Value Affect of Construction Incentive Payments on Pavement Performance

Final Report

August, 2009
RC 1524

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Technical Report Documentation Page

1. Report No.
Research Report RC-1524

2. Government Accession No.

3. MDOT Project Manager
David Smiley

4. Title and Subtitle
Value Affect of Construction Incentive Payments on Pavement Performance

5. Report Date
August 2009

6. Performing Organization Code

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8. Performing Org. Report No.

9. Performing Organization Name and Address
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10. Work Unit No. (TRAIS)

11. Contract No.
2006-0411

11(a). Authorization No.
Z10

12. Sponsoring Agency Name and Address
Michigan Department of Transportation
Construction and Technology Division
P.O. Box 30049, Lansing, MI 48909

13. Type of Report & Period Covered
Final Report

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract
The Michigan Department of Transportation (MDOT) has been using monetary incentive payments for many years to improve contractors' conformance with specifications and their overall workmanship. It was envisioned that incentive/disincentive (I/D) payments would have positive impacts on the long term pavement performance by extending its expected life. However, these impacts have not been quantified, nor qualified. Hence, the department initiated and sponsored this exploratory study to determine whether or not the available data elements in the MDOT data files and project records could adequately support the analyses of the costs and benefits of the I/D program and to perform preliminary data assessment.

Results of the study indicate that the MDOT data files and project records contain sufficient data to perform only limited analyses of the costs and benefits of the I/D program.

17. Key Words
Incentives, disincentives, rigid and flexible pavement performance.

18. Distribution Statement
No restrictions. This document is available to the public through the Michigan Department of Transportation.

19. Security Classification - report
Unclassified

20. Security Classification - page
Unclassified

21. No. of Pages
52

22. Price

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GLOSSORY OF TERMS AS USED IN THIS REPORT

Beginning Mile Point (BMP) and Ending Mile Point (EMP) – The BMP and EMP are a linear reference location within a given control section, marking the beginning and ending mile points of a road segment. The mile point is zero at the beginning of the control section and increases as one travels over the road away from the beginning point of the control section. The term “mile point” is also used as “milepoint”.

Point of Beginning (POB) and Point of Ending (POE) – POB and POE are similar to BMP and EMP; they express the beginning and ending mile points of a project under construction.

Cost of the I/D provisions or program– The cost of the I/D provisions or program is the sum of the extra payments paid by MDOT, or applied, to the project contractor to satisfy the I/D provisions included in the proposal of a given pavement project. In this report, the cost of the I/D program is calculated as percent of the total paving material costs.

Benefits of the I/D provisions or program - The benefits of the I/D provision or program is calculated as the difference between the life extension of a pavement project with I/D provisions and that of a similar project without I/D provision.

Paving Material Costs – The term paving material costs references the costs of all asphalt concrete or portland cement concrete materials used on the trunkline of a project.

I/D Provision – An I/D provision is the specified parameter (such as asphalt content, density, and/or strength) for which I/D pay adjustment factors are specified in the project proposal.

I/D Pay or Penalty Adjustment Factors – The I/D pay/penalty adjustment factors for a pavement project are the specified payment or penalty rates stated in the project proposal relative to each I/D provision.

Pavement Performance – Pavement performance is typically defined by the area above the performance curve or the distress index curve as shown in Figure I. Two or more pavement sections may have the same area above the distress index curves (the same pavement performance) but not necessarily the same behavior over time as shown in Figure I. It is obvious that the agency and user costs of the three pavement sections are not the same. Hence, the pavement performance was not used as an indicator of the benefits of the I/D program.

Pavement Life Extension – Pavement life extension is defined herein as the time in years between rehabilitation and the time when the pavement section accumulate the same distress points (the same distress index) that existed prior to rehabilitation as shown in Figure II. The benefits of the I/D program could be expressed as the difference in the life extension of a pavement project where I/D pay adjustments were applied and the life extension of a similar project without I/D provision or pay adjustments. Unfortunately, available distress data do not support the calculation of the life extension for all pavement projects. Hence, the pavement life was used as an indicator of the benefits of the I/D program. When the time series distress data became available for a long time period (four or more years before and four or more years after the application of pavement fixes), the life extension should be used as an indicator of the benefits of the I/D program.

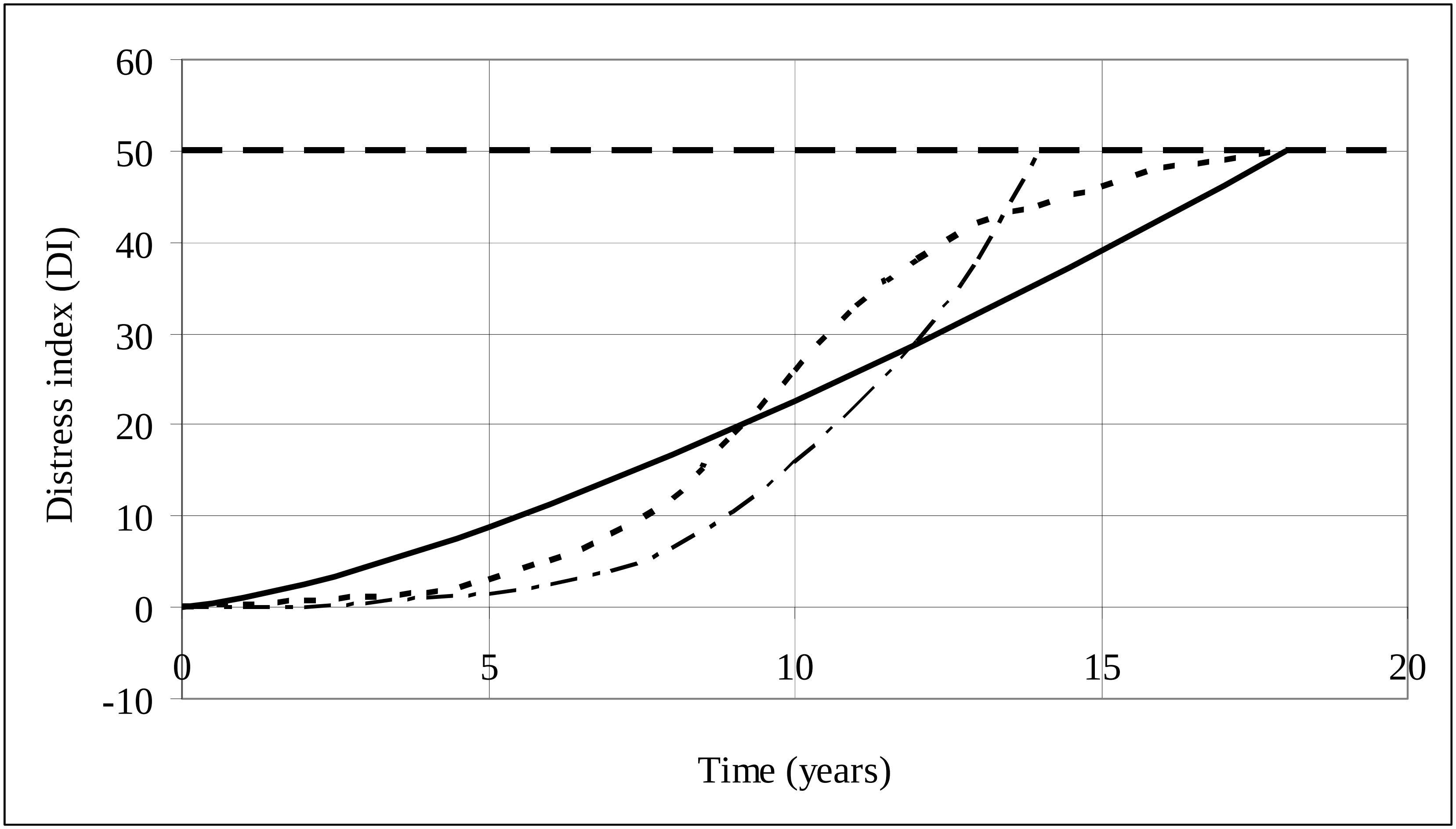

Figure I Three pavement sections having the same area (performance) above the distress index curves

Figure II Schematic presentation of a pavement life extension due to an applied pavement fix

EXECUTIVE SUMMARY

The Michigan Department of Transportation (MDOT) has been using monetary incentive payments for many years to improve contractors' conformance with specifications and their overall workmanship. It was envisioned that incentive/disincentive (I/D) payments/ penalties would have positive impacts on the long term pavement performance by extending its expected life. However, these impacts have not been quantified nor qualified. Hence, the department initiated and sponsored this exploratory study to determine whether or not the available data elements in the MDOT data files and project records could adequately support the analyses of the costs and benefits of the I/D program and to perform preliminary data assessment.

Because of the exploratory nature of the study, the original research plan was modified several times. The modifications, which were made by the research team and the members of the Research Advisory Panel (RAP), were based on the status of the data that would support the study. All modifications are detailed in Chapter 1 of this report.

During the course of the study, the research team searched the following MDOT files and records of seventy seven pavement projects: the project records, the projectwise database, the project microfilms, the pavement management system database, the pavement performance study data files and various MDOT sufficiency rating reports. From each file and for each pavement project, the data that are related to the analyses of the costs and benefits of the MDOT I/D program were identified and tabulated and are included in Chapter 2.

Upon thorough examination of the data found in the project files and records, it was concluded that the available data elements could be used to conduct the following analyses of the MDOT I/D program:

- The average costs and the average benefits of the MDOT I/D program.
- The average impact of the I/D pay adjustments in terms of dollar per paving material costs on long term pavement performance.
- The relative costs and average benefits of the MDOT I/D program per pavement type and per pavement fix alternative.
- The relative impact of the I/D program on the long term performance of each pavement type and fix included in the I/D program.

Two sample analyses were conducted and the results are included in Chapter 3. One sample addresses two rigid pavement reconstruction projects; one jointed plain concrete pavement (JPCP) project with I/D provisions and one jointed reinforced concrete pavement (JRCP) without I/D provision. The second example addresses six JPCP reconstruction projects with I/D provisions having different pay adjustment rates as percent of the total paving material costs. Unfortunately, because of the limited number of projects included in the example, the results of the analyses do not support definite conclusions regarding the impact of the I/D provisions on the long term pavement performance.

The available data found by the research team in the project records and files does not support the following analyses of the I/D program:

- The actual costs and benefits of each I/D provision (density, strength, asphalt contents, etc.) for which I/D pay adjustment rates are specified in the project proposal.
- The impact of the specification levels included in the I/D provisions of the project proposal on the long term pavement performance.

The additional data required for the above two types of analyses may exist in some files that were not searched or identified during this study. These data are:

1. The exact locations along the project where I/D payments were applied.
2. The quality control data along the pavement project.
3. The specific test results for which I/D payments were applied.

Based on the data obtained from the MDOT data files and the data analyses several conclusions and recommendations were made and are included in Chapter 4. Two of these recommendations are repeated here for emphasis.

1. Accelerate the target date at which all data elements of each pavement project from inception to the end of construction are stored in a database accessible to all users for easy storage and retrieval. This would allow all potential users to access the data and information to conduct the necessary analyses. It is estimated that the cost of the implementation to be insignificant since projectwise database already exist. The implementation would decrease the cost of papers, make data retrieval and storage easy, save substantial staff time, and decrease the size of the required storage area for paper copies.
2. Continue the I/D study by funding a second phase to analyze the benefits and costs of the I/D program.

In general, the modified objectives of the study were satisfied. The benefits to MDOT include:

1. The type of costs and benefits analyses of the I/D program that could be conducted given the type of data found in the project files.
2. A list of the necessary data elements that are needed to conduct full analyses of the MDOT I/D program to satisfy the originally envisioned objectives of the study.

CHAPTER 1

INTRODUCTION

1.1 PROBLEM STATEMENT

The Michigan Department of Transportation (MDOT) has been using monetary incentive payments for many years to improve contractors' conformance with specifications and their overall workmanship. It was envisioned that incentive/disincentive (I/D) would have a positive impact on the long term pavement performance by extending its expected life. However, these impacts have not been quantified, nor qualified. Hence, the department initiated and sponsored this study to:

a) Conduct an exploratory search of the MDOT data files and project records to identify available data that are related to the I/D program.
b) Perform preliminary data assessment to determine whether or not the available data could support analyses of the costs and benefits of the MDOT I/D program.

1.2 BACKGROUND

In the 1970s, State Highway Agencies adopted the concept of I/D pay adjustment specifications for I/D provisions that were constructed exceptionally better than the required specifications. This new concept was complementary to that of disincentive pay clauses previously used (1, 2). The envisioned benefits of incentive pay clauses include improved workmanship by encouraging contractors to apply appropriate quality control (QC) measures. The agencies rationale for pay incentives was and still is that the additional cost to assure uniform QC practices will reduce future pavement rehabilitation and maintenance costs (3).

The main objective of disincentive pay clauses is for the highway agencies to recoup part of the anticipated future costs that are likely to arise due to less satisfactory material and ride qualities. For some highway projects and for a variety of reasons, QC measures are either absent or ineffective, which likely leads to less than satisfactory work (1). If the quality of such projects is not seriously deficient, it is not practical to require replacement (reject the work). Hence, the practical solution is to accept the work at a reduced price. Said price reduction is usually difficult to quantify at the time of execution. Better estimates of the agency costs due to substandard material quality can be determined after sufficient pavement condition data are collected and analyzed.

The I/D adjusted payment factors are functions of some of the established specification parameters. Current parameters of MDOT for concrete pavements include strength, air content, and slump and for HMA, density, air voids, and asphalt content (mix conformance).

For MDOT to realize the full benefits of it's I/D program, the specified I/D pay parameters should relate to long-term pavement performance. The long-term pavement performance to be used in the analyses of the benefits is the pavement life in years between construction and the year when the pavement distress index (DI) reaches 50 distress points. Since there are numerous factors that adversely affect long term pavement performance, such relationships are not easy to determine on a project by project basis. Hence, data for a large number of projects both with and without I/D specifications must be collected and analyzed.

1.3 OBJECTIVES

The envisioned overall, long term objectives of the I/D study when all the study phases are successfully completed are to determine:

1. The overall costs and benefits of the I/D program.
2. The costs and benefits of each I/D provision.
3. The appropriateness of each specified pay adjustment factor of each I/D provision.
4. The impact of the I/D program on the pavement life extension for each pavement project and fix type.

These long term objectives cannot be accomplished unless the MDOT project files and records contain the necessary data elements to conduct the study. Hence, Phase I of the incentive study was funded by MDOT to conduct an exploratory search to identify available data in the MDOT data files and project records, and to perform preliminary data assessment to determine whether or not the available data could support analyses of the costs and benefits of the MDOT I/D program.

1.4 RESEARCH PLAN

To accomplish the primary objective of the Phase I study, a research plan consisting of three tasks was developed. For convenience, the three tasks are presented below. During the study, the research plan was modified based on the findings of the research team. The modifications are also presented below at the end of each task.

Task 1 – Review and Project Identification - The activities of the research team in this task are divided into two subtasks as follows:

Subtask 1-1 – Review - In this subtask, the research team:

1. Reviewed and summarized MDOT's historical use of project I/D provisions and their parameters.
2. Identified, for seventy pavement projects, the I/D provisions and their specified I/D pay adjustment rates.
3. Composed a list of data elements that are necessary to conduct the proper analysis to determine the costs and benefits of the MDOT I/D program. For a given pavement project, these data include:

    a. The type of pavement project (CPM, overlay, reconstruction, etc).

b. The specific I/D provisions
c. Historical (raw) distress data, including the distress data collected before the start of project construction and at least four cycles of distress data points after the project completion date.
d. The distress index (DI) and the remaining service life (RSL) that represents the distress data in item c above
e. Traffic data before and after the project completion
f. All subsequent improvement actions that were taken after the project completion.
g. Ride quality index or longitudinal profile data.
h. Rut depth and/or transverse profile data
i. Skid resistance data

The necessary data listed above may be modified based on the results of items 1 and 2 above.

4. Used the MDOT's compiled list of projects with I/D provisions as a starting point and :

    a. Eliminated from the list all projects that received only incentives for ride quality, those projects would be analyzed in Phase II.
    b. Sorted the project list by pavement type (composite, flexible, rigid) and for each pavement type, sorted the projects by type of work (rehabilitation, CPM, reconstruction, etc). This resulted in three independent lists of pavement projects, one for each pavement type.
5. Selected five pavement projects from each list for the data collection activities in subtask 1-2.

Subtask 1-2 – Data Collection

In this sub-task, for each of the 15 selected pavement projects (item 5 of subtask 1-1); the research team searched the MDOT project records, the project proposal and used the MDOT projectwise computer program to:

1. Identify the types of data contained in the files that are relevant to the analyses of the costs and benefits of the I/D program.
2. Summarize all available data elements and identify any missing data elements that are needed to conduct the analyses of the costs and benefits of each I/D provision and its specified pay adjustment factors.

Modifications of Task 1 –- The activities in task 1 were subjected to the following two modifications:

1. The number of pavement project records that were searched was increased from 15 to 75. The reasons for the increase in the number of pavement projects are:

a) Increase the size of the pavement project pool used to determine the percent of the pavement project records that contain the necessary data elements to analyze the costs and benefits of the I/D program (the I/D provisions and their specified pay adjustment factors).
b) Increase the chance of finding two similar pavement projects (the same rehabilitation option) one with I/D provisions and the other without where the data can be compared to assess the impact of the I/D provisions.

2. The list of data elements that are necessary to conduct the proper analysis to determine the costs and benefits of the MDOT I/D program (see item 3 of subtask 1-1) was modified based on the project information obtained from the project record and inputs from the members of the Research Advisory Panel (RAP). For example, the skid resistance data was deleted from the list because the data are collected by MDOT in three year intervals based on predetermined network need basis.

Task 2 – Data Examination - In this task, the research team determined whether or not the data obtained in subtask 1-2 are sufficient to conduct further analyses and to support the activities and the research plan (to be developed) for Phase II of this study. It is assumed herein that if the MDOT data files and project records of 70 percent or more of the projects contain sufficient data to support the analyses of the costs and benefits of the I/D program, then the overall objective of the study can be satisfied. In this case, the objectives and research plan for the Phase II study will be developed. Otherwise, recommendations will be made regarding data collection for possible future analyses of the impacts of the I/D program on pavement performance.

It should be noted that the number of projects (fifteen) to be searched in Phase I is related to the available study budget and not necessarily any statistical analysis of the sample size.

Modifications of Task 2 — During the study, the activities in task 2 were modified to include the results of the MDOT's ongoing pavement performance study. Further, the number of pavement projects that were subjected to data assessment was decreased for two reasons:

1. More efforts were used to increase the number of pavement project records that were searched to obtain available data related to this study.
2. After obtaining the data from the 75 pavement project records, the number of similar pavement projects with and without I/D provisions that can be compared was very small.

Task 3 – Deliverables - Interim Report - Upon completion of task 2, the research team will submit to MDOT an interim report detailing the findings. The report will include a summary of the activities and findings of Phase I, the three lists of pavement projects with and without I/D specifications, and a determination whether Phase II of the project can be executed.

