DEPARTMENT OF TRANSPORTATION

Minnesota Local Agency Pavement Marking: Mining Existing Data

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November 2017

Research Project
Final Report 2017-43

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Pavement marking is important for safety. Maximizing pavement marking performance in terms of increased retroreflectivity, within limited budget constraints, allows agencies to make better decisions toward providing more effective pavement marking performance on their roadway networks. This research project included conducting a survey of local agencies' pavement marking practices, mining existing National Transportation Product Evaluation Program (NTPEP) pavement marking data, and developing recommendations for future pavement marking research to support local agency needs.

The NTPEP pavement marking performance data (related to pavement marking products used by local agencies in Minnesota) was analyzed to provide guidance to local agencies in terms of pavement marking material selection based on performance. The objective included determining pavement marking products of interest to local agencies and developing performance metrics for these products based on existing NTPEP data. The analysis performed on the NTPEP included modeling the deterioration behavior as a function of time. Also two-way ANOVAs were performed to compare various performance measures and the impact of different conditions on these measures.

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FINAL REPORT

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EXECUTIVE SUMMARY

Pavement marking is important for safety. Maximizing pavement marking performance, within limited budget constraints, allows agencies to make better decisions toward providing more effective pavement marking performance on their roadway networks. This project examined existing National Transportation Product Evaluation Program (NTPEP) pavement marking performance data (related to pavement marking products used by local agencies in Minnesota) on two test sites in Minnesota (one on I-35 E and the other on US 10 and TH 63). Results from the performance data analysis can be used to provide guidance to local agencies in terms of what pavement marking products to use. The objective included determining pavement marking products of interest to local agencies and developing performance metrics for these products based on existing NTPEP data. The research project also included conducting a survey of local agency pavement marking practices covering products used for new construction and maintenance applications and performance expectations. The project also covered the development of recommendations for future work to support local agencies' pavement marking needs.

A survey was designed to identify local agencies' current pavement marking practices. The questions in the survey covered: agency information; installation practices; pavement marking materials used; and pavement markings life estimates based on traffic levels.

The conducted survey included a total of 89 responses from 37 (41.57%) cities and 52 (58.43%) counties. Of the 89 cities and counties, 14 (15.73%) classify as urban, 23 (25.84%) classify as suburban, and 52 (58.43%) are rural. The survey included 10 different pavement marking types. Local agencies identified 6 different pavement markings types which are used in Minnesota (waterborne, highbuild waterborne, epoxy, thermoplastic, tape, and urethane). The survey showed that the two most common pavement marking products for cities and counties are waterborne and epoxy. This matches what the MnDOT also uses. It is interesting, though, to see tape, highbuild waterborne, and thermoplastic being utilized in these settings. In future research, the performance of these durable products could be evaluated to provide a good comparison of cost and durability to provide guidance to local agencies.

The survey also covered the use of grooving to protect the pavement markings from traffic and winter maintenance operations. The responses to the grooving question were analyzed to see the impact. Fourteen agencies (12 counties and 2 cities) said they installed latex (waterborne paint) in a groove. Those agencies also said their waterborne paint provided a longer service life (2 to 3 years) compared to surface installed waterborne paint of less than 2 years when compared across different traffic levels. This is anecdotal evidence that grooving extends the service life of pavement markings. More research is still needed to quantify this extension in service life and develop a benefit cost ratio to help agencies make the right decision on grooving. The results from the survey can be summarized by the following conclusions:

- Majority of local agencies use either latex or epoxy for pavement marking applications on long lines and legends

- Majority of the local agencies don't place their pavement markings in grooves. Thirty two agencies using grooving to protect epoxy and 14 use it with latex (waterborne or highbuild waterborne).
- Agencies that placed markings in grooves, indicated better service life for their latex paint. The majority selected 2 to 3 years of service life at multiple traffic levels compared to less than 2 when surface applied.
- The survey results indicated that epoxy and tape outperforms latex at all different levels with the majority of responses indicating 3 years or more than 3 years compared to 1 or 2 years for latex at low traffic and less than 1 year at the higher traffic.

The analysis performed on the NTPEP data included modeling the deterioration behavior as a function of time. Also two-way ANOVAs were performed to compare various performance measures and the impact of different conditions on these measures. The dataset included in this study consists of the following: retroreflectivity values measured in units of mcd/m^2/lux, time of measurement, location of measurement, color of marking, and the surface type. The measurements were taken at 0 (initial), 1, 2, 3, 9, 10, 11, 12, 15, 21, 24, 27, 33 and 36 months. In some sites, measurements were limited to 27 months, others were 24 months. The test samples included in this study were installed either in 2010 or 2013, and they were applied on different surface types (i.e., asphalt or concrete).

To test the impact of various conditions on the performance of pavement marking, hypothesis tests were conducted to compare different performance parameters. The independent variables selected in this study were: pavement surface, year of application, zone where the marking is applied (i.e., wheel or skip), color, and type of pavement marking. The performance indicators selected as the basis for comparison were: measured initial retroreflectivity; ratio of retroreflectivity after 1 and 2 years to the initial retroreflectivity; modeled retroreflectivity monthly deterioration rate; and average retroreflectivity. It should be mentioned that not all samples had a three-year period of monitoring. Therefore, the statistical analysis is limited to a 2 years ratio, and it is assumed that the long-term performance is captured in the modeled deterioration rate. The statistical analysis was extensive; however, general conclusions and observations can be summarized as follows:

- The surface type does not significantly impact the retroreflectivity values throughout the marking service life. However, an impact was detected when relying on the modeled deterioration rate.
- Most pavement markings installed in 2010 had statistically significant higher initial retroreflectivity as compared to the ones installed in 2013. Also the deterioration rates of many markings installed in 2013 were higher as compared to the rates of the markings installed in 2010.
- In most cases, the markings in the wheel zones deteriorated faster, despite the fact that the initial retroreflectivity did not differ significantly. This is expected since higher traffic will reduce the retroreflectivity over time.
- White markings had significantly higher initial retroreflectivity as compared to the yellow markings. The white markings also had deteriorated slower as compared with the yellow markings.

- Different marking types performed differently in terms of initial retroreflectivity and the deterioration rates. They also interacted in many cases with other parameters. This indicates that the same type deteriorates differently when applied in different locations, on different surface types, and even with different colors. This parameter even interacted with the application year, indicating that different practices have evolved differently for different marking types.
- The analysis of the NTPEP data also showed differences in performance between different products. Since latex and epoxy are most commonly used products by local agencies in Minnesota, the report focused on those two comparisons. When comparing initial retroreflectivity values of latex (1b – 2 year and 1c – 3 year) and epoxy (5a), the difference between the two products was statistically significant, with epoxy providing higher values.

Based on the results of the data analysis and survey results, the research team developed the following recommendations for future research:

- Since the NTPEP data from the 2013 Minnesota test deck for grooved markings were not available, a study on the impact of grooving on pavement marking performance for local agencies would be beneficial. The study would include performance and cost and benefit analysis for the most common products used by local agencies.
- Development of a pavement marking application matrix based on pavement remaining life, AADT, functional class, and pavement marking performance will provide guidance to local agencies on when to use certain pavement marking product types to maximize the use of available resources.
- Neither the survey nor the NTPEP test data addressed pavement marking performance on challenging surfaces. MnDOT completed a research project in 2016 (Evaluation of Pavement Markings on Challenging Surfaces - http://www.dot.state.mn.us/research/TS/2016/201608.pdf) to study this topic. Something similar might be necessary in a local agency environment.

CHAPTER 1: INTRODUCTION

This project mined existing National Transportation Product Evaluation Program (NTPEP) pavement marking performance data (related to pavement marking products used by local agencies in Minnesota) to provide guidance to local agencies. The objective included determining pavement marking products of interest to local agencies and developing performance metrics for these products based on existing NTPEP data.

Pavement marking is important for safety. Maximizing pavement marking performance, within limited budget constraints, allows agencies to make better decisions toward providing more effective pavement marking performance on their roadway networks.

This research project included conducting a survey of local agency pavement marking practices, mining existing NTPEP pavement marking data, and developing recommendations for future work to support agency needs. The project tasks are described below.

Task 1- Web Survey

Develop, distribute, and summarize a survey to assess pavement marking products used by local Minnesota agencies. The research team will work with the TAP to review the survey questions and to facilitate survey distribution.

Task 2 - Data Mining (Tasks 2A and 2B were combined)

The research team will work with MnDOT and NTPEP to acquire, analyze, and summarize pavement marking performance data relevant to local agency interests. The 2010 and 2013 MnDOT NTPEP sites' available data will be included in this analysis. The two test sites have 3 years of data gathered.

Task 3: Recommendations

Based on the findings from Task 1 and 2, the research team will develop recommendations for future efforts, which address local agency needs, including additional pavement marking materials and potential field evaluation needs.

Task 4: Compile Report, Technical Advisory Panel Review and Revisions

A draft report will be prepared, following MnDOT publication guidelines, to document project activities, findings and recommendations. This report will need to be reviewed by the Technical Advisory Panel (TAP), updated by the principal investigator to incorporate technical comments, and then approved by the technical liaison before this task is considered complete. Holding a TAP meeting to discuss the draft report and review comments is strongly encouraged. TAP members may be consulted for clarification or discussion of comments.

CHAPTER 2: SURVEY OF EXISTING PRACTICES BY LOCAL AGENCIES

A survey was designed to identify local agencies' current pavement marking practices. The questions in the survey covered the following topics:

1. Agency information:
    a. Agency type: city, county, other
    b. Urban, suburban, or rural
2. Who installs pavement markings:
    a. In-house crews
    b. Contractors
    c. Minnesota DOT
    d. Combination
3. Pavement marking materials used:
    a. Long lines: reconstruction/rehab and maintenance
    b. Legends: reconstruction/rehab and maintenance
    c. Use of grooving
    d. Use of wet-reflective products
    e. Winter maintenance policy on bare lanes
4. Pavement markings life estimate based on traffic levels:
    a. Less than 5,000 AADT
    b. Between 5,000 and 10,000 AADT
    c. Between 10,000 and 15,000 AADT
    d. Between 15,000 and 20,000 AADT
    e. More than 20,000 AADT

This survey is targeted to identify the current practices and needs in pavement marking application at local transportation agencies in Minnesota. The conducted survey included a total of 89 agencies, with 37 (41.57%) cities and 52 (58.43%) counties. Figure 1 shows that of the 89 cities and counties 14 (15.73%) classify as urban, 23 (25.84%) classify as suburban, and 52 (58.43%) are rural. From Figure 2, Minnesota DOT (MnDOT) installs pavement marking only for 2 (2.25%) agencies out of the 89 agencies participated in the survey. Six (6.74%) agencies install their pavement markings in-house. Fifty seven (64.04%) agencies have indicated that they solicit their pavement marking installation to contractors. The 24 agencies left indicated that they install their pavement markings using any combination of in-house crews, contractors, or MnDOT.

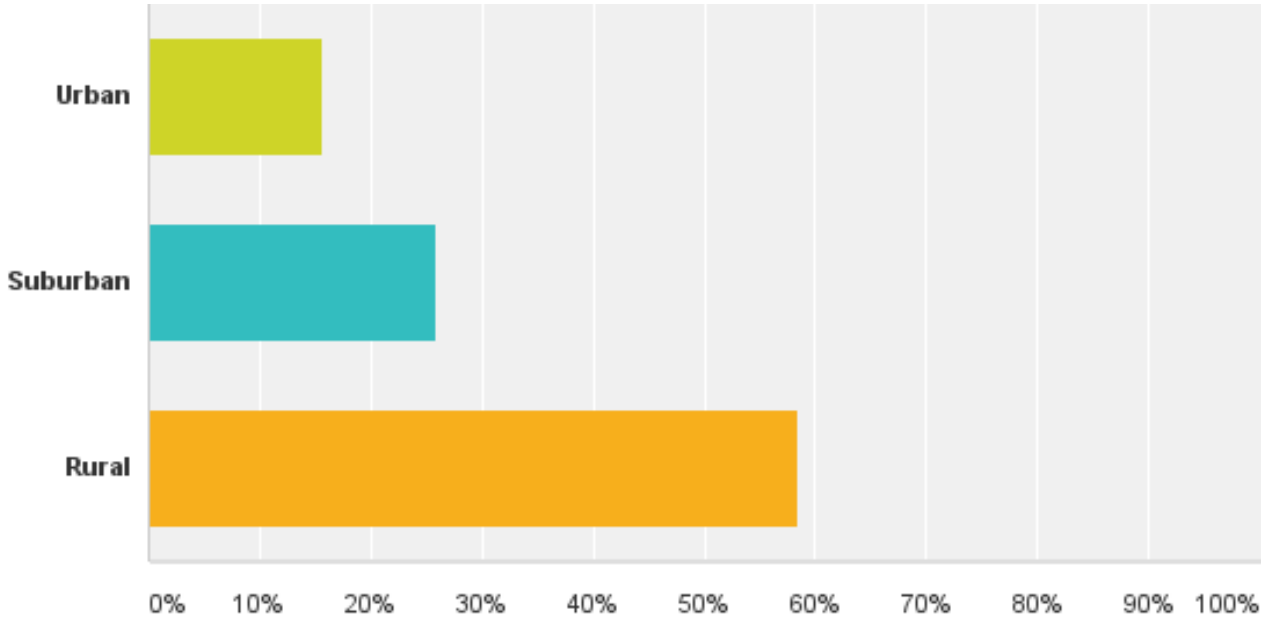
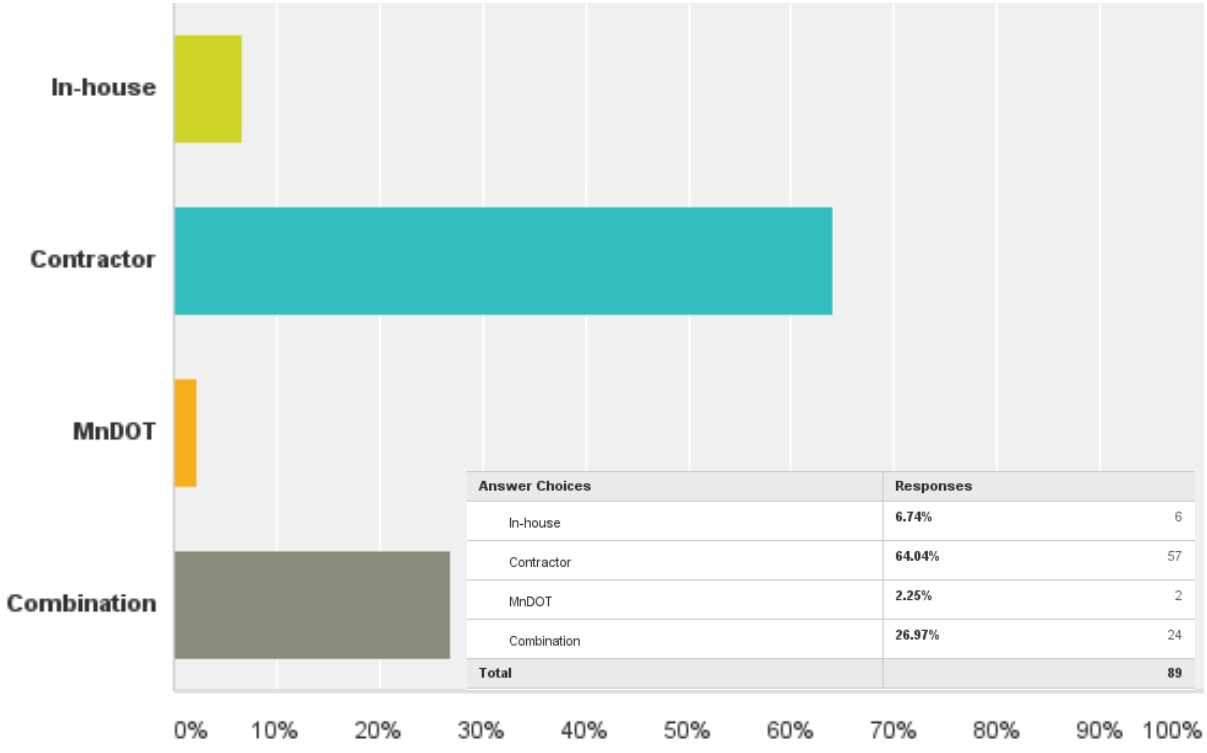


Figure 1. The 89 cities and counties included in the study classification.



