

# Integrating Preventive Maintenance Management into BMS

**RONALD L. PURVIS, P.E.**

*A. G. Lichtenstein & Associates, Inc.*

## ABSTRACT

Until recently maintenance has been virtually ignored in the evolution of bridge management system (BMS) technology. Preventive maintenance (PM) was considered a luxury by all but a few transportation agencies. The consequences of this neglect expanded exponentially with the aging bridge inventory, increased traffic, and use of deicing salts. Consequently, owners now recognize the need to protect the tremendous investment in highway structures. ISTEA and TEA-21 have made more money available to use for this purpose.

Recognizing the importance of PM is only part of the solution to the problem. A potentially significant step is to devise an expert system to determine what to do and when to do it. What is the most cost effective PM strategy for a given situation? What factors influence that strategy? How important is each factor or how sensitive are the factors to various increments of change? Are the current methods of condition assessment adequate to trigger the most cost-effective strategy?

Traditionally, agencies rely on the expertise of experienced individuals to make system and project level decisions regarding PM strategy. The lack of a scientific approach to this management process and inadequate record keeping have made it impossible to evaluate the effectiveness of one strategy versus another in a given situation. This also makes it difficult to build a historical database for refinement of future management decisions.

Biannual inspections currently serve as the primary trigger for initiation of preventative actions. These inspections are usually limited to a subjective visual assessment. Subtle or subsurface problems are not identified. Often the quantified condition data needed for choosing between several remedial alternatives is not collected as part of this inspection.

The cost of repairing the nationwide bridge inventory deficiencies has been estimated at 100 billion dollars. The implementation of a systematic methodology to identify the most cost-effective strategy for protecting these structures from future deterioration represents an enormous opportunity for savings. Such a methodology can be initiated as part of the implementation or expansion of a BMS.

The Strategic Highway Research Program (SHRP) project C-104 looked at many of the factors associated with systematic PM strategies. This project developed a decision making procedure related to cost-effective protection and repair of corrosion damaged concrete bridge members. Topics included rates of deterioration, changes in rates of deterioration resulting from the addition of a protective system, available protective systems, and the comparison of life cycle costs.

This paper discusses the factors that must be considered in the development of a methodology for making cost-effective PM decisions from the perspective of a bridge maintenance engineer. It will also discuss potential modifications that must be made to bridge inspection and BMS programs to implement the methodology.

## **ASSET MANAGEMENT—DOES IT APPLY TO BRIDGES?**

Cost conscientious automobile and homeowners understand the importance of care and maintenance. Car owners change the oil, rotate the tires and reline the brakes to avoid more expensive problems. Homeowners clean the gutters, protect the exposed wood, clean the furnace, recover the roof, etc.

The more experienced asset managers perform these activities at regular intervals based on past performance. Others may wait until there is a visible reason to act. The objective is to manage the asset so that it provides the required level of service at the least cost for the required (or optimum) life. After all, automobiles and homes are major investments. It makes good sense to preserve their value or maximize their service life.

Bridges are the most expensive part of the highway system. It is vitally important for transportation agencies to apply sound asset management strategy to their bridge operations. Computers permit the manager to program activities and analyze complicated alternatives for large numbers of bridges. Knowledge and experience far greater than that of an individual manager or management team can be programmed into the decision making process. Common components of a BMS are as follows:

### **Condition Assessment**

The National Bridge Inspection Program has been in progress for almost 30 years. Most bridges are inspected every two years. A considerable amount of data has been collected since the program began in the early 1970s.

### **Analysis of Alternative Strategies**

For an asset management methodology to provide useful information it must be capable of identifying and providing a quantitative evaluation of alternative strategies. Since alternatives change as new procedures are developed, they must be continually researched and updated. Prescriptive data must be included with each alternative, since not all alternatives are appropriate for every type bridge under all conditions.

