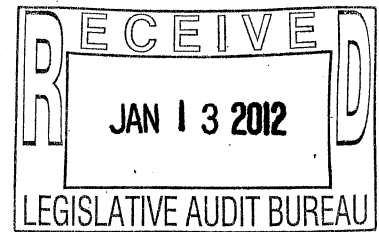


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January 13, 2012

Senator Robert Cowles
Representative Samantha Kerkman,
Co-Chairpersons
Joint Legislative Audit Committee
State Capitol
Madison, Wisconsin 53702

Dear Senator Cowles and Representative Kerkman:

The Department is pleased to present to the Joint Legislative Audit Committee a report titled *Report to the Joint Legislative Audit Committee on the Cost Effectiveness of Warranted HMA Pavements*. The Legislative Audit Bureau (LAB) recommended that the Department prepare and submit a report on the cost effectiveness of asphalt pavement projects constructed with warranties. This recommendation was contained in LAB's Letter Report titled *Construction and Inspections of Asphalt State Highways*, dated March 2011.

If there are any questions, comments or concerns with the report or information contained within, please contact Steve Krebs, Chief Materials Management Engineer at 608 246-7930.

Sincerely,

A handwritten signature in black ink, appearing to read "Mark Gottlieb".

Mark Gottlieb, P.E.
Secretary

✓ Cc: Joe Chrisman

Report Number: WI-01-12

**Report to the Joint Legislative Audit Committee on the
Cost Effectiveness of Warranted HMA Pavements**

FINAL REPORT



January 2012

Report to the Joint Legislative Audit Committee on the
Cost Effectiveness of Warranted HMA Pavements

Research Study # WI-11-01

FINAL REPORT

Report # WI-01-12

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January 2012

This study was conducted by the Materials Management Section, Bureau of Technical Services, Division of Transportation System Development, of the Wisconsin Department of Transportation. The Federal Highway Administration provided financial and technical assistance for this research activity. This publication does not endorse or approve any commercial product even though trade names may be cited, does not necessarily reflect official views or policies of the agency, and does not constitute a standard, specification or regulation.

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16. Abstract <p>The Wisconsin DOT warranty specification, in use since 1995, allows paving contractors flexibility in the selection of materials and methods used in construction. For a five-year warranty period following construction, the contractor guarantees the condition of the pavement. This study compared the cost and performance of hot mix asphalt (HMA) pavements constructed under warranty to pavements constructed using traditional contracting methods.</p> <p>The analyzed costs included materials and construction expenditures, staff costs for time spent reviewing pavements and administering the warranty specification, and maintenance and repair costs through 2011. The DOT's cost for warranted pavements was very similar to that for nonwarranted pavements. The average total project cost for nonwarranted and warranted pavements was \$57.18 and \$57.07 per ton of HMA mixture, respectively.</p> <p>Pavement performance was evaluated using Pavement Distress Index (PDI) and International Roughness Index (IRI). Average PDI values were comparable for nonwarranted and warranted pavements. Warranted pavements had slightly better ride quality, but pavement smoothness was acceptable for all analyzed pavements. Future rehabilitation schedules were also similar for nonwarranted and warranted pavements.</p> <p>The HMA pavement warranty specification is a cost effective contracting method for the Wisconsin DOT.</p>			
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Executive Summary

This report provides the results of an evaluation of the Wisconsin Department of Transportation's hot mix asphalt (HMA) pavement warranty program. This study was motivated by a request from the State Legislative Audit Bureau to examine the cost effectiveness of the warranty program.

The Department's warranty program was initiated in 1995. This program operates under the authority and approval of the Federal Highway Administration's Special Experimental Program -14. The Department has built 230 projects using this delivery method.

A randomly selected group of warranted HMA pavements constructed between 2002 and 2006 was used for analysis. Seventy-three HMA pavements were constructed under warranty during this time period; 38 were evaluated in this study. A comparison group of 37 non warranted pavements was selected for analysis. The time period of 2002 to 2006 was chosen because multiple warranty projects constructed during this time period have developed early distresses. This brings into question their long term performance. Past reports have shown that warranted pavements have significantly better performance than their non warranted counterparts [1]. If the warranty program was not cost effective it would be demonstrated with projects constructed during this time period.

All Department costs related to the construction, maintenance and repair of these pavements were evaluated. The following specific cost items were included: materials and construction, staff charges made during construction (DOT and consultant), maintenance and repairs through 2011, Regional administration staff time, routine distress surveys and special request surveys.

Results of the cost analysis showed that Department expenditures for nonwarranted and warranted projects were similar. The average total project costs were nearly identical: \$57.18 and \$57.07 per ton of HMA mixture for nonwarranted and warranted projects, respectively. The cost for Regional administration and pavement distress surveys was higher for warranted pavements than for nonwarranted pavements. However, this cost represented less than one percent of total project cost. Materials and construction were the greatest Department expense. For both contracting methods, approximately 85 percent of total project expenditures were for materials and construction.

Pavement performance of nonwarranted and warranted pavements was also compared. Performance indicators evaluated were Pavement Distress Index (PDI), which conveys overall pavement condition, and International Roughness Index (IRI), which measures ride quality. These data are collected biennially by the Department. Up to eight years of data were available for the analyzed projects.

Average PDI values were similar for nonwarranted and warranted pavements. After eight years in service, the average PDI for each pavement type was between 12 and 16; a pavement at this PDI level typically has many years of remaining service. There was a statistical difference in pavement smoothness when comparing the two contracting methods, with better ride quality noted in warranted pavements. However, the average IRI was typically less than 1.0 m/km (63 in/mi) for all pavements, which indicated good ride quality overall.

Future pavement rehabilitation costs and schedules were difficult to predict. The Regions provided estimates of the timing of future rehabilitation efforts, when available. Anticipated service lives were comparable for nonwarranted and warranted pavements.

In conclusion, for the pavements analyzed in this study, the cost and performance of nonwarranted and warranted pavements were very similar. While there are differences in the administration of warranted pavements, the HMA warranty program is a cost effective contracting method for the Department. As long as warranty pavements remain cost effective, the Department will continue their use.

1. Background

The Wisconsin Department of Transportation pavement warranty program, established in 1995, is an alternative contracting method that transfers responsibility to the contractor for some aspects of design and construction. The Department stipulates the structural design of warranted pavements, but the contractor is allowed flexibility in selection of materials and construction methods. Responsibility for pavement performance is shifted to the contractor for a warranty period of five years.

The standard nonwarranted contractual practice still accounts for the majority of pavements constructed in Wisconsin, but the number of projects let under warranty has increased over the past several years. The warranty specification and tracking programs have simultaneously evolved. Both hot mix asphalt (HMA) and concrete pavements are constructed under warranty, but it is a more common practice in the HMA pavement program. [1]

In 2009, the Department published a cost and performance evaluation of its HMA pavement warranty program. The study concluded that over the 12-year analysis period (1995-2007), warranted pavements had better performance and cost less to construct and maintain than nonwarranted pavements. The warranty program was therefore determined to be cost effective for the Department. [1]

In March 2011, the State's Legislative Audit Bureau (LAB) published a review of the Department's warranty and quality assurance programs. It also concluded that warranted pavements had less distress than standard contract pavements. However, it raised concerns regarding the management and cost of the warranty program. It was recommended that the DOT reevaluate the cost effectiveness of its HMA warranty program. [2]

The purpose of this study was to conduct a comprehensive analysis of all costs related to warranted and nonwarranted HMA pavements. Costs to the Department during construction, for the duration of the warranty period, and after the warranty's expiration were investigated and compared to costs of nonwarranted HMA pavements. Actual documented expenditures were considered whenever possible. Pavement performance was also included in the analysis.

2. Methodology

2.1 Project Identification

This study investigated costs associated with warranted and nonwarranted projects constructed between 2002 and 2006. This time period was selected for several reasons:

1. The five-year range provided a comprehensive assessment of the warranty program;
2. The warranty period for projects constructed during this time period expired between 2007 and 2011, allowing for analysis of final warranted performance data; and
3. Projects built in 2002 were nine years old at the time of the analysis, which is half of the expected pavement service life for new HMA pavement construction.
4. Multiple warranty projects constructed during this time period have developed early distress.

A total of 73 warranted pavements were constructed between 2002 and 2006 (Table 1). Half of the projects constructed each year were analyzed, for a total of 38 warranted projects. The 38 warranted projects were randomly selected.

Table 1. Number of Warranted HMA Projects Constructed, 2002 to 2006

Region	2002	2003	2004	2005	2006	Total
Northwest (NW)	3	2	5	8	13	31
Southwest (SW)	2	3	5	3	5	18
Northeast (NE)	3	3	3	2	3	14
North Central (NC)	2	1	0	0	3	6
Southeast (SE)	1	0	1	1	1	4
Total	11	9	14	14	25	73
Analysis Projects	6	5	7	7	13	38

A comparison set of 38 nonwarranted HMA projects was selected for analysis. These projects were not randomly selected; rather they were chosen to have locations, pavement types, functional classifications and total HMA mixture tonnages similar to the 38 warranted projects. This list was eventually reduced to 37 projects, as one selected pavement was constructed with concrete and was therefore not suitable for analysis.

The nonwarranted and warranted analysis projects analyzed in this study are listed in Table 2 and 3, respectively. Additional identification information for these projects is available in Appendix 1.

Table 2. Nonwarranted Analysis Projects

Study ID	Region	County	Highway	Const. Year	Type*	Func. Class†	HMA Tons‡
1	NW	Dunn	STH 40	2004	N	M	42,693
2	NC	Langlade	STH 55	2002	N	M	10,250
3	NC	Langlade	STH 64	2003	N	M	21,231
4	NC	Langlade	STH 52	2004	N	M	11,680
5	NC	Waushara	STH 21	2003	N	P	43,950
6	NC	Lincoln	STH 17	2006	O	M	33,470
7	NE	Oconto	STH 22	2002	O	M	12,500
8	NE	Outagamie	USH 45	2003	N	P	26,323
9	NE	Marinette	USH 141	2006	O	P	48,220
10	NE	Winnebago	STH 91	2004	N	M	44,733
11	NE	Outagamie	STH 55	2002	N	M	25,766
12	NW	Clark	STH 73	2002	N	M	74,150
13	NW	Bayfield	USH 2	2002	N	P	52,541
14	NW	Sawyer	STH 77	2003	N	M	27,811
15	NW	Sawyer	STH 70	2005	N	M	68,225
16	NW	Rusk/Sawyer	STH 27	2005	O	M	71,923
17	NW	Buffalo	STH 35	2005	N	M	23,240
18	NW	Trempealeau	USH 53	2005	N	M	41,890
19	NW	Taylor	STH 73	2005	O	M	37,779
20	NW	Sawyer	STH 77	2004	N	M	44,133
22	NC	Iron	USH 2	2006	R	P	64,100
23	NW	Bayfield	USH 63	2006	O	P	28,661
24	NW	St. Croix	STH 29/128	2002	N	M	25,154
25	NW	Burnett	STH 35/70	2005	O	M/P	17,802
26	NW	Washburn	USH 63	2004	O	P	14,103
27	NW	Barron	USH 63	2004	R	P	57,648
28	SE	Racine	STH 83	2004	N	M	41,251
29	SE	Waukesha	STH 164	2005	N	P	69,314
30	SW	Dodge	STH 28	2002	N	M	16,568
31	SW	Crawford	STH 27	2003	N	M	16,250
32	SW	Vernon	STH 131	2003	N	M	40,124
33	SW	Jefferson	STH 19	2006	N	M	25,631
34	SW	Crawford	STH 27	2004	N	M	8,667
35	SW	Sauk	STH 23	2005	N	M	24,860
36	SW	Monroe	STH 27	2006	N	P	69,288
37	SW	Grant	STH 81	2006	N	M	61,400
38	SW	Iowa	USH 14	2004	R	P	103,200

