# Quantifying the Benefits of Pavement Management

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## SYNOPSIS

Pavement management systems (PMS) have been in operation since the early 1970s with varied success in full implementation. Pavement management engineers and maintenance managers understand the value and benefits resulting from the implementation of a PMS. When it comes to decision makers and top-level management, the picture is different. They are interested in benefits that can be translated into monetary values ($) rather than the regular benefits mentioned in the literature. This paper describes the authors attempt to fill in the benefits determination gap and presents a process that can be utilized to quantify benefits.

The paper considers the Iowa Department of Transportation (Iowa DOT) PMS implementation as a case study. The Iowa DOT implemented a PMS in 1998 after an extensive period of evaluation of different tools to conduct pavement management. The Iowa DOT selected dTIMS™ (Deighton Total Infrastructure Management System) as the pavement management software. To quantify the benefits for implementing a PMS, the results from the PMS were compared against the construction program that the Iowa DOT implemented 5 years before PMS existed and 5 years after on the interstate system (2650 2-lane KM). The before PMS comparison was completed in 1997 and the difference between the recommendations from the PMS and the IDOT program was a 3.5% increase in pavement condition (2.64 PCI points). Using the PMS, to achieve a 3.5% increase in condition require an additional investment of $12.5 million over 5 years. When the after analysis was conducted, the difference in condition was 2% (1.45 PCI points). This is equivalent to an additional investment of $7 million over 5 years. The difference between the two comparisons is equal to the benefits derived from implementing the pavement management system. The paper will show the procedure used, the data requirements, and the data analysis.

## INTRODUCTION

Pavement management, in its broadest sense, involves managing all the activities related to the pavement network. These activities include, but are not limited to, planning and programming, design, construction, maintenance, and rehabilitation. A pavement management system provides effective tools and methods that can assist decision makers in formulating optimum strategies for providing and maintaining a serviceable pavement network over a given time period (the planning horizon). A good pavement management system requires an organized and systematic approach for agencies (state or local, public or private) to conduct pavement management activities [1].

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The paper considers the Iowa Department of Transportation (Iowa DOT) PMS implementation as a case study. The Iowa DOT implemented a PMS in 1998 after an extensive period of evaluation of different tools to conduct pavement management. The Iowa DOT selected dTIMS™ (Deighton Total Infrastructure Management System) as the pavement management software. To quantify the benefits for implementing a PMS, the results from the PMS were compared against the construction program that the Iowa DOT implemented 5 years before PMS existed and 5 years after. The before PMS comparison was completed in 1997 covering the period between 1992 and 1996. The after PMS comparison was completed in 2004 covering the period between 1999 and 2003.

## PAVEMENT MANAGEMENT SYSTEMS (PMS)

The Federal Highway Administration defines a pavement management system as "a set of tools or methods that (can) assist decision makers in finding cost-effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition" [2]. A somewhat simplistic description is that pavement management will help pavement engineers and top management in initiating cost-effective decisions relative to the "what," "where," and "when" in terms of pavement maintenance and rehabilitation. What treatment is cost effective; where are treatments needed; and when is the best time to program a treatment?

Even though, pavement management systems will differ depending on the size, organizational structure, and resources of each implementing agency, it should nonetheless, perform the following functions [3]:

- Improve the efficiency of decision-making involving pavement management activities,
- Expand the scope of the pavement management process by incorporating relevant information in the decision making process,
- Provide feedback on the consequences of future decisions,
- Facilitate communication, cooperation, and coordination of pavement management activities within an agency, and
- Ensure consistency of decisions made at different management levels within the same organization.