Answer Choices	Responses	
In-house	6.74%	6
Contractor	64.04%	57
MnDOT	2.25%	2
Combination	26.97%	24
Total		89

Figure 2. Agencies response to who installs their pavement markings

2.1 MARKING MATERIALS INFORMATION

The survey included10 different pavement marking types. Local agencies identified 6 different pavement markings types which are used in Minnesota. Table 1 lists the 10 types included in the survey and the number (percent) of local agencies using those products. Four different questions were asked in regards to the uses of these ten types. The questions were as follows:

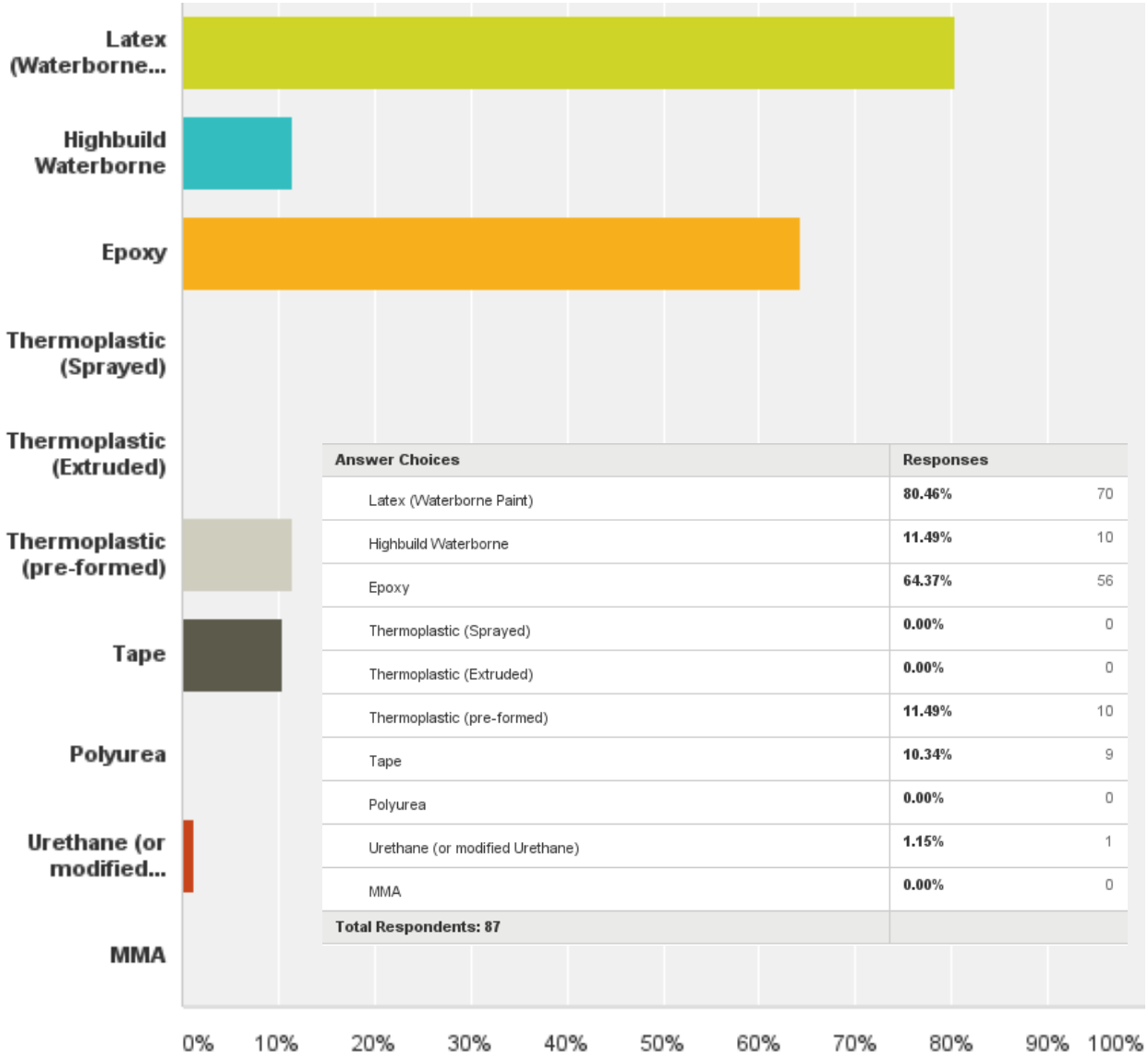
1. Please select all of the pavement marking products used by your agency for long lines on new construction or pavement rehab (skips and edge lines).
2. Please select all of the pavement marking products used by your agency for legends on new construction or pavement rehab (symbols, arrows, crosswalks).
3. Please select all of the pavement marking products used by your agency for long lines for regular maintenance (skips and edge lines).
4. Please select all of the pavement marking products used by your agency for legends for regular maintenance (symbols, arrows, crosswalks).
5. Please tell us if you apply any of these products in a groove or recess in the pavement.

Table 1 also presents the responses to the four questions above. Some agencies indicated using multiple products and thus the total number of product use will be greater than the total number of responses indicated in last row. From the table and Figures 3—6 the Latex (Waterborne Paint) is the most used pavement marking type, followed by the Epoxy paint. On the other hand the Thermoplastic (Extruded) and MMA markings were not used by any of the agencies responded to these questions. Further for the 5th question 40 (46.51%) agencies out of 86 agency indicated that they do not apply any of the products in a groove or recess in the pavement. It can also be noticed that epoxy pavement markings are the most used for grooves and recess.

Table 1. Responses to the 5 questions regarding the uses of different marking types.

	Responses									
Answer Choices	**Q.1 Long Lines (new)**		**Q.2 Legends (new)**		**Q.3 Long Lines (maint.)**		**Q.4 Legends (maint.)**		**Q.5 Grooving**	
Latex (Waterborne Paint)	80.46%	70	64.37%	56	95.35%	82	84.88%	73	16.28%	14
Highbuild Waterborne	11.49%	10	4.60%	4	8.14%	7	2.33%	2	9.30%	8
Epoxy	64.37%	56	48.28%	42	31.40%	27	27.91%	24	37.21%	32
Sprayed Thermo	0.00%	0	1.16%	1	0.00%	0	0.00%	0	0.00%	0
Extruded Thermo	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0
Preformed Thermo	11.49%	10	39.08%	34	2.33%	2	17.44%	15	17.44%	15
Tape	10.34%	9	9.20%	8	1.16%	1	4.65%	4	9.30%	8
Polyurea	0.00%	0	1.15%	1	0.00%	0	0.00%	0	2.33%	2
Urethane	1.15%	1	1.15%	1	1.16%	1	1.16%	1	0.00%	0

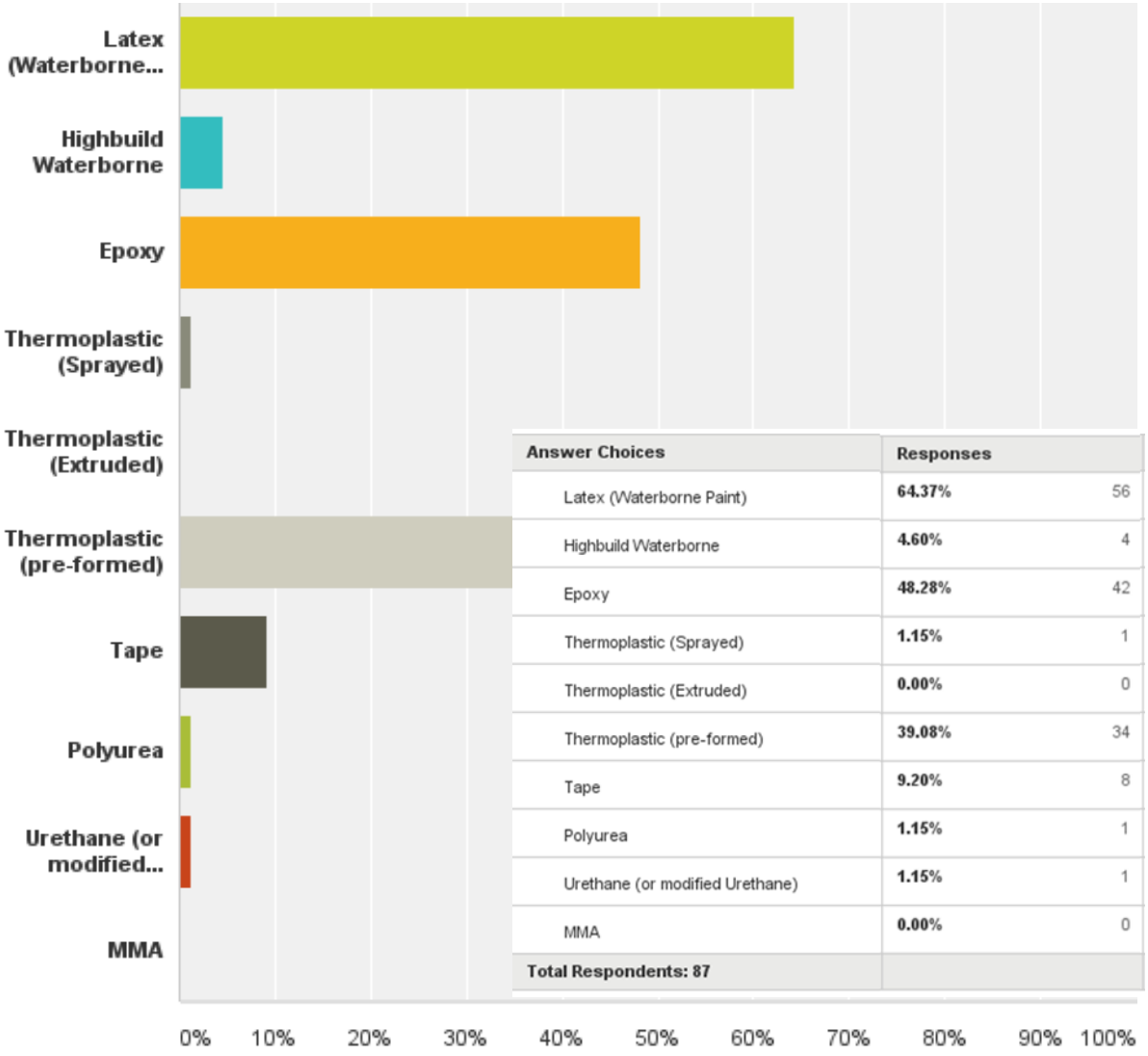
Answer Choices	Responses									
	Q.1 Long Lines (new)		Q.2 Legends (new)		Q.3 Long Lines (maint.)		Q.4 Legends (maint.)		Q.5 Grooving	
Methyl Methacrylate (MMA)	0.00%	0	0.00%	0	0.00%	0	0.00%	0	0.00%	0
Agencies answered	87		87		86		86		86	



Answer Choices	Responses	
Latex (Waterborne Paint)	80.46%	70
Highbuild Waterborne	11.49%	10
Epoxy	64.37%	56
Thermoplastic (Sprayed)	0.00%	0
Thermoplastic (Extruded)	0.00%	0
Thermoplastic (pre-formed)	11.49%	10
Tape	10.34%	9
Polyurea	0.00%	0
Urethane (or modified Urethane)	1.15%	1
MMA	0.00%	0
Total Respondents: 87		

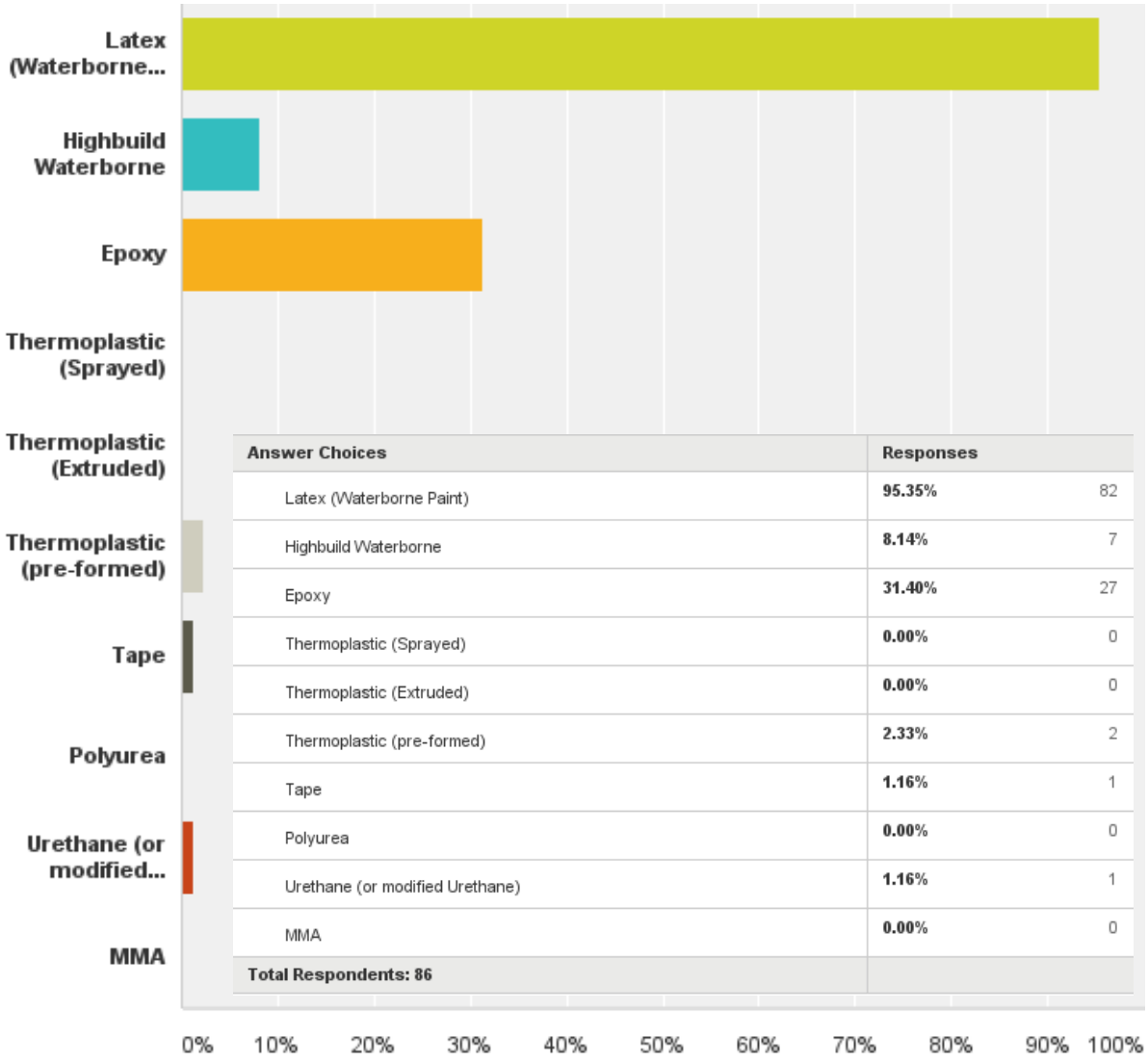
Figure 3. Percentage of markings used for long lines on new construction or rehab (Survey Question 1).