1.5 REPORT LAYOUT

The materials in this report are presented in four chapters as follows:

Executive Summary
Chapter 1 – Introduction
Chapter 2 – Data Collection
Chapter 3 – Data Analyses with Examples
Chapter 4 – Summary, Conclusions, & Recommendations

Appendix A - Literature Review

CHAPTER 2
DATA COLLECTION

2.1 INTRODUCTION AND BACKGROUND

At the outset of this study, the Michigan Department of Transportation (MDOT) provided the research team with a list of 612 pavement projects with I/D provisions that were constructed between 1990 and 2006. The list of projects contained the following information:

- Key ID number related to the source of the information
- Control section
- Job number
- Route number
- Project beginning and ending milepoints
- Description of project location
- Type of work done
- I/D provisions
- Year of construction

At the beginning of this study, the Michigan State University (MSU) research team divided the MDOT I/D project list into two groups. One group included all pavement projects that included ride quality I/D provisions. The second group included the rest of the pavement projects (few projects have no I/D provisions whereas the majority of the projects have material quality I/D provisions). After dividing the pavement projects into two groups, the MSU research team, in cooperation with members of the Research Advisory Panel (RAP), compiled the following initial list of data elements that are needed to conduct comprehensive analyses of the costs and benefits of the MDOT I/D program (the I/D provisions and their specified pay adjustment factors).

- Project identification including control section, job number, route number, location description, pavement type, year of construction, and beginning and ending mile points
- The type of fix (overlay, overlay with pre-overlay repair, patching and overlay, mill and fill, etc.)
- Planned and placed material quantities
- Planned and final material costs
- Planned and final paid incentive dollars
- The specifications as applied to the I/D provisions
- Quality Assurance test results as they relate to the I/D provisions
- The locations along the pavement project where I/D are applied
- The pavement's condition prior to improvement
- Sufficient and reliable pavement condition (distress) data after project completion
- Sufficient and reliable ride quality data in terms of the Ride Quality Index (RQI)
- Traffic counts before and after the project completion

- Subsequent pavement fixes and routine maintenance and their associated costs since project completion, such as the data compiled by the current MDOT pavement performance study.

During the study, the above listed data elements were used by the research team as a reference in its data collection activities.

At the start of the study, the MSU research team requested and obtained from MDOT the project proposals and files of fifteen pavement projects included in the MDOT list of I/D projects. The research team was also granted access to use the MDOT projectwise database and available project microfilms to obtain additional data elements that are related to the analyses of the costs and benefits of the MDOT I/D program. Upon examination of the records of the fifteen pavement projects, it was concluded that, because of the various rehabilitation options and pavement types of the fifteen projects, the number of projects was not sufficient to match two identical pavement projects with and without I/D provisions. Hence, as stated in Chapter 1, the number of pavement projects to be included in the study was increased.

2.2 PAVEMENT PROJECT DATA COLLECTION

The data collection activities commenced when the research team started receiving the requested project records from MDOT and when access to the projectwise database was granted. Overall, the records and proposals of seventy-seven pavement projects were requested from MDOT but only seventy-two were received. The files of five pavement projects were not located by MDOT by the time when this report was written.

The seventy-two pavement project files and records were then examined. It was found that sixty-two project files contain I/D provisions, whereas ten project files contain no I/D provisions. A summary of the data search is presented below.

- The data files and project records of forty-four pavement projects with I/D provisions were found to have sufficient data to perform some analyses of the costs and benefits of the MDOT I/D program.
- Seven pavement projects with I/D provisions contained sufficient data to perform further analyses of the costs of the MDOT I/D program. The benefits of the program however cannot be analyzed because the projects were recently constructed and hence, sufficient distress data are not available to analyze the long-term pavement performance. No further data were collected for these projects.
- The files and records of four pavement projects without I/D provisions were found to have sufficient data to compare the pavement performance to those projects with I/D provisions.
- The files and records of six pavement projects without I/D provisions indicated that the type of fix was preventive maintenance; hence, for these six projects, no further data were requested or collected.

- The files and records of eleven pavement projects were not complete. Some of the records such as the material costs or the amount of I/D payments/penalties were not found.
- The files and records of five pavement projects were not located in time to be included in this report.

Table 2.1 provides a generic list of the available and the data elements that were not found. It should be noted that:

1. The available data elements in the table are those found in the files of forty-four pavement projects. The data files and project records of the other projects were found to have some of the available data listed in Table 2.1.
2. The four data elements listed in the right-hand column of Table 2.1, on the other hand, were not located in any of the files searched by the research team.

Table 2.2 provides a list of all available data that were found in the searched MDOT data files and project records and are relevant to this study. As can be seen from the table, the data for most pavement projects are:

- Year built (year of construction), the data were used to reset the distress index to zero value.
- Key ID number found on the MDOT list of I/D projects.
- Control section (CS), job number (JN), road number, descriptions of project limits, the point of beginning (POB) and the point of ending (POE). These data were used to link different data files related to the project history such as the distress data files. It should be noted that the POB and POE are similar to the beginning and ending mile points.
- The type of work done, which was used to match one pavement project with I/D specifications to a comparable one without I/D specifications.
- Planned and placed quantities in terms of ton for asphalt and square meter for concrete and per project mile. The data were used to indicate whether or not I/D payments are made along the full or partial length of the project.
- The total paving material costs and the total paving material cost per project mile. The data were used to calculate the I/D payments/penalties as percent of the total paving material costs.
- The I/D pay item (i.e., bituminous quality initiative, concrete quality initiative).The data were used to compare the pavement type to that found in the PMS data and to match the project to a similar one without I/D specifications.
- The planned and paid I/D dollars, the data were used to calculate the cost of the I/D per project
- Total applied I/D pay adjustment in terms of dollars per project mile, dollar per planned paving material quantity, dollar per placed paving material quantity, and the I/D pay adjustment expressed in percent of the total paving material costs. The data were used to compute the actual I/D pay adjustment rate, and to assess the impact of this rate on pavement performance. Originally, it was proposed to normalize the I/D payments relative to project length, this however was inadequate because of the

thickness of the pavement surface layer. The calculated I/D pay adjustment in percent of the total paving material costs could be used to compare the specified I/D pay adjustment factors (Stated in the project proposal in percent of the paving material cost). Such a comparison may indicate the estimated percent of the project that received I/D pay adjustment.

- Historical and detailed distress data and distress index for each 0.1 mile of pavement along the project. The data were used to determine the types of distress along the project, the distribution of DI, the average DI for the entire project, the remaining service life (RSL), and to estimate the pavement performance in term of pavement life. It should be noted that the letter "x" in these two columns indicate that the data are available in the MDOT project files.

For all seventy-two pavement projects, there are four data elements that were not found (see Table 2.1). The importance of these data elements and their ramification relative to the analyses of the I/D program are addressed below.

- **QA test results** - No QA test results were found in any MDOT data files and project records that were searched by the research team. The ramification of this is that certain type of analyses or information cannot be obtained. These include:

  1. The basis for I/D payments/penalties (such as density, asphalt content, air voids, etc.).
  2. The level at which the as-constructed material quality met the I/D specifications.
  3. The percent of the project or the number of lots or sublots that met the I/D specifications and received I/D payments/penalties.
  4. The distribution of I/D payments/penalties and I/D pay schedule along the project.
  5. The relationship, if any, between the QA test results and the long-term pavement performance.

- **Reference location along the project where I/D payments/penalties were made –** For any given pavement project with I/D specifications, the I/D payments/penalties may have been carried out in one of the following two scenarios:

  1. I/D payments/penalties extend along the entire length of the pavement project.
  2. I/D payments/penalties were applied along portions of the pavement projects.

  The lack of I/D payments/penalties reference location along the project prevents the analyses of the following issues:

  1. The real impact of the I/D payments/penalties on long-term pavement performance of that portion of the project where I/D payments/penalties were applied.
  2. The right I/D pay adjustment factor for that portion of the project where I/D provisions were applied.
  3. The actual impact of the true I/D pay adjustment factor on pavement performance.

The above consequences of the missing reference location of I/D payments/penalties could be partially alleviated by:

1. Calculating the actual I/D pay adjustment as percent of the paving material cost. The calculated I/D pay adjustment factors are almost always less than the specified factors. The higher calculated I/D pay adjustment factors may indicate one of the following scenarios:

   a) The entire pavement project or higher fraction of the project received I/D pay adjustment.
   b) Higher level of material quality was met.
   c) No disincentive penalties were applied.

   Regardless which scenario is true, care must be taken not to jump to early conclusions.

2. Calculating the average long-term pavement performance in term of pavement life for the entire pavement project.
3. Studying the impact of the calculated I/D rate on the average performance of the pavement project.

- **Basis for I/D payments –** While it is evident from the financial files that a material quality I/D payment/penalty has been applied, it is unknown as to what paving material properties (e.g., density, air voids, VMA, etc.) were qualified. The lack of this information and the QA data noted above make the task of assessing the relative impact of each individual I/D provision and its associated pay adjustment factors on the long term pavement performance impossible.

- **Initial Ride Quality Index (RQI) –** For pavement projects with ride quality I/D provisions, the initial RQI data for which I/D payment/penalty were made are not available in the searched MDOT data files and construction records. Hence, the impact of the RQI level and the RQI pay rate on pavement performance cannot be determined. However, analyses of the average performance of pavement projects with and without I/D provisions could be conducted. It should be noted that for concrete pavement projects with ride quality I/D provisions, the contractor always has the option to grind the pavement surface to receive incentive payments.

In summary, the ramification of these findings is that only some of the long-term objectives of the incentive study stated in Chapter 1 can be accomplished. The available data would support the analyses of:

1. The costs and benefits of the overall I/D program.
2. The cost and benefits of the I/D program based upon each pavement and fix types.
3. The possible impact of the I/D payments/penalties on the observed pavement life extension.

Table 2.1 A summary of data elements that are available and data not found

Desirable data for ideal analyses of the costs and benefits of the I/D program	Available data	Data not found
Project identification		
1. Control section	x	
2. Job number	x	
3. Route number	x	
4. Location description	x	
5. Pavement type	x	
6. Type and cost of fixes	x	
7. Year of construction	x	
8. BMP	x	
9. EMP	x	
Material		
1. Planned paving material quantities	x	
2. Final or placed paving material quantities	x	
3. Planned paving material cost	x	
4. Final paving material cost	x	
5. QC and/or QA test results		x
6. Reference location of I/D payments		x
7. Basis for I/D payments		x
8. Planned incentive ($)	x	
9. Final paid incentive and penalty($)	x	
10. I/D pay adjustment factors	x	
Ride Quality		
1. Initial ride quality index (RQI)		x
Traffic		
1. Traffic Data	x	
Pavement Performance Data		
1. Control section	x	
2. BMP and EMP	x	
3. Route number	x	
4. Pavement type	x	
5. Uniform sections (RSL)	x	
6. 0.1-mile DI before & after construction	x	
7. Raw distress data for each 0.1-mile	x	
8. RQI history	x	