Notes: *N-Reconstruction; R-Reconstruction over rubblized concrete; O-Overlay

†P-Principal Arterial; M-Minor Arterial

Table 3. Warranted Analysis Projects

Study ID	Region	County	Highway	Const. Year	Type*	Func. Class†	HMA Tons‡
1	NC	Waupaca	STH 22	2002	N	M	5,990
2	NC	Oneida	STH 47	2002	N	M	56,050
3	NC	Forest	STH 32	2003	N	M	19,599
4	NC	Oneida	STH 17	2004	N	M	60,954
5	NC	Lincoln	USH 51 S	2006	R	P	60,595
6	NC	Vilas	USH 45	2006	O	P	3,826
7	NE	Winnebago	STH 26	2002	O	P	16,610
8	NE	Winnebago	STH 44	2003	N	M	62,900
9	NE	Marinette	USH 141	2004	O	P	17,340
10	NE	Marinette	STH 64	2004	N	M	33,493
11	NE	Kewaunee	STH 42	2004	N	M	44,000
12	NW	Jackson	USH 10	2002	N	P	53,688
13	NW	Douglas	USH 53	2002	R	P	77,854
14	NW	Buffalo	STH 37	2003	N	M	22,400
15	NW	Trempealeau	USH 10	2005	N	M	40,165
16	NW	Taylor	STH 13	2005	O	P	36,980
17	NW	Washburn	STH 77	2005	N	M	66,522
18	NW	Pierce	STH 29	2005	N	M	29,602
19	NW	Polk	STH 48	2005	N	M	49,560
20	NW	Barron	STH 48	2006	N	M	43,797
21	NW	Chippewa	USH 53	2006	R	P	111,080
22	NW	Burnett	STH 35	2006	N	M	54,123
23	NW	Pepin	STH 35	2006	O	M	18,601
24	NW	Douglas	STH 27	2006	N	M	51,480
25	NW	Clark	USH 10	2006	O	P	15,200
26	NW	Polk	USH 63	2006	O	P	12,959
27	NW	Polk	STH 35	2006	O	P	18,031
28	SE	Racine	STH 11	2004	N	P	48,030
29	SE	Washington	STH 33	2005	N	P	24,320
30	SW	Dodge	STH 60	2002	N	M	23,691
31	SW	Lafayette	STH 78	2003	N	M	17,419
32	SW	Dodge	STH 68	2003	N	M	2,900
33	SW	Dane/Columbia	STH 113	2004	N	M	25,301
34	SW	Rock	STH 67	2004	N	M	5,400
35	SW	Richland	STH 60	2005	N	M	38,895
36	SW	Dodge	STH 73	2006	N	M	42,904
37	SW	Grant	STH 133	2006	N	M	38,516
38	SW	Sauk	STH 23	2006	N	M	44,645

Notes: *N-Reconstruction; R-Reconstruction over rubblized concrete; O-Overlay

†P-Principal Arterial; M-Minor Arterial

‡Total of mainline and ancillary mixture

2.2 Data Analyzed in Cost Evaluation

To compare the cost to the Department for warranted versus nonwarranted HMA pavements, expenditures associated with the construction and administration items described below were collected for all analysis projects.

Materials and Construction

Actual bid cost data were collected from the Bid Express online bid tabulation system. Bid items included costs for both materials and construction. The following bid items were included in this analysis:

- Nonwarranted projects: HMA mixture, asphaltic material, tack coat, quality management program testing (material and density), density incentive
- Warranted projects: HMA pavement mainline, HMA pavement ancillary

Construction Staff Time

Labor costs were tabulated based on actual charges made to each analysis project's construction ID. [3] Charges made for construction activities and management were included for both consultant and DOT staff. DOT staff charges for materials testing were also included.

Consultant charges included overhead and benefit costs, while the available DOT costs were direct labor charges only. The DOT staff charges were therefore adjusted using multipliers that are updated annually by the Department's Office of Policy, Budget and Finance (OPBF) to more accurately compare consultant and DOT staff costs. [4] These multipliers are reported in Appendix 2.

Pavement Distress Review

The Department's Pavement Data Unit (PDU) is responsible for reviewing pavement distresses in the Wisconsin State Trunk Network (STN). All STN pavements are reviewed biennially using automated survey equipment. Warranted pavements are also reviewed at the beginning and end of their warranty periods. In addition, warranted pavements may be reviewed more frequently if the Region makes a special request.

The PDU was interviewed to determine how much staff time was spent reviewing the projects included in this analysis. The information was separated into time spent during routine distress review and special request reviews.

Administrative Staff Time

Regional staff were queried to determine how much time was spent on administrative tasks. These tasks included additional in-person pavement reviews, coordination of repairs and maintenance, and, for warranted projects, time spent in conflict resolution with contractors.

Pavement Maintenance and Repairs

Regions were asked to describe maintenance and repair work conducted by the Department for the analysis pavements. Estimated costs for these activities were reported.

Adjustments and Assumptions

Information collected in the "Pavement Distress Review" and "Administrative Staff Time" categories was reported in hours spent by DOT staff. An average DOT employee hourly wage was calculated using data sent from the OPBF. [3, 4] This wage was increased using the benefit and overhead multipliers listed in Appendix 2 and adjusted to 2011 dollars as described below. The final wage used in the cost analysis was \$72 per hour.

All cost figures were converted to 2011 dollars using consumer price index (CPI) and producer price index (PPI) data from the U.S. Bureau of Labor and Statistics. [5, 6] CPI data were applied to staff wages, and PPI data were used to adjust construction material costs. The CPI and PPI conversion values are provided in Appendix 2.

Costs for crack sealing and pavement seal coating were assumed to be \$5,000 and \$13,000 per lane mile, respectively, in 2011 dollars. These figures were based on Regional estimates and information provided by the Department's Materials Management Section. [7] It was also assumed that, unless otherwise noted by the Regions, nonwarranted pavements were crack sealed during their third year in service. As per the warranty specification, warranted pavements were also crack sealed once during the pavement's warranty period, at contractor cost.

2.3 Data Analyzed in Performance Comparison

The Department's PDU routinely collects information on the condition of STN pavements. The Pavement Distress Index (PDI) is used as an indicator of the overall level of distress present in the pavement. The PDI is reported on a scale of zero to 100, with zero indicating a pavement with no distress. The International Roughness Index (IRI) is a measure of pavement smoothness. It is reported in meters per kilometer (m/km) and inches per mile (in/mi).

The PDI and IRI are collected using the Department's automated survey equipment. Pavement surveys take place every other year; reviews are conducted in the western half of the state in odd years and in the eastern half of the state in even years. For PDI, one tenth-mile segment is reviewed for every one-mile roadway section. The IRI measurements are continuously monitored as the survey vehicle travels at highway speeds, and an average value is reported for each one-mile roadway section.

The PDI and IRI analyzed in this study were collected from the time of each project's construction through the most recently conducted survey. The most recent data available were from 2010 (eastern half of the state) and 2009 (western half). The 2011 PDI and IRI datasets were not available for review at the time of this study.

2.4 Statistical Evaluation

A non-paired t-test was employed to determine statistical difference between datasets analyzed in this study. For instance, this statistical test was used to determine if the total project cost data for nonwarranted projects were statistically different from the corresponding warranted project data. Datasets were defined as statistically different if the two-tailed p-value was less than 0.05.

2.5 Specific Considerations

The LAB report cited several specific points that were not considered in the Department's 2009 evaluation of pavement warranties. [1, 2] These points are outlined below, along with a description of how each was addressed in the current analysis.

The 2009 analysis did not include costs to the Department for warranted pavement repairs if the contractor was exempted from warranty work.

All costs to the Department were considered in the current study. Regions provided dollar amounts for work completed by Department and/or county forces during and after the warranty period. These costs were typically estimated by the Regions.

Long-term maintenance costs were not included in the 2009 evaluation.

For the current evaluation, the Regions were asked to provide information regarding all maintenance and repair activities performed and scheduled for the analysis projects. Costs for work completed or scheduled through 2011 were obtained and are incorporated in the analysis presented in Section 3.1. In most cases, the Regions could provide estimates for timing and type of future maintenance and rehabilitation, but not for associated project costs. Therefore, Departmental expenditures for these activities could not be included in the cost analysis. A qualitative analysis of future rehabilitation efforts was conducted as described in Section 3.4.

The number of special requests to the Department's Pavement Data Unit has increased for warranted pavements, and the cost to perform these requests is high.

The PDU provided a list of all special request surveys completed for the warranted projects analyzed in this study. The cost to conduct these surveys is included in the analysis presented in Section 3.1.

3. Results and Discussion

3.1 Cost Evaluation

The following cost categories were included in the evaluation. These costs are described in Section 2.1.

- Materials and Construction
- Construction Staff Charges - DOT and Consultant
- Maintenance and Repairs through 2011
- Regional Administration
- Pavement Data Unit - Routine Surveys and Special Requests

To provide a consistent platform for comparison, the above costs for a specific project were normalized to the total HMA mixture tonnage specified for that project. (See Table 2 and Table 3 for HMA mixture tonnages.) All costs discussed below are reported in dollars per ton of HMA mixture. Each analysis project's actual costs are listed in Appendix 3.

The sum of the costs listed above represents the total cost to the Department for each project. The total project costs are shown in Figure 1 below. The average total project cost was nearly identical for nonwarranted and warranted pavements: \$57.18/ton and \$57.07/ton, respectively.

The histogram in Figure 2 shows the distribution of total project costs. Most total project costs were between \$40/ton and \$60/ton. A significant number of nonwarranted projects (30 percent) fell in the \$60/ton to \$80/ton total project cost range, while 11 percent of warranted projects were in that cost range.