### **Performance Standards**

Standards or objectives must be developed for each PM procedure that is included in the alternative strategies. Performance standards define the application criteria and the resources necessary to do the work. Performance standards are used to estimate the cost of the procedure for comparing with other alternatives and to budget the work. They are also used to measure the level of performance of the maintenance workers.

### **Asset Valuation**

Since alternative strategies are evaluated in terms of their cost, the system must be continually updated with local cost data. Ideally, the comparisons are calculated based on

life cycle costs, with user costs included in the formula. One alternative is to do nothing. The do-nothing alternative must include the cost of deterioration or damage related to neglect. To estimate this cost the current value of the structure must be included in the database. The current value should be based on replacement cost—not original construction cost.

### **Predictive Models**

Life cycle costing is meaningless without the ability to forecast the rate of deterioration or service life for each alternative. The best method of developing predictive models for the rates of deterioration is by collecting condition data over time. The condition is quantified in terms of a number and plotted in two dimensions with time as the other component. A line (deterioration curve) connects the points and a mathematical formula is used to describe the line. The formula is used to project the line and forecast future deterioration.

Obviously, predictive models are no better than the data on which they are based. The adequacy of the condition data available is dependent on the type of inspection details that were collected and the length of time that the proposed alternative has been used. Testing under accelerated conditions can be substituted or supplemented to define the shape of the deterioration curve when adequate condition data is not available. If you know the shape of the curve, it can be applied to the bridge component by making a condition assessment and establishing only one point. Regardless of how the predictive model is developed, it should be refined over time as appropriate condition data is collected.

### **Resource Allocation Decisions**

In an ideal situation the manager would decide the best alternative for each asset (or bridge), then calculate the total cost per year. This would be used to determine the annual budget. Unfortunately, adequate resources are never made available to do everything that should be done. Therefore, the asset management procedure must be capable of also assessing priorities so that the relative importance of each action can be ranked. It is also important to quantify the cost associated with delaying work that can not be performed. Political decisions to delay expenditures might not be so popular if taxpayers understood the increased costs associated with the delay.

### **Implementation**

The effectiveness of an asset management procedure is dependent on the commitment of everyone involved in the process. When we apply it to our homes and automobiles it is relatively easy to implement because we can personally control the condition assessment, the analysis of alternatives, the budgeting of resources and quality control of the work. When a large agency with thousands of assets attempts to implement new procedures, the results are dependent on the commitment of many people. It is important that each person involved understands how the process works; what it is intended to accomplish; how it will benefit him or her; and the importance of their contribution to the final results.

## **Performance Measurements**

The inclusion of performance measurements is key to the success of a formalized asset management process. Performance measurements should be developed and implemented to determine if the procedures are being properly performed. The purpose of the performance findings is to determine if adjustments are necessary. The performance measurements are an important part of the long term implementation because procedures change, people change, and technology changes. Asset management is a dynamic process that demands ongoing refinement.

## **Challenges**

Those who have implemented asset management procedures in transportation agencies report the following lessons learned:

- The success is dependent on the commitment of frontline workers.
- The goals of the implementation must be customer driven.
- The process should be driven by the operation goals—not systems requirements.

## **IMPORTANCE OF PM**

An ordinary lawn mower purchased in a hardware store for a few hundred dollars includes an owner's manual that covers step-by-step maintenance requirements. Yet a unique bridge costing several million dollars and exposed to severe mechanical and environmental conditions usually includes no owner's manual or maintenance instructions. The most sophisticated and technically advanced structural systems available to a transportation agency are used in the design and construction of bridges.

A basic understanding of how a bridge works is important in performing maintenance activities properly. Bridge maintenance not only requires advanced technical knowledge; it often also requires arduous manual effort under difficult and dangerous conditions. The work combines physical labor with technical and practical knowledge. It often requires an assortment of skilled trade workers including welder, concrete finisher, carpenter, machinist, electrician, and equipment operator.

Bridges, the key links in America's highway system, are deteriorating more rapidly than they are being repaired, rehabilitated, or replaced. Addressing this problem in a unified manner has been made difficult by the range of technologies that are applied in the design of bridges. There are also a number of other reasons why bridge maintenance is becoming an increasingly vital issue in almost all jurisdictions.