It was interesting to see that 9 agencies used tape for long line on new construction or rehab projects. Upon further analysis of the data, 6 counties and 3 cities have indicated using tape for these applications. The majority of these agencies described themselves as either urban or suburban with only two agencies saying they are rural.



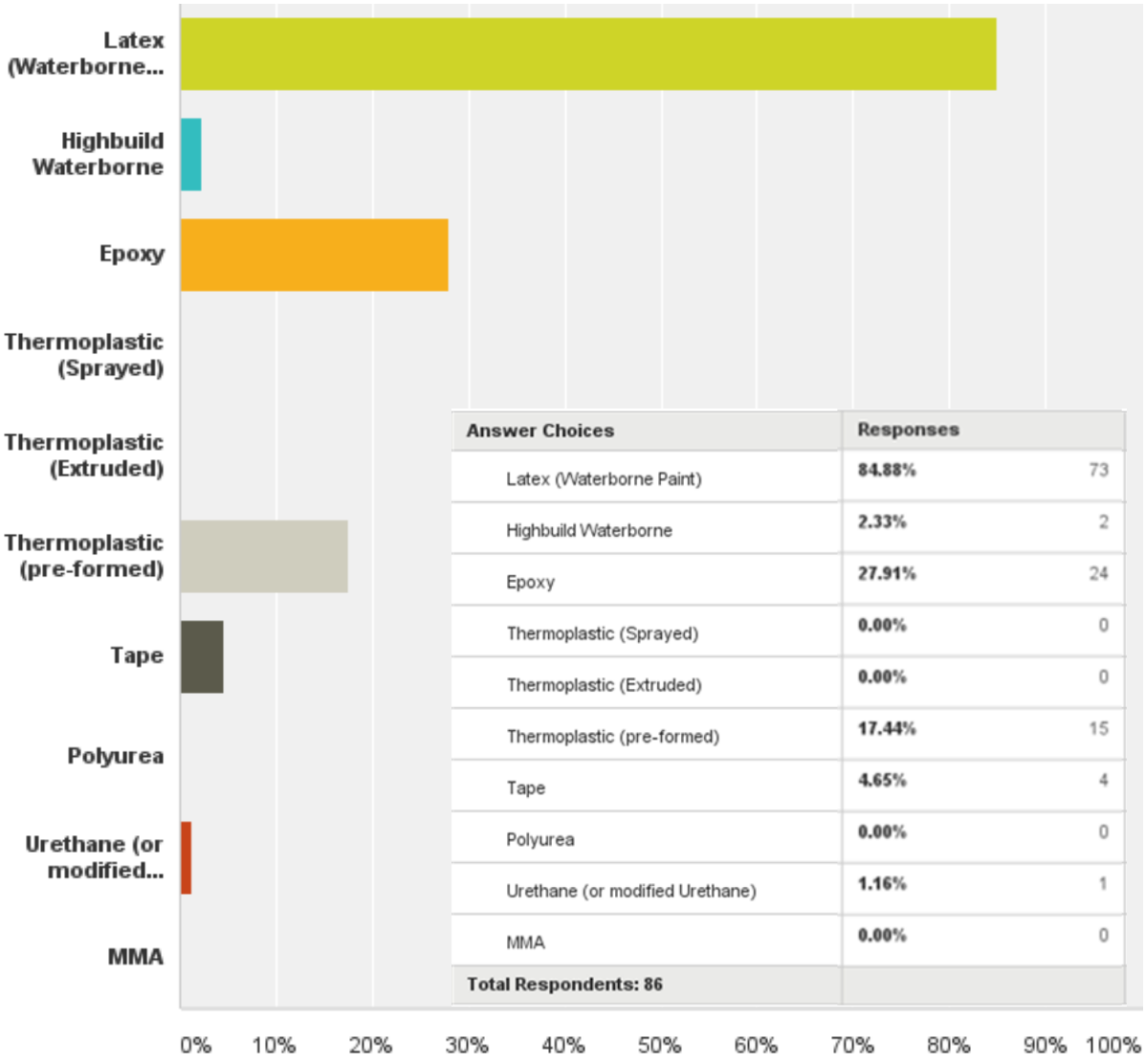
Answer Choices	Responses	
Latex (Waterborne Paint)	64.37%	56
Highbuild Waterborne	4.60%	4
Epoxy	48.28%	42
Thermoplastic (Sprayed)	1.15%	1
Thermoplastic (Extruded)	0.00%	0
Thermoplastic (pre-formed)	39.08%	34
Tape	9.20%	8
Polyurea	1.15%	1
Urethane (or modified Urethane)	1.15%	1
MMA	0.00%	0
Total Respondents: 87		

Figure 4. Percentage of markings used for legend on new construction or rehab (Survey Question 2).



Answer Choices	Responses	
Latex (Waterborne Paint)	95.35%	82
Highbuild Waterborne	8.14%	7
Epoxy	31.40%	27
Thermoplastic (Sprayed)	0.00%	0
Thermoplastic (Extruded)	0.00%	0
Thermoplastic (pre-formed)	2.33%	2
Tape	1.16%	1
Polyurea	0.00%	0
Urethane (or modified Urethane)	1.16%	1
MMA	0.00%	0
Total Respondents: 86		

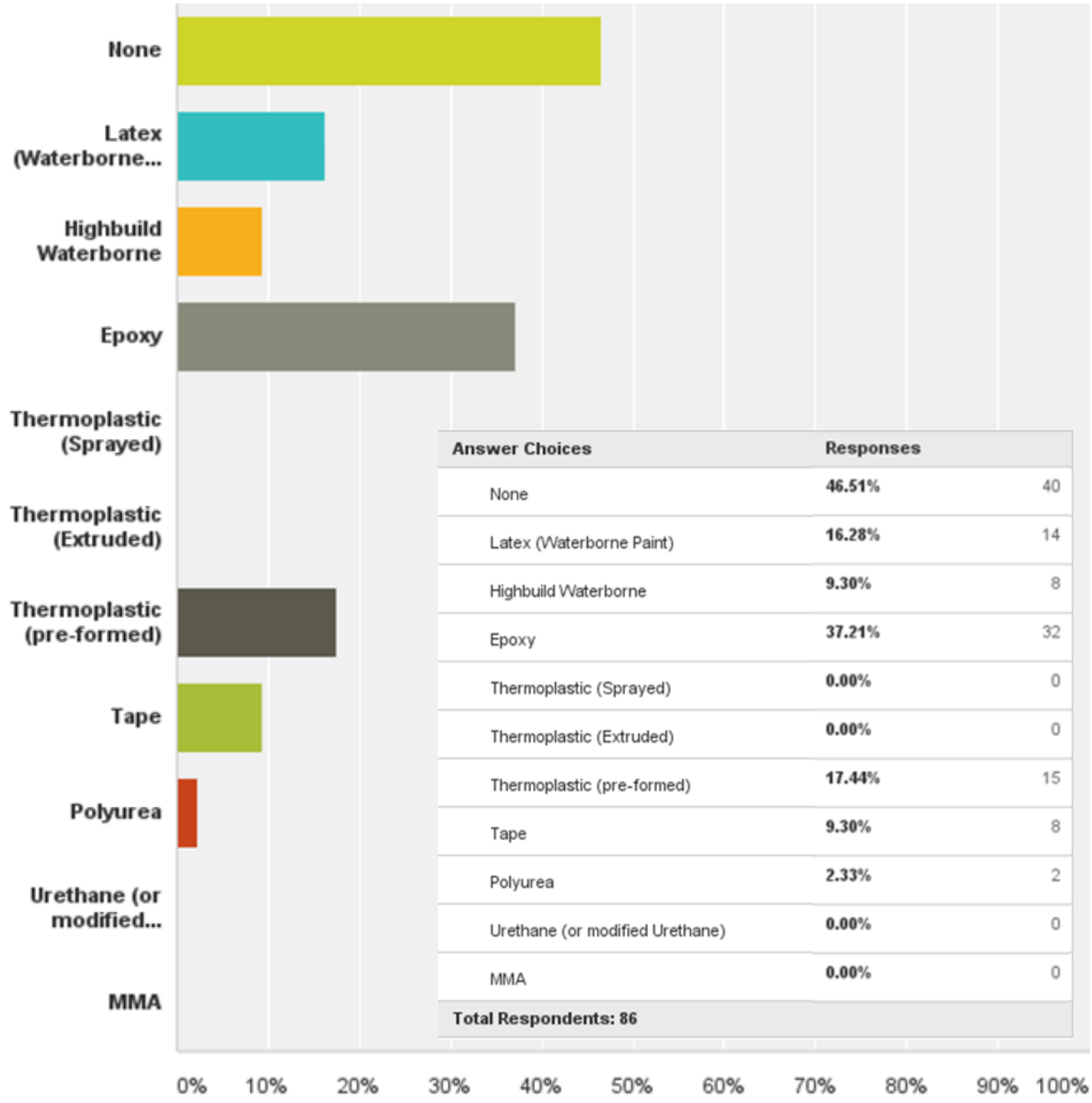
Figure 5. Percentage of markings used for long lines for regular maintenance (Survey Question 3).



Answer Choices	Responses	
Latex (Waterborne Paint)	84.88%	73
Highbuild Waterborne	2.33%	2
Epoxy	27.91%	24
Thermoplastic (Sprayed)	0.00%	0
Thermoplastic (Extruded)	0.00%	0
Thermoplastic (pre-formed)	17.44%	15
Tape	4.65%	4
Polyurea	0.00%	0
Urethane (or modified Urethane)	1.16%	1
MMA	0.00%	0
Total Respondents: 86		

Figure 6. Percentage of markings used for legend for regular maintenance (Survey Question 4).

From Figures 3, 4, 5 and 6 it is obvious that the two most common pavement marking products for cities and counties are latex and epoxy. This matches what the Minnesota DOT also uses. It is interesting though to see tape, highbuild waterborne, and thermoplastic being utilized in these settings. In future research, the performance of these durable products could be evaluated to provide a good comparison of cost and durability to provide guidance to local agencies.



Answer Choices	Responses	
None	46.51%	40
Latex (Waterborne Paint)	16.28%	14
Highbuild Waterborne	9.30%	8
Epoxy	37.21%	32
Thermoplastic (Sprayed)	0.00%	0
Thermoplastic (Extruded)	0.00%	0
Thermoplastic (pre-formed)	17.44%	15
Tape	9.30%	8
Polyurea	2.33%	2
Urethane (or modified Urethane)	0.00%	0
MMA	0.00%	0
Total Respondents: 86		

Figure 7. Percentage of pavement markings used in a groove or recess in the pavement (Survey Question 5).

The research team further analyzed the results from the survey regarding the grooving to see the impact. Fourteen agencies (12 counties and 2 cities) said they installed latex (waterborne paint) in a groove. Those agencies also said their waterborne paint provided a longer service life (2 to 3 years) compared to surface installed waterborne paint of less than 2 years when compared across different traffic levels. This is anecdotal evidence that grooving extends the service life of pavement markings. More research is still needed to quantify this extension in service life and develop a benefit cost ratio to help agencies make the right decision on grooving.

2.2 PAVEMENT MARKING PERFORMACNE

Following the previous questions, participants were asked if they have a "Bare Lane" policy or practice. Out of the 89 agencies participated in the survey, 82 responded to the question and 7 skipped the question. Out of the 82 agencies only 6 agencies indicated that they have a "Bare Lane" policy or practice. Of the 6 agencies, 4 indicated that they apply the policy for roads with all traffic volume levels, 2 indicated they implement the policy to roads with ADT greater than 5,000, and 1 indicated that the policy applies to roads with ADT greater than a 1,000.

The last question in the survey was regarding the estimated life for each product by traffic level for long lines. Tables 2 through 6 present the responses for the last question in the survey. From Tables 2 to 6, despite the fact that Latex paint is the most used, agencies have lower expectations for it in terms of life expectation compared to the epoxy paint. Also, despite their lesser use by agencies, the Thermoplastic (preformed), Tape, and Polyurea paints are expected to have a longer life especially on the sections with ADT higher than 1,000.

Table 2. Expected life of the markings on sections with ADT 0 to 999.

ADT: 0 to 999						
	Less than 1 year	**1 year**	**2 years**	**3 years**	**More than 3 years**	**Total**
Latex (Waterborne Paint)	**2.99%** 2	**29.85%** 20	**46.27%** 31	**17.91%** 12	**2.99%** 2	67
Highbuild Waterborne	**14.29%** 1	**14.29%** 1	**28.57%** 2	**0.00%** 0	**42.86%** 3	7
Epoxy	**5.13%** 2	**0.00%** 0	**0.00%** 0	**17.95%** 7	**76.92%** 30	39
Thermoplastic (Sprayed)	**100.00%** 1	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	1
Thermoplastic (Extruded)	**100.00%** 1	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	1
Thermoplastic (pre-formed)	**8.33%** 1	**0.00%** 0	**0.00%** 0	**0.00%** 0	**91.67%** 11	12
Tape	**18.18%** 2	**9.09%** 1	**0.00%** 0	**0.00%** 0	**72.73%** 8	11
Polyurea	**100.00%** 1	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	1
Urethane (or modified Urethane)	**100.00%** 1	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	1
MMA	**100.00%** 1	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	1

Table 3. Expected life of the markings on sections with ADT 1,000 to 4,999.

ADT: 1,000 to 4,999						
	Less than 1 year	1 year	2 years	3 years	More than 3 years	Total
Latex (Waterborne Paint)	3.23% 2	62.90% 39	29.03% 18	4.84% 3	0.00% 0	62
Highbuild Waterborne	0.00% 0	16.67% 1	33.33% 2	50.00% 3	0.00% 0	6
Epoxy	2.38% 1	0.00% 0	4.76% 2	42.86% 18	50.00% 21	42
Thermoplastic (Sprayed)	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0
Thermoplastic (Extruded)	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0
Thermoplastic (pre-formed)	0.00% 0	0.00% 0	0.00% 0	0.00% 0	100.00% 12	12
Tape	11.11% 1	11.11% 1	0.00% 0	0.00% 0	77.78% 7	9
Polyurea	0.00% 0	0.00% 0	0.00% 0	0.00% 0	100.00% 1	1
Urethane (or modified Urethane)	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0
MMA	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0

Table 4. Expected life of the markings on sections with ADT 5,000 to 9,999.