Table 2.2 Available data for seventy-seven pavement projects

Project Information										Quantity						Paving material costs		Incentive/Disincentive (I/D)							Distress Data	
										Planned			Placed						I/D cost							
								1*		2*	3*	***2/1 or 3/1***	4*	5*	***4/1 or 5/1***	6*	***6/1***		7*	8*	***8/1***	***8/7***	***8/(4 or 5)***	***8/6***		
Year Built	Key ID #	CS	JN	Route	Limits Description of Project	POB	POE	Project length (mile)	Type of Work Done	Asphalt (ton)	Concrete (m^2)	Per project mile	Asphalt (ton)	Concrete (m^2)	Per project mile	Total Paving material Cost	Total Paving Cost per project mile	I/D pay item	Planned I/D pay adjustment ($)	Paid I/D pay adjustment ($)	I/D pay adjustment ($)/project mile ($/mile)	Paid I/D pay adjustment ($)/Planned I/D pay adjustment ($)	Paid I/D adjustment ($)/placed material quantity	Paid I/D adjustment ($)/total paving material cost	0.1 mile DI Data	Detailed Distress Data
1997	3419	06073	32357	US-23	M-65 to Augres East City Limit	0.000	6.300	6.300	Resurfacing and Shoulders	36622		5813	40780.82		6473	$901,232.03	$143,052.70	Bituminous Quality Initiative	$56,350.00	$45,086.58	$7,156.60	1.23	$1.11	5.003%	X	X
1997	3420	06073	32358	US-23	East City Limit Augres to North Co Line	6.300	17.800	11.500	Resurfacing and Shoulders	62179		5407	66195.81		5756	$1,457,072.13	$126,701.92	Bituminous Quality Initiative	$95,000.00	$76,011.09	$6,609.66	1.22	$1.15	5.217%	X	X
1999	Strupulis	08032	45621	M-37	M-43 to Middleville	0.000	9.060	9.060	Bituminous Resurfacing and Shoulder	53710		5928	56948.32		6286	$1,909,297.00	$210,739.18	Bit Quality Initiative	$87,375.00	$126,093.89	$13,917.65	2.35	$2.21	6.604%	X	X
1996	2473	09032	34075	M-13	Wilder Road to I-75/M-13 connector	0.000	4.410	4.410	Bituminous Resurfacing and Shoulders	20252		4592	20788.89		4714	$399,506.00	$90,590.93	Bituminous Quality Initiative	$37,685.00	$64,467.94	$14,618.58	3.18	$3.10	16.137%	X	X
1997	1759	11017	38094	I-94 EB	M-140 to W of Co Road 687	5.875	6.603	0.728	Reconstruct and Overlay		28359	38955		23824.24	32726	$1,361,705.96	$1,870,475.22	Concrete Strength Adjustment	$15,934.00	$31,128.70	$42,759.20	1.10	$1.31	2.286%	X	X
1997	1295	11057	34507	US-31 Rel	US-31 Rel @ Matthew Road	8.888	9.844	0.956	Relocation Route Construction	5625		5884	6716.34		7025	$201,826.02	$211,115.08	Bituminous Quality Initiative	$8,440.00	$14,623.85	$15,296.91	2.60	$2.18	7.246%	X	X
1998	2072	11111	44788	I-196	I-94 to N.County Line	0.000	7.930	7.930	Resurface, Mill and Pulverize	88050		11103	83275.11		10501	$2,638,095.02	$332,672.76	Bituminous Quality Initiative	$133,500.00	-$72,022.50	-$9,082.28	-0.82	-$0.86	-2.730%	X	X
1998	4904	11112	38605	US-31	N of River Road to S of Naomi	14.100	17.800	3.700	Relocation Existing Route	21173		5722	22282.99		6022	$615,188.27	$166,267.10	Bituminous Quality Initiative	$25,052.00	$47,988.96	$12,969.99	2.27	$2.15	7.801%	X	X
2000	Strupulis	12033	45535	I-69	Indiana State Line to Warren Road	0.000	5.800	5.800	Reconstruction and Drainage		140609	24243		138919.3	23952	$2,421,369.81	$417,477.55	Concrete Quality Initiative	$36,691.00	$65,132.72	$11,229.78	0.46	$0.47	2.690%	X	X
2000	Strupulis	12033	45877	I-69	Lake Warren Road to US-12	5.800	11.000	5.200	Reconstruct Existing Road		155830	29967		154984	29805	$2,735,241.41	$526,007.96	Concrete Quality Initiative	$77,936.00	$65,132.72	$12,525.52	0.42	$0.42	2.381%	X	X
2002	Strupulis	12033	49921	I-69	US-12 to State Road	9.700	12.378	2.678	Reconstruct Existing Pavement		83636	31231		84335.97	31492	$1,895,229.07	$707,703.16	Concrete Quality Initiative	$43,432.00	$48,988.40	$18,292.91	0.59	$0.58	2.585%	X	X
2002	Strupulis	13011	38086	M-37	Mosher Avenue to Beechfield Road	0.900	4.760	3.860	Resurface, Mill, and Pulverize	26940		6979	32830.12		8505	$1,300,053.20	$336,801.35	Bit Quality Initiative	$97,318.00	$135,239.94	$35,036.25	5.02	$4.12	10.403%	X	X
2002	Strupulis	13021	38091	M-60	East of West County Line to US-27	0.580	8.977	8.397	Resurface, Mill, and Pulverize	37149		4424	37490.43		4465	$1,505,493.29	$179,289.42	Bit Quality Initiative	$70,400.00	$75,235.52	$8,959.81	2.03	$2.01	4.997%	X	X
1998	1026	13031	34497	M-66	S Drive South N'rthly to L Drive South	2.510	6.360	3.850	Bituminous Resurfacing	14264		3705	13494.98		3505	$338,479.18	$87,916.67	Disincentive Bit Qual Initiative	$22,431.00	-$15,606.46	-$4,053.63	-1.09	-$1.16	-4.611%	X	X
1999	Strupulis	13074	49029	I-69	I-94 to Eaton County Line	1.000	8.820	7.820	Unbonded Conc Overlay		23276	2976		29003.52	3709	$725,088.00	$92,722.25	Concrete Quality Initiative	$110,000.00	$59,424.11	$7,598.99	2.55	$2.05	8.195%	X	X
1997	2957	18031	38620	US-27 BR	US-27 BR @ Colonville Road	1.700	2.000	0.300	Left Turn Lane and Widening for Ramp	3290		10967	2979.25		9931	$87,952.65	$293,175.50	Disincentive Bituminous Mixture	$5,774.00	-$14,004.22	-$46,680.73	-4.26	-$4.70	-15.922%	X	X
1996	2937	18042	32325	M-61	US-27 to E County Line	0.175	8.556	8.381	Pulverize and Resurface	21587		2576	22317.92		2663	$450,387.63	$53,739.13	Bituminous Quality Initiative	$33,381.00	$47,803.67	$5,703.81	2.21	$2.14	10.614%	X	X
1996	3864	28052	35018	M-37	US-31/M-72 to NCL Traverse City	0.081	0.810	0.729	Reconstruct and Widen	5030		6900	5522.49		7575	$135,482.56	$185,847.13	Bituminous Quality Initiative	$8,526.00	$5,653.06	$7,754.54	1.12	$1.02	4.173%	X	X
1997	3865	28052	38617	M-37	US-31, M-37 & M-72 (Front Street)	0.000	0.081	0.081	Widen for center turn lane	321		3963	358.56		4427	$9,348.56	$115,414.32	Bituminous Quality Initiative	$740.00	$0.00	$0.00	0.00	$0.00	0.000%	X	X
1997	4242	39102	32377	M-89	W of 42 nd Street to E of Augusta Drive	4.513	8.448	3.935	Mill and Resurface	15417		3918	17430.98		4430	$425,307.00	$108,083.10	Bituminous Quality Initiative	$25,231.00	$24,699.79	$6,276.95	1.60	$1.42	5.808%	X	X
2000	Kind	41031	34693	M-37	S of Kraft NW to N of 60th St	4.251	7.231	2.980	Reconstruct Boulevard	56735		19039	46267.08		15526	$1,614,197.05	$541,676.86	Bituminous	$174,477.00	$62,471.09	$20,963.45	1.10	$1.35	3.870%	X	X
1996	6555	41031	34695	M-37	S of 44th Street NW to N of 32 nd Street	8.393	10.698	2.305	Reconstruct Boulevard	49101		21302	51544.17		22362	$1,169,224.17	$507,255.61	Bit Quality Initiative	$82,657.50	$78,480.00	$34,047.72	1.60	$1.52	6.712%	X	X
1996	2476	41062	38175	M-11	Chicago Drive to US-131	0.000	3.560	3.560	Resurface, Mill and Pulverize	23300		6545	25501.08		7163	$815,856.12	$229,173.07	Bituminous Quality Initiative	$36,086.00	$13,255.95	$3,723.58	0.57	$0.52	1.625%	X	X
2001	Kind	41131	44778	US-131	S Kent County Line N to 76 th Street	0.000	4.045	4.045	Mill and Resurface	25900		6403	25822.78		6384	$1,219,680.46	$301,527.93	Bituminous	$24,537.00	$60,055.31	$14,846.80	2.32	$2.33	4.924%	X	X
1994	2071	43021	32402	US-10	W. Lake Co Line to M-37	0.000	9.256	9.256	Bituminous Resurfacing	21246		2295	20906		2259	$514,397.00	$55,574.44	Incentive Bituminous Mixture 13A-QA	13A ADJ	$41,314.35	$4,463.52	1.94	$1.98	8.032%	X	X
1997	1945	44011	39584	M-24	Braurer Road to I-69	1.287	9.510	8.223	Resurface, Mill and Pulverize	28321		3444	30777.75		3743	$808,752.50	$98,352.49	Bituminous Quality Initiative	$42,826.50	$65,846.46	$8,007.60	2.33	$2.14	8.142%	X	X
1999	6168	47065	28215	I-96	Chilson Road to W of Dorr Road	4.050	5.460	1.410	Reconstruction and add Lanes		160396	113756		164115.5	116394	$2,237,343.53	$1,586,768.46	Concrete Strength Initiative	Adjustment	$71,031.01	$50,376.60	0.44	$0.43	3.175%	X	X
1999	5232	63043	30157	M-59	At Squirrel Road, Auburn Hills	3.305	3.554	0.249	Construct New Interchange	8709		34976	7619.52		30600	$287,206.83	$1,153,441.07	Bituminous Quality Initiative	$22,110.00	$19,272.86	$77,401.04	2.21	$2.53	6.710%	X	X
1999	5232	63043	30157	M-59	At Squirrel Road, Auburn Hills	3.305	3.554	0.249	Construct New Interchange		58262	233984		57549.88	231124	$1,701,265.83	$6,832,392.87	Conc Quality Initiative	$22,012.00	$36,247.89	$145,573.86	0.62	$0.63	2.131%	X	X
2001	Wilson	74031	45847	M-19	Peck to Sandusky	7.360	18.607	11.247	Resurface, Mill, and Pulverize	38202		3397	35026.8		3114	$1,282,774.66	$114,054.83	HMA	$152,523.00	$68,294.75	$6,072.26	1.79	$1.95	5.324%	X	X
1995	Kallio	75022	34057	US-2	W of Co Rd 432 to the Mackinac Co Line	13.686	25.909	12.223	Bituminous Resurfacing	50842		4160	50313.18		4116	$893,157.09	$73,071.84	HMA	QA ADJ	$81,845.87	$6,696.05	1.61	$1.63	9.164%	X	X
2001	Wilson	79031	45850	M-15	Millington to Vassar	4.349	9.996	5.647	Bituminous Resurface and Bit Shoulder	22194		3930	20223.5		3581	$644,809.74	$114,186.25	HMA	$85,302.00	$57,602.57	$10,200.56	2.60	$2.85	8.933%	X	X
1997	2917	82061	26748	US-12	Belleville Road - Lotz Road	2.790	5.260	2.470	Reconstruct Boulevard	59550		24109	63615.5		25755	$1,592,633.25	$644,790.79	Bituminous Quality Initiative	$95,607.00	$46,440.55	$18,801.84	0.78	$0.73	2.916%	X	X
1997	2917	82061	26748	US-12	Belleville Road - Lotz Road	5.260	5.740	0.480	Reconstruct Boulevard	59550		124063	63615.5		132532	$1,592,633.25	$3,317,985.94	Bituminous Quality Initiative	$95,607.00	$46,440.55	$96,751.15	0.78	$0.73	2.916%	X	X
1997	3225	82144	38108	M-102	Kelly Road to I-94	1.360	2.675	1.315	Resurface Mill and Pulverize	13705		10422	13294.23		10110	$441,911.34	$336,054.25	Bit Quality Initiative	$20,780.00	$13,309.59	$10,121.36	0.97	$1.00	3.012%	X	X
1998	1263	82194	36005	I-75	Fort Street to Grand Boulevard	4.580	6.990	2.410	Road and Shoulder Reconstruction	16678		6920	16886.9		7007	$681,772.92	$282,893.33	Bit Quality Initiative	$10,329.00	-$13,034.39	-$5,408.46	-0.78	-$0.77	-1.912%	X	X
1998	1263	82194	36005	I-75	Fort Street to Grand Boulevard	4.580	6.990	2.410	Road and Shoulder Reconstruction		108094	44852		107511.3	44610	$2,833,029.15	$1,175,530.77	Concrete Quality Initiative	$43,291.00	$60,832.80	$25,241.83	0.56	$0.57	2.147%	X	X
2000	1260	82291	44574	I-275 SB	Newburgh Road To Northline Road	0.000	8.423	8.423	Reconstruction South Bound Road	18971		2252	20626.55		2449	$676,911.46	$80,364.65	Bituminous Quality Initiative	$31,500.00	$63,229.00	$7,506.71	3.33	$3.07	9.341%	X	X
2002	Kirkby	83031	48538	US-131 BR	S of US-131/US-131BR int to SCL Cadillac	4.739	4.850	0.111	Grading & Dr Str, Bit Widen to 5 lanes, C&G	7084		63820	7191.23		64786	$282,820.90	$2,547,936.04	Bituminous - Disincentive	$22,146.00	-$35,400.28	-$318,921.44	-5.00	-$4.92	-12.517%	X	X
2002	Kirkby	83031	48538	US-131 BR	S of US-131/US-131BR int to SCL Cadillac	4.850	5.617	0.767	Grading & Dr Str, Bit Widen to 5 lanes, C&G	7084		9236	7191.23		9376	$282,820.90	$368,736.51	Bituminous - Disincentive	$22,146.00	-$35,400.28	-$46,154.21	-5.00	-$4.92	-12.517%	X	X
1998	1386	83033	33006	US-131 Rel	S Cadillac to M-55	0.000	3.000	3.000	Relocate Existing Route	5817		1939	5956.98		1986	$140,370.01	$46,790.00	Bit Quality Initiative	$10,940.00	$12,646.35	$4,215.45	2.17	$2.12	9.009%	X	X
1997	4781	83033	33007	US-131 RL	N of M-115 to S of Boon Road	3.000	8.450	5.450	Bit construction & 2 new structures	99950		18339	~~~~			$2,510,868.78	$460,709.87	Bit Quality Initiative	$85,529.00	$78,020.67	$14,315.72	0.78	NA	3.107%	X	X
1997	1477	83033	43613	US-131 Rel	S/ Pole Road to N/ 36 Road	6.872	9.738	2.866	New Bridges	21375		7458	19173.56		6690	$506,900.28	$176,866.81	Bituminous Quality Initiative	$34,932.00	$1,741.80	$607.75	0.08	$0.09	0.344%	X	X
1998	1319	83052	37903	M-115	28 Road to E of Lake Mitchell Dr	8.850	17.300	8.450	Cold Milling and Resurfacing	27737		3282	28814		3410	$704,647.61	$83,390.25	Disincentive Bituminous Mixture	$47,850.00	-$6,158.52	-$728.82	-0.22	-$0.21	-0.874%	X	X
Pavement Projects Having No Incentive/Disincentive Provisions										* = Column number. Bold and Italic column heading designates column operation (i.e., *4/1* = column 4 divided by column 1)																
1995	Ramos	11015	29580	I-94	Mile 23 to 28	19.800	23.431		Concrete Paving	200373				201545		$3,400,015.00		Concrete	~~~~	~~~~					X	X
1994	Kind	41132	33805	US-31	I-96 intersection to M-57	0.880	13.077		Pavement Patching	16868				17170.5		$480,774.00		Concrete	~~~~	~~~~					X	X
2000	1260	82291	44574	I-275 SB	Newburgh Road To Northline Road	0.000	8.423		Reconstruction South Bound Road	18971				20626.55		$676,911.46		Concrete	~~~~	~~~~					X	X
2001	6253	63192	34962	M-5	12 Mile Road to N of 14 Mile Road	1.876	4.117		New Route Construction									Concrete	~~~~	~~~~					X	X
Pavement Projects with Preventative Maintenance Fix Type																										
2002	Kind	70024	60495	I-96 WB	96th Ave E 64th Ave	1.910	6.561		Multiple Course Micro-Surfacing							PM project		Bituminous - No Incentive	~~~~	~~~~					X	X
2002	Kind	70024	60265	I-196	64th Ave to 32nd Ave	6.610	10.618		Multiple Layer Micro Surfacing							PM project		Bituminous - No Incentive	~~~~	~~~~					X	X
2002	Kind	70081	60279	M-104	East of Kreuger Rd East to I-96	3.007	7.335		Coldmilling and Resurfacing	9960				9328.57		$389,840.94		Bituminous - No Incentive	~~~~	~~~~					X	X
1999	Kallio	55022	45116	US-2/US-41	US-41in Powers to Delta County Line	0.050	9.580		Bituminous Resurfacing	17473				17227.4		$443,777.82		HMA - NO INCENTIVE/DISINCENTIVE	~~~~	~~~~					X	X
1999	4790	12022	47583	US-12	Lott Road to Quincy/Grange Road	2.166	5.226		Bituminous Overlay	5253				4812.6		$152,318.79		Disincentive Bituminous Mixture	$1,303.95	-$10,317.50					X	X
1998	Kind	70023	38181	I-196	US-31 to I-196	0.020	5.480		Concrete Pavement Restoration	5492				6756.19		$317,540.93		Concrete	~~~~	~~~~					X	X
Pavement Projects Missing Some Data Elements																										
1995	Kallio	75022	34057	US-2	W of Co Rd 432 to the Mackinac Co Line	13.686	25.909		Bituminous Resurfacing	50842				50313.18		$893,157.09		HMA		$81,845.87						
2001	Strupulis	13032	39654	M-66	M-66 at Pennfield Road	4.440	4.760		Bituminous Intersection Improvement	3727								Bit Quality Initiative	13227							
1999	4749	25402	46500	Stewart	ML King Boulevard to Saginaw St	0.000	0.644		Reconstruction	3540						$125,029.65		Disincentive Bit Density	3540							
1996	3716	59051	32346	M-66	M-44 to Sheridan So Village Limit	0.000	6.690		Resurface and Pulverize	34839								Bituminous Quality Initiative	54528							
1995	5773	77041	36541	M-136	Kilgore Road to Beard Road	3.980	8.800		Bituminous Surfacing and Minor Widening									Incen Bit Mix 3B								
1997	Ramos	11017	32516	I-94	Mile 34 to 40	0.033	5.870		Concrete Paving	64270				61293.32		$1,307,994.55		Bit Quality Initiative	1	$137,981.38						
1997	Ramos	11017	32516	I-94	Mile 34 to 40	0.000	2.031		Concrete Paving	159922				158822.7		$2,689,606.85		Concrete		63745.27						
1999	2641	19033	33576	US-27 Rel	Clark Road To Chadwick Road	3.008	8.109		Constructuction of New Road									Bituminous Quality Initiative		$42,221.58						
2000	Kind	41064	33337	I-96	Thornapple River Drive to W of Whitney Dr	1.900	4.064		Reconstruction & Structure Widening	Need voucher summary for 33337								Concrete								
1998	1260	82291	44574	I-275 SB	Newburgh Road To Northline Road	0.000	8.423		Reconstruction South Bound Road	229222				224956		$4,428,293.38		Concrete Quality Initiative		$121,610.12						
2001	Kind	41131	53331	US-131	N of Pearl Street to Ann Street	14.300	16.150		Concrete Pavement Restoration					6062.82		$503,214.06		Concrete								
Pavement Projects that are too Recent(since 2002)																										
2003	Wilson	79032	48599	M-15	Vassar to M-46	0.800	5.340		Resurface, Mill, and Pulverize	7378						$224,063.87		HMA - Disincentive	13032	-$30,771.08						
2003	Ramos	11015	60510	I-94	Exit 23 to the State Line	0.000	19.398		Bituminous Resurfacing							$457,157.95		HMA - No Incentive								
2004	Strupulis	13073	50776	I-69	J Drive South to A Drive North	7.800	12.970		Major Rehabilitation	23649						$786,995.68		HMA Quality Initiative	34641	$40,710.74						
2003	Kind	41063	74453	M-11	At Kalamazoo Avenue and Breton Avenue	1.880	3.017		Reconstruct Intersection									Concrete								
2003	Strupulis	13073	50775	I-69	Girard Road To J Drive South	0.000	7.910		Concrete Reconstruction									Concrete Quality Initiative								
2003	Ramos	11112	38613	US-31Rel	Exit 15 to Exit 24; Ex US-31 to Napier	12.188	21.752		Concrete Paving									Concrete								
2004	Strupulis	13073	50776	I-69	J Drive South to A Drive North	7.800	12.970		Major Rehabilitation	170457						2641409.404		Concrete Quality Initiative	67823	53593.09						
Pavement Projects - Project Files and Records Were Not Located																										
1996	3716	34033	32346	M-66	M-44 to Sheridan So Village Limit	0.000	9.278		Resurface and Pulverize									Bituminous Quality Initiative								
1996	6375	74032	40604	M-19	M-46 to North Sanilac County Line	0.000	18.105		Hot In Place Bituminous Recycling									Disincen Bit Mix & Dens Control								
2001	Kind	41131	56955	US-131NB	N of 28th Street to Wealthy Street	10.328	13.240		Concrete Pavement									Concrete								
2000	Kind	41133	52768	US-131NB	NB Ramps 14 Mi Road to 17 Mi Road	0.635	3.250		Concrete Joint Repair									Concrete								
1997	1759	80023	38094	I-94 EB	M-140 to W of Co Road 687	0.000	2.273		Reconstruct and Overlay									Bituminous Quality Initiative								

CHAPTER 3

DATA ANALYSES

3.1 GENERAL

Recall that Phase I of the study consisted of exploratory efforts to identify the available data in the MDOT data files and project records that can be used to analyze the costs and benefits of the incentives/disincentives (I/D) program. The Phase I study began on the first of October 2007; pavement project files were requested from MDOT and were received by the research team. The files were thoroughly examined and data that are related to these exploratory efforts were extracted from the projects construction records, projectwise database and occasionally from the projects microfilm records. In addition, the pavement condition, the distress index, and the remaining service life data were obtained from the MDOT pavement management system (PMS) database and from the files of MDOT's pavement performance study.

Recall that the primary objective of this phase I study is to conduct an exploratory search to identify available data in the MDOT data files and project records, and to perform preliminary data assessment to determine whether or not the available data would support analyses of the costs and benefits of the MDOT I/D program. The envisioned overall and long term objectives when all the phases of the study are successfully completed are to determine:

1. The overall costs and benefits of the I/D program.
2. The costs and benefits of each I/D provision and its associated pay adjustment factors.
3. The appropriateness of each specified level of each I/D provision.
4. The appropriateness of the I/D pay adjustment factors.
5. The impact of the I/D program on the pavement life extension for each pavement and fix types.

The term "costs" includes all extra payments made to the contractor for achieving or exceeding the specified values or ranges of values of the I/D provisions. In Table 2.2 of this report, the cost of the I/D provision of a given pavement project is expressed in six terms. Only the cost of the I/D provision expressed as percent of the total paving material cost is used in the analyses in this chapter. Such expression of cost minimizes the effects of project length and pavement layer thicknesses.

The term "benefits" is used in this report to express the extra pavement life extension in years that was the direct result of the I/D provisions. For example, if the life extensions of two identical pavement projects (the same pavement and fix types), one with and the other without I/D provisions are the same, then the benefits of the I/D provisions are zero. In reality, the true benefits of the I/D provisions of the above example are negative. Because if the extra I/D payment, which is paid up front is saved to a later time, the money could be used to conduct preventive maintenance action and thus extend the pavement life. The analysis of the true benefits of the I/D provision can be achieved when long term data become available to support life cycle cost analyses.

During the Phase I study, the research team in cooperation with members of the RAP compiled a list (see Table 2.1) of data elements that are necessary to accomplish the long-term objectives of the incentive study. In addition, the research team searched seventy-seven pavement project files and records and compiled the data relevant to this study in a spreadsheet format shown in Table 2.2. The data in the table indicate that:

1. The files and project records of forty-four pavement projects with I/D specifications contain the proper data elements to conduct analyses of the costs and benefits of the I/D program.
2. The files and project records of only four pavement projects without I/D provisions contain the proper data elements that will support the comparison of their pavement performance to those of compatible projects with I/D provisions.

These 48 pavement projects are listed in the project data matrix shown in Table 3.1. The number in each cell in the table indicates the number of pavement projects that were found during the Phase I of the study to have the appropriate data elements for that cell.

It should be noted that the main reason for the low number of pavement project without I/D provisions in Table 3.1 is that, during the Phase I study, the MSU research team concentrated its efforts on the MDOT list of pavement projects with I/D provisions. The four pavement projects in Table 3.1 without I/D provisions were included in the MDOT list. The MSU research team did not compile an additional list of pavement projects without I/D provisions.

Based upon the available data elements, listed in Tables 2.1 and 2.2, of the forty-eight pavement projects listed in Table 3.1, it was determined that analyses of the costs and benefits of each specific I/D provision and its specifies pay adjustment factors cannot be accomplished. However, the available data elements would support:

1. The assessment of the costs and benefits of the MDOT I/D program as a whole.
2. The assessment of the effects of the I/D payment (as a percent of the total paving material cost) on pavement performance.

Two examples of such assessment and analyses are presented below. In the first example, the performance of the two rigid pavement reconstruction projects (one with and one without I/D specifications) were compared. In the second example, the performance of six pavement projects that were subjected to similar fix type, but different I/D payments, were compared.

It should be noted that if a new search of additional pavement project records resulted in placing more pavement projects in each cell, the confidence level in the results of the assessment of the two examples would increase. Higher number of pavement projects in each cell yields more confidence in the results of the analyses.

. Table 3.1 Project data matrix for material and ride quality initiatives

Pavement			Fix type	Disincentive (% of paving cost)			Incentive (% of paving cost)			No I/D provisions
Class	Type			<-10	-10 to -5	>-5 to 0	>0 to 5	>5 to 10	>10	
Freeway	Flexible		New or Rec.	1						
			Overlay							
			Mill & Fill			1				
			Others	1						
	Composite		Overlay			1		1		
			Mill & Fill				1	1		
			Others							
	Rigid	JPCP	New or Rec.				6			
			Overlay							
			Others							1
		JRCP	New or Rec.							3
			Overlay							
			Others							
	Rubblized		Overlay							
			Mill & Fill							
			Others							
Non-freeway	Flexible		New or Rec.				2	3		
			Overlay				1	2		
			Mill & Fill							
			Others			1	2		1	
	Composite		Overlay	1		1		4		
			Mill & Fill				4	4	2	
			Others					1		
	Rigid	JPCP	New or Rec.							
			Overlay					1		
			Others							
		JRCP	New or Rec.				1			
			Overlay							
			Others							
	Rubblized		Overlay							
			Mill & Fill							
			Others							

3.2 EXAMPLE 1 – ASSESSMENT OF I/D PAYMENTS

After the data for the seventy-seven pavement projects were listed in Table 3.2, they were searched to pair two similar concrete pavement projects; one with and the other without I/D provisions. Unfortunately, no exact match was found. The reasons are that:

1. The pool of pavement projects investigated in the Phase I of the study did not include any jointed reinforced concrete pavement (JRCP) project with I/D provisions, it did include JRCP projects without I/D provisions.
2. The pool did not include any jointed plain concrete pavement (JPCP) project without I/D provisions. It included JPCP projects with I/D provisions.