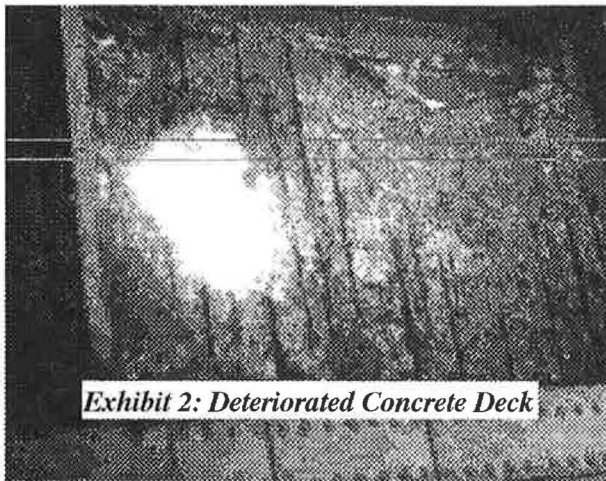
The lack of sufficient commitment of resources to bridge maintenance has resulted in "deferred maintenance." There are two different kinds of deferral. The first is formal or planned deferred maintenance where specific work is omitted or delayed to save a specific amount of money. The second is informal deferred maintenance that is caused by defective budgeting, fund allocating, and reporting procedures.

Damage resulting from plugged scuppers and drains, leaky joints, rutted wearing surfaces and peeled paint accelerates deterioration year after year and compounds repair requirements. If left unrepaired, the damage ultimately imposes a severe limitation on the operational capabilities of the structure, as shown in Exhibits 1, 2, and 3.



## WHAT IS BRIDGE MAINTENANCE?

Bridge maintenance involves cleaning, protecting, and performing relatively minor repairs before deterioration becomes so extensive that major rehabilitation or replacement is required. Historically, transportation agencies have taken a shortsighted approach to



bridge maintenance. Allocation of resources has been insufficient to keep bridges in good condition, and structures have been allowed to deteriorate.

There are two essential reasons for performing bridge maintenance:

- 1). To ensure the safety of the traveling public and
- 2). To preserve the original investment in the structure—an investment that would be much greater at today's replacement cost and even more at tomorrow's.

A bridge in good condition costs less to maintain. Studies have shown that as the condition of a bridge deteriorates, the cost of necessary repairs rises at a rapidly increasing rate. Maintenance can be deferred for a period of time, but the cost of restoring a structure to adequate or good condition is significantly greater than regularly maintaining a good condition. Many transportation agencies in the United States are painfully arriving at this conclusion as they try to stretch available funds to keep deteriorating structures in service.



Bridge maintenance covers a wide range of activities, which can be grouped in two basic categories:

- Those performed on a regularly scheduled basis and
- Those performed as the need arises.

To be effective, both categories of maintenance must be closely coordinated with bridge inspections. For greater efficiency, the optimum time between the performance of regularly scheduled activities must be known for each bridge, which requires inspections at regular intervals to evaluate and adjust the schedule. Ideally, the BMS should include as many as possible of the maintenance activities into the regularly scheduled category.

Regardless of the agency's success at scheduling ordinary bridge maintenance activities, it is inevitable that some work will be necessary on an as-needed basis. When unforeseen circumstances arise, such as damage caused by collision or flash flooding, the repair response must be timely and appropriate. The maintenance repairs should include an inspection to identify problems and determine the urgency of making repairs. Unfortunately, many agencies are using most of their bridge maintenance budgets performing as-needed activities such as repair of potholes in decks because of deferred past maintenance.

### **Definition**

The generally accepted definition of maintenance is work that is performed to keep a facility in its current condition. Some agencies also may include work that is performed to restore the facility to good condition; however, this may be called rehabilitation rather than maintenance.