Implementing a pavement management system in an agency can result in several benefits. The case history of successful and beneficial implementations of pavement management systems is well known and rich. Even though, it is sometimes difficult to measure the direct economic benefits of implementing a pavement management system, one unquestionable benefit lies in the selection of the most cost-effective maintenance and rehabilitation alternatives. This benefit allows, at a minimum, for the most efficient use of funds available to an agency. In addition to direct economic benefits, a pavement management system has many other potential uses, including [4]:

- More accurate and accessible information on the pavement network,
- Quantify the assessment of the condition of the pavement network,
- Ability to track the performance of specific treatment strategies,
- Identify needs to plan future activities and expense budgets,
- Support requests to state legislatures for additional funding for pavement maintenance and rehabilitation activities,
- Justify and support decisions as to project prioritization when dealing with local politicians or the public,
- Improve credibility when dealing with top management within the transportation agency,
- Provide a basis for allocating funds among different districts or agencies, and
- Help select the best rehabilitation measures or strategies for different pavement management sections.

All pavements deteriorate over time because of traffic application and environmental factors. Figure 1, based on research conducted by the Utah Department of Transportation [5], shows the average deterioration rate and the change in repair costs ($\$/m^2$) as the pavement deteriorates. It is clear from Figure 1 that with more frequent early treatments in the life of the pavement, overall life costs will be less than waiting for the pavement to deteriorate. This is the basic principle behind pavement management systems (i.e. it is less expensive to maintain pavements in good condition) [6]. Pavement management practices are based on the concept of finding a cost-effective combination of treatment strategies to apply at any given time to a specific pavement section to maintain or achieve a desired serviceability level.

## METHODOLOGY

This section describes the methodology used to quantify the benefits of implementing the PMS using the Iowa DOT as a case study. The methodology covers the dTIMS™ software operation, the benefits determination process, the before PMS data and analysis, and the after PMS data and analysis.

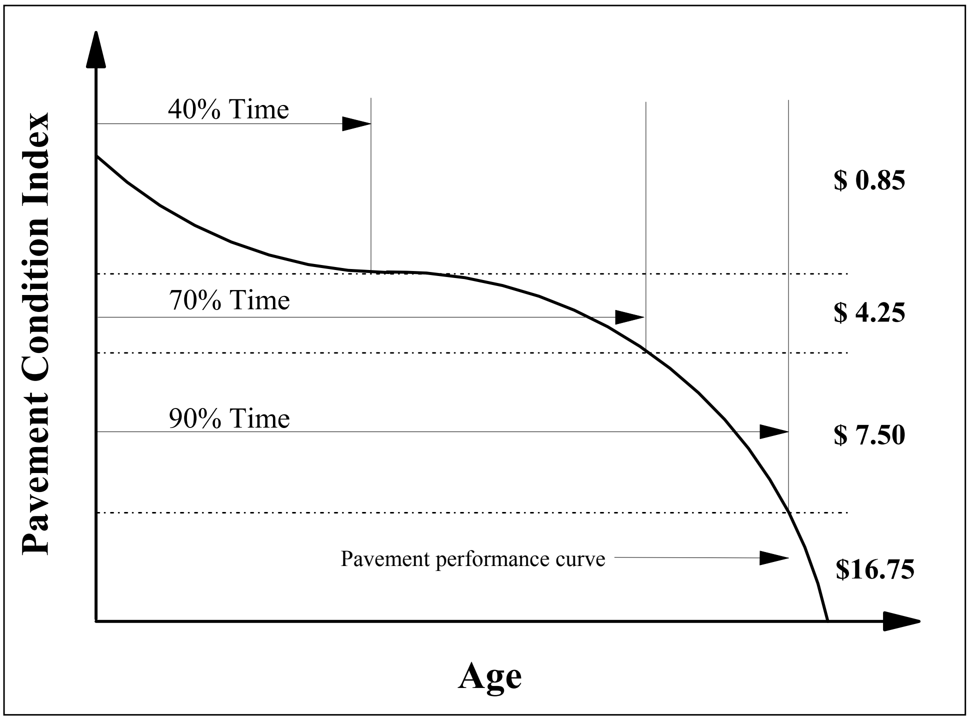


Figure 1 Effect of treatment timing on repair costs [5]

## dTIMS™ Software

dTIMS™ is a software product developed by Deighton Associates Limited [7] which offers a set of tools for implementing a custom database and a custom analysis models. The software allows the user to create and maintain an inventory integrating any and all types of data (roads, bridges, signs, etc…) in one place and relate them together using location referencing. In addition, the software enables the user to perform life cycle cost analysis (LCCA) on those assets, meaning it will forecast condition into the future and determine the best maintenance or rehabilitation action subject to budget constraints.