ADT: 5,000 to 9,999						
	Less than 1 year	1 year	2 years	3 years	More than 3 years	Total
Latex (Waterborne Paint)	**24.39%** 10	**63.41%** 26	**12.20%** 5	**0.00%** 0	**0.00%** 0	41
Highbuild Waterborne	**0.00%** 0	**0.00%** 0	**100.00%** 1	**0.00%** 0	**0.00%** 0	1
Epoxy	**3.33%** 1	**0.00%** 0	**30.00%** 9	**40.00%** 12	**26.67%** 8	30
Thermoplastic (Sprayed)	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	0
Thermoplastic (Extruded)	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	0
Thermoplastic (pre-formed)	**0.00%** 0	**0.00%** 0	**0.00%** 0	**9.09%** 1	**90.91%** 10	11
Tape	**14.29%** 1	**0.00%** 0	**0.00%** 0	**0.00%** 0	**85.71%** 6	7
Polyurea	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**100.00%** 1	1
Urethane (or modified Urethane)	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	0
MMA	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	0

Table 5. Expected life of the markings on sections with ADT 10,000 to 19,999.

ADT: 10,000 to 19,999						
	Less than 1 year	1 year	2 years	3 years	More than 3 years	Total
Latex (Waterborne Paint)	**30.77%** 8	**69.23%** 18	**0.00%** 0	**0.00%** 0	**0.00%** 0	26
Highbuild Waterborne	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**100.00%** 1	1
Epoxy	**5.26%** 1	**5.26%** 1	**31.58%** 6	**31.58%** 6	**26.32%** 5	19
Thermoplastic (Sprayed)	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	0
Thermoplastic (Extruded)	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	0
Thermoplastic (pre-formed)	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**100.00%** 7	7
Tape	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**100.00%** 3	3
Polyurea	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**100.00%** 1	1
Urethane (or modified Urethane)	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	0
MMA	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	**0.00%** 0	0

Table 6. Expected life of the markings on sections with ADT greater than 20,000.

ADT: greater than 20,000						
	Less than 1 year	1 year	2 years	3 years	More than 3 years	Total
Latex (Waterborne Paint)	27.78% 5	72.22% 13	0.00% 0	0.00% 0	0.00% 0	18
Highbuild Waterborne	0.00% 0	100.00% 1	0.00% 0	0.00% 0	0.00% 0	1
Epoxy	16.67% 2	0.00% 0	33.33% 4	16.67% 2	33.33% 4	12
Thermoplastic (Sprayed)	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0
Thermoplastic (Extruded)	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0
Thermoplastic (pre-formed)	0.00% 0	0.00% 0	0.00% 0	0.00% 0	100.00% 5	5
Tape	0.00% 0	0.00% 0	0.00% 0	0.00% 0	100.00% 3	3
Polyurea	0.00% 0	0.00% 0	0.00% 0	0.00% 0	100.00% 1	1
Urethane (or modified Urethane)	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0
MMA	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0.00% 0	0

Table 6 shows the local agencies that provided different pavement marking expected life for traffic levels over 20,000 AADT. Upon further investigation, the majority of the respondents were cities or counties that identified themselves as urban or suburban. For Latex, out of the 18 responses, 12 were cities and 6 urban/suburban counties. For Epoxy, out of the 12 responses, 9 were cities and 3 urban/suburban counties.

CHAPTER 3: LONG-TERM PAVEMENT MARKING PERFORMANCE

Pavement markings are an important aspect that determines the serviceability and quality of highway systems due to their impact on the travelling public, in terms of lateral positioning, messages, and nighttime visibility of the road geometry. In this study, we utilize the data mine available for Minnesota in the NTPEP database. The data set studied includes retroreflectivity values measured over time for pavement markings installed in 2010 and 2013. The 2013 test site included grooved in markings, but no test data were available on the NTPEP site for the grooved in markings and hence it was not included in the analysis. Below are details of each test site:

1. 2010 test site:
    a. Installed July 2010
    b. AADT of 84,000 on US 10, AADT of 43,000 on TH 610
    c. Had materials installed over asphalt and concrete surfaces
    d. A total of 62 different products installed (white and yellow)
    e. Installation conditions: not available
    f. Road surface age: not available
    g. Location: Asphalt: Westbound US Highway 10 between Minnesota TH 65 and University Avenue between miles posts 234 and 233
    Concrete: Westbound Minnesota TH 610 between Zane Ave and West Broadway Ave between mile posts 7 and 6

2. 2013 test site:
    a. Installed July 2013
    b. AADT of 38,000
    c. Had materials installed over asphalt and concrete surfaces
    d. A total of 77 different products installed (white and yellow)
    e. Installation conditions: air temperature: > 80, humidity: < 50
    f. Road surface age: 1 year old (new construction)
    g. Location: Interstate 35E north of Centerville between mile posts 126 and 127

The analysis performed in this study includes modeling the deterioration behavior of the pavement marking in terms of retroreflectivity loss over time. The evaluation is conducted to compare that deterioration for different surface materials, product type, year of application, exposer to wheel contact, and the color of paint. The markings were applied to asphalt and concrete pavement surfaces, and thus one of the aims in this study is to investigate if pavement markings on different surfaces would behave differently. NTPEP grouped the different pavement products into 15 types based on their base constituents and the expected service life. Ten types out of the 15 were used in Minnesota in 2010 and 2013, and thus only 10 types are included in the study. Table 7 provides the type name and its description as provided in the NTPEP.

Table 7. Types of pavement markings used included in the study.

Type	Description
1a	Waterborne Paint 1 yr
1b	Waterborne Paint 2 yr
1c	Waterborne Paint 3 yr
3a	Thermoplastic 3 yr
3b	Preformed Thermoplastic 3 yr
4a	Permanent Polymeric 3 yr
5a	Epoxy 3 yr
5c	Polyurea 3 yr
5d	Methyl Methacrylate (MMA) 3 yr
5e	Multi-Component Durable 3 yr

The pavement markings were also applied on different years, 2010 and 2013. From this study we can depict the change in performance of markings produced and used on different years. This change might be due to enhancements in the production process or the practice. The location of the pavement marking is expected to impact its performance over time. This is expected, because the transverse location relates to the exposure of that region to traffic and wheel contact. In this study, we followed the definition provided in NTPEP user guide; where wheel zones are the ones falling on the wheel track, while the skip zones fall closer to the shoulder, where they are exposed to less traffic. Different marking colors might perform differently due the different chemical properties and contents. **Error! Reference s ource not found.** provides a full list of all products included in the study, their type, color, and the year they were applied.

Table 8. Pavement marking products included in the study.

Year	Color	Type	Product Name
2013	White	1a	White Waterborne PA Spec
2013	Yellow	1a	Yellow Waterborne PA Spec
2010	White	1b	999801
2010	White	1b	999802
2010	Yellow	1b	999803
2010	Yellow	1b	999804
2010	Yellow	1b	999805
2013	White	1b	VP13-W1
2013	White	1b	VP13-W2
2013	White	1b	White WB 982301 / MNW21M1
2013	White	1b	WHITE WB RG1
2013	White	1b	WHITE WB RG2

Year	Color	Type	Product Name
2013	Yellow	1b	VP13-Y7
2013	Yellow	1b	YELLOW WB 982302 / MNY21M1
2013	Yellow	1b	YELLOW WB RG1
2013	Yellow	1b	YELLOW WB RG2
2010	White	1c	High Build Waterborne White
2010	White	1c	Hotline Waterborne White
2010	White	1c	Hotline Waterborne White 2
2010	White	1c	Hotline Waterborne White 3
2010	White	1c	Hotline Waterborne White 4
2010	Yellow	1c	High Build Waterborne Lead-Free Yellow
2010	Yellow	1c	Hotline Waterborne Lead-Free Yellow
2010	Yellow	1c	Hotline Waterborne Lead-Free Yellow 2
2010	Yellow	1c	Hotline Waterborne Lead-Free Yellow 3
2010	Yellow	1c	Hotline Waterborne Lead-Free Yellow 4
2013	White	1c	13W1
2013	White	1c	13W2
2013	White	1c	VP13-W3
2013	White	1c	WHITE WB 982321
2013	Yellow	1c	13Y1
2013	Yellow	1c	13Y2
2013	Yellow	1c	VP13-Y6
2013	Yellow	1c	YELLOW WB 982322
2010	White	3a	998802
2010	Yellow	3a	998801
2013	White	3a	Ozark Materials LLC White Alkyd Thermoplastic
2013	White	3a	WHITE HD THERMO
2013	Yellow	3a	Ozark Materials LLC Lead-Free Yellow Alkyd Thermoplastic
2013	Yellow	3a	YELLOW HD THERMO
2010	White	3b	HotTape™ White
2010	White	3b	PreMark® White
2013	White	3b	HotTape - White
2013	White	3b	Ozark Materials LLC White Preformed Thermoplastic
2013	White	3b	PreMark - White
2013	White	3b	Swarco Preformed Thermoplastic - White - 125 mil
2013	White	3b	Swarco Preformed Thermoplastic - White - 90 mil
2013	Yellow	3b	HotTape - Yellow
2013	Yellow	3b	Ozark Materials LLC Lead-Free Yellow Preformed The
2013	Yellow	3b	PreMark - Yellow
2013	Yellow	3b	Swarco Preformed Thermoplastic - Yellow - 125 mil
2013	Yellow	3b	Swarco Preformed Thermoplastic - Yellow - 90 mil
2010	White	4a	310I
2010	White	4a	3M Stamark 270ES

Year	Color	Type	Product Name
2010	White	4a	3M Stamark 380AW
2010	White	4a	3M Stamark 380I ES
2010	White	4a	Deltaline HDX White (High Durability Intersection)
2010	White	4a	Deltaline XRP-E White (Extended Reflective Perform
2010	White	4a	Deltaline XRP-R White (Extended Reflective Perform
2010	White	4a	Stamark High Performance 390
2010	Yellow	4a	3M Stamark 271ES
2010	Yellow	4a	3M Stamark 381AW
2010	Yellow	4a	Deltaline XRP-E Yellow (Extended Reflective Perfor
2010	Yellow	4a	Deltaline XRP-R Yellow (Extended Reflective Perfor
2010	Yellow	4a	Stamark High Performance 391
2013	White	4a	Deltaline XRP (Extended Reflective Performance) Wh
2013	White	4a	Deltaline XRP-R (Extended Reflective Performance--
2013	White	4a	Deltaline XRP™ White
2013	Yellow	4a	3M Stamark High Performance Tape 381I ES - Yellow
2013	Yellow	4a	Deltaline XRP (Extended Reflective Performance) Y
2013	Yellow	4a	Deltaline XRP-R (Extended Reflective Performance-W
2013	Yellow	4a	Deltaline XRP™ Yellow
2010	White	5a	999901
2010	Yellow	5a	999902
2013	White	5a	HPS 2 WHITE
2013	White	5a	MARK-55 WHITE
2013	White	5a	White Epoxy Traffic Paint
2013	Yellow	5a	HPS 2 YELLOW
2013	Yellow	5a	MARK-55 Non-Lead Yellow
2013	Yellow	5a	Yellow Epoxy Traffic Paint
2010	White	5c	POLY-CARB MARK-75.3 White
2010	White	5c	POLY-CARB MARK-75.4 White
2010	Yellow	5c	POLY-CARB MARK-75.3 NL Yellow
2010	Yellow	5c	POLY-CARB MARK-75.4 NL Yellow
2013	White	5c	3M Liquid Pavement Marking 5001B - White
2013	White	5c	MFUA-12 White Polyurea Two-Component Pavement Mark
2013	Yellow	5c	3M Liquid Pavement Marking 5001B - Yellow
2013	Yellow	5c	MFUA-12 Yellow Polyurea Two-Component Pavement Mar
2010	White	5d	999905
2010	White	5d	MMA Pathfinder
2010	White	5d	White 98:2 Spray MMA
2010	Yellow	5d	999906
2010	Yellow	5d	MMA Pathfinder
2010	Yellow	5d	Yellow 98:2 Spray MMA
2013	White	5d	EVEX-13-1
2013	White	5d	EVPF-13-1

Year	Color	Type	Product Name
2013	White	5d	EVSP-13-1
2013	White	5d	M13W1
2013	White	5d	MMA EXT WHITE
2013	White	5d	MMA STR WHITE
2013	Yellow	5d	EVEX-13-2
2013	Yellow	5d	EVPF-13-2
2013	Yellow	5d	EVSP-13-2
2013	Yellow	5d	M13W2
2013	Yellow	5d	M13Y1
2013	Yellow	5d	M13Y2
2013	Yellow	5d	MMA EXT YELLOW
2013	Yellow	5d	MMA STR YELLOW
2010	White	5e	999903
2010	White	5e	POLY-CARB MARK-65.5 White
2010	Yellow	5e	999904
2010	Yellow	5e	POLY-CARB MARK-65.5 NL Yellow
2013	White	5e	Cem/Stripe
2013	White	5e	MARK-55.9 WHITE
2013	White	5e	MARK-65.5 WHITE
2013	White	5e	MFUA-10 White Modified Polyacrylate Two-Component
2013	Yellow	5e	MARK-55.9 Non-Lead Yellow
2013	Yellow	5e	MARK-65.5 Non-Lead Yellow
2013	Yellow	5e	MFUA-10 Yellow Modified Polyacrylate Two-Component

3.1 ANALYSIS SCHEME

The data set included in this study consists of the following: retroreflectivity values measured in units of mcd/m^2/lux, time of measurement, location of measurement, color of marking, and the surface type. The measurements were taken at 0 (initial), 1, 2, 3, 9, 10, 11, 12, 15, 21, 24, 27, 33 and 36 months. In some sites, the measurements were limited to 27 months. In some cases, data for only 24 months was available. The test samples included in this study were installed either in 2010 or 2013, and they were applied on different surface types (i.e., asphalt or concrete). Table 9 presents the number of tested samples under various conditions. The nomenclature of the variables used in the table and following sections in the report are as follows:

- Year: the year of installation for that pavement marking.
- Zone: the transverse location of the tested sample. Where, wheel indicates the zones that are more prone to wheel contact due to traffic and is referred to as W, whereas S indicates the region that are less prone to traffic (i.e., skip zones).

- Color: the color of the pavement marking in use, where W refers to white paint and Y to yellow paint.
- Type: the marking type as classified in accordance to the NTPEP data mine.

Table 9. Number of tested samples under different categories and instillation condition.