Often, agencies have a working definition of maintenance that is based on who performs the work or how it is funded. These definitions have evolved for the following reasons:

- Traditionally, the federal government has not participated in the funding of maintenance activities.
- Private contractors have been successful in some states at getting legislation or agency policy adopted to restrict DOT maintenance crews from performing work that exceeds a certain cost.
- Some agency maintenance crews do not have the skills or equipment to perform complex work.

### **Traditional Approach**

The traditional approach to bridge maintenance has been that bridges were built and ignored unless a safety problem was reported until they became obsolete or the road was upgraded or relocated. Bridge maintenance was performed as a part of roadway maintenance with minimum attention, resources and understanding of the unique needs of the individual components. Bridge maintenance requires specialists with a different level of expertise than is found on the typical highway maintenance crew.

Large traffic volumes, heavier loads, and the use of deicing chemicals have accelerated bridge deterioration in recent years. In most agencies, bridges have deteriorated faster than they have been repaired or maintained. Agency bridge engineers have recognized the fact that the tremendous investment in existing bridges has to be preserved. Bridges are critical links in our transportation system and states cannot afford to replace them at the rate at which they are deteriorating.

### **Funding/Priority**

Rarely does a state have all the funds that are needed by each department or agency within the government to provide the level of service it considered necessary. Therefore, agencies within the state are competing for funds. This competition extends down the line to units within the agency. Traditionally, maintenance units have been underfunded because the consequences are not always understood.

Since funding levels within agencies are almost always based on the amount allocated in previous years it is very difficult to break the cycle. Deferred maintenance implies that it will be performed at a later date, however, since the budget did not accurately reflect the actual need that level of funding is carried forward. Incremental neglect is very difficult to measure in the short term.

When bridge maintenance is grouped together with highway maintenance, it may be competing with activities, such as mowing or paving, which have a greater immediate impact on the taxpayer or voter. Bridge maintenance is more expensive per mile, and it is often not visible to the motorist.

Studies over the past twenty years have shown convincingly that appropriate bridge maintenance activities, performed at the proper time, are cost-effective. Studies have also shown that it costs less to maintain bridges in a good condition than to maintain them in a poor condition. Therefore, PM is cost-effective and deferring maintenance results in increased costs over the life of the structure.

## **PREVENTIVE MAINTENANCE**

Preventive maintenance (PM) is the performance of maintenance to preserve bridge components in their present condition. Under ideal circumstances, PM is performed on a new bridge to keep it in good condition.

### **Types of PM**

PM activities can be divided into two groups: those performed at specified intervals and those performed as needed. The first group, specified interval maintenance, includes the systematic servicing of bridges on a scheduled basis. The interval varies according to the type of work or activity. Examples of these activities include such tasks as

- Cleaning decks, seats, caps, and salt splash zones;
- Cleaning drainage systems;

- Cleaning expansion joints;
- Cleaning and lubricating expansion bearing assemblies; and
- Sealing concrete decks or substructure elements.

The second group of PM activities is performed when a need is identified by the inspection. The need for this type of maintenance is often related to the environment. Examples of these activities include such tasks as

- Resealing expansion joints;
- Painting of steel members;
- Removing debris from channel;
- Replace wearing surface; and
- Extending or enlarging deck drains.

The concept of PM involves performing small or routine procedures in a timely manner to keep the bridge in good condition and avoid more expensive costs in the future to replace or keep the bridge operational.

### **Importance of PM**

It is important to preserve the investment that has been made in the construction of the bridge. The cost of replacing the average bridge in service today is over ten times its original construction cost.

Similarly, when major repairs or rehabilitation becomes a necessity, the cost is high. The cost analysis completed for one bridge rehabilitation showed that normal PM could have been performed on ten bridges for the same amount of money. This evidence supports the statement made by a bridge inspection engineer that *we simply cannot afford not to perform PM.*

Several articles have been written that show the value of performing PM on bridges. One such report describes New York's experience in bridge maintenance. The report describes how comparisons were made between the condition of bridges and the cost of repairs. The report shows the condition rating, number of structures, average repair cost per bridge for the rating, and finally, the total repair cost, as shown in Exhibit 4. A plot of the average repair cost per structure and the rating is shown in Exhibit 5.

