Abstract

In the 1970s it became clear that pavements could not actually be designed for 30-50 year life; and that they had to be managed. It was found necessary to consider construction, maintenance, rehabilitation, and even reconstruction in the life of pavements, not just “design.” The concept of pavement management was thus born. The authors have jointly about 8 decades of experience in pavement management, and, with others have seen many agencies and engineers realize the qualitative benefits of pavement management. As a result some states, provinces, counties, and cities have adopted PMS but many others have been reticent because we could not quantitatively show them the benefits of changing the way they do business. Defining benefit is required for pavement and asset management. Otherwise, agencies can feel they are doing a good job because they had done it that way for many years.
In the last few years enough research and data collection have been done on active PMS programs to quantify the benefits of pavement management systems and to be able to calculate the benefit/cost ratios and/or the return on investments. In turn, this enables agencies to save large sums of public funds by adopting pavement management. This paper presents the results of 20 years of evaluations of PMS in several active agencies. It shows the benefit/cost ratios to range from $5 to $20 million for each $1 million spent on the pavement management process in their agency.

INTRODUCTION

The proper use of Pavement Management results in qualitative and quantitative benefits. Most modern PMS optimize solutions for the available budgets to the agency and the riding public. This should produce benefits in terms of savings and improved performance. Other benefits include showing management, legislatures, and the road-using public that their money is being spent wisely.

A good PMS will also provide the ability to setup and analyze a subset of a network, such as the areas where gigantic efforts are going into oil/gas production expansion, like the Eagle Ford Shale in Texas or the oil sands in Alberta, Canada. Another benefit of a good PMS is the ability to allocate funds among different assets (pavements, bridges, guardrails, etc.) using a trade-off or cross-optimization analysis (1).

We all know the qualitative benefits but how can we quantify and prove those benefits to others? Many people studied the problem. A study of benefit/costs in PMS (2) defined *Ex post facto* and
Ex ante concepts. The Ex post facto analysis concept is shown in Figure 1 and is the type of analysis used earlier in Arizona (3).

The ex anti analysis, Figure 2, requires a prediction of pavement performance before and after PMS implementation. Such an ex anti before and after prediction of pavement condition is difficult. Choosing performance indicators to be used for determining benefits are often defined in terms of roughness or serviceability index expected for pavements. Akofio-Sowah and AmeKudzi (4) consider these factors together for evaluating transportation asset management. They use the concept of management maturation zone or scale as presented in Table 1 (5). This approach produces good qualitative and analytical assessment of benefit cost in level 4 and level 5 proficient and best practice approaches. It is now clear after several decades of PMS use that the true benefits of PMS increase greatly with time, as an agency system matures from level 1 to level 5.

![Figure 1. Concepts of ex post facto evaluation](image)

Figure 1. Concepts of ex post facto evaluation

After (2)
Figure 2. Concept of *ex ante* evaluation

After (2)
Table 1. Transportation Asset Management Maturity Scale

<table>
<thead>
<tr>
<th>PMS Maturity Level</th>
<th>Description</th>
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<tbody>
<tr>
<td>(1) Initial</td>
<td>No effective support from strategy, processes, or tools. There can be lack of motivation to improve.</td>
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<tr>
<td>(2) Awakening</td>
<td>Recognition of a need, and basic data collection. There is often reliance on heroic effort of individuals.</td>
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<tr>
<td>(3) Structured</td>
<td>Shared understanding, motivation, and coordination. Development of processes and tools.</td>
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<tr>
<td>(4) Proficient</td>
<td>Expectations and accountability drawn from asset management strategy, processes, and tools</td>
</tr>
<tr>
<td>(5) Best Practice</td>
<td>Asset management strategies, processes, and tools are routinely evaluated and improved.</td>
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A standard Benefit/Cost Analysis (BCA) procedure for each of the asset classes considered was put forward in (4). Example benefit and cost factors used in the following performance measures:

- Cost measures
  - Data collection costs (equipment, labor, other)
  - Program implementation costs (software, organizational changes, others)
  - System operation costs (additional labor, system/program maintenance)
- Benefit measures
  - Asset failure and replacement costs (asset value, number of fatalities/injuries, traffic delay hours, labor costs, other costs)
  - Time savings on maintenance, administrative tasks (and decision-making) and work order placement
Quantifiable Benefits

Most of the PMS benefits are difficult to quantify. But it has been reported by others (6,7) that road authorities can accomplish 5-10% more work with a fixed budget by using a PMS. If that budget was $500 million, for example, with only 5% savings this would result in savings of $25 million. The cost of operating a PMS is roughly $1 - $2 million per year. At $1 million the Benefit/Cost ratio is 25 to 1. Even at $2 million annual PMS operating cost, the B/C ratio is 12.5 to 1.