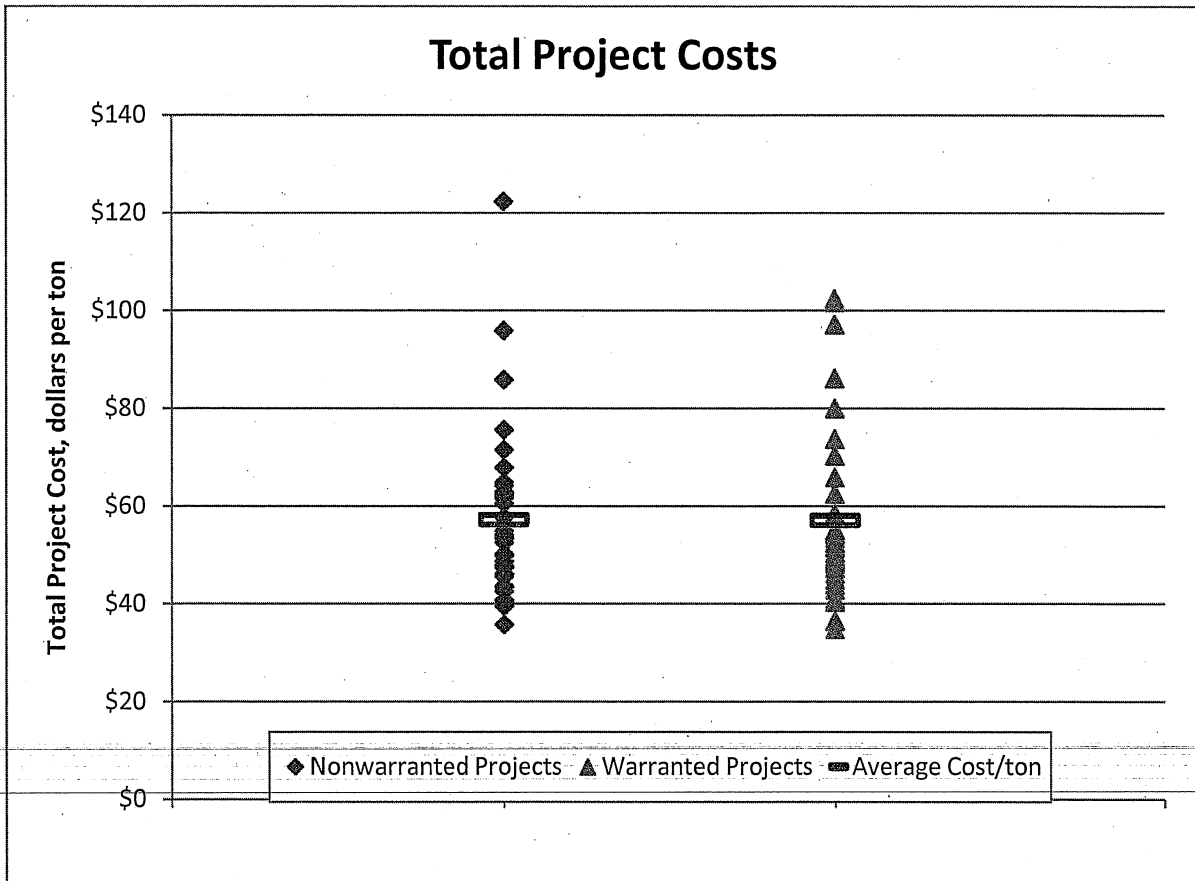


Figure 1. Total project costs for nonwarranted and warranted projects.

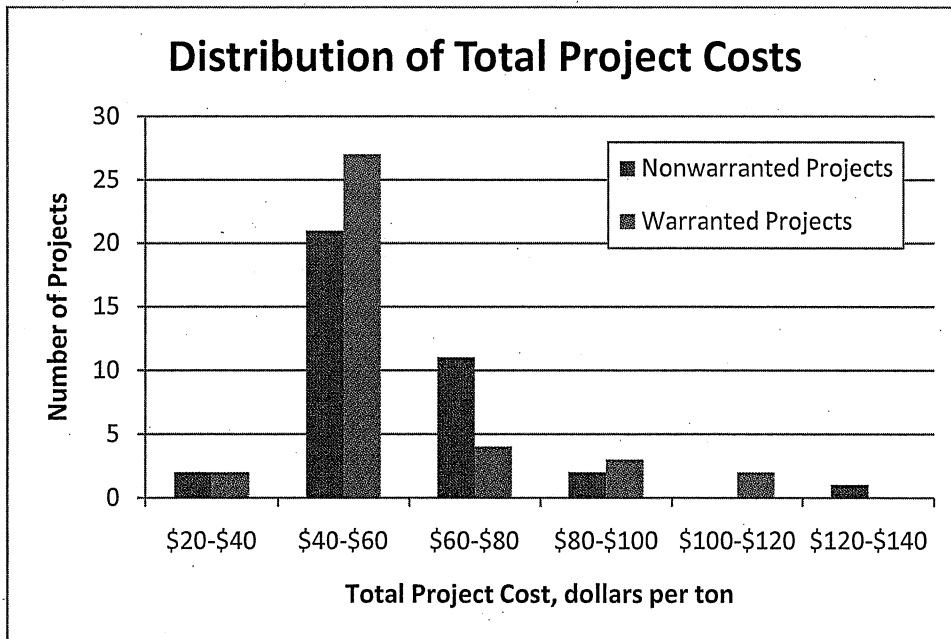


Figure 2. Distribution of total project costs.

Average costs for each of the categories listed at the beginning of this section are shown in Table 4. The data presented in Table 4 represent the average cost per ton in each category for the 37 nonwarranted and 38 warranted projects analyzed. (See Appendix 3 for each project's specific cost data.) The final column of Table 4 indicates whether the nonwarranted and warranted cost data were statistically different, according to the statistical evaluation described in Section 2.4. The data from Table 4 are presented graphically in Figure 3, which shows the percentage of total project cost of each component.

The costs associated with materials and construction were by far the greatest contributors to total project cost. On average, materials, construction and related incentives and quality management costs for nonwarranted pavement materials represented approximately 85 percent of the total project cost (Figure 3). There was not a statistical difference in materials and construction costs between nonwarranted and warranted projects (Table 4).

Charges made by DOT staff during construction were higher for nonwarranted pavements, but consultant staff charges were lower. Neither category showed a statistical difference between the two contracting methods (Table 4). In fact, the two staff cost categories combined represented 12 percent of total project cost for both nonwarranted and warranted pavements (Figure 3).

Maintenance and repair costs were, on average, higher for nonwarranted pavements. This was largely due to the cost of crack sealing those pavements. In comparison, warranted pavements were sealed once at a cost to the contractor during the warranty period. However, the statistical evaluation did not show a difference in maintenance and repair costs between nonwarranted and warranted pavements (Table 4).

In three of the cost categories, the average cost to the Department was statistically higher for warranted projects (Table 4). These categories were Regional Administration, Routine Surveys conducted by the PDU and Special Requests conducted by the PDU. However, these costs were very low compared to the remaining cost components; together they represented less than one percent of the total project cost (Figure 3).

The total project costs for nonwarranted and warranted pavements were not statistically different (Table 4). As noted previously, the average total project costs were nearly identical for the two contracting methods.

In summary, the overall cost to the Department for warranted pavement projects was very similar to the cost for nonwarranted projects. The maintenance and repair category showed a slightly lower cost for warranted pavements, but administration of the warranty program, along with additional distress surveys for warranted pavements, was more costly compared to nonwarranted projects.

Table 4. Average Project Costs, \$/ton

Cost Category	Nonwarranted	Warranted	Statistically Different?
Materials and Construction	48.10	48.40	No
Construction Staff Charges - DOT	5.03	3.88	No
Construction Staff Charges - Consultant	1.52	2.65	No
Maintenance and Repairs	2.48	1.84	No
Regional Administration	0.03	0.13	Yes
Pavement Data Unit - Routine Surveys	0.02	0.15	Yes
Pavement Data Unit - Special Requests	0.00	0.02	Yes
Total Project Cost	57.18	57.07	No

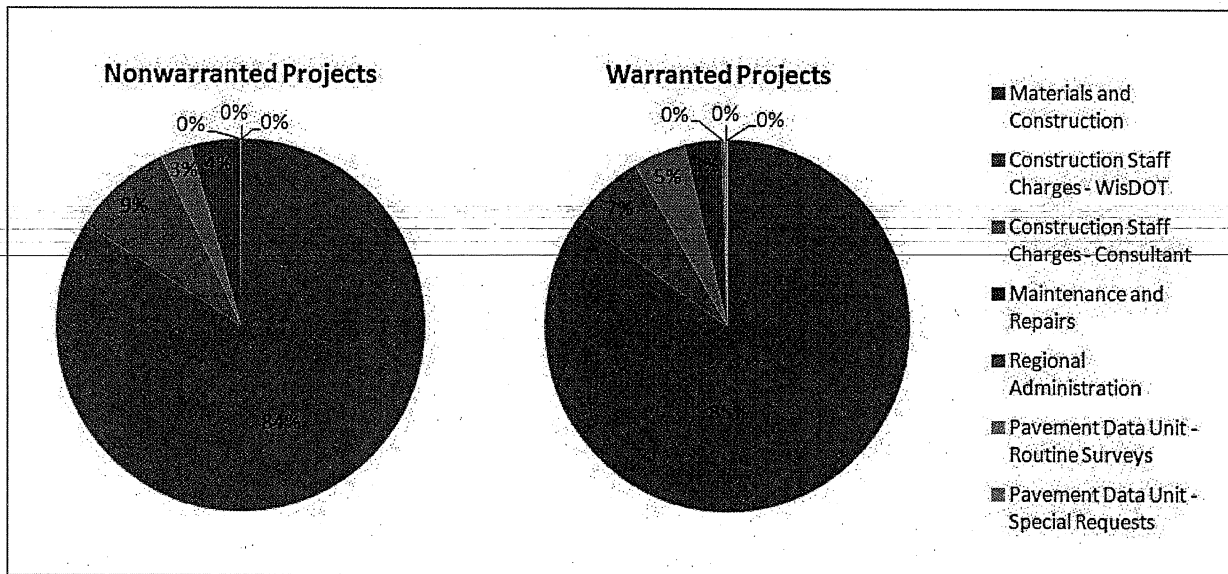


Figure 3. Percentage contribution of cost components to total project cost.

3.2 Warranty Administration Consultant Contract

In July 2011, the Department contracted with an independent consultant to coordinate many of the tracking and administrative duties previously assigned to Regional personnel. These duties include managing a database with information on all pavement warranties, coordinating with contractors to perform warranty work, analyzing warranted pavement distresses and providing technical support and guidance regarding these distresses. [8]

The intent of this contract was to create a unified system for tracking and managing the warranty program and to reduce the time spent by Regions managing warranted projects. Because it was not in effect when this study's projects were under warranty, the cost associated with this contract was not

included in the formal cost analysis presented in Section 3.1. However, the following calculation provides a rough estimate of the contract's cost impact to the Department.

The cost of the warranty administration contract in 2011 was \$133,184 for one year. The total HMA mixture tons paved annually between 2006 and 2011 ranged from 750,000 tons to 960,000 tons.¹ Dividing the contract cost by these warranted mixture tonnages results in a cost range of \$0.14/ton to \$0.18/ton:

$$\frac{\$133,184/\text{year}}{960,000 \text{ ton/year}} = \frac{\$0.14}{\text{ton}} \quad \frac{\$133,184/\text{year}}{750,000 \text{ ton/year}} = \$0.18/\text{ton}$$

These costs are conservative, as the warranty administration consultant is responsible for concrete and dowel bar retrofit pavement warranties, in addition to HMA warranties. The number of concrete and dowel bar retrofit pavement warranties is small.