When comparing bridge conditions and maintenance costs, it was found that the repair cost increased rapidly as the bridge condition worsened. The cost of maintaining a bridge at a condition rating of 5 was relatively modest in comparison to costs when it was allowed to deteriorate further. A second part of the study shows the relationship of the bridge condition to deterioration over time.

A survey was conducted by the American Public Works Association (APWA) to determine the PM that was actually being performed, based on costs and required man-hours. The survey showed that an average of twenty-nine percent of the amount estimated to adequately maintain the bridge deck was actually expended. This value is for PM only and does not include the cost of replacement or major repairs.



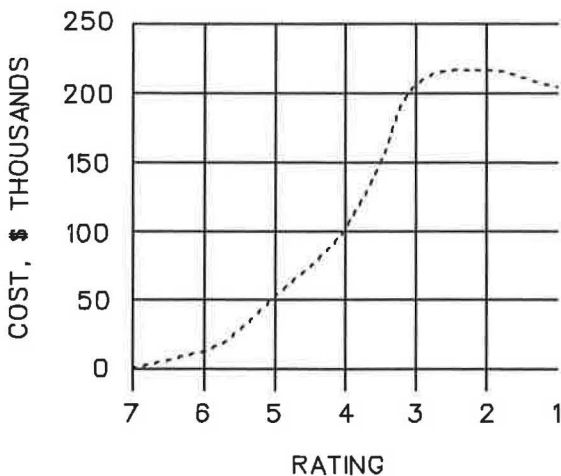
Rating	No. of Structures	Average Repairs Necessary per Structure (\$)	Total Repairs Necessary (\$)
1	60	217,490	13,049,000
2	170	217,490	36,973,000
3	296	211,496	62,603,000
4	931	109,445	101,893,000
5	1714	44,094	75,577,000
6	2192	13,446	29,474,000
7	972	3,238	3,147,000
Grand Total			322,716,000

**Exhibit 4: Cost of Repairs Necessary in 1980**

While the survey is based on only 23 cities and counties, the results are fairly indicative of the money actually being spent for PM. In addition to the need for more PM, the survey also noted a shortfall in the dollars necessary for restoration and rehabilitation work of the same magnitude of difference.

PM is also essential to safety when one considers the possibility of catastrophic failure, such as the bearing failure that happened on the Connecticut Turnpike’s Mianus River Bridge in 1983.

Agencies are beginning to address the cost-effectiveness of PM. The Pennsylvania Department of Transportation has developed *Standards for Bridge Maintenance*, Publication 54, which includes rehabilitation work and PM. Cost-effectiveness is addressed in this study. As BMSs are implemented, it will be possible to measure the cost-effectiveness of PM and establish levels of PM based on the bridge type and location.



**Exhibit 5: Graph of Repair Costs**

**Agency PM Policy**

Several DOTs have implemented procedures in their bridge inspection/maintenance programs to place more emphasis on PM. For example, Pennsylvania has added to the biannual bridge inspection over 76 maintenance items that, if needed, are to be identified with a priority and quantity. This information is used to plan future maintenance work.

In New York State the performance of bridge maintenance units is measured

based on the condition ratings of the bridges for which the units are responsible. The objective of the maintenance crew, when working on a bridge, is to get the condition rating above a certain level—say “6” or above. Rather than spending the entire maintenance budget keeping bridges open that are in poor condition, agencies are recognizing that it is less expensive to concentrate on preventing them from getting in poor condition.