The Iowa DOT implementation of the PMS software is in the use of the analysis models only. The Iowa DOT maintains their pavement management data into an ORACLE database. The analysis model is based on the incremental benefit cost analysis and it also utilizes LCCA. The Iowa DOT has been using the software since 1998 to develop their 5-year construction program for the interstate network (2650 2-lane KM). The PMS software has also been implemented on the remaining network (primary roads in the state), but it is not a centralized operation like the interstate system.

In addition to the analysis model, the following functions are utilized by the Iowa DOT for the development of their annual construction program and also for this analysis of the benefits.

1. The ability to forecast pavement condition. The Iowa DOT has developed performance curves to forecast pavement condition. The interstate system has 6 different performance curves based on pavement type. Three represent portland cement concrete pavements, 2 for composite pavements, and one for full depth asphalt concrete pavements.
2. The ability to commit projects that have been scheduled for future construction. The software has the ability to deal with projects that have already been scheduled (or committed) through out the analysis period. The software will implement the selected treatment; improve the pavement condition, and then start forecasting the deterioration according to the given performance curves for the specific pavement type.
3. The reporting capabilities. The software has the ability to produce overall condition reports (PCI vs. analysis year) for 5 different budget scenarios. Also, a chart representing an investment analysis (dollars vs. condition after 1, 5, 10, 15, and 20 years). Using the investment analysis chart, the user can determine the investment it takes to increase the average network condition by 1 or more PCI points.
4. Economic analysis. The software utilizes the use of the incremental benefit cost (IBC) analysis to conduct the trade off analysis between investments in different projects. The use of the IBC is based not only the initial treatment cost, but also considers the life cycle cost of the project.

## Benefit Determination Process

To be able to determine and quantify the benefits of implementing a pavement management system for the interstate system, a set of data representing the condition information, the implemented construction program for the Iowa DOT interstate network, and the pavement management parameters including: prediction curves, treatment strategies, treatment costs, and treatment benefits. Since the Iowa DOT implemented the PMS in 1998, the before PMS analysis was conducted for the period from 1992 to 1996, and the after PMS analysis was conducted for the period from 1999 to 2003. During the two periods, the actual pavement condition information was collected and the resulting pavement condition predicted by the pavement management software was also compared. The following sections provide a description of the two analysis periods with the resulting pavement condition index (PCI-the PCI is on a scale of 0 to 100, with 100 being the best and 0 being the worst).

To determine the benefits, the difference between the average network PCI resulting from the actual Iowa DOT construction program for the before and after PMS analysis is compared to the PCI resulting from the PMS software recommendations. Since pavement management systems are considered to be a tool to help decision makers make more cost effective decisions, not all the recommendations from the PMS are implemented. So, the actual benefits resulting from the PMS is the difference (in $) between the two analyses as a result of the change in the average network condition.

## Before PMS Analysis

The before PMS analysis was completed in 1998 after the implementation of the Iowa DOT PMS was completed. 1998 was the first year that the Iowa DOT used the output from the PMS to aid in the development of the 5-year interstate maintenance and rehabilitation program.