Because of time and budget limitations, the search for perfect match of pavement projects having the same pavement and fix types was abandoned and the performance of two pavement reconstruction projects (the same fix type) was compared. The first project is a JRCP project along I-94 that was reconstructed in 1995 without I/D provisions. The second is a JPCP project along I-69 that was reconstructed in 2002 with I/D provisions. It should be noted that the research team is well aware that JRCP and JPCP are two different rigid pavement types and the factors affecting their performance are not the same. The main objective of comparing the performance of the two pavement projects is to provide an example of the types of analyses that could be conducted when better or perfect match between pavement and fix types are found. Therefore, results of the comparison should not be and cannot be used to judge the costs and benefits of the MDOT I/D program.

Nevertheless, for the two pavement reconstruction projects along I-94 and I-69, the research team requested and obtained from the MDOT Pavement Management System (PMS) database the following information for each 0.1 mile segment along each project:

1. All available and detailed time series distress points (DP) data since reconstruction.
2. The beginning mile point (BMP) and the ending mile point (EMP) data.

The DP data were then used to calculate the distress index (DI) per 0.1 mile pavement segments along the project by dividing the DP by the number of 0.1 mile pavement segments between the BMP and EMP. Please note that the DP and the DI data are the same when the difference between the BMP and EMP is exactly 0.1 mile.

Tables 3.2 and 3.3 provide a list of the historical detailed data obtained from the PMS database of MDOT and the calculated average DI value for each pavement project. The tables include the following information:

1. The title of the table includes the route name, pavement type, year of reconstruction, the control section and the job number.
2. The distress data for each year are listed in four columns. The first two columns provide the BMP and EMP, the third column lists the DP and the fourth the DI per 0.1 mile pavement segment.

After obtaining the data listed in Tables 3.2 and 3.3, a thorough discussion was held between members of the research team and members of the MDOT Research Advisory Panel (RAP) of this study. The discussion was centered on the source of the data to be used to study the pavement performance. It was decided to use the average DI values from the MDOT Pavement Performance Study. Consequently, the time series DI averages data for each pavement project were requested and obtained from the MDOT Pavement Performance Study. These data are listed in Tables 3.4 and 3.5. It should be noted that no significant differences were found between the DI averages listed in Tables 3.2 and 3.3 and those listed in Tables 3.4 and 3.5.

Other data that were obtained from the MDOT files and project records that are pertinent to the comparison of the performance of the two reconstructed rigid pavement projects are also listed in Tables 3.4 and 3.5. For each of the two pavement projects, the data in the two tables include:

- The pavement type; Table 3.4 for jointed reinforced concrete pavement (JRCP) and Table 3.5 for jointed plain concrete pavement (JPCP)
- The pavement route; I-94 and I-69
- The source of the information including the PMS database of MDOT, the file of the MDOT pavement performance study, the project list of the MDOT I/D study, the project proposal, and the project financial records
- The year of pavement reconstruction and distress data collection
- The BMP and EMP
- The project length in miles
- For each year, the average DI between the given mile points that were obtained from the MDOT Pavement Performance Study.
- The I/D provisions
- The amount of incentive payment in terms of dollars and as percent of the paving material cost
- The type and years of maintenance and pavement preservation fixes that occured after reconstruction

The project records for the 1995 JRCP pavement reconstruction project along I-94 (see Table 3.4) indicate that no I/D provisions or pay adjustments were included in the project proposal or in the financial record. Whereas, the project and financial records of the 2002 JPCP reconstruction project along I-69 (listed in Table 3.5) indicate that the project contractor received $49,988.40 or 2.58 percent of the paving material costs as incentive payment for concrete quality initiative. Nevertheless, the performance of the two pavement reconstruction projects were compared based on the average DI data listed in Tables 3.4 and 3.5.

For each of the two rigid pavement reconstruction projects, Figure 3.1 depicts the average DI values plotted as a function of time since reconstruction. The data are listed in Tables 3.4 and 3.5 and were obtained from the MDOT pavement performance study. The data in the figure indicate that:

Table 3.2 Distress data along the I-94 JRCP pavement project reconstructed in 1995; Control Section 11015, Job Number 29580 (MDOT PMS distress data)

Year - Years after construction																			
1995 - 0				1997 - 2				1999 - 4				2003 - 8				2005 - 10			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
19.381	19.481	0.00	0.00	19.322	19.422	0.00	0.00	19.34	19.44	0.00	0.00	19.357	19.457	14.04	14.04	19.302	19.402	1.25	1.25
19.481	19.581	0.00	0.00	19.422	19.522	0.00	0.00	19.44	19.54	0.75	0.75	19.457	19.557	15.38	15.38	19.402	19.502	0.77	0.77
19.581	19.681	0.00	0.00	19.522	19.622	1.25	1.25	19.54	19.64	1.98	1.98	19.557	19.657	19.84	19.84	19.502	19.602	0.00	0.00
19.681	19.825	0.00	0.00	19.622	19.764	0.53	0.37	19.64	19.783	3.27	2.28	19.657	19.757	18.29	18.29	19.602	19.702	0.25	0.25
19.825	19.861	0.00	0.00	19.764	19.801	0.00	0.00	19.783	19.818	0.00	0.00	19.757	19.857	12.41	12.41	19.702	19.802	2.25	2.25
19.861	20.053	0.00	0.00	19.801	19.992	0.52	0.27	19.818	20.012	4.09	2.11	19.857	19.957	15.14	15.14	19.802	19.902	4.45	4.45
20.053	20.09	0.00	0.00	19.992	20.03	0.00	0.00	20.012	20.047	0.00	0.00	19.957	20.057	30.52	30.52	19.902	20.002	13.96	13.96
20.09	20.19	0.00	0.00	20.03	20.13	0.00	0.00	20.047	20.147	0.94	0.94	20.057	20.157	21.38	21.38	20.002	20.102	6.20	6.20
20.19	20.29	2.00	2.00	20.13	20.23	0.50	0.50	20.147	20.247	7.30	7.30	20.157	20.257	21.82	21.82	20.102	20.202	3.63	3.63
20.29	20.39	0.00	0.00	20.23	20.33	0.00	0.00	20.247	20.347	2.75	2.75	20.257	20.357	14.48	14.48	20.202	20.302	0.25	0.25
20.39	20.49	0.00	0.00	20.33	20.43	0.00	0.00	20.347	20.447	1.50	1.50	20.357	20.457	11.85	11.85	20.302	20.402	1.44	1.44
20.49	20.59	0.00	0.00	20.43	20.53	0.00	0.00	20.447	20.547	1.75	1.75	20.457	20.557	12.04	12.04	20.402	20.502	2.96	2.96
20.59	20.713	0.00	0.00	20.53	20.65	0.00	0.00	20.547	20.67	1.42	1.16	20.557	20.657	17.47	17.47	20.502	20.602	0.75	0.75
20.713	20.726	0.00	0.00	20.65	20.666	0.00	0.00	20.67	20.683	0.00	0.00	20.657	20.757	21.07	21.07	20.602	20.702	12.47	12.47
20.726	20.826	0.00	0.00	20.666	20.766	1.25	1.25	20.683	20.783	4.02	4.02	20.757	20.857	16.18	16.18	20.702	20.802	2.85	2.85
20.826	20.926	0.00	0.00	20.766	20.866	0.00	0.00	20.783	20.883	3.38	3.38	20.857	20.957	13.98	13.98	20.802	20.902	3.17	3.17
20.926	21.026	0.00	0.00	20.866	20.966	0.00	0.00	20.883	20.983	0.50	0.50	20.957	21.057	5.99	5.99	20.902	21.002	1.75	1.75
21.026	21.126	0.00	0.00	20.966	21.066	0.00	0.00	20.983	21.083	0.00	0.00	21.057	21.157	13.56	13.56	21.002	21.102	3.94	3.94
21.126	21.226	0.00	0.00	21.066	21.166	0.00	0.00	21.083	21.183	6.90	6.90	21.157	21.257	10.92	10.92	21.102	21.202	3.98	3.98
21.226	21.326	0.00	0.00	21.166	21.266	0.00	0.00	21.183	21.283	1.98	1.98	21.257	21.357	11.23	11.23	21.202	21.302	2.67	2.67
21.326	21.426	0.94	0.94	21.266	21.366	0.00	0.00	21.283	21.383	3.93	3.93	21.357	21.457	8.38	8.38	21.302	21.402	2.64	2.64
21.426	21.526	0.75	0.75	21.366	21.466	1.50	1.50	21.383	21.483	3.16	3.16	21.457	21.557	12.38	12.38	21.402	21.502	0.66	0.66
21.526	21.626	0.00	0.00	21.466	21.566	0.00	0.00	21.483	21.583	1.44	1.44	21.557	21.657	18.32	18.32	21.502	21.602	0.50	0.50

BMP & EMP = Beginning and ending mile points; DP = The cumulative distress points between the BMP and EMP

DI per 0.1 mile = The DP divided by the number of 0.1 mile pavement segments between the BMP and EMP

Table 3.2 (cont'd).

Year - Years after construction																			
1995 - 0				1997 - 2				1999 - 4				2003 - 8				2005 - 10			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
21.626	21.726	0.00	0.00	21.566	21.666	0.50	0.50	21.583	21.683	0.98	0.98	21.657	21.757	20.21	20.21	21.602	21.702	0.25	0.25
21.726	21.826	0.00	0.00	21.666	21.766	0.75	0.75	21.683	21.783	3.93	3.93	21.757	21.857	21.39	21.39	21.702	21.802	1.00	1.00
21.826	21.926	0.00	0.00	21.766	21.866	0.00	0.00	21.783	21.883	4.52	4.52	21.857	21.957	20.41	20.41	21.802	21.902	2.49	2.49
21.926	22.026	0.00	0.00	21.866	21.966	0.94	0.94	21.883	21.983	2.25	2.25	21.957	22.057	17.51	17.51	21.902	22.002	4.23	4.23
22.026	22.126	0.00	0.00	21.966	22.066	0.50	0.50	21.983	22.083	6.16	6.16	22.057	22.157	12.21	12.21	22.002	22.102	3.65	3.65
22.126	22.226	0.00	0.00	22.066	22.166	0.50	0.50	22.083	22.183	2.63	2.63	22.157	22.257	17.26	17.26	22.102	22.202	2.00	2.00
22.226	22.326	0.00	0.00	22.166	22.266	1.00	1.00	22.183	22.283	10.6	10.6	22.257	22.357	21.06	21.06	22.202	22.302	6.17	6.17
22.326	22.504	0.00	0.00	22.266	22.439	0.00	0.00	22.283	22.46	2.78	1.57	22.357	22.457	13.79	13.79	22.302	22.402	3.05	3.05
22.504	22.526	0.00	0.00	22.439	22.462	0.00	0.00	22.46	22.481	0.00	0.00	22.457	22.557	9.70	9.70	22.402	22.502	4.77	4.77
22.526	22.626	0.00	0.00	22.462	22.562	0.50	0.50	22.481	22.581	2.75	2.75	22.557	22.657	9.39	9.39	22.502	22.602	3.19	3.19
22.626	22.726	0.00	0.00	22.562	22.662	0.50	0.50	22.581	22.681	0.94	0.94	22.657	22.757	12.47	12.47	22.602	22.702	3.75	3.75
22.726	22.826	0.00	0.00	22.662	22.762	0.00	0.00	22.681	22.781	1.00	1.00	22.757	22.857	11.97	11.97	22.702	22.802	3.69	3.69
22.826	22.926	0.00	0.00	22.762	22.862	1.50	1.50	22.781	22.881	0.94	0.94	22.857	22.957	15.60	15.60	22.802	22.902	1.25	1.25
22.926	23.026	0.00	0.00	22.862	22.962	0.00	0.00	22.881	22.981	2.48	2.48	22.957	23.057	9.14	9.14	22.902	23.002	2.50	2.50
23.026	23.126	0.00	0.00	22.962	23.062	0.00	0.00	22.981	23.081	0.50	0.50	23.057	23.157	15.15	15.15	23.002	23.102	1.50	1.50
23.126	23.226	0.00	0.00	23.062	23.162	0.00	0.00	23.081	23.181	2.16	2.16	23.157	23.257	8.39	8.39	23.102	23.202	0.75	0.75
23.226	23.326	0.00	0.00	23.162	23.262	1.05	1.05	23.181	23.281	1.05	1.05	23.257	23.377	6.48	5.40	23.202	23.353	2.65	1.75
23.326	23.446	0.78	0.65	23.262	23.383	0.00	0.00	23.281	23.4	1.38	1.16	23.377	23.415	12.97	34.14				
Average DI			0.11				0.31				2.28				15.41				2.97

BMP & EMP = Beginning and ending mile points; DP = The cumulative distress points between the BMP and EMP
DI per 0.1 mile = The DP divided by the number of 0.1 mile pavement segments between the BMP and EMP
Average DI = The average DI along the project = the sum of the DI per 0.1 mile divided by the number of 0.1 mile pavement segments

Table 3.3 Distress data for the I-69 JPCP project reconstructed in 2002; Control Section 12033, Job Number 49921 (Source, MDOT PMS distress data)

Year - Years after construction											
2003 - 1				2005 - 3				2007 - 5			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
10.906	11.006	0.50	0.50	10.905	11.005	0.00	0.00	10.900	11.000	3.79	3.79
11.006	11.106	0.00	0.00	11.005	11.105	0.00	0.00	11.000	11.100	0.00	0.00
11.106	11.206	0.00	0.00	11.105	11.205	0.00	0.00	11.100	11.200	0.00	0.00
11.206	11.306	0.00	0.00	11.205	11.305	0.00	0.00	11.200	11.300	0.50	0.50
11.306	11.406	0.00	0.00	11.305	11.405	0.00	0.00	11.300	11.400	0.00	0.00
11.406	11.506	0.00	0.00	11.405	11.505	0.00	0.00	11.400	11.500	0.50	0.50
11.506	11.606	0.00	0.00	11.505	11.605	0.00	0.00	11.500	11.600	0.00	0.00
11.606	11.706	0.00	0.00	11.605	11.705	0.36	0.36	11.600	11.700	0.00	0.00
11.706	11.806	0.00	0.00	11.705	11.805	0.12	0.12	11.700	11.800	0.54	0.54
11.806	11.906	0.00	0.00	11.805	11.905	1.40	1.40	11.800	11.900	0.50	0.50
11.906	12.006	0.00	0.00	11.905	12.005	0.00	0.00	11.900	12.000	0.00	0.00
12.006	12.106	0.00	0.00	12.005	12.105	0.00	0.00	12.000	12.100	0.16	0.16
12.106	12.206	0.00	0.00	12.105	12.205	1.32	1.32	12.100	12.200	0.00	0.00
12.206	12.306	0.00	0.00	12.205	12.305	0.24	0.24	12.200	12.300	0.00	0.00
12.306	12.406	1.25	1.25	12.305	12.405	1.50	1.50	12.300	12.400	7.89	7.89
12.406	12.506	0.50	0.50	12.405	12.603	1.34	0.68	12.400	12.500	8.81	8.81
12.506	12.649	0.00	0.00	12.603	12.611	0.50	6.25	12.500	12.607	6.30	5.89
Average DI			0.125				0.668				1.681

BMP & EMP = Beginning and ending mile points;
DP = The cumulative distress points between the BMP and EMP
DI per 0.1 mile = The DP divided by the number of 0.1 mile pavement segments between the BMP and EMP
Average DI = The average DI along the project = the sum of the DI per 0.1 mile divided by the number of 0.1 mile pavement segments

Table 3.4 Summary of the Average DI for the I-94 JRCP project reconstructed in 1995; CS 11015, JN 29580

Data source	Year	BMP	EMP	Project length (miles)	Average DI	Maintenance/ rehabilitation since construction
MDOT-pavement performance study	1995	19.381	23.353	3.972	0.1	2003 & 2004 - Concrete pavement repair 2004 - Diamond grinding
	1997	19.381	23.353	3.972	0.4	
	1999	19.381	23.353	3.972	2.7	
	2003	19.381	23.353	3.972	15.1	
	2005	19.381	23.353	3.972	2.9	
MDOT-I/D project list		19.80	23.431	3.631		
Financial records	NO I/D provisions or pay adjustments were made					

Table 3.5 Summary of the Average DI for the I-69 JPCP project reconstructed in 2002; CS 12033, JN 49921

Data source	Year	BMP	EMP	Project length (miles)	Average DI	Maintenance/ rehabilitation since construction
MDOT-pavement performance study	2003	10.976	12.603	1.627	0.1	None
	2005	10.976	12.603	1.627	0.5	
	2007	10.976	12.603	1.627	1.627	
MDOT - I/D project list		9.7	12.378	2.678		
Financial records	Concrete Quality Initiative - $48,988.40 or 2.58% of paving material cost					

1. For the JRCP reconstruction project along I-94 (solid squares):

   a) The average DI value increases from 0.1 to 15.1 in eight years after reconstruction.
   b) Decreases from 15.1 to 2.9 between the eighth and the tenth year after reconstruction. The improvement in the average DI value is due to the pavement rehabilitation actions (concrete pavement repair and diamond grinding, which is listed in Table 3.4 and indicated in the figure).

2. For the JPCP reconstruction project along I-69 (solid triangles), the average DI values increases from about 0.0 (no distress) to about 1.6 six years after reconstruction.

It can be seen from the figure that about six years after reconstruction, the average DI of the JRCP project is significantly higher than that for the JPCP project. It can also be seen that the rate of deterioration of the JRCP project is much higher than that of the JPCP project. Once again, the reader should keep in mind that:

1. The above observations are for illustrative purposes only.
2. Although the fix type for the two pavement projects is the same, the rigid pavement types are different

In order to estimate the pavement life of each of the two rigid pavement reconstruction projects, two methods were employed:

For each of the two pavement projects, the time series distress index data listed in Tables 3.4 and 3.5 were used by MDOT personnel to:

1. Obtain the statistical parameters of the best fit curve of the data using the MDOT logistical growth model.
2. Predict the pavement life (PL) and the remaining service life (RSL) of each rigid pavement reconstruction project. The MDOT predictions of PL are listed in Table 3.6.

It is evident from the predicted PL values provided in Table 3.6 that the JPCP project along I-69 has performed much better than the JRCP project along I-94. Indeed, the JRCP project has been subjected to concrete repair and diamond grinding whereas the JPCP project has not. Once again, the reader should be cautioned that although this observation is correct, it cannot be supported or extended to judge the benefits and costs of the MDOT I/D program. The reasons are:

1. The rigid pavement type is not the same for both projects.
2. The distress or the DI data used in the analyses cover relatively short period of time (5 years for the JPCP project and 8 years for the JRCP project).

Consequently, the results of the above example are not conclusive relative to the effects of the I/D program on pavement performance, longevity or pavement life extension.

