
Routes:
PSI Limit: 0.0 PCR Limit: 000.0 Skid Limit:

Detailed Optimized M&R Strategy Plan
Sequenced by District, M&R Action

District 12 For 1990 With Budget Constraint of $ 200,000

| County | Road | ---Log--- | | Func | ---Initial--- | | ---Low | | PVMT | M&R | -----Budget Costs----- | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| County | Nbr. | Begin | End | Class | PCR | PSI | SN | SN | TYPE | ACT | Major Rehab | Minor Rehab | Routine | Total |
| CUY | 021R | 0.80 | 5.20 | 44 | 68.0 | 0.0 | 0 | * | COM | 000 | 0 | 0 | 0 | 0 |
| CUY | 090R | 6.70 | 9.40 | 41 | 100.0 | 0.0 | 0 | * | PCC | 000 | 0 | 0 | 0 | 0 |
| CUY | 090R | 9.40 | 9.70 | 41 | 100.0 | 0.0 | 0 | * | PCC | 000 | 0 | 0 | 0 | 0 |
| **TOTAL THIS ACTION** | | | | | | | | | | | | | | |
| CUY | 082R | 11.70 | 12.60 | 43 | 70.0 | 0.0 | 0 | * | COM | 010 | 0 | 0 | 11,700 | 11,700 |
| CUY | 082R | 12.60 | 13.40 | 43 | 78.0 | 0.0 | 0 | * | COM | 010 | 0 | 0 | 10,400 | 10,400 |
| CUY | 090R | 10.40 | 11.70 | 41 | 49.0 | 0.0 | 0 | * | PCC | 010 | 0 | 0 | 84,000 | 84,000 |
| CUY | 480N | 0.20 | 0.40 | 41 | 100.0 | 0.0 | 0 | * | COM | 010 | 0 | 0 | 2,600 | 2,600 |
| CUY | 480N | 0.50 | 2.10 | 41 | 100.0 | 0.0 | 0 | * | COM | 010 | 0 | 0 | 20,566 | 20,566 |
| LAK | 002R | 0.00 | 6.10 | 42 | 76.0 | 0.0 | 0 | * | COM | 010 | 0 | 0 | 88,030 | 88,030 |
| LAK | 090R | 13.00 | 21.50 | 01 | 99.0 | 0.0 | 0 | * | COM | 010 | 0 | 0 | 107,900 | 107,900 |
| LAK | 090R | 21.50 | 29.20 | 01 | 99.0 | 0.0 | 0 | * | COM | 010 | 0 | 0 | 97,500 | 97,500 |
| **TOTAL THIS ACTION** | | | | | | | | | | | 0 | 0 | 422,696 | 422,696 |
| CUY | 077R | 10.40 | 13.80 | 41 | 42.0 | 0.0 | 0 | * | COM | 020 | 0 | 0 | 178,500 | 178,500 |
| CUY | 087R | 3.60 | 5.00 | 43 | 73.0 | 0.0 | 0 | * | COM | 020 | 0 | 0 | 49,000 | 49,000 |
| CUY | 087R | 5.00 | 5.80 | 44 | 73.0 | 0.0 | 0 | * | COM | 020 | 0 | 0 | 28,000 | 28,000 |
| CUY | 091R | 2.50 | 3.40 | 44 | 94.0 | 0.0 | 0 | * | COM | 020 | 0 | 0 | 24,188 | 24,188 |
| CUY | 271R | 3.50 | 6.10 | 41 | 63.0 | 0.0 | 0 | * | COM | 020 | 0 | 0 | 85,050 | 85,050 |
| CUY | 480R | 18.40 | 19.40 | 41 | 55.0 | 0.0 | 0 | * | COM | 020 | 0 | 0 | 70,000 | 70,000 |
| **TOTAL THIS ACTION** | | | | | | | | | | | 0 | 0 | 434,738 | 434,738 |

**FIGURE 8 Output from Report PMS-325: optimized M&R strategy plan.**

Report PM300 — Optimized M&R Strategy Cost Summary

Ohio Department of Transportation

Selection Criteria: District: All — Budget Constraints (in thousands): 1990 $ 70,000; 1991 $ 70,000; 1992 $ 70,000; 1993 $ 70,000; 1994 $ 70,000

Counties:..........................

All Roads:

Routes:

PSI Limits: PCR Limit: Skid Limit:

---------------COST DISTRIBUTION--------------

| BDGT YEAR | TOTAL PROJECTS | TOTAL MILES | MAJOR REHAB. COST | MILE | PROJ. | MINOR REHAB. COST | MILE | PROJ. | ROUTINE MAINT. COST | MILE | PROJ. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 523 | 1,470.14 | 2,736 | 7.60 | 5 | 41,786 | 204.70 | 75 | 25,511 | 1257.84 | 443 |
| 1991 | 512 | 1,518.14 | 11,991 | 20.70 | 11 | 32,471 | 158.88 | 52 | 25,570 | 1338.56 | 449 |
| 1992 | 505 | 1,533.65 | 2,520 | 5.10 | 5 | 42,235 | 198.64 | 57 | 25,275 | 1329.91 | 443 |
| 1993 | 485 | 1,463.72 | 5,157 | 10.59 | 5 | 40,956 | 199.95 | 44 | 23,919 | 1253.18 | 436 |
| 1994 | 473 | 1,381.16 | 10,409 | 13.90 | 10 | 36,385 | 164.46 | 52 | 23,239 | 1202.80 | 411 |
| 1995 | 470 | 1,342.70 | 10,138 | 13.70 | 8 | 37,831 | 186.22 | 70 | 22,063 | 1142.78 | 392 |
| TOTAL | 2968 | 8,709.51 | 42,951 | | | 231,664 | | | 145,577 | | |

**FIGURE 9 Output from Report PM300: optimized M&R strategy cost.**

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