To conduct the before PMS analysis, the actual Iowa DOT construction program for the years 1992 to 1996 was committed in the PMS software database and the average PCI resulting from the program was determined (Figure 2 shows an example of the data used). The next step was to run the PMS software with the same budget used for the Iowa DOT construction program and allow the software to make recommendations for projects to be maintained or rehabilitated. The resulting PCIs from the two programs are compared (see Figure 3). Figure 3 shows the comparison between the resulting PCI from the Iowa DOT program and the PMS analysis. As it can be seen from Figure 3, the PMS recommendations resulted in a PCI of 76.43, while the Iowa DOT program resulted in a PCI of 73.79 (a difference of 2.64 PCI points).

| PMS Section | Route | Committed Treatment | Committed Cost | Committed Year | Committed Budget | Pavement Type |
|---|---|---|---|---|---|---|
| 02911145199799 | 029 | 4S3A | 1 | 4 | CAP | 3A |
| 02911148219799 | 029 | 4S3A | 1 | 4 | CAP | 3A |
| 02911149119799 | 029 | 4S3A | 1 | 4 | CAP | 3A |
| 02911150679799 | 029 | 4S3A | 1 | 4 | CAP | 3A |
| 02921000003699 | 029 | | -1 | -1 | | 3B |
| 02921008933699 | 029 | | -1 | -1 | | 3B |
| 02921019073699 | 029 | | -1 | -1 | | 3A |
| 02921025496599 | 029 | 6S3B | 1 | 1 | CAP | 3B |
| 02921026966599 | 029 | 6S3A | 1 | 1 | CAP | 3A |
| 02921032176599 | 029 | 6S3A | 1 | 1 | CAP | 3A |
| 02921032886599 | 029 | 6S3B | 1 | 1 | CAP | 3B |
| 02921033456599 | 029 | 6S3A | 1 | 1 | CAP | 3A |
| 02921034796599 | 029 | 6S3B | 1 | 1 | CAP | 3B |
| 02921036136599 | 029 | 6S3A | 1 | 1 | CAP | 3A |

4S3A: 4 inch structural overlay for type 3A (composite) pavement
6S3A: 6 inch structural overlay for type 3A (composite) pavement
6S3B: 6 inch structural overlay for type 3B (composite) pavement
CAP: Capital Program Budget