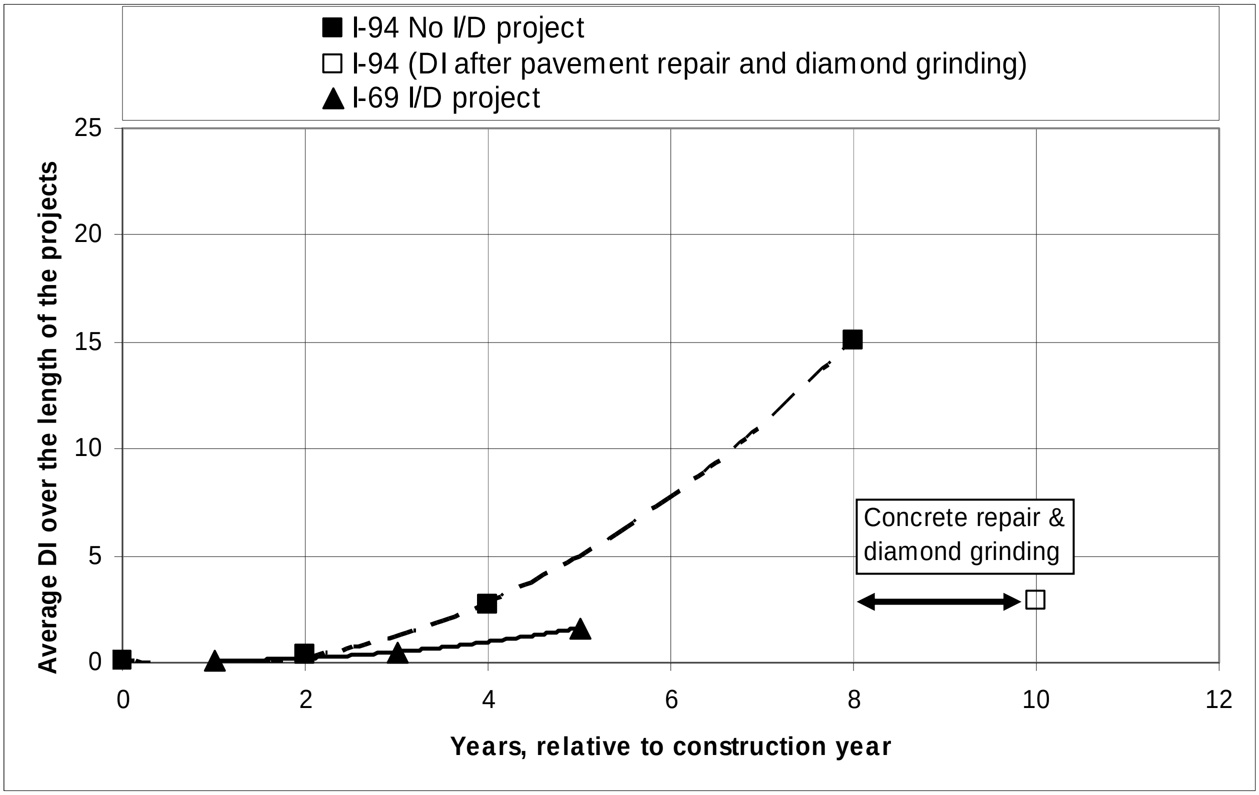

Figure 3.1 The average DI of two rigid pavement projects versus time after construction

Table 3.6 Predicted pavement life using the MDOT logistical growth model

Source	Pavement life (years)	
	I-69 with I/D	I-94 without I/D
The MDOT logistical growth model	22.1	11.04

The analyses of the performance of the two pavement projects in this section should only be used as an example of the analyses to be conducted on two or more pavement projects having almost a perfect match relative to pavement and fix types.

3.3 EXAMPLE 2 – ASSESSMENT OF I/D PAYMENT

In this example, the performances of six jointed plain concrete pavement (JPCP) reconstruction projects, containing I/D provision are compared. The six projects are listed in Table 3.7. For each pavement project, the I/D payment in the table is expressed in term of percent of the total paving material cost. It can be seen from the table that the I/D payment varies from a low of 2.15 percent to a high of 3.18 percent. This variation could be related to two factors:

1. The paid I/D pay rate for which the pavement project or portions of the pavement project were qualified. Unfortunately, during the course of this study, the needed data (e.g., QA data) to determine the actual pay rates and the locations where they were applied were not found.
2. The percent of the pavement project that received incentive and the percent for which the contractor possibly paid some penalties. Those percentages were not determined because the necessary data to conduct the analyses (such as location reference at which I/D payments/penalties were approved) were not found.

It should be noted that the narrow range of the I/D payment and the small number of projects used in the comparison would make it difficult to draw definite conclusions regarding the effects of the I/D payment on pavement performance. This situation could be alleviated if the appropriate data of two or more JPCP projects without I/D provisions or pay adjustment factors were found. Nevertheless, as in example 1, available historical (since reconstruction) distress data and distress points for each 0.1 mile segment along each of the six pavement projects were requested and obtained from the Pavement Management System (PMS) database of MDOT. The research team calculated the DI for each 0.1 mile pavement segment and the average DI of the entire project for each distress survey cycle. This average and the historical DP and DI data, for each pavement project, are listed in Tables 3.8 through 3.12.

Further, upon the decision of the RAP members (see example 1), the research team requested and obtained from the MDOT pavement performance study files:

1. The average DI of each of the six JPCP projects for each distress survey year
2. The BMP and EMP of the project

Other data that are pertinent to the assessment of the effects of the I/D program on pavement performance that were obtained from the MDOT files and project records are listed in Tables 3.13 to 3.17. For each of the six pavement projects, the data in the tables include:

- The pavement type; All 6 projects are jointed plain concrete pavements (JPCP)

Table 3.7 Summary of JPCP reconstruction projects

Project designation	Route name	Control section	Job number	Year of construction	BMP	EMP	I/D payment in percent of total paving material cost
1	I-75	82194	36005	1998	4.8	6.598	2.15
2	I-94 EB	11017	38094	1998	5.617	6.503	2.29
3	I-69	12033	45877	2001	5.8	10.809	2.38
4	I-69	12033	49921	2002	10.976	12.603	2.58
5	I-69	12033	45535	2000	0.006	5.8	2.69
6	I-96	47065	28215	1998	5.671	9.2	3.18

Table 3.8 Distress data for each 0.1 mile of the I-75 JPCP project reconstructed in 1998; CS 82194, JN 36005(from MDOT PMS distress data)

Year - Years after construction															
1999 – 1				2001 - 3				2003 – 5				2005 - 7			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
4.799	4.899	0.00	0.00	4.794	4.894	0.75	0.75	4.800	4.900	0.75	0.75	4.773	4.873	15.06	15.06
4.899	4.999	0.00	0.00	4.894	4.994	0.58	0.58	4.900	5.000	0.50	0.50	4.873	4.973	6.69	6.69
4.999	5.099	0.00	0.00	4.994	5.094	0.00	0.00	5.000	5.100	0.00	0.00	4.973	5.073	1.44	1.44
5.099	5.199	0.00	0.00	5.094	5.194	0.00	0.00	5.100	5.200	0.00	0.00	5.073	5.173	0.00	0.00
5.199	5.299	0.16	0.16	5.194	5.294	1.80	1.80	5.200	5.300	2.21	2.21	5.173	5.273	3.10	3.10
5.299	5.399	0.50	0.50	5.294	5.394	0.00	0.00	5.300	5.400	0.00	0.00	5.273	5.373	0.88	0.88
5.399	5.499	0.00	0.00	5.394	5.494	0.00	0.00	5.400	5.500	0.00	0.00	5.373	5.473	0.00	0.00
5.499	5.599	0.00	0.00	5.494	5.594	0.00	0.00	5.500	5.600	0.00	0.00	5.473	5.573	0.00	0.00
5.599	5.699	0.00	0.00	5.594	5.694	1.05	1.05	5.600	5.700	0.00	0.00	5.573	5.673	0.00	0.00
5.699	5.799	0.00	0.00	5.694	5.794	0.00	0.00	5.700	5.800	0.00	0.00	5.673	5.773	0.00	0.00
5.799	5.899	0.00	0.00	5.794	5.894	1.75	1.75	5.800	5.900	0.00	0.00	5.773	5.873	0.94	0.94
5.899	5.999	0.00	0.00	5.894	5.994	0.00	0.00	5.900	6.000	0.00	0.00	5.873	5.973	0.00	0.00
5.999	6.099	0.00	0.00	5.994	6.094	0.75	0.75	6.000	6.100	0.00	0.00	5.973	6.073	2.33	2.33
6.099	6.199	0.00	0.00	6.094	6.194	0.00	0.00	6.100	6.200	0.00	0.00	6.073	6.173	0.50	0.50
6.199	6.299	0.00	0.00	6.194	6.294	0.00	0.00	6.200	6.300	0.00	0.00	6.173	6.273	0.48	0.48
6.299	6.399	0.00	0.00	6.294	6.394	0.75	0.75	6.300	6.400	0.00	0.00	6.273	6.373	0.00	0.00
6.399	6.598	0.00	0.00	6.394	6.494	0.75	0.75	6.400	6.500	1.05	1.05	6.373	6.475	0.49	0.48
				6.494	6.650	0.00	0.00	6.500	6.642	0.00	0.00	6.475	6.507	3.44	10.74
												6.507	6.668	0.00	0.00
Average DI			0.039				0.454				0.251				2.244

Table 3.9 Distress data for each 0.1 mile of the I-69 JPCP project reconstructed in 2001; CS 12033, JN 45877 (from MDOT PMS distress data)

Year - Years after construction															
2001 - 1				2003 - 3				2005 - 5				2007 - 7			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
5.8	5.9	0.00	0.00	5.806	5.906	0.00	0.00	5.805	5.905	0.00	0.00	5.8	5.9	0.50	0.50
5.9	6	0.00	0.00	5.906	6.006	0.00	0.00	5.905	6.005	0.00	0.00	5.9	6	0.50	0.50
6	6.1	0.00	0.00	6.006	6.106	0.00	0.00	6.005	6.105	0.00	0.00	6	6.1	0.00	0.00
6.1	6.2	0.00	0.00	6.106	6.206	0.00	0.00	6.105	6.205	0.24	0.24	6.1	6.2	0.00	0.00
6.2	6.3	0.00	0.00	6.206	6.306	0.00	0.00	6.205	6.305	0.00	0.00	6.2	6.3	0.50	0.50
6.3	6.4	0.00	0.00	6.306	6.406	0.00	0.00	6.305	6.405	0.20	0.20	6.3	6.4	0.00	0.00
6.4	6.5	0.00	0.00	6.406	6.506	0.00	0.00	6.405	6.505	0.00	0.00	6.4	6.5	1.88	1.88
6.5	6.6	0.00	0.00	6.506	6.606	0.00	0.00	6.505	6.605	0.00	0.00	6.5	6.6	1.67	1.67
6.6	6.7	0.00	0.00	6.606	6.706	0.00	0.00	6.605	6.705	0.00	0.00	6.6	6.7	0.00	0.00
6.7	6.8	0.00	0.00	6.706	6.806	0.00	0.00	6.705	6.805	0.00	0.00	6.7	6.8	0.00	0.00
6.8	6.9	0.00	0.00	6.806	6.906	0.00	0.00	6.805	6.905	0.00	0.00	6.8	6.9	0.00	0.00
6.9	7	0.00	0.00	6.906	7.006	0.00	0.00	6.905	7.005	0.00	0.00	6.9	7	0.00	0.00
7	7.1	0.00	0.00	7.006	7.106	0.00	0.00	7.005	7.105	0.50	0.50	7	7.1	0.00	0.00
7.1	7.2	0.00	0.00	7.106	7.206	0.00	0.00	7.105	7.205	0.40	0.40	7.1	7.2	0.94	0.94
7.2	7.3	0.00	0.00	7.206	7.306	0.00	0.00	7.205	7.305	0.00	0.00	7.2	7.3	0.00	0.00
7.3	7.4	0.00	0.00	7.306	7.406	0.00	0.00	7.305	7.405	0.00	0.00	7.3	7.4	0.08	0.08
7.4	7.5	0.00	0.00	7.406	7.506	0.00	0.00	7.405	7.505	0.00	0.00	7.4	7.5	0.12	0.12
7.5	7.6	0.00	0.00	7.506	7.606	0.00	0.00	7.505	7.605	0.00	0.00	7.5	7.6	0.00	0.00
7.6	7.7	0.00	0.00	7.606	7.706	0.00	0.00	7.605	7.705	0.00	0.00	7.6	7.7	0.00	0.00
7.7	7.8	0.00	0.00	7.706	7.806	0.00	0.00	7.705	7.805	0.00	0.00	7.7	7.8	0.00	0.00
7.8	7.9	0.00	0.00	7.806	7.906	0.00	0.00	7.805	7.905	0.00	0.00	7.8	7.9	0.00	0.00
7.9	8	0.00	0.00	7.906	8.006	0.00	0.00	7.905	8.005	0.00	0.00	7.9	8	0.50	0.50
8	8.1	0.00	0.00	8.006	8.106	0.00	0.00	8.005	8.105	0.00	0.00	8	8.1	0.00	0.00
8.1	8.2	0.00	0.00	8.106	8.206	0.00	0.00	8.105	8.205	0.00	0.00	8.1	8.2	0.00	0.00
8.2	8.3	0.00	0.00	8.206	8.306	0.00	0.00	8.205	8.305	0.00	0.00	8.2	8.3	0.00	0.00

Table 3.9 (cont'd).

Year - Years after construction															
2001 – 1				2003 - 3				2005 - 5				2007 - 7			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
8.3	8.4	0.00	0.00	8.306	8.406	0.00	0.00	8.305	8.405	0.00	0.00	8.3	8.4	0.50	0.50
8.4	8.5	0.00	0.00	8.406	8.506	0.00	0.00	8.405	8.505	0.00	0.00	8.4	8.5	0.00	0.00
8.5	8.6	0.00	0.00	8.506	8.606	0.00	0.00	8.505	8.605	0.00	0.00	8.5	8.6	0.00	0.00
8.6	8.7	0.00	0.00	8.606	8.706	0.00	0.00	8.605	8.705	0.00	0.00	8.6	8.7	1.44	1.44
8.7	8.8	0.00	0.00	8.706	8.806	0.00	0.00	8.705	8.805	0.00	0.00	8.7	8.8	3.50	3.50
8.8	8.9	0.00	0.00	8.806	8.906	0.00	0.00	8.805	8.905	0.00	0.00	8.8	8.9	0.00	0.00
8.9	9	0.00	0.00	8.906	9.006	0.00	0.00	8.905	9.005	0.00	0.00	8.9	9	0.00	0.00
9	9.1	0.00	0.00	9.006	9.106	0.00	0.00	9.005	9.105	0.00	0.00	9	9.1	0.24	0.24
9.1	9.2	0.00	0.00	9.106	9.206	0.00	0.00	9.105	9.205	0.00	0.00	9.1	9.2	0.00	0.00
9.2	9.3	0.00	0.00	9.206	9.306	0.00	0.00	9.205	9.305	0.00	0.00	9.2	9.3	0.50	0.50
9.3	9.4	0.00	0.00	9.306	9.406	0.00	0.00	9.305	9.405	0.00	0.00	9.3	9.4	0.00	0.00
9.4	9.5	0.00	0.00	9.406	9.506	1.00	1.00	9.405	9.505	0.00	0.00	9.4	9.5	0.00	0.00
9.5	9.6	0.00	0.00	9.506	9.606	0.00	0.00	9.505	9.605	0.00	0.00	9.5	9.6	0.00	0.00
9.6	9.7	0.00	0.00	9.606	9.706	0.00	0.00	9.605	9.705	0.00	0.00	9.6	9.7	0.00	0.00
9.7	9.8	0.00	0.00	9.706	9.806	0.00	0.00	9.705	9.805	0.00	0.00	9.7	9.8	0.50	0.50
9.8	9.9	0.00	0.00	9.806	9.906	0.00	0.00	9.805	9.905	0.24	0.24	9.8	9.9	0.50	0.50
9.9	10	0.00	0.00	9.906	10.006	0.00	0.00	9.905	10.005	0.00	0.00	9.9	10	0.12	0.12
10	10.1	0.00	0.00	10.006	10.106	0.00	0.00	10.005	10.105	0.50	0.50	10	10.1	0.00	0.00
10.1	10.2	0.00	0.00	10.106	10.206	0.00	0.00	10.105	10.205	0.12	0.12	10.1	10.2	0.16	0.16
10.2	10.3	0.00	0.00	10.206	10.306	0.00	0.00	10.205	10.305	0.32	0.32	10.2	10.3	0.00	0.00
10.3	10.4	0.00	0.00	10.306	10.406	0.00	0.00	10.305	10.405	0.00	0.00	10.3	10.4	0.00	0.00
10.4	10.5	0.00	0.00	10.406	10.506	0.00	0.00	10.405	10.505	0.00	0.00	10.4	10.5	0.00	0.00
10.5	10.6	0.00	0.00	10.506	10.606	0.00	0.00	10.505	10.605	0.00	0.00	10.5	10.6	0.00	0.00
10.6	10.7	0.00	0.00	10.606	10.706	0.00	0.00	10.605	10.705	0.40	0.40	10.6	10.7	0.00	0.00
10.7	10.809	0.00	0.00	10.706	10.806	0.00	0.00	10.705	10.805	0.00	0.00	10.7	10.8	0.00	0.00
Average DI			0				0.02				0.0584				0.283

Table 3.10 Distress data for each 0.1 mile of the I-69 JPCP project reconstructed in 2000; CS 12033, JN 45535 (from MDOT PMS distress data)

