Strategic Planning for Pavement Preventive Maintenance

Michigan Department of Transportation's "Mix of Fixes" Program

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Concrete freeways in Michigan's state network.

The amount of travel on the Michigan state highway system has increased more than 30 percent since 1986, yet the number of lane-miles to support the traffic has increased by only 3 percent. In the early 1990s, demands on Michigan's highway network increased, but the available resources decreased. Operating revenues failed to keep pace with needs, and Michigan Department of Transportation (DOT) staffing was reduced substantially.

In 1992, the Michigan DOT developed a program to preserve the highway network's pavement and bridge structures. Department leaders committed themselves to implementing the program and pledged revenues and staffing for the initiative.

The exclusive purpose of the Michigan Capital Preventive Maintenance Program is to preserve pavement and bridge structures, delay future deterioration, and improve overall conditions cost-effectively and efficiently. This article focuses on the state's pavement preventive maintenance program.

Lane-Miles To Upkeep

Michigan DOT is responsible for a highway network of 27,345 lane-miles (44,008 lane-kilometers). The roadway pavements are asphalt, concrete, and composites of asphalt on concrete. The state highway system represents about 8 percent of the state's lane-miles of roads but carries approximately 55 percent of all travel and 72 percent of commercial travel in Michigan—more than 50 billion annual vehicle-miles of travel (AVMT) and more than 4 billion AVMT of commercial travel.

In 1991, the Intermodal Surface Transportation Efficiency Act made highway preventive maintenance eligible for federal-aid funds. The National Highway System bill, which became law in November 1995, strengthened the provision: "A preventive maintenance activity shall be eligible for federal assistance…if the state demonstrates to the satisfaction of the Secretary that the activity is a cost-effective means of extending the useful life of a Federal-Aid Highway."

"Mix of Fixes" Approach

Michigan DOT satisfies public expectations by implementing a comprehensive strategy for pavement preservation. The Department initiated a pavement preventive maintenance program in conjunction with a pavement management system. In the last decade, both programs have become integral in the Department's investment decision making.

The preventive maintenance program meets public expectations for safe, smooth, and well-maintained roads by applying cost-effective treatments to correct minor pavement deficiencies before the problems become major. The pavement management system departs from traditional approaches that had focused on reactive maintenance and reconstruction.

The strategy combines long-term fixes (reconstruction), medium-term fixes (rehabilitation), and

short-term fixes (preventive maintenance). In this "mix of fixes" approach, each fix category has a critical role in improving the future condition of the state highway network.

Reconstruction

Reconstruction involves the complete replacement of the pavement structure with a new equivalent—a long-term action that is designed to last at least 20 years. Most favorable to the traveling public, reconstruction is also the most costly fix. Like most transportation agencies, Michigan DOT does not have sufficient funds to sustain the level of investment for continual reconstruction of the highway network.

In addition, directing available funds to highway reconstruction neglects the majority of the network. Figure 1 illustrates the consequence of using a long-term reconstruction strategy without rehabilitation and preventive maintenance programs—the roads remain predominantly in poor condition.

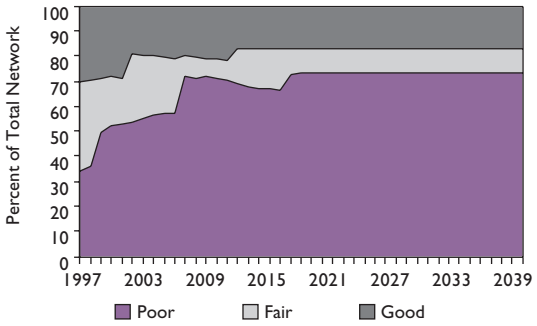

FIGURE 1 Projected condition of Michigan's highway network under reconstruction-only strategy over 40-year period with funding of $400 million per year (1997 highway budget; projections adjusted for inflation).

Rehabilitation

Rehabilitation applies structural enhancements to improve a pavement's load-carrying capability and extend the service life. Most rehabilitation projects are designed to last 10 to 20 years.

Although less costly than reconstruction, rehabilitation to improve the overall network condition still requires a prohibitive level of investment. Combined with a reconstruction program, rehabilitation can provide a marginal increase in pavement performance, but the results are not optimal, as illustrated in Figure 2.