Figure 2 Inventory data with the committed program in the PMS software

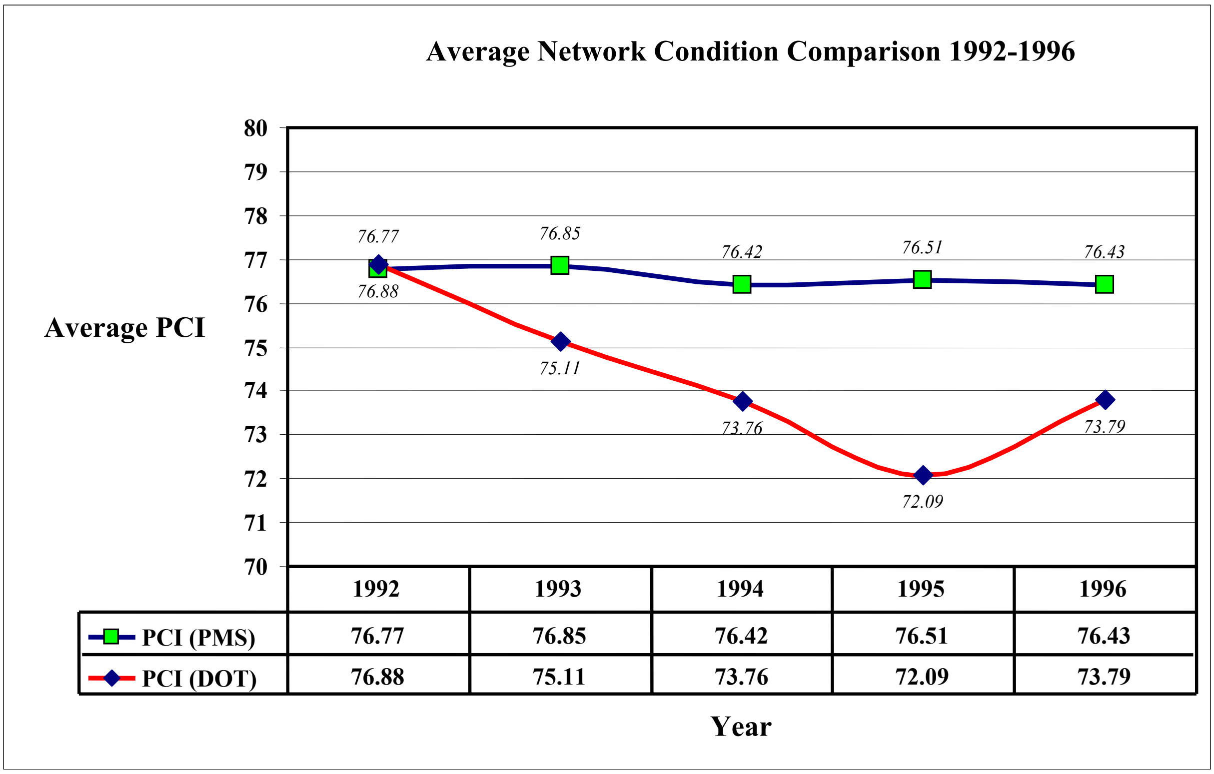


Figure 3 Before PMS average condition (PCI) comparison

To determine the value in $ for the improved pavement condition, multiple analysis runs of the PMS software with different budgets were used. The budget that resulted in PCI values similar to the Iowa DOT construction program of 73.79 was selected. The difference between the selected budget ($162.5 million) and the actual budget spent by the Iowa DOT between 1992 and 1996 ($175 million) represents the value of the benefits of implementing the PMS system ($12.5 million). This $12.5 million translates to roughly $5 million for every 1 PCI point over a 5 year period. This number ($5 million per PCI point) will be used again in the after PMS analysis.

## After PMS Analysis

The after PMS analysis was completed in 2004 after the Iowa DOT PMS was used as a tool to develop the interstate construction program for 5 years. 1998 was the first year that the Iowa DOT used the output from the PMS to aid in the development of the 5-year interstate maintenance and rehabilitation program.

To conduct the after PMS analysis, the actual Iowa DOT construction program for the years 1999 to 2003 was committed in the PMS software database and the average PCI resulting from the program was determined. The next step was to run the PMS with the same budget used for the Iowa DOT construction program and allow the software to make recommendations for projects selected for maintenance or rehabilitation. The resulting PCIs from the Iowa DOT actual construction program are shown in Figure 4. Figure 5 shows the resulting PCIs from the PMS recommendation for the same budget. Figure 6 shows the comparison between the resulting PCI from the Iowa DOT program and the PMS analysis. As it can be seen from Figure 6, the PMS recommendations resulted in a PCI of 73.08, while the Iowa DOT program resulted in a PCI of 71.63 (a difference of 1.45 PCI points). Based on the before PMS analysis, this increase in the PCI represents an additional investment of $7.5 million.