Year - Years after construction															
2001 - 1				2003 - 3				2005 - 5				2007 - 7			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
0.000	0.100	0.00	0.00	0.006	0.106	0.00	0.00	0.005	0.105	0.00	0.00	0.000	0.100	0.00	0.00
0.100	0.200	0.00	0.00	0.106	0.206	0.00	0.00	0.105	0.205	0.00	0.00	0.100	0.200	0.00	0.00
0.200	0.300	0.00	0.00	0.206	0.306	0.00	0.00	0.205	0.305	0.00	0.00	0.200	0.300	0.00	0.00
0.300	0.400	0.00	0.00	0.306	0.406	0.00	0.00	0.305	0.405	0.00	0.00	0.300	0.400	0.00	0.00
0.400	0.500	0.00	0.00	0.406	0.506	0.00	0.00	0.405	0.505	0.00	0.00	0.400	0.500	0.00	0.00
0.500	0.600	0.00	0.00	0.506	0.606	0.00	0.00	0.505	0.605	0.00	0.00	0.500	0.600	0.50	0.50
0.600	0.700	0.00	0.00	0.606	0.706	0.00	0.00	0.605	0.705	0.00	0.00	0.600	0.700	0.50	0.50
0.700	0.800	0.00	0.00	0.706	0.806	0.00	0.00	0.705	0.805	0.00	0.00	0.700	0.800	0.00	0.00
0.800	0.900	0.00	0.00	0.806	0.906	0.00	0.00	0.805	0.905	0.12	0.12	0.800	0.900	0.50	0.50
0.900	1.000	0.00	0.00	0.906	1.006	0.00	0.00	0.905	1.005	0.16	0.16	0.900	1.000	0.50	0.50
1.000	1.100	0.00	0.00	1.006	1.106	0.00	0.00	1.005	1.105	0.76	0.76	1.000	1.100	0.50	0.50
1.100	1.200	0.00	0.00	1.106	1.206	0.00	0.00	1.105	1.205	0.12	0.12	1.100	1.200	0.50	0.50
1.200	1.300	0.00	0.00	1.206	1.306	0.00	0.00	1.205	1.305	0.24	0.24	1.200	1.300	0.00	0.00
1.300	1.400	0.00	0.00	1.306	1.406	0.00	0.00	1.305	1.405	0.32	0.32	1.300	1.400	0.00	0.00
1.400	1.500	0.00	0.00	1.406	1.506	0.00	0.00	1.405	1.505	0.72	0.72	1.400	1.500	0.00	0.00
1.500	1.600	0.00	0.00	1.506	1.606	0.00	0.00	1.505	1.605	0.24	0.24	1.500	1.600	0.00	0.00
1.600	1.700	0.00	0.00	1.606	1.706	0.00	0.00	1.605	1.705	0.56	0.56	1.600	1.700	0.52	0.52
1.700	1.800	0.00	0.00	1.706	1.806	0.00	0.00	1.705	1.805	0.00	0.00	1.700	1.800	0.00	0.00
1.800	1.900	0.00	0.00	1.806	1.906	0.00	0.00	1.805	1.905	0.00	0.00	1.800	1.900	0.00	0.00
1.900	2.000	0.00	0.00	1.906	2.006	0.00	0.00	1.905	2.005	0.00	0.00	1.900	2.000	0.00	0.00
2.000	2.100	0.00	0.00	2.006	2.106	0.00	0.00	2.005	2.105	0.00	0.00	2.000	2.100	0.50	0.50
2.100	2.200	0.00	0.00	2.106	2.206	0.00	0.00	2.105	2.205	0.00	0.00	2.100	2.200	0.00	0.00
2.200	2.300	0.00	0.00	2.206	2.306	0.00	0.00	2.205	2.305	0.12	0.12	2.200	2.300	0.00	0.00
2.300	2.400	0.00	0.00	2.306	2.406	0.94	0.94	2.305	2.405	0.84	0.84	2.300	2.400	0.04	0.04
2.400	2.500	0.00	0.00	2.406	2.506	0.00	0.00	2.405	2.505	0.00	0.00	2.400	2.500	0.00	0.00
2.500	2.600	0.00	0.00	2.506	2.606	0.00	0.00	2.505	2.605	0.00	0.00	2.500	2.600	0.00	0.00

Table 3.10 (cont'd)

Year - Years after construction															
2001 - 1				2003 - 3				2005 - 5				2007 - 7			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
2.600	2.700	0.00	0.00	2.606	2.706	0.00	0.00	2.605	2.705	0.50	0.50	2.600	2.700	0.00	0.00
2.700	2.800	0.00	0.00	2.706	2.806	0.00	0.00	2.705	2.805	0.00	0.00	2.700	2.800	0.00	0.00
2.800	2.900	0.00	0.00	2.806	2.906	0.00	0.00	2.805	2.905	0.00	0.00	2.800	2.900	0.00	0.00
2.900	3.000	0.00	0.00	2.906	3.006	0.00	0.00	2.905	3.005	0.00	0.00	2.900	3.000	0.00	0.00
3.000	3.100	0.00	0.00	3.006	3.106	0.00	0.00	3.005	3.105	0.00	0.00	3.000	3.100	0.00	0.00
3.100	3.200	0.00	0.00	3.106	3.206	0.00	0.00	3.105	3.205	0.16	0.16	3.100	3.200	0.00	0.00
3.200	3.300	0.00	0.00	3.206	3.306	0.00	0.00	3.205	3.305	0.00	0.00	3.200	3.300	0.00	0.00
3.300	3.400	0.00	0.00	3.306	3.406	0.00	0.00	3.305	3.405	0.32	0.32	3.300	3.400	0.00	0.00
3.400	3.500	0.00	0.00	3.406	3.506	0.00	0.00	3.405	3.505	0.44	0.44	3.400	3.500	0.00	0.00
3.500	3.600	0.00	0.00	3.506	3.606	0.00	0.00	3.505	3.605	0.64	0.64	3.500	3.600	0.00	0.00
3.600	3.700	0.00	0.00	3.606	3.706	0.00	0.00	3.605	3.705	0.16	0.16	3.600	3.700	0.00	0.00
3.700	3.800	0.00	0.00	3.706	3.806	0.00	0.00	3.705	3.805	0.32	0.32	3.700	3.800	0.00	0.00
3.800	3.900	0.00	0.00	3.806	3.906	0.00	0.00	3.805	3.905	0.12	0.12	3.800	3.900	0.00	0.00
3.900	4.000	0.00	0.00	3.906	4.006	0.00	0.00	3.905	4.005	0.00	0.00	3.900	4.000	0.00	0.00
4.000	4.100	0.00	0.00	4.006	4.106	0.00	0.00	4.005	4.105	0.16	0.16	4.000	4.100	0.00	0.00
4.100	4.200	0.00	0.00	4.106	4.206	0.00	0.00	4.105	4.205	0.00	0.00	4.100	4.200	0.00	0.00
4.200	4.300	0.00	0.00	4.206	4.306	0.00	0.00	4.205	4.305	0.00	0.00	4.200	4.300	0.00	0.00
4.300	4.400	0.00	0.00	4.306	4.406	0.00	0.00	4.305	4.405	0.00	0.00	4.300	4.400	0.00	0.00
4.400	4.500	0.00	0.00	4.406	4.506	0.00	0.00	4.405	4.505	0.00	0.00	4.400	4.500	0.00	0.00
4.500	4.600	0.00	0.00	4.506	4.606	0.00	0.00	4.505	4.605	0.00	0.00	4.500	4.600	0.00	0.00
4.600	4.700	0.00	0.00	4.606	4.706	0.00	0.00	4.605	4.705	0.00	0.00	4.600	4.700	0.00	0.00
4.700	4.800	0.00	0.00	4.706	4.806	0.00	0.00	4.705	4.805	0.00	0.00	4.700	4.800	0.00	0.00
4.800	4.900	0.00	0.00	4.806	4.906	0.00	0.00	4.805	4.905	0.16	0.16	4.800	4.900	2.00	2.00
4.900	5.000	0.00	0.00	4.906	5.006	0.00	0.00	4.905	5.005	0.00	0.00	4.900	5.000	0.00	0.00
5.000	5.100	0.00	0.00	5.006	5.106	0.00	0.00	5.005	5.105	0.00	0.00	5.000	5.100	0.00	0.00
5.100	5.200	0.00	0.00	5.106	5.206	0.00	0.00	5.105	5.205	0.00	0.00	5.100	5.200	0.94	0.94

Table 3.10 (cont'd)

Year - Years after construction															
2001 - 1				2003 - 3				2005 - 5				2007 - 7			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
5.200	5.300	0.00	0.00	5.206	5.306	0.00	0.00	5.205	5.305	0.00	0.00	5.200	5.300	0.04	0.04
5.300	5.400	0.00	0.00	5.306	5.406	0.00	0.00	5.305	5.405	0.00	0.00	5.300	5.400	0.00	0.00
5.400	5.500	0.00	0.00	5.406	5.506	0.00	0.00	5.405	5.505	0.00	0.00	5.400	5.500	0.00	0.00
5.500	5.600	0.00	0.00	5.506	5.606	0.50	0.50	5.505	5.605	2.00	2.00	5.500	5.600	6.97	6.97
5.600	5.700	0.00	0.00	5.606	5.706	0.00	0.00	5.605	5.705	0.00	0.00	5.600	5.700	0.00	0.00
5.700	5.800	0.00	0.00	5.706	5.806	0.00	0.00	5.705	5.805	0.00	0.00	5.700	5.800	0.00	0.00
Average DI			0.00				0.025				0.158				0.241

Table 3.11 Distress data for each 0.1 mile of the I-96 JPCP project reconstructed in 1998; CS 47065, JN 28215 (from MDOT PMS distress data)

Year - Years after construction															
1999 - 0				2001 - 2				2003 - 4				2005 - 6			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
5.671	5.771	0.00	0.00	5.600	5.700	0.00	0.00	5.600	5.700	3.69	3.69	5.600	5.700	9.38	9.38
5.771	5.871	0.00	0.00	5.700	5.800	2.50	2.50	5.700	5.800	8.75	8.75	5.700	5.800	23.68	23.68
5.871	5.971	0.00	0.00	5.800	5.900	1.50	1.50	5.800	5.900	7.75	7.75	5.800	5.900	20.32	20.32
5.971	6.071	0.00	0.00	5.900	6.000	1.00	1.00	5.900	6.000	5.25	5.25	5.900	6.000	16.63	16.63
6.071	6.264	0.00	0.00	6.000	6.100	0.00	0.00	6.000	6.100	6.50	6.50	6.000	6.100	10.11	10.11
6.264	6.302	0.00	0.00	6.100	6.200	3.00	3.00	6.100	6.200	2.00	2.00	6.100	6.200	14.13	14.13
6.302	6.402	0.00	0.00	6.200	6.300	0.75	0.75	6.200	6.300	8.66	8.66	6.200	6.300	19.80	19.80
6.402	6.502	0.00	0.00	6.300	6.400	0.00	0.00	6.300	6.400	12.75	12.75	6.300	6.400	30.93	30.93
6.502	6.602	0.00	0.00	6.400	6.500	1.50	1.50	6.400	6.500	12.94	12.94	6.400	6.500	25.54	25.54
6.602	6.702	0.00	0.00	6.500	6.600	0.00	0.00	6.500	6.600	6.00	6.00	6.500	6.600	18.80	18.80
6.702	6.802	0.00	0.00	6.600	6.700	0.50	0.50	6.600	6.700	8.00	8.00	6.600	6.700	25.82	25.82
6.802	6.902	0.00	0.00	6.700	6.800	0.00	0.00	6.700	6.800	7.75	7.75	6.700	6.800	26.17	26.17
6.902	7.002	0.00	0.00	6.800	6.900	0.00	0.00	6.800	6.900	4.00	4.00	6.800	6.900	23.50	23.50
7.002	7.102	0.00	0.00	6.900	7.000	0.00	0.00	6.900	7.000	2.50	2.50	6.900	7.000	21.32	21.32
7.102	7.202	0.00	0.00	7.000	7.100	3.00	3.00	7.000	7.100	11.50	11.50	7.000	7.100	25.96	25.96
7.202	7.302	0.00	0.00	7.100	7.200	2.25	2.25	7.100	7.200	15.13	15.13	7.100	7.200	25.83	25.83
7.302	7.402	0.00	0.00	7.200	7.300	0.25	0.25	7.200	7.300	11.88	11.88	7.200	7.300	21.67	21.67
7.402	7.502	0.00	0.00	7.300	7.400	0.00	0.00	7.300	7.400	7.75	7.75	7.300	7.400	16.33	16.33
7.502	7.602	0.00	0.00	7.400	7.500	0.75	0.75	7.400	7.500	1.50	1.50	7.400	7.500	4.69	4.69
7.602	7.702	0.00	0.00	7.500	7.600	0.00	0.00	7.500	7.600	6.75	6.75	7.500	7.600	22.26	22.26
7.702	7.802	0.00	0.00	7.600	7.700	0.00	0.00	7.600	7.700	3.25	3.25	7.600	7.700	21.83	21.83
7.802	7.902	0.16	0.16	7.700	7.800	11.50	11.50	7.700	7.800	6.00	6.00	7.700	7.800	17.24	17.24
7.902	8.002	0.00	0.00	7.800	7.900	6.00	6.00	7.800	7.900	21.68	21.68	7.800	7.900	26.23	26.23
8.002	8.102	0.00	0.00	7.900	8.000	2.75	2.75	7.900	8.000	10.75	10.75	7.900	8.000	22.95	22.95
8.102	8.202	0.00	0.00	8.000	8.100	9.75	9.75	8.000	8.100	18.10	18.10	8.000	8.100	24.05	24.05

Table 3.11 (cont'd)

Year - Years after construction															
1999 - 0				2001 - 2				2003 - 4				2005 - 6			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
8.202	8.302	0.00	0.00	8.100	8.200	8.00	8.00	8.100	8.200	15.94	15.94	8.100	8.200	21.00	21.00
8.302	8.402	1.00	1.00	8.200	8.300	3.75	3.75	8.200	8.300	19.44	19.44	8.200	8.300	23.55	23.55
8.402	8.502	0.00	0.00	8.300	8.400	0.00	0.00	8.300	8.400	8.94	8.94	8.300	8.400	19.78	19.78
8.502	8.602	0.00	0.00	8.400	8.500	1.00	1.00	8.400	8.500	2.50	2.50	8.400	8.500	15.40	15.40
8.602	8.702	0.00	0.00	8.500	8.600	3.50	3.50	8.500	8.600	11.94	11.94	8.500	8.600	23.22	23.22
8.702	8.802	0.00	0.00	8.600	8.700	1.00	1.00	8.600	8.700	11.00	11.00	8.600	8.700	22.67	22.67
8.802	8.902	0.00	0.00	8.700	8.800	0.00	0.00	8.700	8.800	9.69	9.69	8.700	8.800	20.21	20.21
8.902	9.002	0.00	0.00	8.800	8.900	0.00	0.00	8.800	8.900	4.00	4.00	8.800	8.900	18.25	18.25
9.002	9.102	0.00	0.00	8.900	9.000	0.00	0.00	8.900	9.000	11.00	11.00	8.900	9.000	19.71	19.71
9.102	9.202	1.00	1.00	9.000	9.100	0.00	0.00	9.000	9.100	5.69	5.69	9.000	9.100	13.69	13.69
				9.100	9.200	1.75	1.75	9.100	9.200	4.44	4.44	9.100	9.200	15.05	15.05
Average DI			0.062				1.833				8.761				20.214

Table 3.12 Distress data for each 0.1 mile of the I-94 JPCP project reconstructed in 1998; CS 11017, JN 38094 (from MDOT PMS distress data)

Year - Years after construction																			
1999 - 2				2001 - 4				2003 - 6				2005 - 8				2007 - 10			
BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile	BMP	EMP	DP	DI per 0.1 mile
5.617	5.717	0.32	0.32	5.603	5.703	0.00	0.00	5.605	5.705	0.66	0.66	5.602	5.702	0.50	0.50	5.616	5.716	14.80	14.80
5.717	5.817	0.16	0.16	5.703	5.803	0.00	0.00	5.705	5.805	0.00	0.00	5.702	5.802	0.00	0.00	5.716	5.816	17.25	17.25
5.817	5.917	0.16	0.16	5.803	5.903	0.00	0.00	5.805	5.905	0.00	0.00	5.802	5.902	1.69	1.69	5.816	5.916	18.44	18.44
5.917	6.017	0.00	0.00	5.903	6.003	0.00	0.00	5.905	6.005	0.00	0.00	5.902	6.002	0.50	0.50	5.916	6.016	9.98	9.98
6.017	6.117	0.00	0.00	6.003	6.103	0.00	0.00	6.005	6.105	0.00	0.00	6.002	6.102	0.00	0.00	6.016	6.116	9.50	9.50
6.117	6.217	0.00	0.00	6.103	6.203	0.00	0.00	6.105	6.205	0.16	0.16	6.102	6.202	2.28	2.28	6.116	6.216	3.98	3.98
6.217	6.317	0.00	0.00	6.203	6.303	0.00	0.00	6.205	6.305	0.00	0.00	6.202	6.302	5.64	5.64	6.216	6.316	5.00	5.00
6.317	6.417	0.00	0.00	6.303	6.403	0.00	0.00	6.305	6.405	0.00	0.00	6.302	6.402	4.36	4.36	6.316	6.416	6.50	6.50
6.417	6.590	1.07	0.62	6.403	6.503	0.75	0.75	6.405	6.505	0.75	0.75	6.402	6.599	12.55	6.37	6.416	6.516	8.75	8.75
Average DI			0.140				0.083				0.174				2.371				10.467

- The pavement route; I-75, I-94EB, I-96, and I-69
- The source of the information including the PMS database of MDOT, the file of the MDOT pavement performance study, the project list of the MDOT I/D study, the project proposal, and the project financial records
- The year of pavement reconstruction and distress data collection
- The BMP and EMP
- The project length in miles
- For each distress survey year, the average DI between the given mile points that were obtained from the MDOT Pavement Performance Study.
- The I/D provisions
- The amount of incentive payment in terms of dollars and as percent of the paving material cost
- The type and years of maintenance and pavement preservation fixes that were made after reconstruction

It should be noted that, the distress data from the PMS database and the summary of the average DI values for one of the I-69 projects (CS 12033 JN 49921), which was also part of Example 1, are provided in Tables 3.3 and 3.5, respectively.

As indicated in Tables 3.5 and 3.13 through 3.17, each of the six JPCP pavement reconstruction projects contained I/D provisions but different incentive payments, which varied from 2.15 to 3.18 percent of the total paving material cost. The data (the amount of the I/D payment received by the contractor and the paving material cost for each project) were obtained from the project financial record.

The performance of the six pavement projects were compared based on the Average DI data listed in Table 3.5, and 3.13 through 3.17 that were obtained from the MDOT pavement performance study data files. The main objective of such comparison is to assess whether or not the size of the I/D payment impacts pavement performance.

Figure 3.2 depicts (for the six JPCP reconstruction projects) the average DI values (listed in Table 3.5, and 3.13 through 3.17) plotted as a function of time since reconstruction. The data in the figure indicate that:

1. The pavement project on I-96 with the highest I/D percent payment (3.18 percent of the total paving material cost) has the highest rate of deterioration. The average DI increased from 0.06 to 20.36 in 6 years after reconstruction. Indeed, the project was subjected to concrete repair & diamond grinding in 2005 (6 years after construction).
2. The data from all six projects appear to indicate that the I/D percent payments have no effect on pavement performance.

The data for the JPCP project along I-75 and two of the three JPCP projects along I-69 (JN 45877 and 45535) indicate I/D payment from 2.15 to 2.69 percent of the total paving material cost were made and the pavements experienced relatively low deterioration rates. The average DI for the three pavement projects increased from 0.0 to 0.6 in about 7 years after reconstruction as shown in Figure 3.3.