The Regional staff time cost for warranted project administration was \$0.13/ton (Table 4). The consultant contract cost will replace a good portion of the Regional staff time cost; the exact impact is not yet known. Because Regional staff time will not be reduced to zero, the total cost of Regional staff time and the consultant contract will be higher than when the contract was not in place. However, the cost increase is not significant (the total cost will still be less than one percent of total project cost), and it is expected that the warranty program will benefit from more unified management under the consultant contract.

3.3 Performance Evaluation

To compare the performance of nonwarranted and warranted HMA pavements, the PDI and IRI performance indicators were evaluated. These values are described in Section 2.3. The PDI and IRI were gathered for all projects and sorted according to pavement age. The data were further classified by the type of HMA pavement; i.e., new pavement structure and HMA overlays of existing HMA pavement.²

The average PDI values are presented in Table 5. Average IRI values are presented in and Table 6 and

¹ The number of HMA warranties paved annually during that period ranged from 15 in 2011 to 29 in 2009. [9,10]

² None of the pavements analyzed in this study were HMA overlays of concrete pavement.

Table 7, with metric and English units, respectively. The data for PDI and IRI are also shown graphically in Figure 4 and Figure 5, respectively. In these figures, red data points represent the average PDI or IRI at a given age. The blue shaded areas show one standard deviation on either side of the average; this demonstrates the scatter of the PDI and IRI data and indicates an expected range of performance based on the analysis projects. For pavement ages where no blue shaded area is shown, the standard deviation was zero.

The results of statistical evaluations are also provided in Table 5, Table 6 and

Table 7. These results indicate whether there was a statistical difference in performance between nonwarranted and warranted pavements, according to the statistical evaluation described in Section 2.4.

Discussion - New Pavement

At most pavement ages, the difference in PDI between nonwarranted and warranted pavements was not statistically significant (Table 5). In addition, the plots in Figure 4-a/b show similar trends in the increase in PDI over time for both contracting types. There was more scatter in the warranted pavement PDI data, however, as indicated by higher standard deviation (Figure 4-b).

A statistical difference did exist in IRI between nonwarranted and warranted pavements, as noted in Table 6 and

Table 7, with warranted pavements exhibiting less roughness. This trend is also demonstrated in Figure 5-a/b. Although warranted pavements tended to be smoother, the average IRI values for both nonwarranted and warranted pavements were typically less than 1 m/km (63 in/mi). This indicates that the ride quality was satisfactory, regardless of contracting method.

The pavement ages for which a statistical difference existed for PDI were opposite to the ages where a difference existed for IRI (see Table 5 and Table 6/

Table 7). It is unknown why this was so.

Discussion - Overlay

Eight nonwarranted and eight warranted overlay pavements were analyzed in this study. A small number of data points were available compared to new pavement construction. The result was less consistent trends for PDI and IRI over time, as noted in Figure 4-c/d and Figure 5-c/d. In addition, there were several ages where no data existed for the overlay pavements.

There were several pavement ages where PDI was higher for nonwarranted pavements and some ages where it was higher for warranted pavements. There was a statistical difference in PDI at ages 2 and 4 (Table 5). However, given the small number of sample pavements in the overlay category, it was not possible to conclude that one contracting type resulted in better performance. In addition, the scatter of the data noted in Figure 4-c/d indicated that pavements constructed under both contracting methods could be expected to fall within the same performance range by their eighth year in service.

The average IRI value for warranted overlay pavements was typically lower than the IRI of nonwarranted overlay pavements (Table 6/

Table 7). There was a statistical difference in 3 out of the 7 pavement ages for which a comparison could be made. However, as noted for the new construction pavements, the average IRI values reported for the overlay pavements were generally within a range that indicated a good level of ride quality.

Table 5. Average Pavement Distress Index Values

Pvmt. Age	NEW PAVEMENT			OVERLAY		
	Non-warranted	Warranted	Statistically Different?	Non-warranted	Warranted	Statistically Different?
0	0.00	0.00	No	0.00	0.00	No
1	0.79	0.76	No	7.67	4.57	No
2	3.22	3.95	No	10.26	3.67	Yes
3	6.01	5.67	No	8.80	11.72	No
4	5.52	14.46	Yes	15.25	10.23	Yes
5	12.20	9.88	No	23.50	N/A	
6	6.81	12.73	Yes	10.00	20.43	No
7	12.29	15.47	No	N/A	N/A	
8	12.10	15.40	No	13.00	15.67	No

N/A - Data not available for pavements of this age.

Table 6. Average International Roughness Index Values, m/km

Pvmt. Age	NEW PAVEMENT			OVERLAY		
	Non-warranted	Warranted	Statistically Different?	Non-warranted	Warranted	Statistically Different?
0	0.84	0.67	Yes	1.04	0.73	Yes
1	0.86	0.72	Yes	0.87	0.76	Yes
2	0.84	0.78	Yes	0.72	0.65	No
3	0.87	0.81	Yes	1.02	0.82	Yes
4	0.96	0.92	No	0.81	0.78	No
5	0.94	0.82	Yes	1.44	N/A	
6	1.02	1.03	No	0.76	0.74	No
7	0.98	0.81	Yes	N/A	N/A	
8	1.02	0.90	Yes	0.90	1.00	No

N/A - Data not available for pavements of this age.

Table 7. Average International Roughness Index Values, in/mi

Pvmt. Age	NEW PAVEMENT			OVERLAY		
	Non-warranted	Warranted	Statistically Different?	Non-warranted	Warranted	Statistically Different?
0	53.2	42.5	Yes	65.9	46.3	Yes
1	54.5	45.6	Yes	55.1	48.2	Yes
2	53.2	49.4	Yes	45.6	41.2	No
3	55.1	51.3	Yes	64.6	52.0	Yes
4	60.8	58.3	No	51.3	49.4	No
5	59.6	52.0	Yes	91.2	N/A	
6	64.6	65.3	No	48.2	46.9	No
7	62.1	51.3	Yes	N/A	N/A	
8	64.6	57.0	Yes	57.0	63.36	No

N/A - Data not available for pavements of this age.

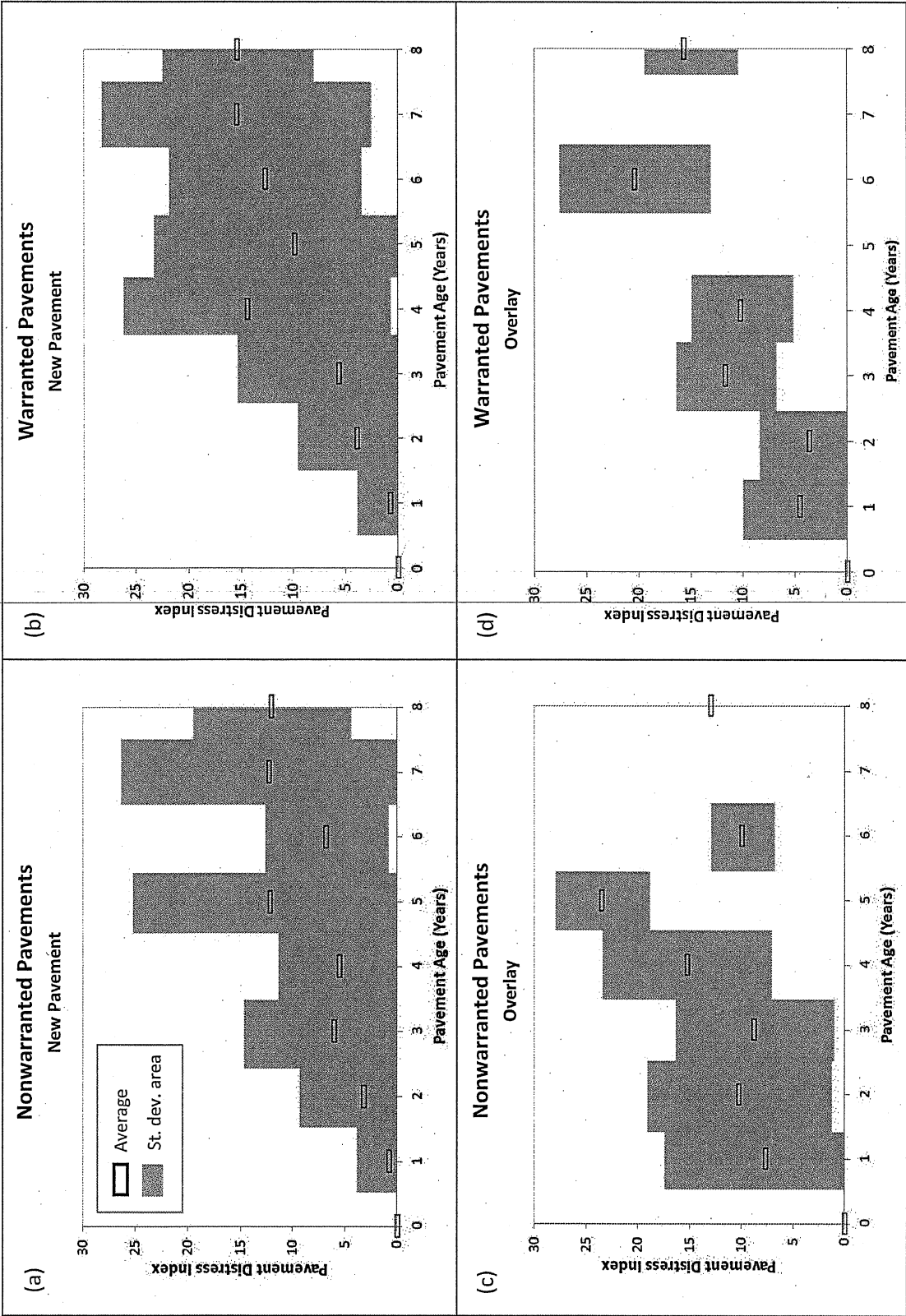


Figure 4. Pavement Distress Index for (a) nonwarranted new pavements, (b) warranted new pavements, (c) nonwarranted overlay pavements, and (d) warranted overlay pavements.