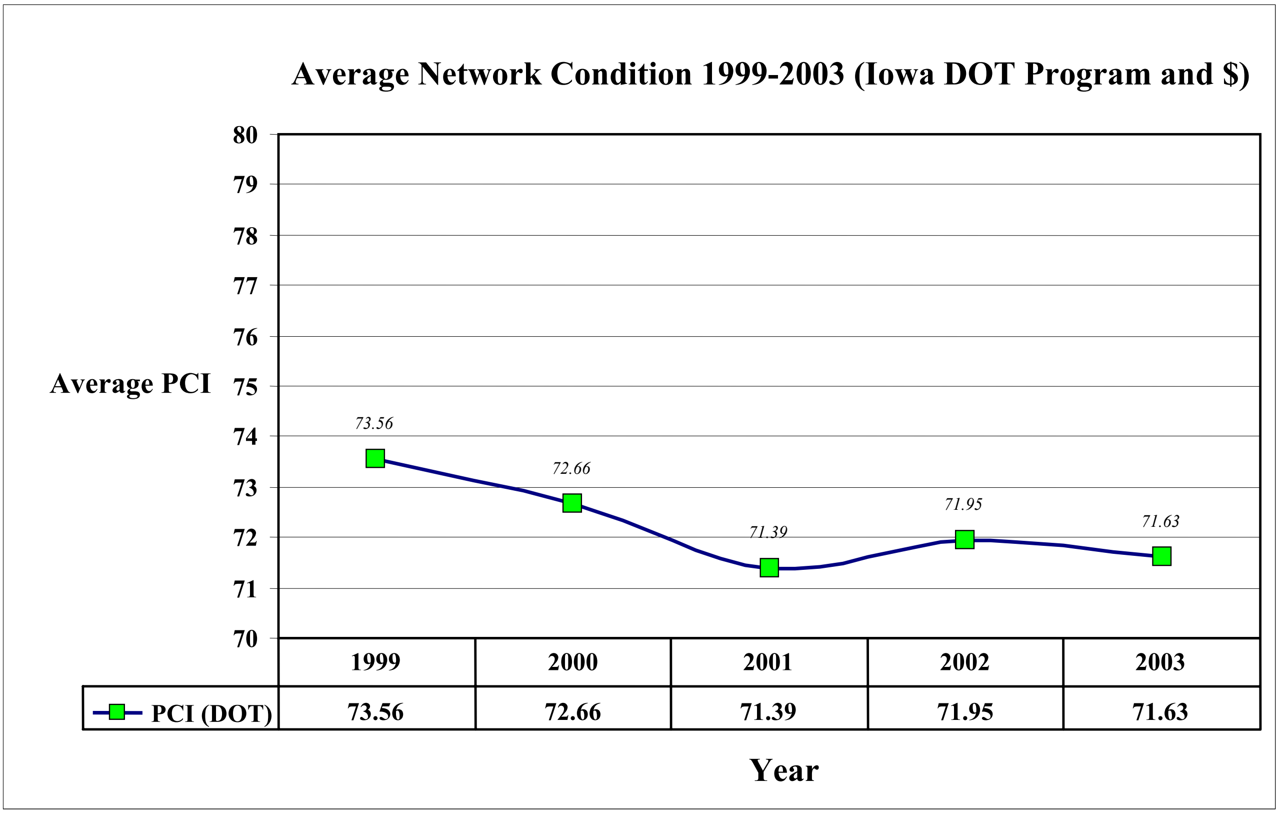


Figure 4 After PMS PCI results for the Iowa DOT construction Program

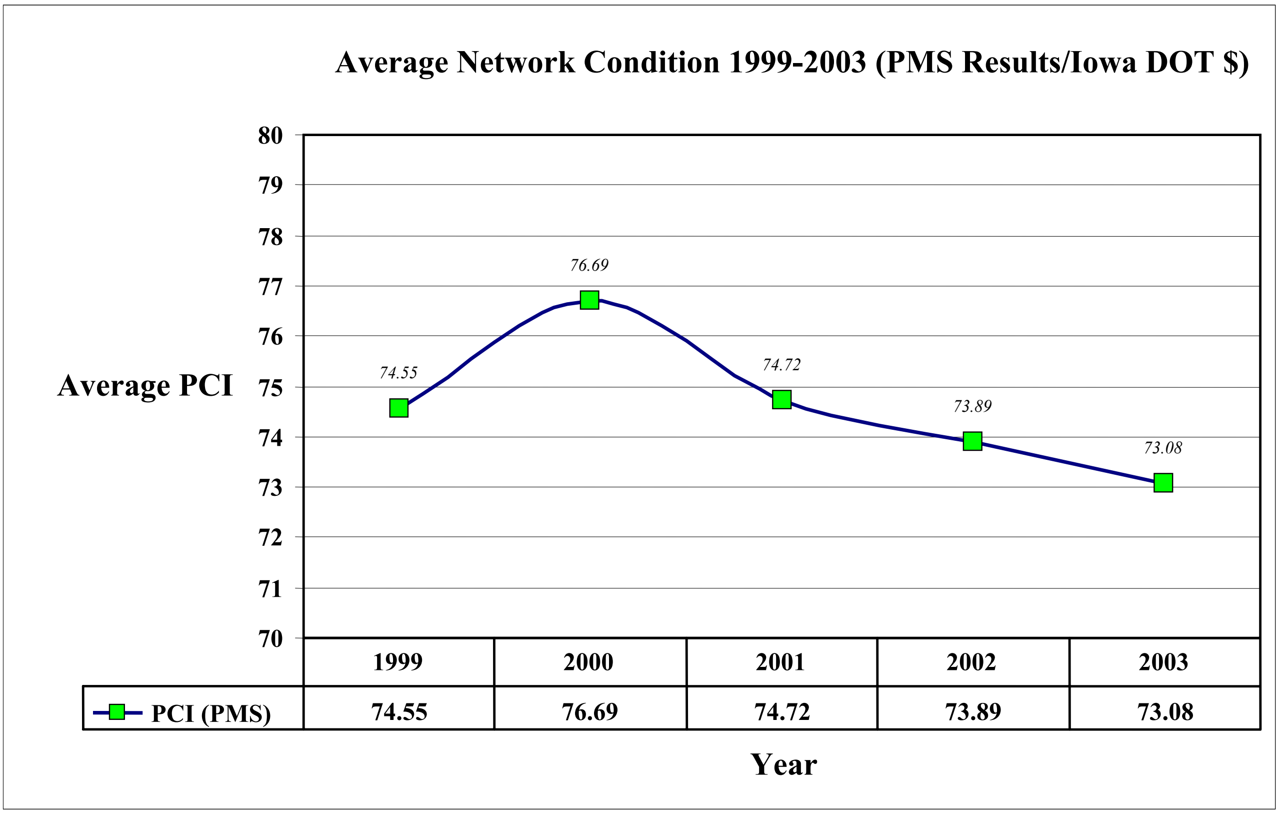


Figure 5 After PMS PCI results for the dTIMS™ recommendation

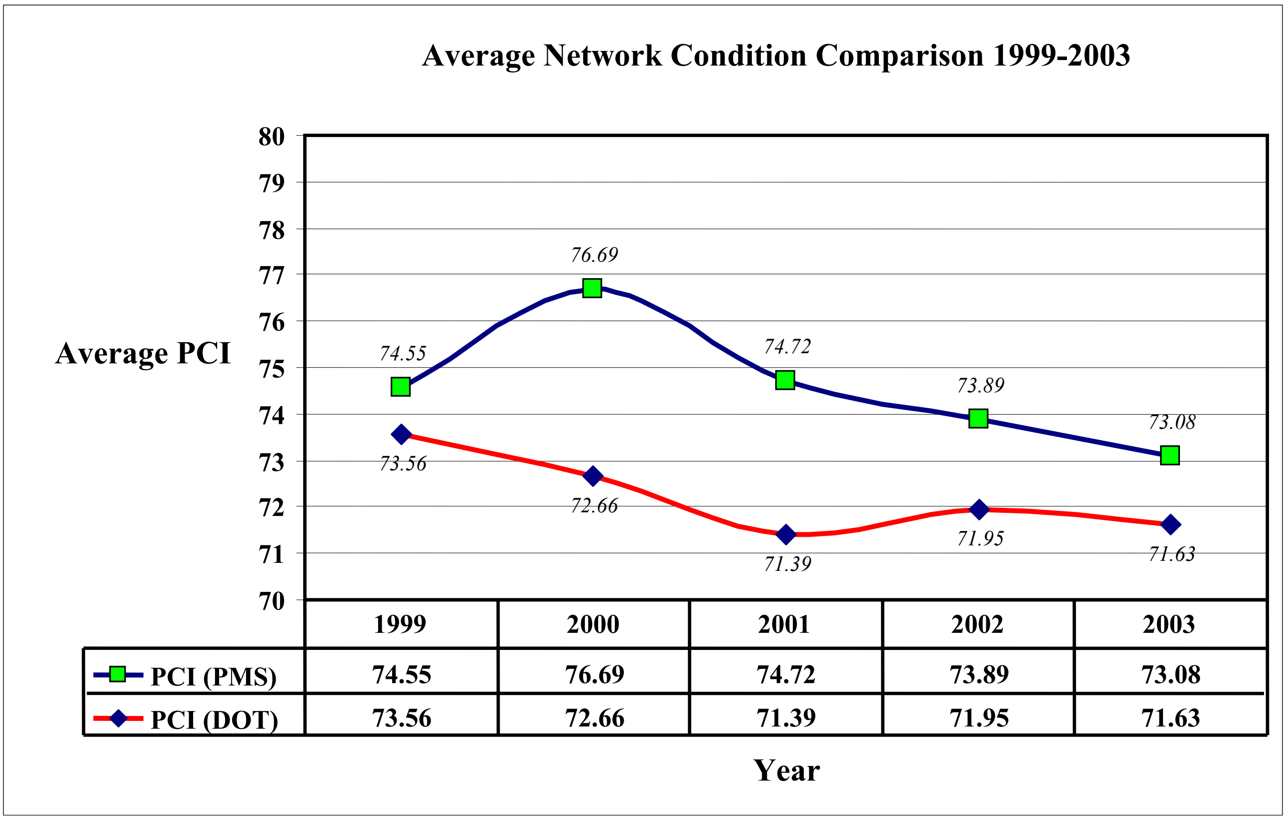


Figure 6 After PMS average condition (PCI) comparison

## RESULTS

As it can be seen from Figures 3 and 6, the PMS recommendation for maintenance and rehabilitation program resulted in an improvement in the condition (PCI) over the 5-year analysis period using the same budget as the Iowa DOT used. The before PMS analysis showed a more substantial increase in investment to achieve the same condition ($12.5 million) compared to the after PMS analysis ($7.5 million). The benefits resulting from the implementation of the pavement management system at the Iowa DOT is considered to be the difference between the two numbers.