Table 3.13 Summary of the average DI for the 1998 reconstructed JPCP project along I-75; CS 82194, JN 36005

Data source	Year	BMP	EMP	Project length (miles)	Average DI	Maintenance/ rehabilitation since construction
MDOT-pavement performance study	1999	4.8	6.598	1.798	0.0	
	2001	4.8	6.598	1.798	0.5	
	2003	4.8	6.598	1.798	0.3	
	2005	4.8	6.598	1.798	0.6	
MDOT - I/D project list		4.58	6.99	2.41		
Financial records	Concrete Quality Initiative - $60,832.80 – 2.15% of the paving material cost					

Table 3.14 Summary of the average DI for the 1998 reconstructed JPCP project along EB I-94; CS 11017, JN 38094

Data source	Year	BMP	EMP	Project length (miles)	Average DI	Maintenance/ rehabilitation since construction
MDOT-pavement performance study	1999	5.617	6.503	0.886	0.196	
	2001	5.617	6.503	0.886	0.085	
	2003	5.617	6.503	0.886	0.2	
	2005	5.617	6.503	0.886	1.8	
	2007	5.617	6.503	0.886	7.354	
MDOT - I/D project list		5.875	6.603	0.728		
Financial records	Concrete Strength Adjustment - $31,128.70 – 2.29% of the paving material cost					

Table 3.15 Summary of the average DI for the 2001 reconstructed JPCP project along I-69; CS 12033, JN 45877

Data source	Year	BMP	EMP	Project length (miles)	Average DI	Maintenance/ rehabilitation since construction
MDOT-pavement performance study	2001	5.8	10.809	5.009	0	
	2003	5.8	10.809	5.009	0	
	2005	5.8	10.809	5.009	0.1	
	2007	5.8	10.809	5.009	0.283	
MDOT - I/D project list		5.8	11.0	5.2		
Financial records	Concrete Quality Initiative - $65,132.72 – 2.38% of the paving material cost					

Table 3.16 Summary of the average DI for the 2000 reconstructed JPCP project along I-69; CS 12033, JN 45535

Data source	Year	BMP	EMP	Project length (miles)	Average DI	Maintenance/ rehabilitation since construction
MDOT-pavement performance study	2001	0.006	5.8	5.794	0	
	2003	0.006	5.8	5.794	0	
	2005	0.006	5.8	5.794	0.2	
	2007	0.006	5.8	5.794	0.2	
MDOT - I/D project list		0	5.8	5.8		
Financial records	Concrete Quality Initiative - $65,132.72 – 2.69% of the paving material cost					

Table 3.17 Summary of the average DI for the 1998 reconstructed JPCP project along I-96; CS 47065, JN 28215

Data source	Year	BMP	EMP	Project length (miles)	Average DI	Maintenance/ rehabilitation since construction
MDOT-pavement performance study	1999	5.671	9.2	3.529	0.063	2005 - Concrete pavement repair & diamond grinding
	2001	5.671	9.2	3.529	1.827	
	2003	5.671	9.2	3.529	8.69	
	2005	5.671	9.2	3.529	20.297	
MDOT- I/D project list		4.05	5.46	1.41		
Financial records	Concrete Strength Initiative - $71,031.01 – 3.18% of the paving material cost					

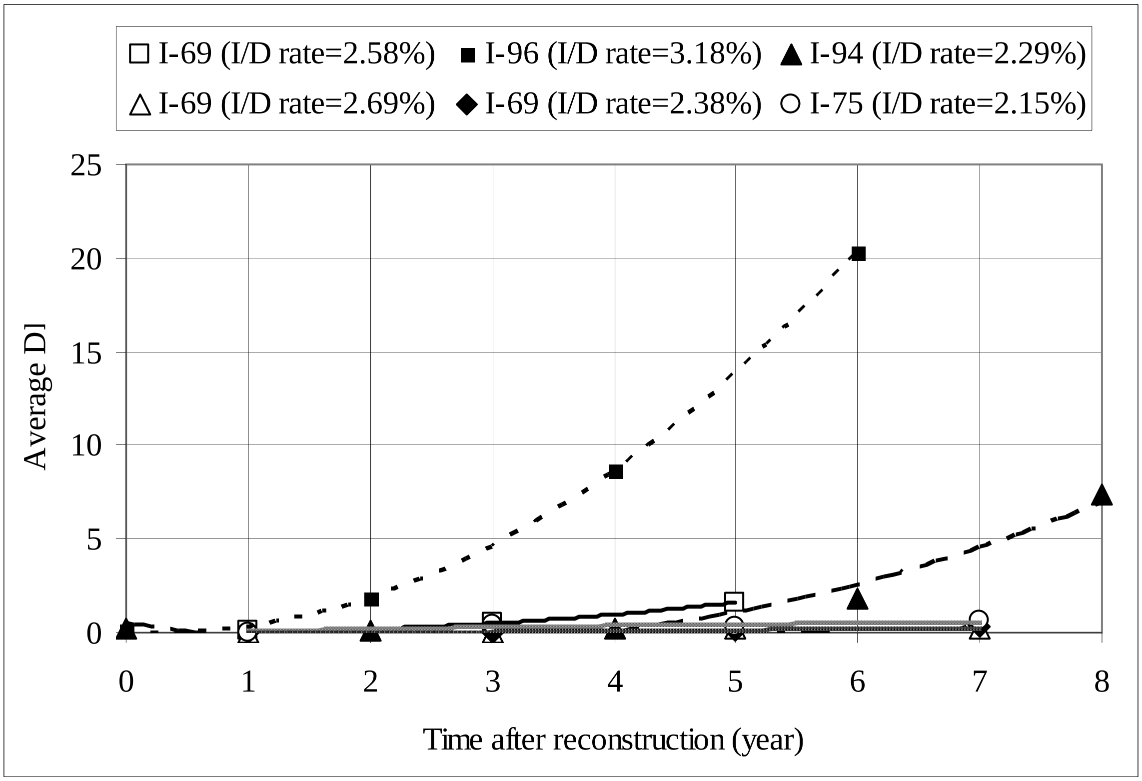

Figure 3.2 DI of six JPCP projects versus time

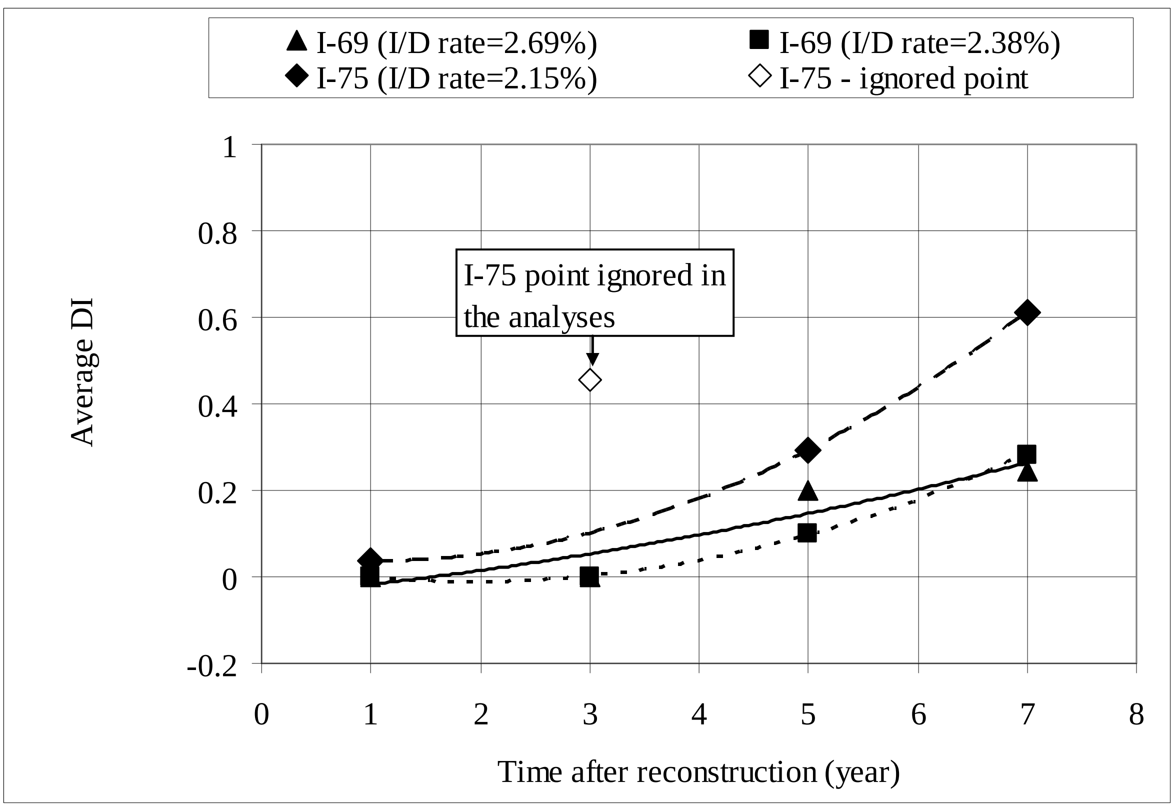

Figure 3.3 DI of three JPCP projects versus time

As in Example 1, the DI data for each of the six reconstruction projects were analyzed using the MDOT logistical growth model to estimate the PL of each JPCP reconstruction project. The estimated values are listed in Table 3.19 and plotted in Figure 3.4. After examining the data shown in the figure, it was decided to label the data point with an I/D pay rate of 3.18 an outlier. The remaining data were then used to generate the best fit exponential function stated in the figure. It can be seen from the figure that, in general, the higher the I/D percent payments, the higher is the estimated PL. This observation must be viewed with extreme caution. The reasons are:

1. The small range of the I/D pay adjustment factors of the six projects.
2. Only three pavement projects from a pool of six pavement projects were used in the comparison.

The above scenarios indicate that a definitive conclusion regarding the effects of the I/D pay adjustment factors on pavement performance cannot be drawn. This is similar to the conclusion reached from Example 1. The main reason is the limited number of pavement projects in each cell of Table 3.1. Once again, the analyses of the two examples should only be viewed as an example of the analyses to be conducted in future studies of the effectiveness of the MDOT I/D program.

Table 3.19 Predicted pavement life of the six JPCP reconstruction projects

Route name	I-75	I-94	I-69	I-69	I-69	I-96
Control section	82194	11017	12033	12033	12033	47065
Job number	36005	38094	45877	49921	45535	28215
I/D payment in percent of total paving material cost	2.15	2.29	2.38	2.58	2.69	3.18
Pavement life (years) from the MDOT logistical growth model	14.6	11.9	23.6	22.1	50.2	9.8

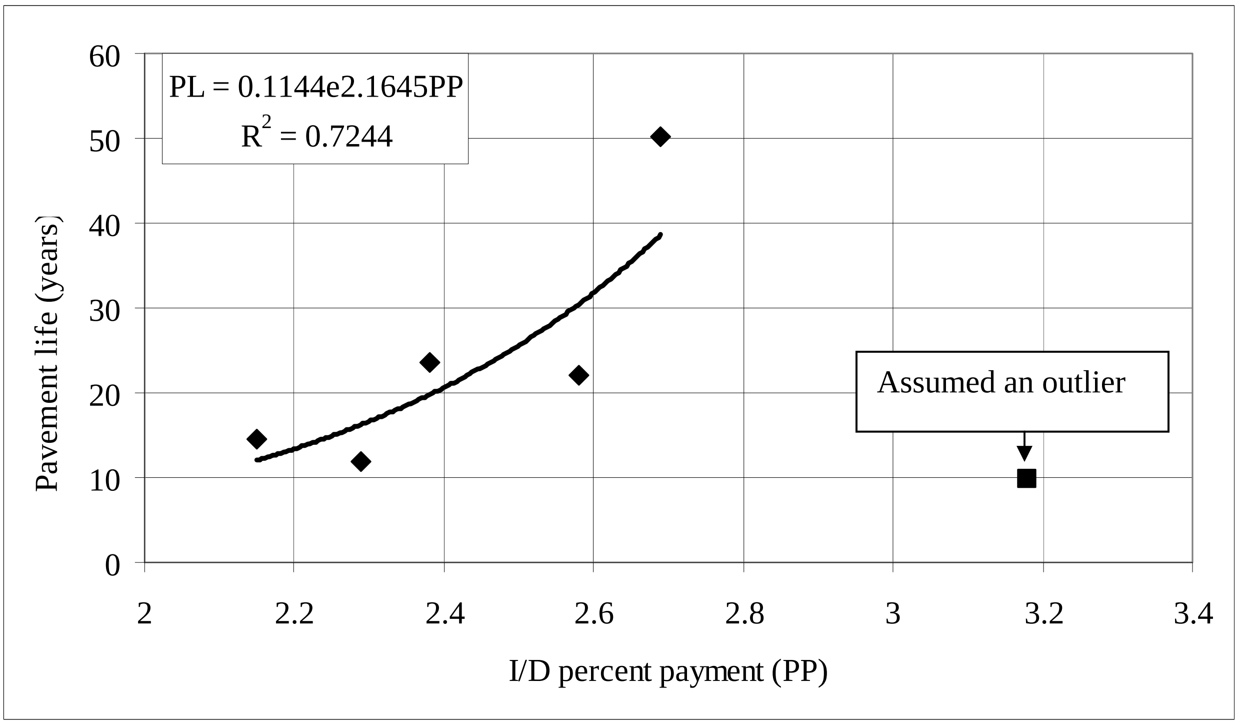

Figure 3.4 Pavement life estimated using MDOT logistical growth model vs. I/D payment in percent of total paving material cost

CHAPTER 4
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1 SUMMARY

The Michigan Department of Transportation (MDOT) has been using monetary incentive payments for many years to improve contractors' conformance with specifications and their overall workmanship. The costs and benefits of such improvements however, have not been documented or analyzed. Consequently, this exploratory study was funded by MDOT to find out whether or not the MDOT data files and project records contain the necessary data elements to analyze the costs and benefits of the I/D program. During the study, the research team searched the files and project records of seventy-two pavement projects, four projects without I/D provisions and sixty-eight with I/D provisions. It was found that the data files and project records of fifty-five pavement projects (about 76 percent) contain sufficient data to perform analyses of the costs and benefits of the I/D program. Two examples of such analyses are included in chapter 3. Based on the results of the analyses and the available data, the conclusions and recommendation presented in the next two sections were drawn.

4.2 CONCLUSIONS

Based upon the pavement project data collected during the course of this study and the data assessment of Examples 1 and 2 presented in Chapter 3, the following conclusions were drawn:

1. Analyses of the costs and benefits of the MDOT I/D program could be conducted in three steps as follows:

    a) Establish one pool of pavement projects "Pool A" where I/D provisions and I/D pay adjustments were applied. Calculate the total dollar amount of the I/D pay adjustments.
    b) Establish a second pool of pavement projects "Pool B" where no I/D provisions or I/D pay adjustments were applied.
    c) Compare the performance of all pavement projects in Pool A to that of the projects in Pool B. The comparison would result in three possible outcomes as follows:

        c1) The average performance of the pavement projects in Pool A is equal to or less than that the average performance of the pavement projects in Pool B. This implies that the I/D program is generating negative benefits.
        c2) The average performance of the pavement projects in Pool A is better that that of the average performance of the pavement projects in Pool B. However, the improvement in performance (the benefits) is less than or equal to the total amount of the I/D pay adjustments that calculated in step a. This implies that the I/D program is not delivering the desired outcome of higher benefits (the average improvement in the pavement performance)

relative to the cost (the sum of the dollar amount of the applied I/D pay adjustments).

c3) The average performance of the pavement projects in Pool A is much better that the average performance of the pavement projects in Pool B. And the improvement in the average performance (the benefits) is higher than the sum of the dollar amount of the applied I/D pay adjustments that was calculated in step a). This implies that the I/D program is delivering the desired outcome (higher benefits than cost).

2. Analyses of the costs and benefits of the MDOT I/D program for each pavement type could be conducted. This can be accomplished using the same three steps as in item 1 above except that the pavement projects in each of Pools A and B of item 1 are divided into four groups. One group per pavement type (flexible, JPCP, JRCP and composite pavements). After establishing the four groups, perform the above stated three steps analyses of items a, b and c for each pavement type.
3. Analyses of the costs and benefits of the I/D program for each fix type and for each pavement type could be conducted. This can be accomplished using the same three steps as in item 1 above except that the pavement projects in each of the eight groups of step 2 are divided into several subgroups, one subgroup per pavement fix type. After establishing the subgroups, perform the above stated three steps analyses of items a, b and c for each pavement and fix type.
4. The effects of various I/D payments/penalties expressed as percentages of the total paving material costs could be determined.
5. Analyses of the cost and benefits of each specific provision (pay item) of the MDOT I/D program could be conducted if, and only if, data regarding the specific I/D provision (item) for which pay adjustment was applied could be found in the MDOT data files especially those files that were not searched during the course of this study.
6. The relationship between pavement performance and the specified ranges of each of the I/D provision for which pay adjustments were applied could be determined if, and only if, all of the following data can be located:

   a. The MDOT's QA test results.
   b. Reference location along the pavement where each specified range of the I/D provision was satisfied and the specified pay adjustment was applied.
   c. The initial ride quality index (RQI) – RQI for which I/D payments/penalties were made.

4.3 RECOMMENDATIONS

Based on the findings of this Phase I study, the research team strongly recommends the immediate implementation of the following items:

1. For each pavement project, store all the project data from inception to the end of construction in a database accessible to all users. This would allow all potential users to access the data and information to conduct the necessary analyses. It is estimated that the cost of the implementation to be insignificant since projectwise database

already exist and the data are currently collected and kept on different paper files. Indeed, the implementation would decrease the cost of papers, make data retrieval and storage easier, save substantial staff time, make MDOT greener, and decrease the size of the required storage area for paper copies.

2. Convert the existing location reference system (control section, milepoint, and road number) to a geographical information based system (GIS). The GIS could be used to link different data files of the same pavement project and would increase the accuracy of identifying the boundaries of a pavement section. Once again, the expected cost of the implementation is insignificant since GIS is currently used by the department.
3. For each pavement project, establish electronic links between all the data files of that project. Such links could be based on a common reference location system (GIS).
4. For each pavement project with I/D provisions, document the reference locations of all test results that satisfies or failed the specified ranges of the I/D provision. Further, document the locations for which pay adjustments were applied.
5. Continue the I/D study by funding a second phase to analyze the benefits and costs of the I/D program.
6. Explore the possibility of adding I/D provisions for the lower pavement structural layers (base and subbase), they affect pavement performance.

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APPENDIX A
LITERATURE REVIEW

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LITERATURE REVIEW

A.1 INTRODUCTION

The highway sector in the USA and the rest of the world is perhaps the most conservative segment of the construction industry. Although highway contractors have implemented many new construction technologies, until recently, the contracting methods have basically remained the same. After the designs of highway projects were completed and approved, State Highway Agencies (SHAs) have traditionally awarded them to the lowest bidders. This approach, while providing a level ground for contractors, has its limitations. For example, sometimes, the method may not emphasize product quality and other factors that affect long-term pavement performance.

Since the 1980s, rehabilitation, resurfacing, reconstruction, or restoration work has characterized the majority of the highway construction projects. These types of projects require a high-quality product and timely completion to minimize any negative impacts (such as safety, traffic delays, and economic loss) to the traveling public. The above requirements and the limited available resources for highway construction and maintenance accelerated the search for alternatives to the traditional lowest bidder approach. Most SHAs modified their quality assurance (QA) programs and some included in the pavement project proposals, specifications for incentive/disincentive (I/D) pay adjustments. Over time the attributes of I/D programs used by SHAs have been expanded to include ride quality, early completion, material quality and so forth.

A.2 MDOT PRACTICE

In the beginning, the I/D provisions used by the Michigan Department of Transportation (MDOT) addressed extra payments/penalties for early or late finish of paving projects. In February 2000, MDOT completed an evaluation of the use of early completion clauses on 26 projects let and completed in 1998 and 1999. The average I/D pay amount for these 26 projects was $18,500 (about 1.5% of the contract amount) and the average project user delay savings was estimated at $610,500. Results of the evaluation indicated that 65% of the 26 projects were completed early, 12% were completed on time and 23% were completed late. MDOT found that the average completion time of pavement projects with early completion incentives was 19% less than similar projects without I/D provisions for early completion although the contracts for the latter projects include expedited schedule clause requiring the contractor to work a six calendar-day week.