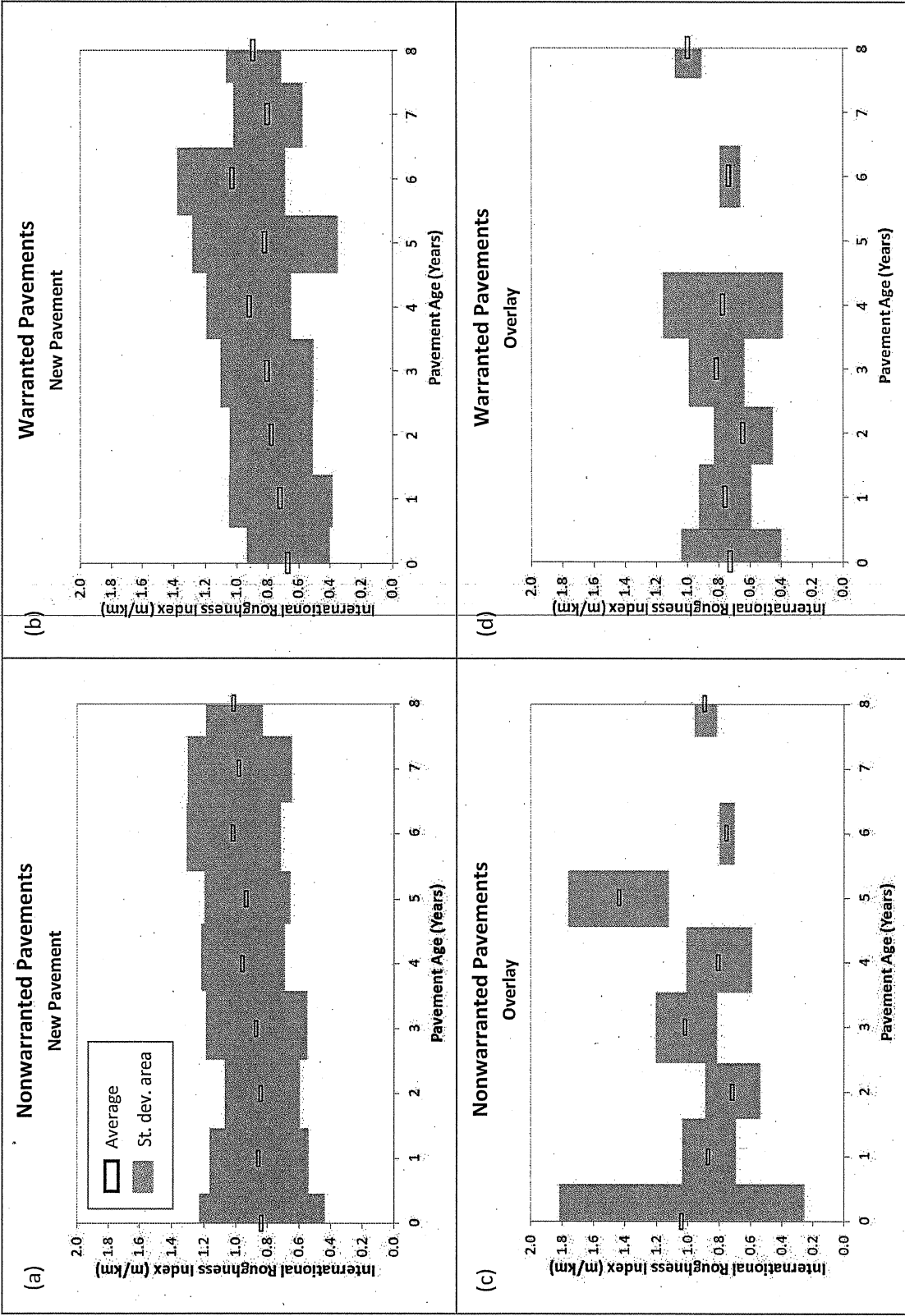


Figure 5. International Roughness Index for (a) nonwarranted new pavements, (b) warranted new pavements, (c) nonwarranted overlay pavements, and (d) warranted overlay pavements.

3.4 Pavement Rehabilitation

When a pavement has reached the end of its functional service life, it is rehabilitated or reconstructed. Future rehabilitation of the analyzed pavements would typically involve an HMA overlay or mill and HMA overlay. At the time of this study, three projects had been rehabilitated or reconstructed after 5 to 8 years in service. One nonwarranted pavement and one warranted pavement had undergone rehabilitation, and one warranted pavement had undergone full reconstruction. These projects are identified in Table 8. The two warranted pavements had a rubblized concrete base. The rubblized base material might have been a factor in the performance of these pavements, as described in a separate study. [11]

Table 8. Projects that were Reconstructed or Rehabilitated

Study ID	Pavement Structure	Rehabilitation/Reconstruction
13-Nonwarranted	5.5-in HMA over new base	2-in mill and 2-in HMA overlay
13-Warranted	5-in HMA over rubblized concrete base	Reconstruct HMA pavement
21-Warranted	7-in HMA over rubblized concrete base	2-in mill and 2-in SMA* overlay

*Stone-matrix asphalt

An estimated future rehabilitation schedule was provided by the Regions for the remaining pavements analyzed in this study. Because many of the pavements will not require rehabilitation for eight or more years, the Regions could not provide information on the exact timing of future rehabilitations, nor the expected costs of these jobs. Therefore, the full cost to the Department for each analyzed project cannot be determined until the projects have reached their ultimate service lives.

The estimated rehabilitation schedules provided by the Regions were used to perform a qualitative analysis of pavement service life. Approximate service lives were projected and compared to the initial pavement service lives used in life cycle cost analysis calculations during pavement design. [12] The results of this analysis are listed in Table 9. Initial pavement service lives used in DOT design are shown in Table 10. See Appendix 4 for rehabilitation information provided by the Regions.

The results presented in Table 9 indicated that the estimated service lives of many nonwarranted and warranted pavements were expected to be less than the initial service lives defined in the pavement design. There were a greater number of warranted pavements estimated to require rehabilitation before their design service lives. However, as approximately half of the pavements fell into the "Information not available" category, it was difficult to draw definite conclusions from this information.

In summary, the expected rehabilitation schedules for nonwarranted and warranted pavements are similar. The rehabilitation information provided by the Regions was estimated based on current pavement condition. As the pavements approach their ultimate service life, it will become easier to make a detailed comparison of nonwarranted and warranted pavements.

Table 9. Estimated Pavement Service Life Comparison

	Number of Nonwarranted Pavements	Number of Warranted Pavements
Meet or exceed design life	5	2
0-2 years less than design life	1	6
2-4 years less than design life	7	5
4+ years less than design life	3	5
Information not available	21	20

Table 10. Design Service Lives of Relevant Pavement Types [12]

Construction Type	Initial Design Service Life (Years)
HMA - Traditional or Deep-Strength	18
HMA over Pulverized HMA	18
HMA over Rubblized Concrete	22
HMA Overlay over Traditional HMA Pavement	12
Mill and HMA Overlay over Traditional HMA Pavement	12

4. Conclusions

Based on the results presented in Section 3, the following six conclusions were made:

1. *The total cost to the Department for nonwarranted and warranted HMA pavements was approximately equal.*

For the projects evaluated in this study, the average costs for nonwarranted and warranted HMA pavements were nearly identical. The analyzed costs included materials and construction; Department and consultant staff charges made during construction; staff time devoted to pavement distress review and coordination of repairs; and maintenance and repair costs through 2011. Actual costs were used whenever possible.

The total project costs, normalized to HMA mixture tonnage, were \$57.18/ton and \$57.07/ton for nonwarranted and warranted projects, respectively. There was not a statistical difference in total cost when comparing nonwarranted and warranted projects.

2. *The cost of staff time devoted to project administration was small, but it was greater for warranted projects.*

Project administration activities evaluated in this study included review of pavement condition and, for warranted pavements, coordination with contractors to assure necessary warranty repairs were completed. These duties were performed by Regional staff and members of the Department's Pavement Data Unit. In total, the cost for project administration activities represented less than one percent of total project cost.

While the cost to perform these activities was small, it was greater for warranted projects than for nonwarranted projects. There was a statistical difference in project administration costs when comparing nonwarranted and warranted projects.

3. *The cost of the new consultant contract for warranty program administration is approximately equal to the cost of Regional warranty administration.*

In July 2011, a consultant contract was executed to provide administrative and technical support to the Regions for management of the warranty program. The average Regional warranty administration cost without consultant support was \$0.13/ton. The new consultant contract cost could range from \$0.14/ton to \$0.18/ton. The consultant effort will replace a good portion of the Regional duties and will not have a major cost impact.

4. *Pavement distress, as measured by the Pavement Distress Index (PDI), was similar for nonwarranted and warranted pavements.*

There was typically no statistical difference between the PDI measured for nonwarranted and warranted pavements at a given pavement age. For projects with new pavement structure (i.e., not overlays), there was a statistical difference at ages 4 and 6, and the level of distress was higher in warranted pavements. For overlay pavements, there was a statistical difference at ages 2 and 4, and the level of distress was higher in nonwarranted pavements. The expected range of PDI values, measured by the standard deviation, was similar for both contracting types.

For pavements with new structure, this conclusion was in contrast to results from the 2009 DOT evaluation of warranted pavements. The earlier study, which evaluated pavement performance from the program's inception in 1995 through 2007, concluded that the PDI of HMA pavements constructed under warranty was significantly lower than the PDI of nonwarranted pavements through age 12. For HMA overlay pavements, the 2009 study also concluded that the level of performance was approximately equal for nonwarranted and warranted pavements. [1] It should be noted that the 2009 evaluation included all warranted pavements constructed through 2007, i.e., a different subset of projects than in this study.

-
5. *Ride quality, as measured by the International Roughness Index (IRI), was very good for all pavements but better for warranted pavements.*

A statistical difference in IRI was noted between nonwarranted and warranted pavements. New construction warranted pavements tended to be smoother than nonwarranted pavements at all ages. Warranted overlay pavements were also smoother; a statistical difference was noted through age three. However, the IRI was very good (typically 1.0 m/km [63 in/mi] or less) for pavements constructed under both contract types.

6. *The anticipated rehabilitation schedule is similar for nonwarranted and warranted pavements.*

Based on estimated schedules for pavement rehabilitation, nonwarranted and warranted pavements will have comparable initial service lives. One nonwarranted pavement and two warranted pavements have been rehabilitated or reconstructed prior to their initial design service life.

5. Recommendations

1. *Continue to monitor cost and performance.*

It is recommended that a cost and performance evaluation of the pavement warranty program be conducted periodically. Many changes have been made to the warranty specifications and tracking system over the last several years. These changes will likely help streamline the warranty process and increase the effectiveness of the program. However, any resulting changes to cost and performance also need to be considered.

2. *Determine whether nonwarranted and warranted pavements achieve similar service lives.*

The actual service lives of warranted pavements should be evaluated and compared to actual service lives of nonwarranted pavements constructed under similar conditions. This requires many years of data and tracking but would provide the most accurate evaluation of cost effectiveness of the warranty program. The first warranted HMA pavements, constructed in 1995, will likely reach their initial service lives within the next five years.

3. *Evaluate the effectiveness of the new consultant contract for warranty program administration.*

The intent of the consultant contract for warranty administration, which went into effect in July 2011, is to provide a more unified management approach of warranties statewide, and to reduce the Regions' time spent on warranty management. If successful, this contract has the potential to resolve several of the concerns noted by the LAB in its March 2011 review of the warranty program. [2]

References

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11. Battaglia, I. and Paye, B. "Investigation of Early Distress in Wisconsin Rubblized Pavements." Research Study No. WI-10-02, Report No. WI-02-11, Wisconsin Department of Transportation. July 2011.
12. Wisconsin Department of Transportation Facilities Development Manual. Chapter 14, "Pavements;" Section 15, "Pavement Type Selection;" Subject 10, "Life Cycle Cost Analysis Computation Parameters." Nov. 2009.