Surface Type	Year	Zone	Color	Type									
				1a	1b	1c	3a	3b	4a	5a	5c	5d	5e
Asphalt	2010	W	W	N/A	2	5	1	2	8	1	2	3	2
			Y	N/A	3	5	1	N/A	5	1	2	3	2
		S	W	N/A	2	5	1	2	8	1	2	3	2
			Y	N/A	3	5	1	N/A	5	1	2	3	2
	2013	W	W	1	5	4	2	5	3	3	2	6	4
			Y	1	4	4	2	5	4	3	2	8	3
		S	W	1	5	4	2	5	3	3	2	6	4
			Y	1	4	4	2	5	4	3	2	8	3
Concrete	2010	W	W	N/A	2	5	1	2	8	1	2	3	2
			Y	N/A	3	5	1	N/A	5	1	2	3	2
		S	W	N/A	2	5	1	2	8	1	2	3	2
			Y	N/A	3	5	1	N/A	5	1	2	3	2
	2013	W	W	1	5	4	2	5	3	3	2	6	4
			Y	1	4	4	2	5	4	3	2	8	3
		S	W	1	5	4	2	5	3	3	2	6	4
			Y	1	4	4	2	5	4	3	2	8	3

3.2 DETERIORATION MODEL

The collected data over time exhibits a deterioration behavior, where the retroreflectivity (i.e., *R*) drops as a function of time (i.e., *t*) in months. The deterioration behavior is best modeled using an exponential decay function (Equation 1). The model is a two parameter model, where β_0 indicates the average (i.e., fitted) initial value of retroreflectivity and β_1 controls the decay rate.

$$R(t) = \beta_0 e^{\beta_1 t} \quad (1)$$

This deterioration model has a unique characteristic, where at each point in time *t* the retroreflectivity (i.e., R_2) drops by β_2% of the previous month retroreflectivity (i.e., R_1) value. This can be described by Equation 2. It should be noticed that the retroreflectivity monthly deterioration rate is unit less; however, it is defined per month period of time.

$$\beta_2 = \frac{R_1 - R_2}{R_1} = \frac{\beta_0 e^{\beta_1 t} - \beta_0 e^{\beta_1 (t+1)}}{\beta_0 e^{\beta_1 t}} = 1 - e^{\beta_1} \quad (2)$$

Figure 8 shows the actual retroreflectivity values and the fitted decay functions with the parameters. The data sets are for product 999801. The product is white paint of type 1b. Booth test samples were applied in 2010 at skip and wheel zones on an asphalt surface. It can be seen that wheel zone is deteriorating faster than skip zone. This is reflected by a smaller β_1 value, which correspond to a smaller β_2 value. Similar models were fitted for each monitored data set. This resulted in 476 models fitted for different conditions and products. Appendix A provides the fitting results for each individual data set.

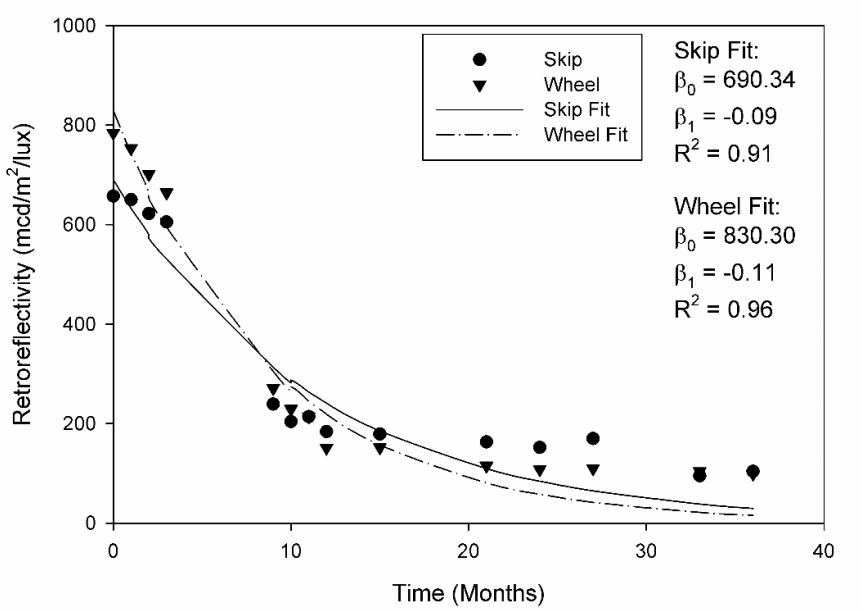


Figure 8. Measured and fitted retroreflectivity vs. time for product 999801, white latex (waterborne paint) installed in 2010 on wheel and skip zones.

3.3 STATISTICAL ANALYSIS

To test the impact of various conditions on the performance of pavement marking, hypothesis tests were conducted to compare different performance parameters. The independent variables selected in this study are: the pavement surface, the year of application, the zone were the marking is applied (i.e., wheel or skip), the color, and the type of pavement marking (Table 10). The performance indicators selected as the basis for comparison are: the measured initial retroreflectivity; the ratio of retroreflectivity after one and two years to the initial retroreflectivity; the modeled retroreflectivity monthly deterioration rate (i.e., β_2); and the average retroreflectivity. It should be mentioned that not all samples had three years period of monitoring. Therefore, the statistical analysis is limited to two

years ratio, and it is assumed that the long term performance is captured in the modeled deterioration rate. Also type 1a is not included in the statistical analysis, because this type was not used in year 2010 and thus there is a very limited number of data points to be included in the analysis.

Table 10. Pavement marking products applied in 2010 and 2013.

	Year	
	2010	2013
Product		1a
	1b	1b
	1c	1c
	3a	3a
	3b	3b
	4a	4a
	5a	5a
	5c	5c
	5d	5d
	5e	5e

The major hypothesis test performed in this study is a second degree factorial (i.e., two-way) analysis of variance (ANOVA). This will result in comparisons between the pavement marking performance under various conditions and the interaction between each two of these conditions. The null hypotheses in the tests are equal independent variables means for groups with different independent variables. For example, when comparing the initial retroreflectivity for markings applied on asphalt or concrete, the test compares all markings applied on asphalt to all markings applied on concrete surfaces, regardless of the type, year of application, or any other condition. The results of the tests can be summarized with p-values. If the p-value is less than significance level α, which is 1 minus the confidence level, then the null hypothesis can be rejected. Rejecting the null hypothesis indicates that there is enough statistical evidence that the difference between the mean initial retroreflectivity is significant.

3.4 ANOVA RESULTS FOR INITIAL RETROREFLECTIVITY

Table 11 presents the results for the two-way ANOVA conducted on all data sets, excluding the type 1a products due to the limit observations in that category. The dependent variable under test is the initial retroreflectivity measured in the field. In the table p-values are reported, and at a 95% confidence level p-values less than 5% (i.e., 0.05) indicate statistically significant difference. The significantly different levels are indicated by an asterisk (*).

From **Error! Reference source not found.**, it can be seen that the conditions that have statistically s ignificant differences in the initial mean retroreflectivity are only the year the marking was applied, the color, and the type of the marking. Also there is interaction between the type and the year. Based on

these results, and the fact that average initial retroreflectivity of markings applied in 2010 was 595.28 mcd/m^2/lux, while the average initial retroreflectivity markings applied in 2013 was 457.11 mcd/m^2/lux; it can be concluded that the average initial retroreflectivity of markings applied in 2010 was significantly higher than the average initial value of markings applied in 2013. As for the color it can be concluded that the white pavement markings had significantly higher average initial retroreflectivity (i.e., 623.95 mcd/m^2/lux) as compared to the average initial retroreflectivity of the yellow markings (i.e., 397.84 mcd/m^2/lux).

Table 11. ANOVA test results, p-values, comparing the initial retroreflectivity values for different variables and their interactions.

Variable	P-value
Surface	0.79
Year	<0.01*
Zone	0.52
Color	<0.01*
Type	<0.01*
Surface*Year	0.67
Surface*Zone	0.73
Surface*color	0.98
Surface*Type	0.99
Year*Zone	0.85
Year*Color	0.69
Year*Type	<0.01*
Zone*Color	0.49
Zone*Type	1.00
Color*Type	0.53

Due to the multiple marking types (i.e., 9 types excluding type 1a) included in the analysis, separate t-tests were performed to compare the differences for various types. **Error! Reference source not found.** p resents the results of the individual t-tests for different types comparing the initial average retroreflectivity. The T-test can be a one or two-tailed test. In many cases, the one tail test might be significant while the two tail test is not. In this study we are concerned with the one tail test, since we are interested in identifying which initial average retroreflectivity is higher. The diagonal represents the average initial retroreflectivity for the type falling on that diagonal. Off-diagonal cells are reported with statistically significant (S) or not statistically significant (NS). This is due to the fact that there are three p-values reported for each t-test, the two-tailed test, the left tail and the right tail test. However, from the values and the significance result one can know which type has a statistically significant higher initial average retroreflectivity. The significance is based on a 95% confidence level. It should be mentioned that the table is symmetric, thus only the upper diagonal tests are reported. For example, type 3a has an

average initial retroreflectivity of 443.79 mcd/m^2/lux, and has statistically significant higher initial average retroreflectivity (443.79 mcd/m^2/lux) as compared to type 1c (324.40 mcd/m^2/lux).

Table 12. T-test results, for individual comparisons between the initial average retroreflectivity values for different marking type.

Type	1b Latex 2 yr	1c Latex 3 yr	3c Thermo	3b Preformed Thermo	4a Tape	5a Epoxy	5c Poly	5d MMA	5e Mix durable
1b	351	NS	NS	NS	S	S	NS	S	S
1c		324	S	NS	S	S	NS	S	S
3a			443	NS	S	S	S	S	NS
3b				406	S	S	NS	S	S
4a					891	S	S	S	S
5a						589	S	S	S
5c							326	S	S
5d								574	S
5e									469

The interaction behavior contains many possible combinations (i.e., 153 combinations). However, the most interesting conclusion from the table, is the one comparing the initial average retroreflectivity of the same type applied on two different years. This indicates the changes in practice and marking properties for the same type at different installation years. In that regard, the initial average retroreflectivity of type 1c significantly increased from 2010 to 2013. On the other hand, the initial average retroreflectivity of types 5a, 5d, and 5e decreased in 2013 as compared to the markings installed in 2010.

Finally, from Table 12, the surface type and the zone, where the markings were applied are not significant factors impacting the initial average retroreflectivity. This indicates that the performed tests are not biased towards a certain pavement surface type or zone. The bias might rise in the case that one surface type or zone started with higher initial average retroreflectivity, accordingly, the decay performance might differ for different surface types or zones.

3.5 ANOVA RESULTS FOR 1 YEAR RETROREFLECTIVITY RATIO

Table 13 presents the results for the two-way ANOVA conducted on all data sets excluding the type 1a products due to the limit observations in that category. The dependent variable under test is the ratio of the average retroreflectivity after one year service to the initial average retroreflectivity measured in the field (i.e., R1/R0). In the table p-values are reported, and compares to 95% confidence level, therefore, p-values less than 5% (i.e., 0.05) indicate statistically significant difference.

From Table 13, it can be seen that the conditions that have statistically significant differences in R1/R2 are only the zone, the color, and the type of the marking. Also, there is significant interaction between the surface and year; the year and zone; the year and type; and the zone and type. The table also provides the comparison between the ratios for the different levels in the significant conditions. In the interaction terms we normally limit our analysis to comparing each level projected on two levels, but not all combinations. The third column in the table provides the statistically significantly different contrasts of interest and their mean values for purposes of comparison. It is interesting how different types can deteriorate differently at the wheel/skip zones. For instance, all other types not included in the zone*type interaction actually did not behave differently in wheel zones compared to skip zones.

Table 13. ANOVA test results, p-values, comparing R1/R0 retroreflectivity values for different variables and their interactions.

Variable	P-value	Significant contrasts/ Notes
Surface	0.52	—
Year	0.38	—
Zone	<0.01*	S = 0.47
		W = 0.27
Color	<0.01*	W = 0.41
		Y = 0.33
Type	<0.01*	See Table 8
Surface*Year	<0.01*	Concrete, 2010 = 0.40
		Concrete, 2013 = 0.32
Surface*Zone	0.81	—
Surface*color	0.84	—
Surface*Type	0.27	—
Year*Zone	0.04*	Wheel, 2010 = 0.30
		Wheel, 2013 = 0.24
Year*Color	0.22	—
Year*Type	<0.01*	4a, 2010 = 0.29
		4a, 2013 = 0.11
		5d, 2010 = 0.50
		5d, 2013 = 0.40
Zone*Color	0.10	—
Zone*Type	<0.01*	1b, Wheel = 0.25
		1b, Skip = 0.60
		1c, Wheel = 0.19
		1c, Skip = 0.49
		3a, Wheel = 0.23
		3a, Skip = 0.52
		5c, Wheel = 0.34
		5c, Skip = 0.53
		5d, Wheel = 0.37
		5d, Skip = 0.54
		5e, Wheel = 0.34

Variable	P-value	Significant contrasts/ Notes
		5e, Skip = 0.51
Color*Type	0.31	—

Table 14 represents the results of the individual t-test for different types comparing R1/R0. The significance is based on a 95% confidence level. From the table it can be noticed that type 4a has the lowest R1/R0 value, and the difference between the ratio for type 4a and all other types is significant. This indicates that type 4a has the least capability to retain its retroreflectivity after one year of service.

Table 14. T-test results, for individual comparisons between R1/R0 retroreflectivity values for different marking type.

Type	1b Latex 2 yr	1c Latex 3 yr	3c Thermo	3b Preformed Thermo	4a Tape	5a Epoxy	5c Poly	5d MMA	5e Mix durable
1b	0.42	S	NS	S	S	S	NS	NS	NS
1c		0.34	NS	NS	S	NS	S	S	S
3a			0.40	NS	S	NS	NS	NS	NS
3b				0.32	S	NS	S	S	S
4a					0.23	S	S	S	S
5a						0.37	S	S	S
5c							0.44	NS	NS
5d								0.42	NS
5e									0.43

3.6 ANOVA RESULTS FOR 2 YEARS RETROREFLECTIVITY RATIO

Table 15 presents the results for the two-way ANOVA conducted on all data sets excluding the type 1a products due to the limit observations in that category. The dependent variable under test is the ratio of the average retroreflectivity after two year service to the initial average retroreflectivity measured in the field (i.e., R2/R0). In the table p-values are reported, and at a 95% confidence level p-values less than 5% (i.e., 0.05) indicate statistically significant difference.

From Table 15, it can be seen that at the one way level, the only condition that does not have statistically significant difference in R2/R0 is the surface type, and thus the surface type does not impact the average loss of retroreflectivity after two years. However, from the interactions, it can be seen that the surface type interacts with all other variables except the color. For the year of installation, markings placed on 2013 deteriorated faster than the ones placed in 2010 for markings placed on concrete; however for asphalt surfaces, the year did not impact the two years deterioration behavior.

Table 15. ANOVA test results, p-values, comparing R2/R0 retroreflectivity values for different variables and their interactions.