Special I/D provisions for ride quality were included in some MDOT project contracts. Later, special I/D provisions for material quality (such as strength, density, asphalt contents, etc.) were included. These special I/D provisions were dynamic in nature and they were changed from one year to another. The special I/D provisions included specified acceptance levels, the pay scale and the pay items (19). The main objective of these special I/D provisions was to get the contracting community to employ different and innovative techniques to improve the paving operation, and therefore improve the long term pavement performance. These efforts have precipitated the first performance based contract project for the rehabilitation of a 5.5 mile long segment of M115 in Clare County, Michigan and the replacement of the superstructure on two bridges. The project was let in 2007 and was scheduled for completion in late 2008.

Like MDOT, other State Highway Agencies used I/D provisions and specifications to improve pavement performance. Their practices and the terminologies used in the provisions are summarized in the next section.

A.3 GENERAL PRACTICE

Most State Highway Agencies and Departments of Transportation, including MDOT, have used bonus payment systems or I/D programs for a number of years in order to improve project construction quality. The envisioned benefits of the I/D programs include improved workmanship by encouraging contractors to apply appropriate Quality Control (QC) measures. Most, if not all, SHAs have learned from long-term experience that failure to satisfy material and construction specifications, in most cases, results in premature failure of some of the pavement components (17). Hence, since the late 1950s and early 1960's, SHAs became aware of the importance of developing and implementing Quality Assurance (QA) programs to ensure satisfactory or acceptable quality of materials and pavement construction. The contents of QA programs have evolved over time, and currently most SHAs implement third or fourth generation QA programs. Some QA programs include QC components only, whereas others contain QC and independent assurance (IA) components. The process or procedures used in the implementation of QA programs vary substantially from one SHA to another. Such variations are related to many issues including (14):

1. The number of factors or attributes (such as early finish, ride quality, material quality and so forth) and their levels used in the QC components of the QA program for acceptance purposes.
2. The test methods, frequencies, and sample locations included in the QC.
3. The levels of risks used for acceptance (no pay adjustment), rejection (no pay adjustment), and for incentives/disincentives (pay adjustment).
4. The I/D pay schedule or rates included in the project specifications.
5. The entity (whether a contractor or the agency) that conducts the QC tests and the method of verification of the test results.
6. The method by which the independent assurance component of the QA program is administered.

The above six issues are addressed in the National Cooperative Highway Research Program (NCHRP) Synthesis 346 (14) as follows: "The ways these issues have been addressed reflect the evolutionary process that the QA programs have undergone over the last thirty years. Some of the major changes that have taken place emerged from title 23, part 637, Code of Federal Regulations (23 CFR 637), the Federal Highway Administration (FHWA) "Quality Assurance Procedures for Construction." The 23 CFR 637 regulations that were adopted in 1995 require, among many other construction related issues, that each SHA develop a QA program for the National Highway System under their jurisdiction.

In the NCHRP Synthesis 346, forty-five SHAs were surveyed regarding their I/D specifications, I/D pay items, and QA programs. Results of the survey are summarized below.

Regarding pay adjustment provisions for HMA:

- Thirty-nine SHAs use pay adjustment provisions
- Six SHAs use an accept/reject plan
- No single agency uses only incentive clauses, whereas nine agencies use only disincentive clauses, and thirty-two use both (14).

Relative to the type of QA programs for hot-mix asphalt (HMA) (14):

- Two SHAs use material quality and methods provisions.
- Twenty-one SHAs use QA programs with the contractor controlling the quality and the agency performing the acceptance tests (QC).
- Twenty-five SHAs use QA programs with the contractor controlling the quality and the agency using contractor test results in the acceptance division.

For asphalt pavement reconstruction and rehabilitation, the attributes that are used by SHAs for QC and acceptance of HMA vary from one agency to another. Based on their responses to the NCHRP questionnaire, the number of agencies using the specified attributes for QC and acceptance are listed in Table 2.1 (14):

Table 2.1 Attributes used for QC and acceptance of HMA

Attributes	QC	Acceptance
Asphalt content	40	40
Gradation	43	33
Compaction	28	44
Aggregate fractured faces	25	23
Air voids	20	26
Voids in mineral aggregates	26	23
Voids filled with asphalt	19	13
Asphalt film thickness	13	22
Ride quality	16	39
Based on responses from 44 SHAs		

Likewise, the SHAs were surveyed regarding Portland cement concrete pavements (PCCP). Their responses are summarized below (14).

Regarding pay adjustment clauses:

- Twenty-eight SHAs use I/D pay adjustment clauses
- Seventeen agencies use accept/reject plans
- One agency uses only incentives, twelve use only disincentives, and sixteen use both

Regarding the PCCP QA programs (14):

- Fifteen agencies use material quality and methods provisions
- Eleven agencies perform QC testing for acceptance.
- Sixteen agencies use QA programs with the contractor controlling the quality and the agency performing the acceptance tests (QC).
- Thirteen agencies use QA programs with the contractor controlling the quality and the agency using contractor test results for acceptance.

For concrete pavement reconstruction and rehabilitation, the attributes that are used by SHAs for QC and acceptance of PCCP vary from one agency to another. Based on their responses to the NCHRP questionnaire, the numbers of agencies using the specified attributes for QC and acceptance are listed in Table 2.2 (14):

Table 2.2 Attributes used for QC and acceptance of PCCP

Attributes	QC	Acceptance
Air content	25	38
Thickness	14	36
Slump	24	33
Cylinder strength	18	31
Gradation	25	26
Beam strength	14	18
Water-cement ratio	12	16
Aggregate fractured faces	7	6
Sand equivalence	0	3
Permeability	0	3
Core strength	0	2
Ride quality	1	15
Based on the responses of 40 SHAs		

In the 1970s the concept of incentive pay clauses (pay adjustment) for product quality that was exceptionally better than required by the specifications arose amongst many SHAs. This concept was complementary to the disincentive pay clauses previously used for a product of which quality did not meet specifications. According to a research study conducted by the Oregon State Highway Division and Oregon State University in 1979, the Illinois Department of Transportation was the only agency to provide a bonus (incentive) payment for high quality and uniform work. Most SHAs applied a negative pay adjustment for construction and material qualities that did not meet the specifications (3). The incentive and disincentive payments encouraged contractors to apply appropriate

QC measures to ensure that the finished product quality was equal to or exceeded the specified quality levels.
The rationale of the SHAs for using incentive payments is that the small additional cost of good QC practices spent in advance is better than being faced with the anticipated future costs of poor quality construction, which may lead to premature failure of pavements, excessive maintenance repairs and possibly unsafe driving conditions (14). For example, a statistical review of fifty pavement projects in California, it was determined that the costs of projects with I/D specifications increased by approximately three percent. Analysis of the QC test data from these projects indicated that the increase in cost is more than compensated for by the projected reductions in future rehabilitation costs (2).

To this end, the SHAs and Transportation Departments in other countries use various terminologies in their I/D programs. For the benefits of the reader, these terminologies are captured in the next section.

A.4 TERMINOLIGIES FOR I/D

The term incentive/disincentive (I/D) is not unique, nor it is universal. Several terminologies have been used to express different I/D clauses. These include I/D, liquidated damages, and lane rentals. A contract provision that is called “disincentives” in one SHA might be called “liquidated damages” in another. Regardless of the terminology used, there is a basic and single principle included in every type of I/D clause. Contractually, the clause states that the payment amount is contingent on variations in the outcomes. The simplest clause in a construction contract specifies the work to be performed and the price to be paid for it, leaving claims attributed to variations from the uniquely specified outcomes to be settled through administrative or legal processes. Nevertheless, the various terminologies used are summarized below.

Incentives/disincentives (I/D)

Construction specifications containing I/D clauses are considered end-result specifications. End-result specifications require the contractor to take complete responsibility for producing and placing a product. The SHA’s responsibility is to either accept or reject the final product or to apply a price adjustment appropriate with the degree of compliance with the specifications (1, 5). The pay adjustments may include incentives, disincentives or both. For example, for late or early completion, the disincentive specification dictates a payment reduction, typically assessed on a per-day basis, for the tardy completion of construction or of some intermediate milestones. The incentive specification, on the other hand, dictates a bonus, also typically assessed on a per-day basis, for the early completion of construction or of some intermediate milestones. The specifications often set a cap on the size of the incentive payment but not on the disincentive reduction. Since 1984, I/D specifications have been acceptable for all Federal Aid Highway projects. Currently, the FHWA suggests that the I/D amounts be based upon estimates of items such as traffic safety, traffic maintenance, and road user delay costs. The I/D specifications may include pay adjustment for material quality and for pavement smoothness (ride quality) (19).

Liquidated Damages

Liquidated damages are equivalent to disincentive payments; they do not include incentive payments. In general, liquidated damages are related to administrative, engineering, supervisory, and inspection costs, and other expenses that the agency incurs due, for example, to late project completion. Typically, liquidated damages do not consider the cost impact on the road users.(19, 29).The most common type of liquidated damage specifications are disincentives for late project completion. A typical liquidated damage clause specifies that payment reduction be assessed on a per day basis. Finally, liquidated damages can be applied at interim milestones (15).

Lane Rentals

The lane rental concept was first developed and implemented by the British Department of Transport in 1983. The lane rental clause assesses a rental fee against the contractor, typically on a per-lane per-hour basis, for the length(s) of time that a contractor closes one or more lanes of an existing road. A fee based on the estimated hours of closure is incorporated into the contract specifications, so that if the work is completed on time the contractor will be paid the bid price. The user cost and/or the impacts of traffic redistribution due to traffic disruption form the basis for the lane rental fee (19, 23, 25). Typical projects in which lane rentals are often implemented include pavement joint repair, replacement of overhead signs, and paving (15).

Between 1984 and 1989 the British Department of Transport implemented lane rental contracts on 100 projects at a total contract price of $500 million. They estimated that more than 2400 days of lane closure were saved compared to conventional contracts, which represents economic savings of approximately $100 million. The total bonus cost (incentive) was about $16 million or 3.2 percent of the total contract price of the projects (4).

Lane rental has the highest potential for reducing lane occupancy during construction, especially on projects with high-traffic volumes. The Oklahoma Department of Transportation has adopted the “Construction Lane-mile Rentals” policy as common practice. The practice was initiated to reduce user delay by encouraging contractors to work during nonpeak hours and to minimize the length of work zone closures. Limiting the length of work zones increases the public’s acceptance of the work zone, because they no longer see miles of work zones without construction activity. Similarly, the Oregon Department of Transportation has a lane rental specification allowing lane rental in 15 minute increments, with charges as high as $50,000 per lane per hour during peak use periods, with no fees during nighttime hours (13).

The Minnesota Department of Transportation (Mn/DOT), has also implemented the lane rental concept into a few of its pavement projects and the benefits of this concept as observed by field personnel include (9):

- Contractors were faster at taking down lane closures
- Contractors were required to think more about reducing contract time during the bidding process
- Inspectors saw a reduction in lane closures where no/minimal amount of work was being done
- Incentives for limited lane rentals encouraged contractors to reduce lane closure times

Please note that according to members of the Research Advisory Panel (RAP), MDOT employs lane rental on many projects. However, in the project records that were searched during this study, no information were found documenting the procedure or the provisions used.

The most commonly used attributes in I/D, liquidated damages, and lane-rental programs are summarized below.

2.2 ATTRIBUTES OF I/D PROGRAMS

A given I/D program may include one or more categories of attributes. In general, the three categories used by most SHAs are early completion, ride quality and paving material quality. These are summarized below.

Early Completion

It has been determined that traffic volumes are continuing to rise on the majority of roads throughout the country. With the rising traffic volumes, highway capacities during peak hours of the day are nearing capacity. Disruption to the traffic flow due to road construction during these peak hours can cause high levels of user costs (delay, extra fuel cost, wear and tear, etc.). While the level of user costs is difficult to quantify, it is a national consensus that it needs to be reduced as much as possible. For early completion programs, SHAs set I/D payments in an attempt to reward the contractor with an amount that is equal to the benefit of early completion or the cost of delayed completion (18). In the summary of the NCHRP Project 20-7, it is stated that contractors and the highway agencies in favor of awarding early completion bonuses believe that the amount assessed against the contractor for late completion should equal that for early completion (16).

Ride Quality

The ride quality of a pavement can be defined as the level of comfort experienced by the passengers of a vehicle as it traverses the pavement at the posted speed limit. Equipment such as the California profilograph, regular straightedge, profilometer, and rolling straightedge are most commonly used for measuring pavement smoothness or ride quality (21). Numerous studies from the Federal Highway Administration (FHWA), National Cooperative Highway Research Program (NCHRP), and the National Asphalt Pavement Association (NAPA) have found that pavements built smoother tend to last longer. The main reason is the increases in the dynamic loads that are caused by rougher pavements, which lead to shorter pavement life (22, 30).

The two most commonly used pavement roughness indices are the International Roughness Index (IRI) and Profilograph Index (PrI). The IRI can be calculated from the longitudinal pavement profile measured by any profiler calibrated to the outputs of the quarter car simulator. The PrI is based on profilograph measurements of the longitudinal profile of a pavement section. Computer programs are then used to compute the PrI. The PrI is determined by counting the number of locations along a pavement section where the profile trace falls outside a specified limit. Both IRI and PrI are reported in units of inches/mile or meters/kilometer and are collected in either one or both of the wheelpaths within a pavement lane (24).

Some of the other smoothness indices used by SHAs include (24):

- RN: Ride Number (used by Florida and New Hampshire DOTs for HMA specifications)
- MRN: Mays Ride Number (used by Arizona and South Carolina DOTs)
- CSI: Cumulative Straightedge Index (used by North Carolina DOT for HMA specifications)
- RQI: Ride Quality Index (used by MDOT for both asphalt and concrete pavement specifications)

The application of ride quality I/D specifications for either flexible or rigid pavements motivate the contractors to construct the pavement to a predetermined desired smoothness. Most SHAs use ride quality incentive specifications and virtually all SHAs require that the contractor either correct a pavement that doesn’t meet a specified smoothness level or accept a pay reduction (disincentive). For the SHAs which do use ride quality I/D, pay adjustments generally take the form of either a lump-sum dollar amount for each lot, or a multiplier applied to the contract unit price paid for the paving material (24). The I/D payments for pavement smoothness in current specifications are based on subjective judgment. The extent to which they actually reflect cost benefits (or lack thereof) is unknown. It has been suggested that the I/D should be rationally based on the increase or decrease in future costs that will be incurred by the SHA and by the users over the life of the pavement (22). Further, most SHAs permit diamond grinding for correction of both PCC and HMA surfaces to achieve desired smoothness specifications, while others require full removal and replacement or additional overlay for correction of HMA pavement.

Material Quality

The primary goal of a highway quality assurance (QA) program is to produce pavements that will provide adequate service throughout their intended design lives with minimal maintenance. Therefore, several SHA’s incorporate material quality I/D specifications into their construction contracts. The material quality I/D specifications vary amongst the

SHAs and depend upon the pavement type (asphalt or concrete). Some of the most commonly used parameters include:

Asphalt pavements

- Density
- In-place air voids
- Asphalt content
- Aggregate gradation
- Voids in mineral aggregate (VMA)
- Thickness

Concrete pavements

- Thickness
- Air content
- Slump
- Strength
- Gradation
- Water-cement ratio

Most SHAs express the I/D pay adjustment rates as a percentage of the unit bid price. The total I/D pay adjustment amount is then calculated as the product of the specified rate and the appropriate quantity. While this material quality I/D pay adjustment rates approach becomes more popular amongst SHAs, there is no consistent practice regarding the magnitude of the pay adjustment rates and their relationships to long term pavement performance. Therefore, there is a need for a method to relate the as-built material quality to the actual pavement performance (28).

A.5 I/D ATTRIBUTES VERSUS PAVEMENT PERFORMANCE

To increase the benefits of the I/D program regarding material and ride quality, the specifications must be related to long-term pavement performance. Performance-Related Specifications (PRS) describe the desired level of material and construction quality factors that have been found to correlate with fundamental engineering properties that affect and predict long-term pavement performance (8). These factors are amenable to acceptance testing at the time of pavement construction. PRS are difficult to develop, but offer the ideal parameters for I/D payments that result in the ultimate benefits to the agency by decreasing the life cycle cost (3, 27).

PRS are intended to identify the level of quality providing the best balance between cost and performance. Typical material parameters that can be used in PRS include asphalt content, density and strength. Presently, the use of PRS in the USA is limited. The NCHRP synthesis 212 reports that in 1995 several performance-related federal and state projects were underway and that only the New Jersey DOT has implemented PRS for PCC pavements only (12). Subsequent to the NCHRP report, several studies were initiated to develop PRS for asphalt concrete pavements. NCHRP and FHWA funded a five-year study (Westrack) to develop PRS for asphalt concrete pavements using the

Westrack facilities. The study, which was completed in February 2000 included PRS based on the HMA volumetric factors only. Questions have been raised regarding the broad applicability of these PRS given that all performance data resulted only from the testing in Nevada. It is expected that future reports will resolve some of these issues. In the mean time, the use of the Westrack-based PRS would require substantial field calibration (19). In discussions about the future direction of PRS, it was stated that PRS, when correctly applied, could identify the level of quality that provides the best balance between cost and performance and ensure the attainment of that level in the constructed pavements (18).

In Canada, the agencies that have implemented PRS include the highway departments of British Columbia, Alberta, Quebec, New Brunswick, Nova Scotia, Public Works and Government Services Canada, and the Department of National Defense. Most of the agencies with the exception of Quebec have only recently implemented a PRS system and are using it on a limited number of projects. In Quebec, PRS are included in all of their major pavement construction and rehabilitation contracts. Additionally, Quebec has indicated that it is very difficult to evaluate the effect of implementing PRS on the service life, construction costs, and maintenance requirements on the pavements. However, the general consensus is that the implementation of PRS have increased initial construction costs and reduced the variability in pavement construction, which would likely result in an increased pavement life and reduced maintenance costs (7).

A.6 OTHER CONTRACTING METHOD - WARRANTY SPECIFICATIONS

A warranty specification is a type of performance-based contract in which the SHA specifies pavement performance only and the contractor warrants the pavement for performance over a specific period of time (24). During the warranty period, the contractor is responsible to repair, at their own expense, any pavement defects that exceed the specified thresholds. This type of warranty assigns a large portion of the pavement performance risk to the contractor. Traditionally, within the United States construction contracts usually require the contractor to provide a warranty for a pavement project for only one year after project completion, although the design life of most pavements is much longer than one year. Therefore, SHAs are increasingly requesting longer term warranties (6).

Examples of the pavement performance thresholds for a five year warranty specification, used by the Indiana Department of Transportation include (24):

- IRI – 133 inches/mile
- Rut depth –0.375 inches
- Surface friction number – average of 35 and no single section below 25
- Transverse cracking – Severity 2 as defined by Indiana DOT
- Longitudinal cracking – 18 ft per 500 ft pavement section

Warranty specifications usually specify performance over two to seven years and have been specified for up to twenty years. Some European highway agencies have been using asphalt pavement warranties for more than forty years, but they have been used sparingly in the United States. This is mainly due to the industry being reluctant to change and due to the severe legal restrictions that the Federal Government and the bond companies place on warranty use (26). However, the Wisconsin DOT has occasionally used a five-year asphalt pavement warranty. After examination of case study data from their warranty program it was determined that the data shows a significant improvement in the quality of construction when comparing ride and distress values for warranted and non-warranted pavement sections (10).