Preventive Maintenance

Preventive maintenance applies lower-cost treatments to retard a highway's deterioration, maintain or improve the functional condition, and extend the pavement's service life. With various short-term treatments, preventive maintenance can extend pavement life an average of 5 to 10 years. Applied to the right road at the right time—when the pavements are mostly in good condition—preventive maintenance can improve the network condition significantly at a lower unit cost.

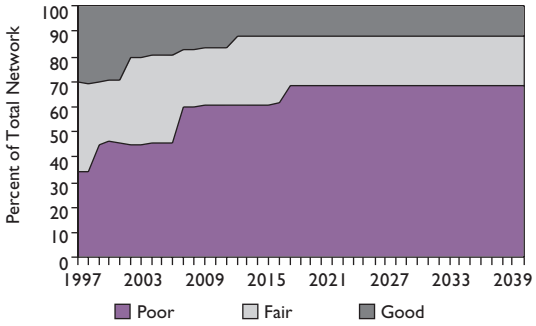

FIGURE 2 Projected condition of Michigan's highway network with combined reconstruction and rehabilitation programs (10- to 30-year fixes), at funding of $400 million per year (adjusted for inflation).

Combining Components

Combining all three programs into a single comprehensive strategy achieves the most manageable highway network, as shown in Figure 3. The total funding in Figure 3 is exactly the same as for the strategies in Figures 1 and 2, but the roadway conditions are predominantly good and fair for the long term.

Preventive maintenance is perhaps the single most influential component of the network strategy, allowing the Department to manage pavement condition. Preventive maintenance postpones costly reconstruction or rehabilitation activities by extending the service life of the original pavement. The challenge is to ascertain the right time to apply a treatment to achieve maximum benefit or return on investment.

Routine maintenance is important for a highway; but routine maintenance is a holding action, main-

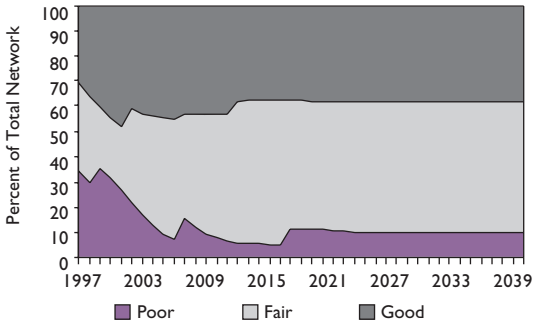

FIGURE 3 Projected condition of Michigan's highway network with combined reconstruction, rehabilitation, and preventive maintenance programs (5- to 30-year fixes), at funding of $400 million per year (adjusted for inflation).

taining the service level without extending the pavement life. Routine maintenance will not improve the overall condition of a highway network.

Partnerships for Training

Many of the surface treatments and repair techniques adopted for the new program were not familiar at first to Michigan DOT personnel. For example, microsurfacing had been applied only to a limited number of locations in Michigan before 1992, and the benefits were not well known. Similarly, the Department did not have working knowledge and experience with chip seals and certain kinds of concrete repairs.

Established contractors and suppliers were asked to develop training workshops to educate Department personnel about the new treatments. The workshops have proved popular and successful. The training partnership with contractors and suppliers has continued and has contributed to improvements in products and materials.

Surface Treatments

From the beginning, the program's emphasis has been on targeting pavement surface defects caused by the environment and by deficiencies in materials, not on deficiencies in the pavement structure caused by traffic loading.

Surface treatments for flexible pavement surfaces include microsurfacing, chip seals, slurry seals, crack sealing, 3/4-inch (20-mm) overlays of ultrathin hot-mix asphalt, and 1.5-inch (40-mm) hot-mix asphalt overlays. In some situations, it was cost-effective to treat curb and gutter pavement sections by cold-milling and resurfacing with a 1.5-inch hot-mix asphalt overlay.

Treatments for rigid pavements include full-depth concrete pavement repairs, joint resealing, dowel-bar retrofits, minor spall repair, crack sealing, and diamond grinding. Later, the removal and replacement of narrow bituminous shoulders (less than 1 meter) were added as acceptable treatments.