The Texas DOT has reported that tracking performance of all assets including pavement mileage helps know when and how to better expend maintenance funds. They have a $1.4 billion annual maintenance budget. Assuming 80% of that budget, about $1.2 billion, is spent on pavements and the use of a management system saves 5%, an annual saving of $60 million accrues. This represents a B/C ratio of 15-30 to 1, based on the cost of operating the Maintenance Management System, MMS, which is $1-2 million/year in Texas. If a DOT wants to extend the benefits of PMS they should also consider other engineering systems applications (3).

Benefit/Cost of Developing and Using PMS

In the 1990’s it was difficult to assess financial costs of pavement management software. The costs obviously depend on the size of the agency and highway network being managed and the number of users who will have access to the software on a per-user basis. It also depends on the customization the agency requires in its contract agreement with the provider. Information based
on discussions with various DOTs and PMS software providers suggest that upfront acquisition, installation, and training on the software can run from $700,000 to $1.7 million for a DOT with 30,000 - 100,000 center line miles of highway and 20 - 50 licensed users. Subsequent annual software maintenance and annual user license fees can run $200,000 - $700,000 annually, again depending on size and potential upgrades requested.

Similar anecdotal information shows that these agencies spend $300 million to $700 million annually on building and maintaining pavements. The same varied sources show that their pavement budgets can be extended 5-10% further using PMS to provide the correct treatment in the right place at the correct or optimum time. This is in effect a cost savings or benefit of pavement management. Since these figures are not exact, let's look at a range of possibilities.

Consider an example DOT and to be realistically conservative use an initial cost of $1.0 million to acquire the PMS software, and an annual in-house cost of $500,000 for staff and operation of the PMS. Carrying the example further spread initial costs over three years for an annual cost of ~ $300,000. Therefore average annual PMS costs are 3 x $500 + $300 = $1.8 million/year. If the annual pavement budget is $500 million, a savings due to PMS of even only 1% would produce $5.0 million annual saving. Extending this further results in the following:

1% savings equals $5.0 million, thus B/C = $5 m divided by $1.8 m/yr = 2.8
2% savings = $10.0 million – B/C = 10 divided by $1.8 m/yr = 5.5
5% savings = $25.0 million – B/C = 25 divided by $1.8m/yr = 13.9
Thus, for even very modest expected savings using a good PMS, the benefit/cost ratio ranges from about 3 to 14. These calculations do not include extra benefits obtained in maintenance management because of better data furnished to the maintenance section from the PMS. They also do not include benefits to senior administration through up-to-date knowledge of pavement conditions and future needs.

**Example Benefits of PMS for Arizona DOT**

The Arizona DOT has used PMS since 1980, and in 1998 decided to study its effectiveness (3, 8).

After all performance indicators (roughness, cracking, etc.) were studied, a statistical analyses (9) showed roughness (IRI) as the most significant factor. The analysis showed an average initial period roughness (1981/83) to be 68.3 inches per mile (IPM) with an average rate of increase of 1.96 IPM per year. The 1993/95 (post-PMS) period showed average initial roughness of 64 IPM and a rate of increase of only 1.86 IPM per year. Thus, on average all pavements were about 6.7% smoother after 16 years of good PMS.

It was also shown that Pre-PMS pavements on average reached the ADOT maximum tolerable IRI level of 93 IPM at 12.3 years of age. For the after-PMS (1993/95) period this was 14.9 years. If the extra life benefits are compared to the costs of operating the PMS we can make a reasonable estimate of benefit/cost ratios. Overall the average benefits totaled $423 million and
total PMS costs were approximately $8.3 million over 16 years including amortization of the
cost of developing the software (3). This gives an overall benefit/cost ratio over 50 to 1.

The improved level of performance also produces savings in user costs. According to World
Bank experience (10) user benefits can be four to ten times road expenditures. Even if half the
benefits were due to improved materials and construction and not PMS implementation, the B/C
ratio would still be about 25 to 1.