Variable	P-value	Significant contrasts/ Notes
Surface	0.06	—
Year	0.04	2010 = 0.29 2013 = 0.26
Zone	<0.01*	S = 0.34 W = 0.21
Color	<0.01*	W = 0.30 Y = 0.25
Type	<0.01*	See Table 10
Surface*Year	0.03*	Concrete, 2010 = 0.29 Concrete, 2013 = 0.23
Surface*Zone	<0.01*	Asphalt, W = 0.25 Concrete, W = 0.23
Surface*color	0.67	—
Surface*Type	<0.01*	Different marking types applied on different surfaces deteriorate differently after two years of service.
Year*Zone	<0.01*	The only combination that did not have enough evidence of significant difference is the deterioration of markings applied 2010 and 2013 in wheel zone.
Year*Color	0.20	—
Year*Type	<0.01*	1c, 2010 = 0.28 1c, 2013 = 0.21 4a, 2010 = 0.23 4a, 2013 = 0.08 5a, 2010 = 0.23 5a, 2013 = 0.38 5d, 2010 = 0.37 5d, 2013 = 0.20
Zone*Color	0.02*	The impact of color on the deterioration for pavement markings in the wheel zone is insignificant.
Zone*Type	<0.01*	1b, Wheel = 0.18 1b, Skip = 0.42 1c, Wheel = 0.13 1c, Skip = 0.36 4a, Wheel = 0.11 4a, Skip = 0.19 5a, Wheel = 0.25 5a, Skip = 0.36 5c, Wheel = 0.28 5c, Skip = 0.43 5d, Wheel = 0.25 5d, Skip = 0.33 5e, Wheel = 0.28

Variable	P-value	Significant contrasts/ Notes
		5e, Skip = 0.47
Color*Type	0.31	—

Table 16 presents the results of the individual t-test for different types comparing R2/R0. The significance is based on a 95% confidence level

Table 16. T-test results, for individual comparisons between R1/R0 retroreflectivity values for different marking type.

Type	1b Latex 2 yr	1c Latex 3 yr	3c Thermo	3b Preformed Thermo	4a Tape	5a Epoxy	5c Poly	5d MMA	5e Mix durable
1b	0.29	S	NS	S	S	NS	S	NS	S
1c		0.25	NS	NS	S	S	S	S	S
3a			0.29	S	S	NS	S	NS	S
3b				0.17	NS	S	S	S	S
4a					0.18	S	S	S	S
5a						0.34	NS	NS	S
5c							0.36	S	NS
5d								0.25	S
5e									0.38

3.7 ANOVA RESULTS FOR RETROREFLECTIVITY MONTHLY DETERIORATION RATE

In this section, the monthly deterioration rate as defined in Equation 2 is used to perform two-way ANOVA under different conditions and independent variables. Table 17 presents the results for the two-way ANOVA conducted on all data sets excluding type 1a products due to the limit observations in that category. In the table, p-values are reported, and p-values less than 5% (i.e., 0.05) indicate statistically significant difference at a 95% confidence level. From the table it can be seen that all factors affected the modeled deterioration rate of retroreflectivity.

Table 18 presents the results of the individual t-test for different types comparing the fitted retroreflectivity monthly deterioration rate. The significance is based on a 95% confidence level.

Table 17. ANOVA test results, p-values, comparing the monthly retroreflectivity deterioration rate values for different variables and their interactions.

Variable	P-value	Significant contrasts/ Notes
Surface	<0.01*	Asphalt = 0.08 Concrete = 0.10
Year	<0.01*	2010 = 0.08 2013 = 0.10
Zone	<0.01*	W = 0.10 S = 0.07
Color	<0.01*	W = 0.08 Y = 0.10
Type	<0.01*	See Table 12
Surface*Year	<0.01*	The markings placed on concrete surfaces in 2013 are significantly different from all other markings.
Surface*Zone	0.01*	There is not enough evidence that markings applied in skip zones on both surface types are different.
Surface*color	0.90	—
Surface*Type	0.23	—
Year*Zone	0.06	—
Year*Color	0.49	—
Year*Type	<0.01*	1c, 2010 = 0.09 1c, 2013 = 0.11 3a, 2010 = 0.10 3a, 2013 = 0.07 4a, 2010 = 0.09 4a, 2013 = 0.18 5d, 2010 = 0.07 5d, 2013 = 0.09
Zone*Color	0.61	—
Zone*Type	<0.01*	There is not enough evidence that types 3a, 3b, 5a, and 5d perform differently when comparing the markings applied on wheel zones and skip zones.
Color*Type	0.27	—

Table 18. T-test results, for individual comparisons between R1/R0 retroreflectivity values for different marking type.

Type	1b Latex 2 yr	1c Latex 3 yr	3c Thermo	3b Preformed Thermo	4a Tape	5a Epoxy	5c Poly	5d MMA	5e Mix durable
1b	0.08	S	NS	S	S	NS	S	NS	S
1c		0.10	NS	NS	S	S	S	S	S
3a			0.08	S	S	NS	S	NS	S
3b				0.11	S	S	S	S	S
4a					0.12	S	S	S	S
5a						0.07	NS	NS	NS
5c							0.06	S	NS
5d								0.08	S
5e									0.06

3.8 ANOVA RESULTS FOR AVERAGE RETROREFLECTIVITY

In this section, ANOVA was performed to compare the average retroreflectivity of different markings applied under different conditions. **Error! Reference source not found.** presents the results for the two-w ay ANOVA conducted on all data sets excluding type 1a products due to the limit observations in that category. In the table, p-values are reported, and p-values less than 5% (i.e., 0.05) indicate statistically significant difference at a 95% confidence level.

Despite its simplicity, the comparison based on the average retroreflectivity conveys interesting facts. All single level factors affect the average except the surface type, thus on average the pavement markings on asphalt would not be very different from the markings applied to concrete surfaces. Also, the average retroreflectivity of markings applied to the pavements in 2010 were significantly higher than the ones applied in 2013. As expected the average retroreflectivity in wheel zones are less than the ones measured for markings on skip zones. Finally, it can be seen that white markings have a higher average retroreflectivity compared to the yellow markings.

Table 19. ANOVA test results, p-values, comparing the average retroreflectivity values for different variables and their interactions.

Variable	P-value	Significant contrasts/ Notes
Surface	0.47	—
Year	<0.01*	2010 = 296.96
		2013 = 223.29
Zone	<0.01*	W = 232.22
		S = 274.80
Color	<0.01*	W = 319.11
		Y = 184.80
Type	<0.01*	See Table 14
Surface*Year	0.93	—
Surface*Zone	0.09	—
Surface*color	0.94	—
Surface*Type	0.97	—
Year*Zone	0.93	—
Year*Color	0.07	—
Year*Type	<0.01*	1b, 2010 = 247.37
		1b, 2013 = 173.42
		4a, 2010 = 400.44
		4a, 2013 = 332.70
		5a, 2010 = 427.91
		5a, 2013 = 235.87
		5d, 2010 = 398.25
		5d, 2013 = 267.21
		5e, 2010 = 308.15
		5e, 2013 = 195.49
Zone*Color	0.53	—
Zone*Type	0.97	—
Color*Type	0.59	—

Table 20 presents the results of the individual t-test for different types comparing the fitted retroreflectivity monthly deterioration rate. The significance is based on a 95% confidence level.

Table 20. T-test results, for individual comparisons between R1/R0 retroreflectivity values for different marking type.

Type	1b Latex 2 yr	1c Latex 3 yr	3c Thermo	3b Preformed Thermo	4a Tape	5a Epoxy	5c Poly	5d MMA	5e Mix durable
1b	198	S	NS	NS	S	S	NS	S	NS
1c		158	S	NS	S	S	NS	S	SS
3a			233	NS	S	S	NS	S	NS
3b				201	S	S	NS	S	S
4a					386	NS	S	NS	S
5a						283	S	NS	S
5c							198	S	S
5d								299	S
5e									240

CHAPTER 4: SUMMARY AND CONCLUSIONS

This study aimed to analyze the available data in the NTPEP data mine for Minnesota in addition to presenting and analyzing results from a local agency pavement marking use survey. The NTPEP dataset included 10 types of pavement markings applied on 2 types of surfaces (i.e., asphalt and concrete), at 2 different years (i.e., 2010 and 2013), and with different colors (i.e., white and yellow). The data consist of monitored retroreflectivity over a sufficient period of time, extending to 3 years, and at 2 different zones on the pavement, which captures the impact of traffic. The local agency pavement marking survey had 89 responses (52 counties and 37 cities).

The analysis performed on the NTPEP included modeling the deterioration behavior as a function of time. Also two-way ANOVAs were performed to compare various performance measures and the impact of different conditions on these measures. The measures were: initial average retroreflectivity, ratio between the average retroreflectivity after 1 year of service to the initial average retroreflectivity (R1/R0), ratio between the average retroreflectivity after 2 years of service to the initial average retroreflectivity (R2/R0), deterioration rate estimated from the deterioration models, and average retroreflectivity. The analysis was extensive; however, general conclusions and observations can be summarized as follows:

- The surface type does not significantly impact the retroreflectivity values throughout the marking's service life. However, an impact was detected when relying on the modeled deterioration rate.
- Most pavement markings installed in 2010 had statistically significant higher initial retroreflectivity as compared to those installed in 2013. Also the deterioration rates of many markings installed in 2013 were higher as compared to the rates of the markings installed in 2010.
- In most cases, the markings on the wheel zones deteriorated faster, despite the fact that the initial retroreflectivity did not differ significantly. This is expected since higher traffic will reduce retroreflectivity over time.
- White markings had significantly higher initial retroreflectivity as compared to the yellow markings. The white markings had also deteriorated slower as compared to the yellow markings.
- Different marking types performed differently in terms of initial retroreflectivity and deterioration rates. They also interacted in many cases with other parameters. This indicates that the same type deteriorates differently when applied in different locations, on different surface types, and even with different colors. This parameter even interacted with the application year indicating that different practices have evolved differently for different marking types.

The analysis of the NTPEP data also showed differences in performance between different products. Since latex and epoxy are the most commonly used products by local agencies in Minnesota, the report

focused on those two comparisons. When comparing initial retroreflectivity values of latex (1b – 2 year and 1c – 3 year) and epoxy (5a), the difference between the two products was statistically significant with epoxy providing higher values.

One of the findings from the NTPEP test data was that the test site in 2013 had different deterioration values compared to the 2010 test sites for the same pavement marking products. This might be related to the difference in AADT (2013 site had 37,000 compared to 10,000 for 2010) or installation practices.

Analysis of the survey responses showed that latex (waterborne paint) and epoxy products are the most commonly used type of pavement markings for either new or maintenance applications on new construction or re-striping. Few local agencies also use thermoplastic and tape products for both long lines and legends. Here is a summary of the findings from the survey:

- Majority of local agencies use either latex or epoxy for pavement marking applications on long lines and legends
- Majority of the local agencies don't place their pavement markings in grooves. Thirty two agencies use grooving to protect epoxy and 14 use it with latex (waterborne or highbuild waterborne).
- Agencies that placed markings in grooves indicated better service life for their latex paint. The majority selected 2 to 3 years of service life at multiple traffic levels compared to less than 2 years when surface applied.
- The survey results indicated that epoxy and tape outperforms latex at all different levels with the majority of responses indicating 3 years or more than 3 years compared to 1 or 2 years for latex at low AADT and less than 1 year at the higher AADT.

Based on the results of the data analysis and survey results, the research team developed the following recommendations for future research:

- Since the NTPEP data from the 2013 Minnesota test deck for grooved markings were not available, a study on the impact of grooving on pavement marking performance for local agencies would be beneficial. The study would include performance and cost/benefit analysis for the most commonly used products by local agencies.
- Development of a pavement marking application matrix based on pavement remaining life, AADT, functional class, and pavement marking performance will provide guidance to local agencies on when to use certain pavement marking product types to maximize the use of available resources.
- Neither the survey nor the NTPEP test data addressed pavement marking performance on challenging surfaces. MnDOT completed a research project in 2016 (Evaluation of Pavement Markings on Challenging Surfaces - http://www.dot.state.mn.us/research/TS/2016/201608.pdf) to study this topic. Something similar might be necessary in a local agency environment.

APPENDIX A

Table A-1 below presents the results for individual tests monitored over time. The table includes the coefficient of determination (R^2) for all fitted models. Most models had high R^2 values.

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	1c	High Build Waterborne Lead-Free Yellow	Yellow	w	2010	251.37	-0.12	0.94	213.00	0.20	0.13	0.05	88.21	11.39
concrete	1c	Hotline Waterborne Lead-Free Yellow	Yellow	w	2010	256.70	-0.18	0.90	206.00	0.06	0.08	0.05	70.00	16.57
concrete	1c	Hotline Waterborne Lead-Free Yellow 4	Yellow	w	2010	160.51	-0.11	0.93	133.00	0.24	0.17	0.08	59.14	10.65
concrete	1b	999801	White	w	2010	430.30	-0.07	0.94	457.00	0.37	0.22	0.03	194.50	7.22
concrete	1c	Hotline Waterborne Lead-Free Yellow 2	Yellow	w	2010	190.37	-0.14	0.89	146.00	0.17	0.14	0.08	62.07	13.02
concrete	1c	Hotline Waterborne Lead-Free Yellow 3	Yellow	w	2010	231.17	-0.16	0.90	180.00	0.11	0.12	0.07	68.29	15.07

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	3a	998801	Yellow	w	2010	446.40	-0.18	0.88	350.00	0.09	0.09	0.03	122.79	16.16
concrete	3a	998802	White	w	2010	709.51	-0.10	0.89	610.00	0.34	0.24	0.02	282.21	9.52
concrete	5c	POLY-CARB MARK-75.3 NL Yellow	Yellow	w	2010	87.07	-0.09	0.86	106.00	0.26	0.19	0.13	38.36	8.55
asphalt	5c	POLY-CARB MARK-75.3 NL Yellow	Yellow	w	2010	92.11	-0.16	0.75	108.00	0.16	0.15	0.14	32.50	15.04
concrete	1c	Hotline Waterborne White	White	w	2010	441.64	-0.14	0.89	330.00	0.17	0.08	0.05	139.14	13.14
asphalt	1c	Hotline Waterborne Lead-Free Yellow	Yellow	w	2010	269.21	-0.18	0.95	243.00	0.09	0.07	0.07	77.29	16.35
concrete	3b	PreMark® White	White	s	2010	661.84	-0.11	0.84	480.00	0.31	0.25	0.04	252.93	10.16
asphalt	1c	Hotline Waterborne Lead-Free Yellow 3	Yellow	w	2010	266.61	-0.15	0.97	251.00	0.13	0.11	0.07	86.71	13.99
concrete	1b	999801	White	s	2010	691.47	-0.06	0.93	635.00	0.51	0.35	0.03	350.64	5.76

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	3a	998802	White	s	2010	780.62	-0.16	0.90	606.00	0.15	0.03	0.03	227.50	14.46
concrete	3a	998801	Yellow	s	2010	449.84	-0.18	0.88	339.00	0.06	0.05	0.05	122.29	16.17
asphalt	1c	Hotline Waterborne Lead-Free Yellow 2	Yellow	w	2010	228.35	-0.15	0.96	234.00	0.15	0.12	0.08	77.36	13.54
concrete	1c	High Build Waterborne White	White	w	2010	395.61	-0.09	0.93	319.00	0.37	0.16	0.06	163.71	8.52
concrete	1c	Hotline Waterborne White 3	White	w	2010	400.26	-0.13	0.92	322.00	0.17	0.13	0.06	132.00	12.48
concrete	3b	HotTape™ White	White	s	2010	544.35	-0.11	0.87	379.00	0.51	0.15	0.05	204.00	10.02
concrete	5d	Yellow 98:2 Spray MMA	Yellow	w	2010	557.21	-0.13	0.90	407.00	0.15	0.06	0.05	183.93	12.09
concrete	1c	Hotline Waterborne White 2	White	w	2010	356.77	-0.09	0.93	295.00	0.42	0.17	0.07	148.07	8.41
asphalt	1c	Hotline Waterborne Lead-Free Yellow 4	Yellow	w	2010	189.76	-0.08	0.96	185.00	0.30	0.23	0.11	85.86	7.69