Appendix 1. Project Information

Table A1-1. Nonwarranted Project Information

Study ID	Region	County	Highway	Limits	Construction ID	Contract ID
1	NW	Dunn	STH 40	STH 29 - Fifth Ave	8620-00-70	20031111033
2	NC	Langlade	STH 55	Sth 64 - Mole Lake	9155-10-72	20010918008
3	NC	Langlade	STH 64	Charlotte - Clover Road	9140-07-70	20030610048
4	NC	Langlade	STH 52	USH 45 - STH 64 East	9175-05-70	20040413041
5	NC	Waushara	STH 21	Redgranite - Winnebago Co Ln	6180-03-74	20030211024
6	NC	Lincoln	STH 17	STH 64 - Hay Meadow Creek	9030-07-70	20060110022
7	NE	Oconto	STH 22	SCL - Gillett	9180-13-71	20020312022
8	NE	Outagamie	USH 45	CTH W - New London	1146-11-76	20030114014
9	NE	Marinette	USH 141	Wausaukee - Amberg	1491-07-71	20051213031
10	NE	Winnebago	STH 91	WCL - Waukau/STH 116	6496-04-71	20040309023
11	NE	Outagamie	STH 55	CTH S - Sth 54	6564-01-72	20011009015
12	NW	Clark	STH 73	Neillsville - Greenwood	7050-01-73	20011211033
13	NW	Bayfield	USH 2	WCL - Iron River	1180-36-71	20020312041
14	NW	Sawyer	STH 77	CTH A - Ghost Lake	8520-09-71	20030610050
15	NW	Sawyer	STH 70	Oxbo Flambeau River bridge - ECL	8170-22-71	20040810018
16	NW	Rusk/Sawyer	STH 27	Ladysmith - Brunet River Bridge	8180-11-71	20050712030
17	NW	Buffalo	STH 35	SCL to STH 54	7161-07-61	20050510035
18	NW	Trempealeau	USH 53	Pigeon Falls - STH 121	1637-02-60	20050510029
19	NW	Taylor	STH 73	Hannibal - Ingram (CTH M to NCL)	8210-08-71	20050712024
20	NW	Sawyer	STH 77	USH 63 - CTH K	8520-13-71	20040413044
22	NC	Iron	USH 2	CTH B to MI SL	1185-03-70	20050913007
23	NW	Bayfield	USH 63	Grandview - STH 118	1560-20-71	20051108026
24	NW	St. Croix	STH 29/128	Elmwood - Glenwood City	7630-00-70	20020709034
25	NW	Burnett	STH 35/70	STH 70 to CTH X; STH 35 - Viola Lake Rd	8010-41-60	20050712029
26	NW	Washburn	USH 63	Balsam St - USH 53	1550-19-71	20040608031
27	NW	Barron	USH 63	Cumberland - North County Line	1550-17-71	20031111038
28	SE	Racine	STH 83	SCL - South Sewer Ln	2241-06-70	20040309012
29	SE	Waukesha	STH 164	Pewaukee Road	2748-03-71	20050208014
30	SW	Dodge	STH 28	Lynn St to CTH TW	3270-01-61	20011211005
31	SW	Crawford	STH 27	Seneca - Mt Sterling	5542-03-71	20021112021
32	SW	Vernon	STH 131	Rockton - Ontario	5111-06-71	20020212030
33	SW	Jefferson	STH 19	STH 89 - CTH G	3050-00-60	20060214005
34	SW	Crawford	STH 27	Mt Sterling - NCL	5543-01-73	20031111027
35	SW	Sauk	STH 23	Loganville - Reedsburg	5080-01-66	20041214001
36	SW	Monroe	STH 27	Cashton - Sparta	5144-01-73	20060214006
37	SW	Grant	STH 81	USH 61 - Platteville	5225-01-71	20060314006
38	SW	Iowa	USH 14	Wisconsin River - Mazomanie Rd	1640-01-72	20040413002

Table A1-2. Warranted Project Information

Study ID	Region	County	Highway	Limits	Construction ID	Contract ID
1	NC	Waupaca	STH 22	FV&W RR to CTH N	6590-05-72	20011009019
2	NC	Oneida	STH 47	USH 8 to Kildare Rd	9050-10-70	20020409049
3	NC	Forest	STH 32	SCL to Wabeno	9130-03-70	20021112031
4	NC	Oneida	STH 17	USH 8 to Birchwood Dr	9040-05-70	20030114043
5	NC	Lincoln	USH 51 S	CTH S to USH 8	1178-07-70	20050510040
6	NC	Vilas	USH 45	Wall St to Railroad St	1600-27-60	20060711020
7	NE	Winnebago	STH 26	SCL to CTH N	1110-02-71	20020611014
8	NE	Winnebago	STH 44	SCL to STH 91	6110-14-71	20030708023
9	NE	Marinette	USH 141	CTH Z to CTH R	1491-06-71	20030812008
10	NE	Marinette	STH 64	CTH E to Marinette limits	9160-07-71	20040309025
11	NE	Kewaunee	STH 42	Duvall St to CTH K	1470-15-71	20040608013
12	NW	Jackson	USH 10	WCL to STH 27	1523-05-71	20010918006
13	NW	Douglas	USH 53	Kent Rd to USH 2	1199-11-71	20020409050
14	NW	Buffalo	STH 37	STH 35 to CTH F	7125-05-71	20030311047
15	NW	Trempealeau	USH 10	Eleva Easterly to USH 53	1537-01-72	20041214021
16	NW	Taylor	STH 13	Allman St to CTH N	1610-00-79	20050111027
17	NW	Washburn	STH 77	WCL to CTH I	8560-12-71	20050208034
18	NW	Pierce	STH 29	USH 63 to CTH CC	7630-01-71	20050308039
19	NW	Polk	STH 48	STH 35 to CTH E	8820-10-71	20050412038
20	NW	Barron	STH 48	CTH NN to NCL	8570-09-71	20050510045
21	NW	Chippewa	USH 53	40th Ave to CTH B	1191-09-73	20060110025
22	NW	Burnett	STH 35	Webster to Danbury	8010-37-71	20060214037
23	NW	Pepin	STH 35	Elm St to NCL	7180-01-71	20060314038
24	NW	Douglas	STH 27	ECL to Rush Lake Rd	8150-19-71	20060411041
25	NW	Clark	USH 10	USH 12 to Bachelors Ave	1520-06-61	20060711021
26	NW	Polk	USH 63	CTH J to USH 8	1550-00-61	20060808022
27	NW	Polk	STH 35	3rd Ave to USH 8	8060-01-64	20060808024
28	SE	Racine	STH 11	Crossway Rd to CTH C	1320-06-70	20040309011
29	SE	Washington	STH 33	STH 175 to Rock River	1410-04-70	20050308011
30	SW	Dodge	STH 60	STH 67 to ECL	3040-01-60	20020514001
31	SW	Lafayette	STH 78	State Line to STH 11	5260-00-60	20020917001
32	SW	Dodge	STH 68	Hamilton St to CTH FF	6070-00-71	20030408016
33	SW	Dane/Columbia	STH 113	CTH V to Bellin St	5280-00-72	20030408006
34	SW	Rock	STH 67	E. Freedom Ln to Maxworthy Rd	3663-00-71	20040413003
35	SW	Richland	STH 60	CTH T to STH 80	5190-06-73	20050308032
36	SW	Dodge	STH 73	Moriah Rd to WW treat plant ent	6060-02-60	20050913004
37	SW	Grant	STH 133	Blue River to Muscoda Rd	5616-02-71	20051213004
38	SW	Sauk	STH 23	STH 33 to I 90	5060-00-72	20060314005

Appendix 2. Wage Adjustment and Price Index Information

Table A2-1. Consultant and Department Comparison Multipliers [4]

Year	Multiplier
2002	2.49
2003	3.01
2004	3.03
2005	2.96
2006	2.63

Table A2-2. Producer Price Index (PPI) [6]

Year	PPI
2001	139.9
2002	133.8
2003	137.0
2004	147.9
2005	162.4
2006	187.9
2007	197.6
2008	227.3
2009	204.1
2010	218.9
2011	240.3

Table A2-3. Consumer Price Index (CPI) [5]

Year	CPI
2002	174.8
2003	177.7
2004	182.9
2005	187.4
2006	193.6
2007	199.2
2008	207.2
2009	203.2
2010	208.0
2011	215.9

Appendix 3. Project Cost Data

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Table A3-1. Project Cost Data, 2011 Dollars, Non-Warranted Projects

Study ID	Materials and Construction	Construction Staff Charges (DOT)	Construction Staff Charges (Consultant)	Maintenance and Repairs	Regional Administration	Pavement Data Unit Routine Surveys	Pavement Data Unit Special Requests	Total
1	\$2,806,042	\$51,993	\$108,219	\$85,137	\$1,449	\$640	\$0	\$3,053,480
2	\$530,495	\$60,176	\$9,887	\$29,597	\$652	\$228	\$0	\$631,036
3	\$1,090,544	\$44,279	\$4,081	\$25,581	\$580	\$183	\$0	\$1,165,246
4	\$596,252	\$273,935	\$0	\$12,162	\$507	\$91	\$0	\$882,948
5	\$1,978,666	\$96,466	\$235,138	\$38,371	\$580	\$274	\$0	\$2,349,495
6	\$1,278,857	\$2,116	\$0	\$82,426	\$362	\$480	\$0	\$1,364,241
7	\$515,446	\$6,322	\$57,155	\$29,597	\$0	\$228	\$0	\$608,749
8	\$1,303,816	\$412,650	\$44,478	\$25,581	\$0	\$183	\$0	\$1,786,707
9	\$2,079,351	\$38,300	\$0	\$105,976	\$0	\$617	\$0	\$2,224,243
10	\$1,765,311	\$216,312	\$305,528	\$60,812	\$0	\$457	\$0	\$2,348,420
11	\$1,039,531	\$16,172	\$56,748	\$118,389	\$0	\$914	\$0	\$1,231,755
12	\$3,284,311	\$227,102	\$1,538	\$177,584	\$1,739	\$1,371	\$0	\$3,693,645
13	\$3,069,139	\$673,690	\$252	\$765,046	\$0	\$799	\$0	\$4,508,926
14	\$1,405,698	\$31,575	\$304	\$63,951	\$1,884	\$571	\$0	\$1,503,983
15	\$2,920,579	\$8,717	\$8,781	\$21,146	\$2,029	\$183	\$0	\$2,961,435
16	\$2,804,076	\$7,923	\$61,307	\$179,745	\$2,029	\$1,553	\$0	\$3,056,633
17	\$1,273,234	\$21,030	\$0	\$42,293	\$1,304	\$365	\$0	\$1,338,227
18	\$1,957,819	\$1,615	\$12,651	\$10,573	\$1,304	\$91	\$0	\$1,984,054
19	\$1,294,157	\$4,527	\$85,378	\$105,732	\$2,029	\$914	\$0	\$1,492,736
20	\$1,478,493	\$32,984	\$554	\$60,812	\$1,884	\$457	\$0	\$1,575,184
22	\$3,106,335	\$6,828	\$5,528	\$94,201	\$362	\$548	\$0	\$3,213,801
23	\$1,582,202	\$55,765	\$0	\$94,201	\$2,029	\$548	\$0	\$1,734,744
24	\$1,448,885	\$55,252	\$1,534	\$73,993	\$2,029	\$571	\$0	\$1,582,265
25	\$1,054,629	\$22,638	\$0	\$74,013	\$2,029	\$640	\$0	\$1,153,948
26	\$836,935	\$11,638	\$0	\$24,325	\$1,884	\$183	\$0	\$874,965
27	\$3,054,905	\$165,323	\$289,324	\$72,975	\$2,029	\$548	\$0	\$3,585,104
28	\$1,559,251	\$363,276	\$88	\$36,487	\$0	\$274	\$0	\$1,959,376
29	\$2,560,268	\$808,030	\$225,955	\$126,879	\$0	\$411	\$0	\$3,721,543
30	\$940,469	\$17,669	\$19,449	\$59,195	\$652	\$457	\$0	\$1,037,890
31	\$875,460	\$101,106	\$0	\$63,951	\$1,015	\$571	\$0	\$1,042,103
32	\$2,036,549	\$1,654,758	\$63,777	\$89,532	\$1,015	\$799	\$0	\$3,846,431
33	\$1,120,144	\$5,615	\$5,541	\$82,426	\$362	\$480	\$0	\$1,214,568
34	\$698,154	\$230,419	\$106,356	\$24,325	\$725	\$183	\$0	\$1,060,162
35	\$1,003,415	\$64,321	\$0	\$63,439	\$507	\$548	\$0	\$1,132,231
36	\$3,321,558	\$104,427	\$88,490	\$176,626	\$580	\$1,028	\$0	\$3,692,709
37	\$2,290,045	\$30,067	\$53,877	\$105,976	\$507	\$617	\$0	\$2,481,090
38	\$4,089,661	\$24,843	\$239,154	\$145,949	\$797	\$1,096	\$0	\$4,501,501