Building Up the Budget

Since its inception in 1992, the Capital Preventive Maintenance Program has had a dedicated budget, assuring that funds are protected and used for their designated purpose. The first year, the program was funded at $12 million, with $6 million for pavement preventive maintenance and $6 million for bridge preventive maintenance. With federal-aid eligibility, Michigan's funding obligation was approximately 20 percent of the program's total cost.

The pavement preventive maintenance budget has increased steadily, reaching $25 million in 1997. In 1998, the Transportation Equity Act for the 21st Century revised the federal funding formulas, and Michigan received a much needed revenue increase.

Chip seal operation addresses pavement surface defects on flexible pavement.

In addition, Governor John Engler obtained a gasoline tax increase to improve the state's transportation system. Michigan DOT leaders have demonstrated commitment to the program by designating a greater portion of funds for pavement preventive maintenance. Today the pavement preventive maintenance program has an annual budget of $60 million, and the budget will increase to $73.5 million in 2003.

Rating Conditions

The rating of pavement conditions on the state-managed highway system is based on standard criteria such as distress, ride quality, friction, and rutting. Detailed data are collected for the pavement management system and used by pavement engineers, but usually the data are translated into ratings of "good" or "poor" for easier understanding by other agencies and the public.

Left: Applying sealant to a flexible pavement. *Right:* Continuous microsurfacing, applied to high-volume, flexible-pavement roads in Michigan, fills ruts, improves skid resistance, retexturizes surface, and removes distortions.

Clockwise from above:

Dowel-bar retrofit eliminates faulting in rigid pavements, allowing load transfer from one slab to another.

Diamond grinding improves ride quality of concrete road surfaces.

Resealing joints on portland cement concrete pavement.

In explaining the Michigan Road Strategy to the public, officials made a distinction between freeways and nonfreeways. Freeways referred to all Interstate highways, as well as other limited-access state highways. Nonfreeways represented all of the remaining highways that are not limited-access, including all two-lane roads.

Pavement condition data for 1996 indicated that 79 percent of Michigan's freeways and 56 percent of the nonfreeways were in good condition. In 1997, the State Transportation Commission established a specific 10-year condition goal—to have 95 percent of freeways and 85 percent of nonfreeways in good condition by 2007.

The only viable strategy was to implement a three-tiered program of reconstruction, rehabilitation, and preventive maintenance. The approach addresses the worst highways through reconstruction, the poor highways by rehabilitation, and the good highways with aggressive preventive maintenance.

Optimizing Funds

The mix-of-fixes approach helps optimize available funds to meet network condition needs. In estimating the outcome of a mix-of-fixes strategy, Michigan DOT relies on the Road Quality Forecasting System, which uses current condition data from the pavement management system to predict future network conditions at different levels of investment. The forecasting model has proved an invaluable tool.

Integrating pavement preventive maintenance with reconstruction and rehabilitation produces dramatic results in the network's condition. Even the most skeptical traditionalist soon recognizes that preventive maintenance is the only cost-effective means to improve overall pavement condition. More than a program of short-term treatments, preventive maintenance is a management tool that optimizes funding allocations.

Balancing Service Life

The bar chart in Figure 4 shows the remaining service life of a typical pavement network that failed to implement a mix-of-fixes strategy. The unequal distribution of remaining service life represents a significant future problem when the largest group approaches no remaining life. With no service life remaining, the pavements are candidates only for rehabilitation and reconstruction.

Large surges in construction can be devastating to overall maintenance. First, large fluctuations in funding are required—an unpopular alternative for the public. Second, the variation in construction activities from year to year creates staffing and logistical problems for the highway agency and the contractor. The practice of hiring and laying off personnel as workloads change hurts employees and disrupts the organization. Finally, contractors and suppliers need a stable source of work to survive in the marketplace. Years of heavy workloads followed by years of light workloads can force many contractors out of business.

Preventive maintenance can alter the distribution of a pavement's remaining service life. By targeting large concentrations of pavements with similar remaining service lives, preventive maintenance treatments can balance projected workloads before a management problem develops (Figure 5). Balancing the remaining life of the network pavements will ensure manageable workloads at available funding.