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	5c	POLY-CARB MARK-75.3 NL Yellow	Yellow	s	2010	157.96	-0.14	0.93	160.00	0.18	0.14	0.13	55.86	13.08
concrete	4a	Deltaline XRP-E Yellow (Extended Reflective Perfor	Yellow	w	2010	506.05	-0.16	0.92	593.00	0.10	0.05	0.04	157.07	14.59
concrete	1c	Hotline Waterborne Lead-Free Yellow	Yellow	s	2010	231.31	-0.14	0.88	177.00	0.15	0.14	0.12	78.29	12.70
concrete	5d	Yellow 98:2 Spray MMA	Yellow	s	2010	539.85	-0.12	0.77	325.00	0.27	0.18	0.07	190.57	11.18
concrete	1c	Hotline Waterborne White 4	White	w	2010	363.65	-0.06	0.88	285.00	0.62	0.24	0.08	179.50	6.05
asphalt	1c	Hotline Waterborne Lead-Free Yellow	Yellow	s	2010	261.23	-0.16	0.93	229.00	0.13	0.11	0.10	82.57	14.54
asphalt	1c	High Build Waterborne Lead-Free Yellow	Yellow	w	2010	266.58	-0.13	0.96	276.00	0.18	0.12	0.09	96.00	12.08

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	1c	Hotline Waterborne White 3	White	w	2010	431.42	-0.14	0.96	397.00	0.15	0.12	0.07	144.14	13.26
concrete	4a	Deltaline XRP-R Yellow (Extended Reflective Perfor	Yellow	w	2010	581.58	-0.12	0.92	653.00	0.20	0.06	0.04	204.79	11.49
asphalt	4a	Deltaline XRP-E Yellow (Extended Reflective Perfor	Yellow	w	2010	541.69	-0.14	0.98	539.00	0.12	0.08	0.06	180.21	13.12
concrete	1c	Hotline Waterborne Lead-Free Yellow 3	Yellow	s	2010	190.44	-0.08	0.87	153.00	0.33	0.27	0.20	85.86	7.81
asphalt	1c	Hotline Waterborne Lead-Free Yellow 3	Yellow	s	2010	241.45	-0.10	0.92	226.00	0.27	0.22	0.14	99.57	9.48
asphalt	4a	Deltaline XRP-E Yellow (Extended	Yellow	s	2010	625.56	-0.15	0.93	538.00	0.14	0.12	0.06	194.43	14.35

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
		Reflective Perfor												
concrete	1c	Hotline Waterborne Lead-Free Yellow 4	Yellow	s	2010	135.85	-0.03	0.90	115.00	0.75	0.59	0.29	90.79	3.12
concrete	5c	POLY-CARB MARK-75.4 NL Yellow	Yellow	w	2010	113.71	-0.04	0.92	109.00	0.61	0.41	0.30	71.64	3.74
asphalt	1c	Hotline Waterborne White 2	White	w	2010	353.11	-0.11	0.95	349.00	0.22	0.17	0.10	139.50	10.07
asphalt	1c	Hotline Waterborne Lead-Free Yellow 2	Yellow	s	2010	227.55	-0.10	0.93	234.00	0.26	0.20	0.15	96.07	9.21
asphalt	4a	Deltaline XRP-R Yellow (Extended Reflective Perfor	Yellow	w	2010	683.23	-0.12	0.98	689.00	0.14	0.10	0.05	243.00	11.74
asphalt	1c	Hotline Waterborne White	White	w	2010	488.84	-0.14	0.95	441.00	0.15	0.12	0.08	164.21	13.15
asphalt	1c	Hotline Waterborne	Yellow	s	2010	183.32	-0.06	0.96	176.00	0.47	0.33	0.20	98.71	5.42

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
		Lead-Free Yellow 4												
concrete	1c	Hotline Waterborne Lead-Free Yellow 2	Yellow	s	2010	142.48	-0.04	0.93	128.00	0.55	0.45	0.28	85.14	4.25
concrete	5d	White 98:2 Spray MMA	White	w	2010	583.84	-0.07	0.72	284.00	0.78	0.17	0.13	276.64	6.42
concrete	5c	POLY-CARB MARK-75.3 NL Yellow	Yellow	s	2010	156.82	-0.05	0.90	152.00	0.39	0.34	0.26	88.64	4.91
concrete	4a	Deltaline XRP-R White (Extended Reflective Perform	White	w	2010	796.66	-0.17	0.94	906.00	0.10	0.06	0.05	240.36	15.78
concrete	5e	POLY-CARB MARK-65.5 NL Yellow	Yellow	w	2010	177.07	-0.04	0.93	180.00	0.59	0.43	0.26	112.86	3.61
asphalt	4a	Deltaline XRP-E White (Extended Reflective Perform	White	w	2010	702.13	-0.15	0.96	755.00	0.12	0.08	0.06	230.36	13.88
concrete	4a	3M Stamark 271ES	Yellow	w	2010	454.10	-0.14	0.97	484.00	0.16	0.10	0.10	155.00	13.31

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	4a	3M Stamark 271ES	Yellow	w	2010	492.68	-0.13	0.95	480.00	0.14	0.13	0.11	173.00	12.63
asphalt	5c	POLY-CARB MARK-75.4 NL Yellow	Yellow	w	2010	171.15	-0.05	0.76	171.00	0.39	0.32	0.30	98.43	4.81
asphalt	4a	Deltaline XRP-R Yellow (Extended Reflective Perfor	Yellow	s	2010	657.72	-0.12	0.93	596.00	0.23	0.23	0.09	246.07	10.95
asphalt	5d	Yellow 98:2 Spray MMA	Yellow	w	2010	351.80	-0.04	0.84	238.00	0.85	0.52	0.22	206.29	4.35
concrete	4a	Deltaline HDX White (High Durability Intersection)	White	w	2010	247.16	-0.06	0.91	261.00	0.36	0.20	0.20	124.79	6.25
concrete	4a	Deltaline XRP-E White (Extended Reflective Perform	White	w	2010	583.58	-0.12	0.90	681.00	0.17	0.08	0.08	216.00	11.08
asphalt	4a	Deltaline HDX White (High	White	w	2010	274.71	-0.06	0.92	283.00	0.30	0.26	0.20	143.21	5.84

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
		Durability Intersection)												
asphalt	1c	High Build Waterborne Lead-Free Yellow	Yellow	s	2010	259.02	-0.07	0.89	261.00	0.32	0.26	0.22	124.43	7.15
asphalt	1c	Hotline Waterborne White 3	White	s	2010	393.24	-0.11	0.92	375.00	0.26	0.20	0.15	158.14	10.06
asphalt	1c	Hotline Waterborne White 4	White	w	2010	351.58	-0.07	0.94	336.00	0.36	0.27	0.17	174.43	6.47
concrete	5d	MMA Pathfinder	Yellow	w	2010	454.39	-0.12	0.91	503.00	0.20	0.13	0.12	173.07	11.29
concrete	5e	999903	White	w	2010	1360.90	-0.12	0.94	1544.00	0.17	0.09	0.04	482.07	11.69
asphalt	5d	Yellow 98:2 Spray MMA	Yellow	s	2010	322.86	-0.04	0.80	226.00	0.85	0.67	0.29	202.64	3.71
concrete	5d	999906	Yellow	s	2010	1031.90	-0.10	0.94	944.00	0.29	0.22	0.07	422.07	9.15
asphalt	4a	Deltaline XRP-E White (Extended Reflective Perform	White	s	2010	693.63	-0.13	0.91	607.00	0.18	0.23	0.11	250.79	11.87

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	4a	3M Stamark 381AW	Yellow	w	2010	714.85	-0.14	0.97	765.00	0.18	0.08	0.09	244.00	12.95
asphalt	5c	POLY-CARB MARK-75.4 NL Yellow	Yellow	s	2010	177.20	-0.04	0.76	166.00	0.52	0.42	0.42	111.21	3.85
concrete	4a	3M Stamark 271ES	Yellow	s	2010	577.60	-0.11	0.87	481.00	0.24	0.23	0.15	222.43	10.74
concrete	5a	999902	Yellow	w	2010	593.13	-0.12	0.81	810.00	0.19	0.13	0.09	230.64	10.97
asphalt	1c	Hotline Waterborne White 2	White	s	2010	320.84	-0.07	0.90	328.00	0.36	0.29	0.22	161.57	6.44
concrete	5e	POLY-CARB MARK-65.5 NL Yellow	Yellow	s	2010	185.66	-0.02	0.63	177.00	0.70	0.80	0.41	138.86	2.19
concrete	3b	HotTape™ White	White	w	2010	559.11	-0.09	0.86	515.00	0.24	0.12	0.14	234.14	8.72
concrete	5c	POLY-CARB MARK-75.4 NL Yellow	Yellow	s	2010	114.34	-0.02	0.58	121.00	0.64	0.69	0.61	91.86	1.62
asphalt	5e	POLY-CARB MARK-65.5 NL Yellow	Yellow	w	2010	282.98	-0.06	0.86	269.00	0.41	0.34	0.28	154.29	5.40

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	4a	Deltaline XRP-R White (Extended Reflective Perform	White	w	2010	742.74	-0.11	0.95	790.00	0.16	0.14	0.10	284.57	10.76
asphalt	4a	3M Stamark 271ES	Yellow	s	2010	549.29	-0.11	0.91	465.00	0.24	0.19	0.16	214.14	10.33
concrete	5e	999904	Yellow	w	2010	577.78	-0.11	0.79	768.00	0.17	0.12	0.10	225.29	10.68
asphalt	1c	High Build Waterborne White	White	w	2010	450.95	-0.07	0.94	445.00	0.34	0.24	0.17	224.57	6.43
concrete	5c	POLY-CARB MARK-75.4 White	White	w	2010	504.53	-0.06	0.93	451.00	0.49	0.27	0.18	262.86	5.74
asphalt	3b	HotTape™ White	White	w	2010	460.03	-0.06	0.91	422.00	0.36	0.22	0.19	231.64	6.06
asphalt	5e	999903	White	w	2010	1235.96	-0.14	0.98	1204.00	0.11	0.08	0.07	411.00	13.15
asphalt	5d	White 98:2 Spray MMA	White	w	2010	474.71	-0.03	0.82	324.00	0.91	0.65	0.25	306.64	3.42
concrete	4a	3M Stamark 270ES	White	w	2010	644.89	-0.14	0.94	691.00	0.15	0.10	0.12	224.71	13.27

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	5e	POLY-CARB MARK-65.5 White	White	w	2010	328.71	-0.04	0.93	313.00	0.56	0.40	0.26	197.86	4.18
concrete	5d	White 98:2 Spray MMA	White	s	2010	418.06	-0.02	0.51	223.00	1.65	1.39	0.38	318.29	2.01
asphalt	3b	HotTape™ White	White	s	2010	497.55	-0.06	0.88	402.00	0.55	0.34	0.21	250.64	6.19
asphalt	4a	3M Stamark 270ES	White	w	2010	780.15	-0.14	0.95	773.00	0.13	0.13	0.12	269.07	13.29
asphalt	1c	Hotline Waterborne White	White	s	2010	434.94	-0.09	0.88	408.00	0.27	0.24	0.22	192.57	8.48
concrete	4a	Stamark High Performance 391	Yellow	w	2010	1507.13	-0.12	0.98	1518.00	0.20	0.06	0.06	538.86	11.23
concrete	5c	POLY-CARB MARK-75.3 White	White	w	2010	490.03	-0.06	0.92	477.00	0.42	0.24	0.19	252.36	6.01
asphalt	4a	Deltaline HDX White (High Durability Intersection)	White	s	2010	271.59	-0.04	0.90	268.00	0.56	0.50	0.35	172.71	3.67
concrete	4a	3M Stamark 380I ES	White	w	2010	1190.96	-0.08	0.89	884.00	0.50	0.12	0.11	532.79	7.29

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	3b	PreMark® White	White	w	2010	637.60	-0.06	0.90	562.00	0.54	0.18	0.17	323.43	5.88
concrete	4a	Deltaline XRP-E Yellow (Extended Reflective Perfor	Yellow	s	2010	526.36	-0.07	0.96	514.00	0.40	0.26	0.18	262.21	6.36
concrete	4a	Deltaline HDX White (High Durability Intersection)	White	s	2010	255.90	-0.03	0.88	250.00	0.58	0.56	0.38	172.93	3.09
concrete	4a	Deltaline XRP-R Yellow (Extended Reflective Perfor	Yellow	s	2010	669.67	-0.06	0.93	627.00	0.41	0.33	0.15	340.21	6.12
asphalt	1c	Hotline Waterborne White 4	White	s	2010	324.88	-0.04	0.90	319.00	0.50	0.40	0.30	193.14	4.37
asphalt	1b	999801	White	w	2010	830.30	-0.11	0.96	784.00	0.19	0.14	0.13	318.21	10.52
asphalt	3a	998801	Yellow	w	2010	375.19	-0.07	0.82	333.00	0.34	0.33	0.30	186.07	6.72

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	5d	MMA Pathfinder	Yellow	w	2010	416.54	-0.05	0.95	394.00	0.45	0.32	0.25	238.43	4.70
concrete	1c	High Build Waterborne Lead-Free Yellow	Yellow	s	2010	205.17	-0.02	0.91	184.00	0.74	0.59	0.54	150.00	2.38
concrete	4a	310I	White	w	2010	897.81	-0.08	0.96	964.00	0.36	0.13	0.10	400.93	7.73
asphalt	1b	999801	White	s	2010	690.34	-0.09	0.91	657.00	0.28	0.23	0.16	302.71	8.40
asphalt	3a	998801	Yellow	s	2010	323.51	-0.04	0.70	298.00	0.61	0.54	0.35	195.36	4.25
concrete	4a	Deltaline XRP-R White (Extended Reflective Perform	White	s	2010	1031.92	-0.12	0.91	917.00	0.19	0.19	0.11	387.86	11.13
asphalt	5a	999902	Yellow	w	2010	515.83	-0.08	0.86	577.00	0.27	0.24	0.19	247.43	7.27
asphalt	5e	999904	Yellow	w	2010	636.08	-0.10	0.90	673.00	0.22	0.18	0.16	271.00	9.19
concrete	4a	3M Stamark 270ES	White	s	2010	795.60	-0.11	0.85	667.00	0.23	0.24	0.16	307.64	10.81