Table A3-2. Project Cost Data, 2011 Dollars, Warranted Projects

Study ID	Materials and Construction	Construction Staff Charges (DOT)	Construction Staff Charges (Consultant)	Maintenance and Repairs	Regional Administration	Pavement Data Unit Routine Surveys	Pavement Data Unit Special Requests	Total
1	\$307,529	\$7,715	\$264,198	\$0	\$217	\$2,625	\$0	\$582,284
2	\$2,310,907	\$209,751	\$154	\$0	\$217	\$3,060	\$0	\$2,524,089
3	\$790,947	\$58,247	\$10,922	\$0	\$217	\$2,770	\$0	\$863,103
4	\$2,995,151	\$971,676	\$49,981	\$0	\$217	\$2,818	\$0	\$4,019,844
5	\$1,966,854	\$142,851	\$2,282	\$0	\$217	\$2,915	\$0	\$2,115,120
6	\$266,455	\$0	\$0	\$0	\$217	\$2,625	\$0	\$269,297
7	\$797,686	\$4,729	\$52,615	\$0	\$0	\$2,721	\$0	\$857,752
8	\$3,258,906	\$8,942	\$96,233	\$0	\$0	\$2,963	\$0	\$3,367,044
9	\$916,798	\$3,800	\$31,979	\$0	\$0	\$2,770	\$0	\$955,347
10	\$1,587,834	\$100,345	\$0	\$0	\$0	\$2,866	\$0	\$1,691,045
11	\$1,647,112	\$7,835	\$49,373	\$74,013	\$0	\$3,011	\$0	\$1,781,344
12	\$2,545,955	\$78,887	\$71	\$0	\$11,594	\$3,011	\$7,247	\$2,646,766
13	\$3,635,847	\$142,606	\$0	\$4,190,143	\$4,420	\$2,963	\$0	\$7,975,980
14	\$1,498,773	\$187,212	\$237,521	\$0	\$4,420	\$2,818	\$0	\$1,930,745
15	\$1,856,669	\$41,226	\$27,991	\$0	\$11,594	\$3,060	\$0	\$1,940,541
16	\$1,275,424	\$2,093	\$64,279	\$0	\$3,333	\$2,818	\$3,623	\$1,351,571
17	\$2,935,005	\$492,297	\$49,173	\$0	\$18,044	\$3,108	\$0	\$3,497,627
18	\$1,154,915	\$48,610	\$0	\$0	\$4,420	\$2,818	\$3,623	\$1,214,387
19	\$2,104,300	\$127,744	\$107,115	\$0	\$9,783	\$3,108	\$0	\$2,352,050
20	\$1,723,103	\$127,338	\$154,094	\$0	\$10,870	\$2,915	\$5,435	\$2,023,754
21	\$4,277,199	\$6,447	\$60,811	\$1,224,000	\$30,363	\$3,253	\$10,870	\$5,612,943
22	\$2,530,474	\$86,429	\$14,519	\$0	\$3,333	\$2,866	\$0	\$2,637,622
23	\$974,029	\$16,102	\$13,751	\$0	\$7,174	\$2,770	\$0	\$1,013,826
24	\$2,973,874	\$33,541	\$0	\$0	\$3,333	\$3,011	\$0	\$3,013,759
25	\$741,489	\$0	\$0	\$0	\$3,333	\$2,963	\$0	\$747,786
26	\$738,082	\$0	\$0	\$0	\$10,508	\$2,866	\$0	\$751,456
27	\$1,031,341	\$0	\$0	\$0	\$9,421	\$2,915	\$5,435	\$1,049,111
28	\$2,389,824	\$178,599	\$434,437	\$0	\$0	\$2,866	\$0	\$3,005,726
29	\$1,036,135	\$218,706	\$32	\$0	\$0	\$2,673	\$0	\$1,257,547
30	\$1,030,540	\$87,699	\$0	\$0	\$978	\$2,818	\$0	\$1,122,035
31	\$788,914	\$6,040	\$64,261	\$0	\$1,087	\$2,818	\$0	\$863,121
32	\$201,456	\$90,220	\$82	\$0	\$725	\$2,625	\$0	\$295,107
33	\$1,407,610	\$455,036	\$590	\$0	\$1,087	\$2,866	\$0	\$1,867,190
34	\$328,483	\$100,419	\$0	\$0	\$797	\$2,625	\$0	\$432,324
35	\$1,551,938	\$22,678	\$400,132	\$126,880	\$4,928	\$2,818	\$0	\$2,109,374
36	\$2,413,724	\$38,841	\$46,517	\$0	\$1,304	\$3,011	\$0	\$2,503,398
37	\$1,809,711	\$11,500	\$86,062	\$0	\$1,304	\$2,818	\$0	\$1,911,394
38	\$1,886,495	\$25,459	\$0	\$0	\$4,565	\$2,818	\$0	\$1,919,337

Table A3-3. Cost per Ton of HMA, 2011 Dollars, Non-Warranted Projects

Study ID	Materials and Construction	Construction Staff Charges (DOT)	Construction Staff Charges (Consultant)	Maintenance and Repairs	Regional Administration	Pavement Data Unit Routine Surveys	Pavement Data Unit Special Requests	Total \$/ton
1	\$65.73	\$1.22	\$2.53	\$1.99	\$0.03	\$0.01	\$0.00	\$71.52
2	\$51.76	\$5.87	\$0.96	\$2.89	\$0.06	\$0.02	\$0.00	\$61.56
3	\$51.37	\$2.09	\$0.19	\$1.20	\$0.03	\$0.01	\$0.00	\$54.88
4	\$51.05	\$23.45	\$0.00	\$1.04	\$0.04	\$0.01	\$0.00	\$75.59
5	\$45.02	\$2.19	\$5.35	\$0.87	\$0.01	\$0.01	\$0.00	\$53.46
6	\$38.21	\$0.06	\$0.00	\$2.46	\$0.01	\$0.01	\$0.00	\$40.76
7	\$41.24	\$0.51	\$4.57	\$2.37	\$0.00	\$0.02	\$0.00	\$48.70
8	\$49.53	\$15.68	\$1.69	\$0.97	\$0.00	\$0.01	\$0.00	\$67.88
9	\$43.12	\$0.79	\$0.00	\$2.20	\$0.00	\$0.01	\$0.00	\$46.13
10	\$39.46	\$4.84	\$6.83	\$1.36	\$0.00	\$0.01	\$0.00	\$52.50
11	\$40.35	\$0.63	\$2.20	\$4.59	\$0.00	\$0.04	\$0.00	\$47.81
12	\$44.29	\$3.06	\$0.02	\$2.39	\$0.02	\$0.02	\$0.00	\$49.81
13	\$58.41	\$12.82	\$0.00	\$14.56	\$0.00	\$0.02	\$0.00	\$85.82
14	\$50.54	\$1.14	\$0.01	\$2.30	\$0.07	\$0.02	\$0.00	\$54.08
15	\$42.81	\$0.13	\$0.13	\$0.31	\$0.03	\$0.00	\$0.00	\$43.41
16	\$38.99	\$0.11	\$0.85	\$2.50	\$0.03	\$0.02	\$0.00	\$42.50
17	\$54.79	\$0.90	\$0.00	\$1.82	\$0.06	\$0.02	\$0.00	\$57.58
18	\$46.74	\$0.04	\$0.30	\$0.25	\$0.03	\$0.00	\$0.00	\$47.36
19	\$34.26	\$0.12	\$2.26	\$2.80	\$0.05	\$0.02	\$0.00	\$39.51
20	\$33.50	\$0.75	\$0.01	\$1.38	\$0.04	\$0.01	\$0.00	\$35.69
22	\$48.46	\$0.11	\$0.09	\$1.47	\$0.01	\$0.01	\$0.00	\$50.14
23	\$55.20	\$1.95	\$0.00	\$3.29	\$0.07	\$0.02	\$0.00	\$60.53
24	\$57.60	\$2.20	\$0.06	\$2.94	\$0.08	\$0.02	\$0.00	\$62.90
25	\$59.24	\$1.27	\$0.00	\$4.16	\$0.11	\$0.04	\$0.00	\$64.82
26	\$59.34	\$0.83	\$0.00	\$1.72	\$0.13	\$0.01	\$0.00	\$62.04
27	\$52.99	\$2.87	\$5.02	\$1.27	\$0.04	\$0.01	\$0.00	\$62.19
28	\$37.80	\$8.81	\$0.00	\$0.88	\$0.00	\$0.01	\$0.00	\$47.50
29	\$36.94	\$11.66	\$3.26	\$1.83	\$0.00	\$0.01	\$0.00	\$53.69
30	\$56.76	\$1.07	\$1.17	\$3.57	\$0.04	\$0.03	\$0.00	\$62.64
31	\$53.87	\$6.22	\$0.00	\$3.94	\$0.06	\$0.04	\$0.00	\$64.13
32	\$50.76	\$41.24	\$1.59	\$2.23	\$0.03	\$0.02	\$0.00	\$95.86
33	\$43.70	\$0.22	\$0.22	\$3.22	\$0.01	\$0.02	\$0.00	\$47.39
34	\$80.55	\$26.59	\$12.27	\$2.81	\$0.08	\$0.02	\$0.00	\$122.32
35	\$40.36	\$2.59	\$0.00	\$2.55	\$0.02	\$0.02	\$0.00	\$45.54
36	\$47.94	\$1.51	\$1.28	\$2.55	\$0.01	\$0.01	\$0.00	\$53.30
37	\$37.30	\$0.49	\$0.88	\$1.73	\$0.01	\$0.01	\$0.00	\$40.41
38	\$39.63	\$0.24	\$2.32	\$1.41	\$0.01	\$0.01	\$0.00	\$43.62