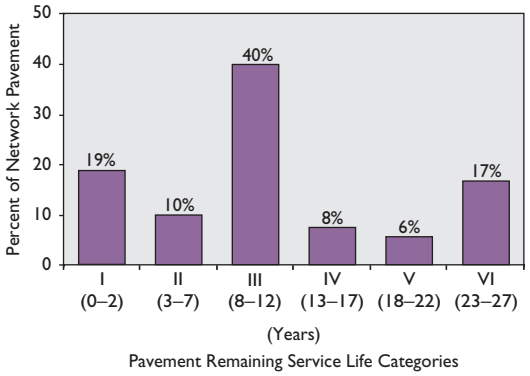

FIGURE 4 Remaining service-life distribution of typical pavement network maintained without mix-of-fixes strategy, based on current condition of roadways.

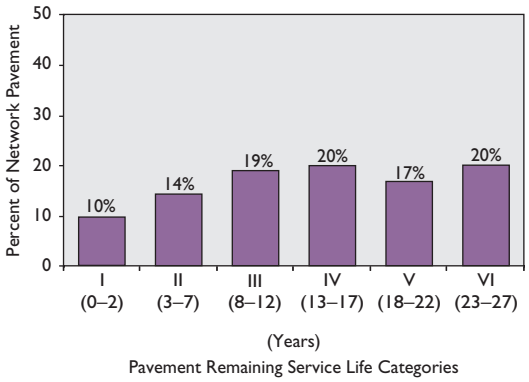

FIGURE 5 Remaining service-life distribution of pavement network that incorporates preventive maintenance approach.

Managing the Process

Data Collection

Every year pavement condition data are collected for half of the Michigan highway network, so that the entire network is surveyed every two years, and the cycle repeats. The survey collects information by videotaping one lane, providing a record of all distress in the pavement surface. The videotape is tagged by location and analyzed in 10-foot segments, with each segment assigned a distress index number that increases with the level of severity.

In addition, the survey collects ride quality and rut measurements for the pavement management system. The new data are compared with historical data to forecast future pavement conditions in terms of remaining service life.

Michigan DOT's seven regional offices are using the pavement condition data to create long-term strategies and projects to achieve the State Transportation Commission's 10-year condition goal. Each region's strategy relies on the Road Quality Forecasting System to recognize needs and variability within assigned budget targets.

Call for Projects

The Department annually issues a call for projects, allowing the regions to introduce candidate projects for roads and bridges. Projects involving reconstruction and rehabilitation are planned for five years away. At the end of each construction season, new projects for reconstruction and rehabilitation supply the next fifth year. Preventive maintenance projects are identified only for one year away, because the projects must address pavement deficiencies early on, before the problems become serious.

The annual call for projects assures that the programs are consistent with the state's long-range plan and its Transportation Improvement Program. The Department gains an opportunity to make midcourse corrections if program adjustments become necessary. But the call for projects also emphasizes the principle that preventive maintenance will improve the overall highway network's pavement condition cost-effectively.

Evaluating Performance

The value of pavement preventive maintenance is anchored to the performance of the treatments—the key is not how long the treatments last but the life-extending value imparted to the pavement. Michigan DOT annually assesses the life-extending value of the different treatments. A team of independent engineers, experienced and knowledgeable about pavements, performs the evaluations.

Data Analysis and Field Tests

The evaluations concentrate on treatments that are several years old. Before a field investigation of the treatment, information is gathered, including details about the original pavement section, construction history, historical and current traffic counts, and pavement management system condition data. The condition data on distress, ride quality, and rutting are of primary interest and include the years preceding and following the treatment application.

After the data analysis, the field phase begins. A representative number of segments are chosen to provide an accurate assessment of pavement surface condition. Each segment measures 0.1 mile (160 meters) in length. All of the selected segments are surveyed carefully and the extent and severity of each type of distress are recorded. Performance curves are developed, and the life-extending value of the treatment is extracted for each project.