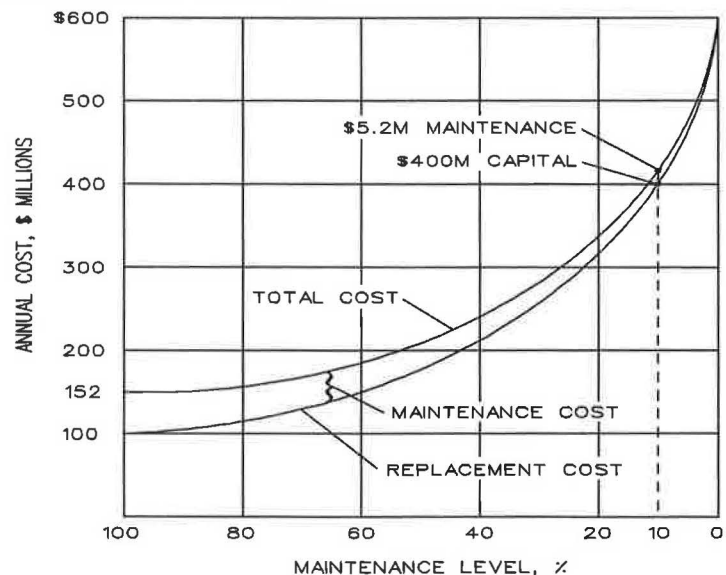
During 1988–89, a consortium of civil engineering departments of New York City colleges and universities administered by the Center for Infrastructure Studies at Columbia University undertook the development of a PM management system (PMMS) for New York City. The system concentrates on bridges in “good” to “very good” condition, although it makes it clear that PM must also be performed on “fair” to “poor” bridges until a steady state is reached. The objectives of the New York City PM plan are to

1. Keep the rating of bridge condition at a constant level; and
2. Maximize the life of bridges before major rehabilitation or replacement.

Exhibit 6 provides an example of the total annual cost of PM and replacement/rehabilitation. Note that as the level of maintenance decreases, the total cost increases dramatically. The group concluded that “the consequences of [NYC] not adopting some form of PMMS could be catastrophic.” Exhibit 7 summarizes the cost and workers required for the NYC PM program.

### ASSESSING BRIDGE MAINTENANCE NEEDS

Bridge inspectors identify a major part of the work performed by bridge maintenance units. Some agencies are beginning to evaluate the performance of the maintenance crews by the condition ratings from inspection reports. In one state, the bridge maintenance crews are asked to keep the condition ratings of their bridges at 5 or better and their performance is evaluated based on the inspectors’ ratings after maintenance is performed. A thorough, documented inspection is essential for determining maintenance requirements and making practical recommendations on suggested courses of action to correct or preclude bridge defects or deficiencies. Regular inspections should be considered as a primary maintenance responsibility. Inspections should not be confined to searching only for



**Exhibit 6: Total Annual Bridge Costs**

Maintenance Activity	Number of crews	Crew size	Total staff	Total Cost
Debris removal	14.81	5	74	\$2,941,853
Sweeping	5.11	1	5	299,690
Clean drain system	10.95	4	44	1,847,938
Clean pier/abut tops	5.19	5	26	1,595,406
Clean open gratings	0.17	5	1	37,223
Clean expansion joints	7.21	7	50	1,957,635
Wash salt splash zone	8.45	7	59	2,631,704
Painting of steel	24.66	11	271	19,438,300
Spot paint steel	21.36	5	107	8,737,013
Paint salt splash zone	7.27	11	80	5,667,292
Patch sidewalks	7.59	3	23	1,544,535
Crack sealing	4.89	5	24	1,603,081
Electrical maintenance	2.50	5	13	936,500
Oil mechanical parts	3.50	3	11	575,400
Replace wearing surfaces	0.20	30	6	1,614,980
Total personnel required	—	—	794	—
Total cost of program	—	—	—	51,428,550

***Exhibit 7: Summary of Statistics for Preventive Maintenance Management***

defects that may exist. They should also anticipate problems that could occur, and these problem areas should be indicated in the report.