So, to be able to quantify the benefits, the resulting increase in investment from the before PMS analysis is compared to the after PMS analysis. If the two numbers were the same, then the conclusion would be that the Iowa DOT did not gain any benefits by implementing the PMS. In this case, there was a difference of approximately $5 million between the before and after analysis. This is an indication of the monetary benefits resulting from the implementation of the pavement management system. The $5 million is spread over a 5-year period making the annual benefit equal to about $1 million. Compared to the cost of implementing the PMS for the interstate system, the benefits far outweigh the costs.

Further analysis of the data showed also that the resulting average network condition from the PMS matched very well with the actual condition data collected throughout the two analysis periods (before and after PMS). This is a confirmation of the accuracy of the performance parameters developed for the interstate system. Also, the projects selected by the Iowa DOT matched very closely with the recommendations from the PMS. Sometimes the timing was different or the treatment was different, but the majority of the projects identified were the same for the two programs.

## CONCLUSIONS

In conclusions, this paper shows how a process was used to quantify the benefits of implementing a pavement management system. Even though dTIMS™ was used in this case, this process can be used by different agencies utilizing different pavement management systems provided it does have the ability to do some of the functions discussed here. The paper shows that the implementation of the Iowa DOT PMS for the interstate resulted in substantial benefits (improved condition) that can be put in monetary value at $5 million over

5 years and can help in getting more support from decision makers to widen the use of management systems and consider different assets like bridges for example.

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