Figure 6 provides a simplified depiction of the life-extending benefit of a treatment. The graph shows a typical deterioration curve interrupted when a preventive maintenance treatment is applied to a pavement in good condition. The preventive maintenance

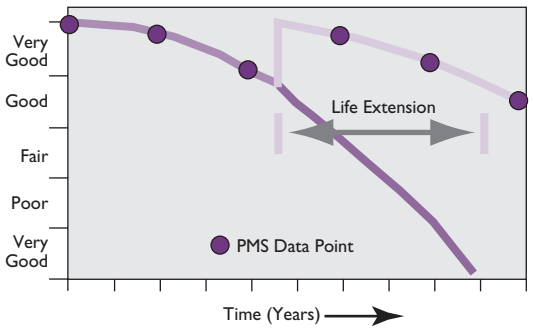

FIGURE 6 Life-extending benefit of preventive maintenance treatment.

improves the condition for a period, until the pavement returns to the condition before the treatment. The time the pavement condition was improved by the treatment is the life extension given to the original pavement, or the extended service life.

The pavement management system's measurements of pavement condition over a period of time before and after the application of preventive maintenance makes it possible to determine the extended service life of a treatment.

Prescribing Treatments

Although evaluations continue, the extended service life of a preventive maintenance treatment depends on the pavement's rate of deterioration. Pavement condition is possibly the most important factor in achieving the maximum benefit from a preventive maintenance treatment.

An engineer should evaluate a highway like a doctor diagnosing a patient—each patient has different physical traits, and the doctor prescribes a medication to fit the particular individual. Similarly, the engineer must select a preventive maintenance treatment that fits the unique condition of the pavement.

Michigan DOT prescribes treatments according to pavement condition measures, not by schedules for timely applications. The likely gains in extended service life from various treatments applied to different types of pavement are indicated in Table 1.

TABLE 1 Extended Service Life Gains for Preventive Maintenance Treatments

Treatment	Pavement Type	Extended Service Life (years)[a]
Overband crack fillling	Flexible	Up to 2
	Composite	Up to 2
Crack sealing	Flexible	Up to 3
	Composite	Up to 3
	Rigid	Up to 3
Single chip seal	Flexible	3 to 6
	Composite	N/A[b]
Double chip seal	Flexible	4 to 7
	Composite	3 to 6
Slurry seal	Flexible	N/A[b]
	Composite	N/A[b]
Microsurfacing (single course)	Flexible	3 to 5[c]
	Composite	N/A[b]
Microsurfacing (multiple course)	Flexible	4 to 6[c]
	Composite	N/A[b]
Ultrathin hot-mix asphalt, .75-in. (20-mm) overlay	Flexible	3 to 5[c]
	Composite	3 to 5[c]
Hot-mix asphalt, 1.5-in. (40-mm) overlay	Flexible	5 to 10
	Composite	4 to 9
Hot-mix asphalt, 1.5-in (40-mm) mill and overlay	Flexible	5 to 10
	Composite	4 to 9
Joint resealing	Rigid	3 to 5
Spall repair	Rigid	Up to 5
Full-depth concrete repairs	Rigid	3 to 10
Diamond grinding	Rigid	3 to 5[c]
Dowel-bar retrofit	Rigid	2 to 3[c]
Concrete pavement restoration	Rigid	7 to 15[c]

NOTES

[a] The time range is the expected life-extending benefit given to the pavement, not the anticipated longevity of the treatment.

[b] Sufficient data are not available to determine life-extending value.

[c] Additional information is necessary to quantify the extended life more accurately.

Consolidating Gains

The mix-of-fixes approach provides the greatest flexibility to the highway agency in enhancing pavement performance, with a three-tier program of reconstruction, rehabilitation, and preventive maintenance. An agency can address the worst highways through reconstruction, improve poor highways by rehabilitation, and preserve good highways with timely preventive maintenance. Preventive maintenance can improve pavement performance cost-effectively and efficiently, as measured by such attributes as ride quality, safety, and remaining service life.

In Michigan, pavement preventive maintenance is now integrated into a strategy designed to meet long-term pavement condition goals. Funding for the pavement preventive maintenance program has grown steadily from $6 million to $73.5 million annually. The performance of the preventive maintenance treatments and the extension of service life imparted to the original pavements are evaluated regularly.

Michigan DOT has a strong partnering relationship with preventive maintenance contractors and suppliers for improving products and materials. As a result, even better-performing treatments are expected in the future.

Resources

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