Regular inspections are conducted every two years under the federally mandated National Bridge Inspection (NBI) Program. The emphasis has traditionally been to identify immediate safety concerns and establish rehabilitation and replacement priorities. As a result, these inspections do not normally provide the type of data necessary to develop maintenance schedules, programs, and budgets.

In the future BMSs will be able to generate maintenance and repair needs and establish short and long range budgets. In the meantime, maintenance inspections and federally mandated inspections can be used to complement each other for maximum efficiency.

**Inspection Performed by Maintenance Supervisors**

Bridge maintenance crews should also function as inspectors whenever they are in the field working. It is important to look for defects that might represent a potential safety hazard or a defect that will cause problems in the future. It is much easier to correct the problem while at the site than to go back again.

Maintenance crews may spend more time at a bridge site than the inspector. When cleaning and preparing for a repair, they may expose problems that the inspector could not see. The best results can be achieved when the bridge maintenance personnel and inspectors work together as a team.

## **Resource Estimating**

The condition inspection reporting system should include information that can be used for estimating the resource requirements necessary to maintain or rehabilitate a bridge. The accuracy of estimating is improved when it is performed in the field in conjunction with the inspection. Quantities are measured in the field that can be used for computing a cost estimate later in the office. The engineer and supervisor working together can anticipate specific procedures that are needed, and the accuracy of the estimate will be improved. When preparing estimates, engineering office personnel are hindered by a lack of familiarity with a specific site and the special circumstances likely to be encountered. They are, therefore, limited to the use of statistical averages for determining time and resource requirements. Field estimate data eliminates this problem. The obligation of the engineer and supervisor to perform the maintenance activity within the estimate is easier to fulfill when the field estimate procedure is used.

## **INTEGRATING PM INTO BMS**

### **A Proactive Approach to Bridge Maintenance**

The FHWA-sponsored Bridge Maintenance Training Course has been presented approximately forty times nationwide to frontline workers on state Department of Transportation bridge maintenance crews. The course material emphasizes the importance of PM and the participants are encouraged to discuss PM activities that are performed on the bridges in their area of responsibility. While many understand the value of PM, almost all admit to being in the predicament of having to use their maintenance resources on bridges in poor condition—while the newer bridges deteriorate. Almost everything currently being done to bridges is reactive.

Concrete bridge decks are a good example. Agencies spend over half their bridge maintenance budgets on concrete decks. The typical scenario is to build a new deck and ignore it until spalling and potholes begin to cause problems with the riding surface. The period of time that it takes for this to occur in most northern states ranges from 12 to 20 years depending on the quality of the original construction and the deicing salt applied. The average bridge in service today is almost fifty years old. With the proper design, quality construction and PM, bridge decks could last as long as the bridge. However, if PM is delayed until spalling begins it is too late. The deck is doomed and the cycle repeats several times during the life of a typical bridge.

A proactive PM strategy for concrete bridge decks would involve cleaning the deck at appropriate intervals to minimize the problems related to debris and salt accumulation. The permeability of the surface and chloride penetration would also be monitored and appropriate protection such as a sealant, membrane, or overlay applied to prevent the salt reaching the reinforcing steel. Spalls and potholes indicate that the salt concentration at the rebar level is unacceptable. When that occurs, the only remedial alternative is an expensive deck rehabilitation or replacement.

A similar scenario might be used to illustrate the importance of PM on deck joints, bearings, painted steel members, substructures susceptible to scour, etc. Bridges

fail or require expensive repairs because of problems related to any of these components that could be avoided by programming appropriate routine PM procedures.

In most state DOTs the BMS implementation has not advanced to the point that it is used to program maintenance, or any other work. Therefore, the inclusion of PM activities is inconsequential at this point. However, the goal is to use the BMS as a tool in programming work. If PM is to be included in the programming, the system must trigger the appropriate PM strategy at the most cost-effective time to achieve the optimum service life.

### **Elements of a PM Strategy**

Previously in this paper the elements of a BMS were discussed. If PM is to be included, it must be considered in the development of each element.