Using the World Bank, conservative level of user benefits of 4 times expenditures the overall
benefit/cost ratio is 100 to 1. These are real observed benefits. Even if your agency does only
1/10th as well as Arizona and World Bank studies show, every dollar invested in good PMS
implementation will pay $10 or more in dividends.

Example Benefits of Management Systems for Pinellas County Public Works, Florida

In 2005 the Public Works Department of Pinellas County, Florida (PCPW) set out to improve
benefits in the Department using best business practices. In October 2006, they were provided
with a web-based MMS (Maintenance Management System). More than 40 existing computer
systems in Pinellas were replaced with three new systems.

In 2011 PCPW reported major cost savings, much greater organizational efficiency and higher
productivity including the following quantified benefits (1):
• The new systems eliminated the need to acquire 2 other computer systems which had been budgeted near $500,000.

• The Mowing department alone saved $1.7 million by a better match between quantity and quality, inventory and methods.

• The labor pool was reduced to 51 employees, plus a reduction to 70 pieces of equipment.

• The productivity in units per hour increased by 45%.

• In 2004 it was anticipated that the annual savings produced by the new systems would be $2-3 million, but the documented Budget reduction is $6 million.

Other reported general benefits were:

• Joint participation of Senior Management, Supervisors and all staff members resulted in a common goal and improved the team spirit in the organization.

• Overall there were improvements in efficiency, decision making, organizational development, accountability, planning, reporting, speed of information gathering and transparency.

• Public Works now accounts for all maintenance work and resources, cost, location and accomplishment in terms of being fully tracked.

Pinellas County is a good example that smaller organizations can also make major savings with appropriate PMS and MMS. While this is derived from a maintenance management system it clearly indicates many benefits that good pavement management systems software can also be expected to produce.
Example Savings for Cities and Counties

In 2014 Kercher Engineering (12) summarized an evaluation they did for a city agency with 90 miles of streets. The first step was a good pavement condition survey. The cost of that survey was $15,000. The results of the survey is a color coded map of road condition for the city which shows the condition of the road network for city officials and engineers, a first step forward.

Step two was to do a single year analysis where the cost of analysis and a resulting report cost an additional $5,000, (total $20,000). That analysis produced a list of treatments including estimated cost of each treatment required for each road segment so that the staff could rank the roads to be treated. However, such a "current year’s selection of treatments" is not optimized and does not maximize the use of the cities limited resources. It also gives no idea of what the future performance or needs in the road system are. Kercher reports that this is "not the best we can do for the taxpayer."

The third level is a multi-year analysis which adds pavement management software and reporting at $15,000 total, bringing the expenditures to a level of $35,000. This expense produces treatment and cost per segment, predicted future performance for each segment, and a multi-year ranking for all segments based on a ranking criterion in the software. Plus you can predict future condition of the network. This level 3 still does not maximize the use of limited resources. It is still not "the best we can do" for taxpayers.
At the fourth level the team can perform an optimization. The total cost would be the cost of data plus cost of the analysis and a report plus the cost of software, $20,000 (total $55,000). This will produce 1) treatment cost per segment, 2) predicted future performance, 3) an optimized work plan, 4) will predict "the best possible" future condition of the network and 5) will maximize the use of the city's limited resources. The priority ranking procedure, Figure 3, results in a $40 million backlog at the end of a 10 year analysis. The optimization or highest level analysis, however, should only have a $31 million backlog for the same annual budget. Thus, the city saves an estimated $9 million over ten years for an additional cost for optimization of only $55,000 per year or $550,000 ten year total, a 16 to 1 rate of return on investment.

Kercher also ran a study for a medium sized county with 700 miles of street comparing full optimization versus priority ranking. (Figure 4) For the same budget level, the county will be able maintain a PCI level of 77 at the end of 10 years using optimization whereas for ranking only, their PCI level drops to 58 on average in 10 years.
Figure 3. Priority ranking analysis: $40 million Backlog
Optimized Analysis: $31 million Backlog (12)
Figure 4. Overall Condition Index (PCI) (12)

Summary

There is no denying that the proper use of a good PMS produces substantial benefits. While there is no precise method of defining those benefits, studies show B/C can range from a lower bound of 10:1 and much more counting user costs savings, up to 25:1 or even more.

References


8. FHWA/NHI Course #131105 “Analysis of PMS Data for Engineering Applications”, 2006