Table A3-4. Cost per Ton of HMA, 2011 Dollars, Warranted Projects

Study ID	Materials and Construction	Construction Staff Charges (DOT)	Construction Staff Charges (Consultant)	Maintenance and Repairs	Regional Administration	Pavement Data Unit Routine Surveys	Pavement Data Unit Special Requests	Total \$/ton
1	\$51.34	\$1.29	\$44.11	\$0.00	\$0.04	\$0.44	\$0.00	\$97.21
2	\$41.23	\$3.74	\$0.00	\$0.00	\$0.00	\$0.05	\$0.00	\$45.03
3	\$40.36	\$2.97	\$0.56	\$0.00	\$0.01	\$0.14	\$0.00	\$44.04
4	\$49.14	\$15.94	\$0.82	\$0.00	\$0.00	\$0.05	\$0.00	\$65.95
5	\$32.46	\$2.36	\$0.04	\$0.00	\$0.00	\$0.05	\$0.00	\$34.91
6	\$69.64	\$0.00	\$0.00	\$0.00	\$0.06	\$0.69	\$0.00	\$70.39
7	\$48.02	\$0.28	\$3.17	\$0.00	\$0.00	\$0.16	\$0.00	\$51.64
8	\$51.81	\$0.14	\$1.53	\$0.00	\$0.00	\$0.05	\$0.00	\$53.53
9	\$52.87	\$0.22	\$1.84	\$0.00	\$0.00	\$0.16	\$0.00	\$55.10
10	\$47.41	\$3.00	\$0.00	\$0.00	\$0.00	\$0.09	\$0.00	\$50.49
11	\$37.43	\$0.18	\$1.12	\$1.68	\$0.00	\$0.07	\$0.00	\$40.49
12	\$47.42	\$1.47	\$0.00	\$0.00	\$0.22	\$0.06	\$0.13	\$49.30
13	\$46.70	\$1.83	\$0.00	\$53.82	\$0.06	\$0.04	\$0.00	\$102.45
14	\$66.91	\$8.36	\$10.60	\$0.00	\$0.20	\$0.13	\$0.00	\$86.19
15	\$46.23	\$1.03	\$0.70	\$0.00	\$0.29	\$0.08	\$0.00	\$48.31
16	\$34.49	\$0.06	\$1.74	\$0.00	\$0.09	\$0.08	\$0.10	\$36.55
17	\$44.12	\$7.40	\$0.74	\$0.00	\$0.27	\$0.05	\$0.00	\$52.58
18	\$39.01	\$1.64	\$0.00	\$0.00	\$0.15	\$0.10	\$0.12	\$41.02
19	\$42.46	\$2.58	\$2.16	\$0.00	\$0.20	\$0.06	\$0.00	\$47.46
20	\$39.34	\$2.91	\$3.52	\$0.00	\$0.25	\$0.07	\$0.12	\$46.21
21	\$38.51	\$0.06	\$0.55	\$11.02	\$0.27	\$0.03	\$0.10	\$50.53
22	\$46.75	\$1.60	\$0.27	\$0.00	\$0.06	\$0.05	\$0.00	\$48.73
23	\$52.36	\$0.87	\$0.74	\$0.00	\$0.39	\$0.15	\$0.00	\$54.50
24	\$57.77	\$0.65	\$0.00	\$0.00	\$0.06	\$0.06	\$0.00	\$58.54
25	\$48.78	\$0.00	\$0.00	\$0.00	\$0.22	\$0.19	\$0.00	\$49.20
26	\$56.96	\$0.00	\$0.00	\$0.00	\$0.81	\$0.22	\$0.00	\$57.99
27	\$57.20	\$0.00	\$0.00	\$0.00	\$0.52	\$0.16	\$0.30	\$58.18
28	\$49.76	\$3.72	\$9.05	\$0.00	\$0.00	\$0.06	\$0.00	\$62.58
29	\$42.60	\$8.99	\$0.00	\$0.00	\$0.00	\$0.11	\$0.00	\$51.71
30	\$43.50	\$3.70	\$0.00	\$0.00	\$0.04	\$0.12	\$0.00	\$47.36
31	\$45.29	\$0.35	\$3.69	\$0.00	\$0.06	\$0.16	\$0.00	\$49.55
32	\$69.47	\$31.11	\$0.03	\$0.00	\$0.25	\$0.91	\$0.00	\$101.76
33	\$55.63	\$17.98	\$0.02	\$0.00	\$0.04	\$0.11	\$0.00	\$73.80
34	\$60.83	\$18.60	\$0.00	\$0.00	\$0.15	\$0.49	\$0.00	\$80.06
35	\$39.90	\$0.58	\$10.29	\$3.26	\$0.13	\$0.07	\$0.00	\$54.23
36	\$56.26	\$0.91	\$1.08	\$0.00	\$0.03	\$0.07	\$0.00	\$58.35
37	\$46.99	\$0.30	\$2.23	\$0.00	\$0.03	\$0.07	\$0.00	\$49.63
38	\$42.26	\$0.57	\$0.00	\$0.00	\$0.10	\$0.06	\$0.00	\$42.99

Appendix 4 - Estimated Rehabilitation Schedules

Table A4-1. Rehabilitation and Service Life Information for Nonwarranted Pavements

Study ID	Region	County	Highway	Year of Const.	Anticipated Year of Rehabilitation	Initial Design Service Life (Years)
1	NW	Dunn	STH 40	2004	2018-2020	18
2	NC	Langlade	STH 55	2002	>2017	18
3	NC	Langlade	STH 64	2003	>2017	18
4	NC	Langlade	STH 52	2004	>2017	18
5	NC	Waushara	STH 21	2003	>2017	18
6	NC	Lincoln	STH 17	2006	>2017	12
7	NE	Oconto	STH 22	2002	*	12
8	NE	Outagamie	USH 45	2003	*	18
9	NE	Marinette	USH 141	2006	*	12
10	NE	Winnebago	STH 91	2004	*	18
11	NE	Outagamie	STH 55	2002	*	18
12	NW	Clark	STH 73	2002	2017-2018	18
13	NW	Bayfield	USH 2	2002	2007 †	18
14	NW	Sawyer	STH 77	2003	2017-2018	18
15	NW	Sawyer	STH 70	2005	2019-2021	18
16	NW	Rusk/Sawyer	STH 27	2005	2018-2020	12
17	NW	Buffalo	STH 35	2005	2018-2020	18
18	NW	Trempealeau	USH 53	2005	2014	18
19	NW	Taylor	STH 73	2005	2016	12
20	NW	Sawyer	STH 77	2004	2018-2020	18
22	NC	Iron	USH 2	2006	>2017	22
23	NW	Bayfield	USH 63	2006	2020-2022	12
24	NW	St. Croix	STH 29/128	2002	2015-2018	18
25	NW	Burnett	STH 35/70	2005	2019-2021	12
26	NW	Washburn	USH 63	2004	2020-2022	12
27	NW	Barron	USH 63	2004	2019-2021	22
28	SE	Racine	STH 83	2004	>2018	18
29	SE	Waukesha	STH 164	2005	>2018	18
30	SW	Dodge	STH 28	2002	*	18
31	SW	Crawford	STH 27	2003	*	18
32	SW	Vernon	STH 131	2003	*	18
33	SW	Jefferson	STH 19	2006	*	18
34	SW	Crawford	STH 27	2004	*	18
35	SW	Sauk	STH 23	2005	*	18
36	SW	Monroe	STH 27	2006	*	18
37	SW	Grant	STH 81	2006	*	18
38	SW	Iowa	USH 14	2004	*	22

* Information not available

† Mill and overlay in 2007

Table A4-2. Rehabilitation and Service Life Information for Warranted Pavements

Study ID	Region	County	Highway	Year of Const.	Anticipated Year of Rehabilitation	Initial Design Service Life (Years)
1	NC	Waupaca	STH 22	2002	>2017	18
2	NC	Oneida	STH 47	2002	>2017	18
3	NC	Forest	STH 32	2003	>2017	18
4	NC	Oneida	STH 17	2004	>2017	18
5	NC	Lincoln	USH 51 S	2006	>2017	22
6	NC	Vilas	USH 45	2006	>2017	12
7	NE	Winnebago	STH 26	2002	*	12
8	NE	Winnebago	STH 44	2003	*	18
9	NE	Marinette	USH 141	2004	*	12
10	NE	Marinette	STH 64	2004	*	18
11	NE	Kewaunee	STH 42	2004	*	18
12	NW	Jackson	USH 10	2002	2014-2016	18
13	NW	Douglas	USH 53	2002	2010	22
14	NW	Buffalo	STH 37	2003	2016-2018	18
15	NW	Trempealeau	USH 10	2005	2016-2018	18
16	NW	Taylor	STH 13	2005	2020-2022	12
17	NW	Washburn	STH 77	2005	†	18
18	NW	Pierce	STH 29	2005	2019-2021	18
19	NW	Polk	STH 48	2005	2017-2018	18
20	NW	Barron	STH 48	2006	2018-2020	18
21	NW	Chippewa	USH 53	2006	2011 ‡	22
22	NW	Burnett	STH 35	2006	2022-2024	18
23	NW	Pepin	STH 35	2006	2016-2018	12
24	NW	Douglas	STH 27	2006	2022-2024	18
25	NW	Clark	USH 10	2006	2016-2018	12
26	NW	Polk	USH 63	2006	2016-2018	12
27	NW	Polk	STH 35	2006	2016-2018	12
28	SE	Racine	STH 11	2004	>2018	18
29	SE	Washington	STH 33	2005	>2018	18
30	SW	Dodge	STH 60	2002	*	18
31	SW	Lafayette	STH 78	2003	*	18
32	SW	Dodge	STH 68	2003	*	18
33	SW	Dane/Columbia	STH 113	2004	*	18
34	SW	Rock	STH 67	2004	*	18
35	SW	Richland	STH 60	2005	++	18
36	SW	Dodge	STH 73	2006	*	18
37	SW	Grant	STH 133	2006	*	18
38	SW	Sauk	STH 23	2006	++	18

* Information not available

† Chip seal anticipated in 2012

‡ Mill and overlay in 2011

++ Will require mill and overlay before normally expected