#### *Condition Assessment*

First and foremost, maintenance needs must be given high priority when the bridge is inspected. Bridge inspectors must be trained to recognize and report maintenance needs. This should include conducting (or scheduling) the appropriate tests to monitor unseen needs such as the depth and concentration of salt penetration into the concrete. Maintenance needs must be monitored to collect the information necessary to program the PM procedures. Maintenance quality should also be monitored to adjust the procedures to achieve the desired results at the minimum cost. While some PM activities are programmed at regular intervals, others are programmed to respond to changes in the condition of the bridge. The timing of those activities programmed at regular intervals is refined as a result of the inspection findings.

Some agencies currently include an assessment of PM needs as a part of the bridge inspection—others do not. Some agencies perform separate inspections by the maintenance unit to identify maintenance needs. This lack of uniformity in BMS (element level) condition data requirements should include the necessary inspection input to accurately monitor the need for, and quality of, PM. The inspection data must also be sufficiently detailed to monitor incremental changes in condition caused by neglected maintenance. This type of condition data is needed to develop and refine the prediction models.

#### *Performance Standards*

How do you measure PM and how much is necessary to achieve the optimum results? Each PM procedure must be identified and the resources required to perform the procedure defined. Performance standards are necessary to budget the activity and measure the degree of success that is achieved. These standards may be refined over time as the results are documented.

#### *Analysis of Alternative Strategies*

All the alternative procedures that might be used on a bridge must be programmed into the BMS. The manager would use the BMS to select the best procedure and time for its application. Traditionally, problems trigger remedial actions. Managers who ignore PM

tend to wait until problems create an unacceptable situation before they look at alternative strategies. To avoid this costly mistake, the strategy of keeping the bridge in good condition by performing PM should be included in the analysis. For this to be effective, the “window of consideration” for alternative strategies must begin when the bridge is in good condition.

#### *Asset Valuation*

Decisions regarding what to do to a bridge are generally made by evaluating alternative strategies using cost as the comparison criteria. Traditionally, PM has been ignored as an alternative because the condition of the structure had deteriorated to the point that it could not solve the problem. Current unit costs for all PM procedures must be determined and included in the system. To accurately assess the alternatives and demonstrate the true value of PM, life-cycle costs should be calculated, with user costs included in the formula. One alternative is to do nothing or delay the action. The cost of this alternative must include the cost of deterioration or damage related to neglect.

#### *Predictive Models*

The value of PM is best demonstrated when the rate of deterioration can be accurately forecasted. Unfortunately, predictive models for rates of deterioration are very difficult to develop for bridge components because there are many variables and some are very difficult to define on an existing bridge. For example, the rate of deterioration is greatly influenced by the quality of the original construction. The rate of deterioration for a repair is greatly influenced by the condition of the material left in place adjacent to the repair. The fact that the rate of deterioration is very difficult to predict on a new or recently repaired bridge makes it more difficult to accurately estimate the value of PM.

The most accurate method of developing predictive models for the rates of deterioration on a specific bridge member is by collecting condition data over time for that specific member. On a new or recently repaired bridge the model must be selected from past performance of other similar situations. The better you can match the situation the more accurate the initial model. This model should be refined as condition data is collected.

#### *Resource Allocation Decisions*

A common mistake in the resource allocation process is to put PM in competition with existing repair/rehabilitation needs. Since there is always political pressure to take care of the immediate needs, the PM will always lose. The justification for PM has nothing to do with the urgency to correct existing problems. Decisions related to the use of PM should be compared with the future cost of not performing this work. The reason that the urgent repair work is needed is PM was not performed in the past. The problem will never be solved if the cycle is not stopped. Separate funds must be made available for PM and never sacrificed to solve immediate problems caused by its past neglect.

#### *Implementation*

BMS implementation should be viewed not just as an opportunity to make the job easier or quicker—it is also an opportunity to do the job better. BMS provides the tools to make better PM decisions and turn around the bridge deterioration problem in this country. The key is to recognize the potential and program the appropriate alternatives, including PM.