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	5d	MMA Pathfinder	Yellow	s	2010	578.33	-0.07	0.89	549.00	0.37	0.28	0.20	276.29	7.10
asphalt	4a	3M Stamark 380I ES	White	w	2010	1098.41	-0.06	0.92	938.00	0.41	0.38	0.12	557.14	6.04
asphalt	5e	POLY-CARB MARK-65.5 NL Yellow	Yellow	s	2010	266.30	-0.04	0.76	255.00	0.50	0.43	0.46	165.29	3.97
asphalt	4a	3M Stamark 270ES	White	s	2010	849.86	-0.13	0.87	724.00	0.20	0.21	0.17	309.86	12.00
asphalt	4a	3M Stamark 381AW	Yellow	w	2010	987.04	-0.11	0.93	880.00	0.18	0.20	0.14	389.21	10.05
concrete	5d	MMA Pathfinder	White	w	2010	792.31	-0.11	0.88	948.00	0.20	0.11	0.13	316.00	10.20
asphalt	5c	POLY-CARB MARK-75.3 White	White	w	2010	538.98	-0.07	0.88	545.00	0.34	0.25	0.22	271.00	6.44
asphalt	1c	High Build Waterborne White	White	s	2010	390.78	-0.05	0.89	402.00	0.44	0.35	0.31	226.00	4.70
concrete	4a	Deltaline XRP-E White (Extended Reflective Perform	White	s	2010	741.57	-0.07	0.92	711.00	0.36	0.28	0.18	355.00	7.01

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	5e	POLY-CARB MARK-65.5 White	White	w	2010	455.10	-0.04	0.90	417.00	0.53	0.41	0.31	270.14	4.37
concrete	1c	Hotline Waterborne White 3	White	s	2010	309.82	-0.03	0.90	287.00	0.64	0.61	0.46	217.07	2.75
asphalt	5d	999906	Yellow	s	2010	1014.89	-0.09	0.90	903.00	0.31	0.29	0.15	431.50	8.93
asphalt	4a	Deltaline XRP-R White (Extended Reflective Perform	White	s	2010	755.15	-0.09	0.85	716.00	0.28	0.33	0.19	332.79	8.59
concrete	1c	Hotline Waterborne White 4	White	s	2010	295.59	-0.02	0.90	262.00	0.90	0.74	0.52	229.50	1.87
asphalt	5a	999902	Yellow	s	2010	550.54	-0.07	0.84	596.00	0.33	0.31	0.23	271.07	6.90
asphalt	5d	MMA Pathfinder	Yellow	s	2010	392.73	-0.03	0.91	370.00	0.63	0.52	0.37	255.50	3.44
concrete	4a	Stamark High Performance 390	White	w	2010	2059.47	-0.06	0.86	1751.00	0.63	0.09	0.08	1015.64	6.00

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	1c	Hotline Waterborne White	White	s	2010	330.21	-0.02	0.89	278.00	0.87	0.70	0.50	243.71	2.28
asphalt	3b	PreMark® White	White	s	2010	648.73	-0.05	0.85	525.00	0.59	0.49	0.27	360.07	5.07
concrete	4a	3M Stamark 381AW	Yellow	s	2010	928.23	-0.10	0.86	824.00	0.29	0.24	0.17	392.50	9.08
asphalt	3b	PreMark® White	White	w	2010	652.71	-0.05	0.97	610.00	0.56	0.36	0.24	369.36	4.81
asphalt	3a	998802	White	w	2010	655.46	-0.08	0.86	596.00	0.37	0.29	0.26	311.93	7.28
asphalt	5d	MMA Pathfinder	White	w	2010	1061.30	-0.08	0.95	990.00	0.29	0.23	0.15	495.07	7.27
concrete	5e	999904	Yellow	s	2010	760.86	-0.08	0.86	749.00	0.29	0.27	0.20	344.86	8.15
concrete	5a	999901	White	w	2010	1195.31	-0.11	0.89	1443.00	0.23	0.13	0.11	476.79	10.23
concrete	4a	3M Stamark 380AW	White	w	2010	1338.66	-0.10	0.91	1121.00	0.33	0.12	0.14	548.07	9.16
asphalt	5c	POLY-CARB MARK-75.4 White	White	w	2010	557.35	-0.05	0.84	516.00	0.43	0.33	0.30	306.36	5.31

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	1c	Hotline Waterborne White 2	White	s	2010	282.07	-0.02	0.95	262.00	0.86	0.77	0.60	225.50	1.64
concrete	5a	999902	Yellow	s	2010	836.23	-0.09	0.86	862.00	0.26	0.27	0.18	379.43	8.15
asphalt	5e	999904	Yellow	s	2010	593.44	-0.08	0.81	632.00	0.31	0.30	0.26	287.71	7.24
asphalt	4a	3M Stamark 381AW	Yellow	s	2010	954.78	-0.08	0.87	857.00	0.32	0.26	0.19	437.43	7.63
concrete	1c	High Build Waterborne White	White	s	2010	308.50	-0.02	0.84	257.00	0.98	0.84	0.64	247.93	1.60
concrete	4a	310I	White	s	2010	1043.96	-0.09	0.89	990.00	0.29	0.24	0.17	446.07	9.00
concrete	5e	POLY-CARB MARK-65.5 White	White	s	2010	324.21	-0.01	0.73	310.00	0.82	0.85	0.56	264.71	1.48
asphalt	5c	POLY-CARB MARK-75.3 White	White	s	2010	554.10	-0.05	0.79	532.00	0.42	0.39	0.33	314.29	4.99
concrete	5d	999906	Yellow	w	2010	1009.62	-0.08	0.92	1104.00	0.28	0.18	0.16	459.00	7.77
asphalt	5a	999901	White	w	2010	1284.62	-0.09	0.93	1323.00	0.24	0.21	0.13	556.21	8.72

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	4a	310I	White	w	2010	740.89	-0.05	0.76	1040.00	0.28	0.25	0.17	406.29	5.34
concrete	5e	999903	White	s	2010	1620.33	-0.08	0.94	1591.00	0.33	0.26	0.11	727.21	7.88
asphalt	4a	310I	White	s	2010	837.58	-0.08	0.86	925.00	0.30	0.30	0.19	390.64	7.71
asphalt	4a	3M Stamark 380I ES	White	s	2010	1004.58	-0.07	0.88	928.00	0.43	0.37	0.20	499.86	6.50
asphalt	4a	Stamark High Performance 391	Yellow	w	2010	1544.12	-0.09	0.96	1638.00	0.23	0.20	0.12	681.29	8.17
asphalt	3a	998802	White	s	2010	613.04	-0.05	0.83	592.00	0.58	0.41	0.32	363.36	4.42
asphalt	5d	999906	Yellow	w	2010	1001.91	-0.08	0.91	982.00	0.30	0.25	0.20	475.00	7.24
concrete	4a	Stamark High Performance 391	Yellow	s	2010	1652.28	-0.09	0.91	1571.00	0.30	0.25	0.13	719.71	8.48
concrete	4a	3M Stamark 380I ES	White	s	2010	984.32	-0.05	0.91	905.00	0.50	0.39	0.22	551.79	4.94
asphalt	5a	999901	White	s	2010	1310.11	-0.09	0.89	1273.00	0.32	0.27	0.16	582.43	8.31
asphalt	5d	White 98:2 Spray MMA	White	s	2010	533.34	-0.02	0.83	439.00	0.87	0.77	0.49	388.57	2.40

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	5d	MMA Pathfinder	White	s	2010	1017.09	-0.07	0.88	953.00	0.35	0.32	0.23	496.29	6.87
concrete	5c	POLY-CARB MARK-75.3 White	White	s	2010	497.98	-0.03	0.77	476.00	0.53	0.51	0.46	331.29	3.26
asphalt	5e	POLY-CARB MARK-65.5 White	White	s	2010	434.75	-0.03	0.79	409.00	0.65	0.56	0.56	304.21	2.79
concrete	5d	MMA Pathfinder	White	s	2010	964.52	-0.07	0.85	897.00	0.35	0.31	0.26	476.57	6.70
asphalt	5c	POLY-CARB MARK-75.4 White	White	s	2010	548.27	-0.04	0.76	498.00	0.57	0.46	0.47	354.21	3.55
concrete	5a	999901	White	s	2010	1535.97	-0.09	0.92	1529.00	0.29	0.25	0.16	679.29	8.31
asphalt	5e	999903	White	s	2010	1137.26	-0.07	0.91	1110.00	0.39	0.28	0.22	573.07	6.36
concrete	5d	999905	White	w	2010	1454.67	-0.06	0.91	1518.00	0.35	0.22	0.17	740.71	6.08
asphalt	4a	3M Stamark 380AW	White	s	2010	1256.01	-0.05	0.85	1192.00	0.48	0.41	0.25	699.14	5.09
concrete	5c	POLY-CARB MARK-75.4 White	White	s	2010	466.27	-0.02	0.52	445.00	0.66	0.73	0.67	370.71	1.70

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	5d	999905	White	s	2010	1306.39	-0.06	0.81	1209.00	0.43	0.43	0.25	679.29	6.06
asphalt	5d	999905	White	w	2010	1365.37	-0.05	0.92	1303.00	0.42	0.33	0.24	747.57	5.27
asphalt	4a	Stamark High Performance 391	Yellow	s	2010	1516.15	-0.07	0.86	1632.00	0.34	0.29	0.19	725.71	7.22
concrete	5d	999905	White	s	2010	1399.76	-0.05	0.88	1390.00	0.47	0.38	0.24	802.14	4.77
concrete	4a	3M Stamark 380AW	White	s	2010	1198.05	-0.04	0.77	1193.00	0.56	0.51	0.32	762.36	3.69
asphalt	4a	3M Stamark 380AW	White	w	2010	1514.46	-0.06	0.82	1268.00	0.32	0.40	0.30	785.36	6.02
asphalt	4a	Stamark High Performance 390	White	w	2010	1873.12	-0.04	0.96	2046.00	0.47	0.40	0.25	1159.71	3.89
asphalt	4a	Stamark High Performance 390	White	s	2010	1806.34	-0.05	0.80	2110.00	0.44	0.43	0.26	1071.86	4.43
concrete	4a	Stamark High Performance 390	White	s	2010	1773.26	-0.02	0.95	1854.00	0.70	0.60	0.35	1292.21	2.40
asphalt	1b	999802	White	s	2010	606.59	-0.08	0.94	562.00	0.38	0.27		332.45	7.56

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	1b	999802	White	w	2010	697.56	-0.09	0.95	595.00	0.26	0.17		346.55	9.05
asphalt	1b	999803	Yellow	s	2010	444.78	-0.14	0.93	384.00	0.15	0.13		176.91	13.42
asphalt	1b	999804	Yellow	s	2010	360.05	-0.07	0.92	337.00	0.39	0.32		203.82	7.11
asphalt	1b	999805	Yellow	s	2010	259.65	-0.05	0.90	252.00	0.54	0.46		175.82	4.50
asphalt	1b	999803	Yellow	w	2010	473.14	-0.17	0.93	387.00	0.10	0.08		169.91	15.46
asphalt	1b	999804	Yellow	w	2010	341.27	-0.08	0.95	311.00	0.34	0.25		187.45	7.49
asphalt	1b	999805	Yellow	w	2010	283.38	-0.06	0.96	273.00	0.37	0.31		171.73	6.02
concrete	1b	999802	White	s	2010	391.33	-0.02	0.90	363.00	0.87	0.71		335.45	1.63
concrete	1b	999802	White	w	2010	396.41	-0.06	0.91	381.00	0.51	0.25		248.18	5.47
concrete	1b	999803	Yellow	s	2010	298.38	-0.05	0.95	280.00	0.49	0.38		195.45	4.91
concrete	1b	999804	Yellow	s	2010	273.32	-0.02	0.93	259.00	0.78	0.67		222.64	2.21

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	1b	999805	Yellow	s	2010	307.45	-0.02	0.89	297.00	0.85	0.72		263.18	1.65
concrete	1b	999803	Yellow	w	2010	296.16	-0.15	0.96	285.00	0.13	0.15		117.27	13.73
concrete	1b	999804	Yellow	w	2010	266.77	-0.05	0.88	259.00	0.52	0.29		169.27	5.30
concrete	1b	999805	Yellow	w	2010	340.93	-0.06	0.92	346.00	0.47	0.24		203.36	6.16
asphalt	1a	White Waterborne PA Spec	White	s	2013	520.70	-0.10	0.97	506.00	0.29	0.16		240.33	9.34
asphalt	1a	White Waterborne PA Spec	White	w	2013	587.12	-0.18	0.98	560.00	0.10	0.05		185.92	16.86
asphalt	1a	Yellow Waterborne PA Spec	Yellow	s	2013	326.70	-0.09	0.96	311.00	0.34	0.19		158.50	8.52
asphalt	1a	Yellow Waterborne PA Spec	Yellow	w	2013	318.35	-0.14	0.97	304.00	0.13	0.07		118.67	13.10
asphalt	1b	VP13-W1	White	s	2013	167.92	-0.01	0.46	173.00	0.94	0.58		143.92	1.42
asphalt	1b	VP13-W2	White	s	2013	239.57	-0.02	0.52	247.00	0.89	0.64		201.50	1.61

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	1b	White WB 982301 / MNW21M1	White	s	2013	329.45	-0.02	0.75	342.00	0.78	0.53		259.50	2.28
asphalt	1b	WHITE WB RG1	White	s	2013	391.36	-0.02	0.88	384.00	0.83	0.48		304.92	2.38
asphalt	1b	WHITE WB RG2	White	s	2013	455.42	-0.05	0.99	443.00	0.59	0.30		282.92	4.91
asphalt	1b	VP13-W1	White	w	2013	208.33	-0.12	0.95	228.00	0.14	0.10		86.50	11.35
asphalt	1b	VP13-W2	White	w	2013	331.68	-0.11	0.95	380.00	0.19	0.11		143.92	10.53
asphalt	1b	White WB 982301 / MNW21M1	White	w	2013	366.62	-0.04	0.94	377.00	0.50	0.41		239.75	4.34
asphalt	1b	WHITE WB RG1	White	w	2013	451.08	-0.06	0.93	448.00	0.33	0.38		254.08	6.26
asphalt	1b	WHITE WB RG2	White	w	2013	508.51	-0.10	0.95	474.00	0.19	0.24		228.08	9.63
asphalt	1b	VP13-Y7	Yellow	s	2013	196.25	-0.07	0.95	201.00	0.40	0.23		105.25	7.02
asphalt	1b	YELLOW WB 982302 / MNY21M1	Yellow	s	2013	233.58	-0.04	0.87	237.00	0.63	0.38		164.83	3.46

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	1b	YELLOW WB RG1	Yellow	s	2013	227.56	-0.04	0.92	209.00	0.67	0.31		149.17	4.27
asphalt	1b	YELLOW WB RG2	Yellow	s	2013	202.43	-0.03	0.90	194.00	0.80	0.32		143.08	3.39
asphalt	1b	VP13-Y7	Yellow	w	2013	226.28	-0.13	0.97	233.00	0.11	0.09		88.08	12.48
asphalt	1b	YELLOW WB 982302 / MNY21M1	Yellow	w	2013	262.05	-0.11	0.94	246.00	0.19	0.21		114.33	10.51
asphalt	1b	YELLOW WB RG1	Yellow	w	2013	281.86	-0.11	0.95	265.00	0.20	0.22		123.67	10.34
asphalt	1b	YELLOW WB RG2	Yellow	w	2013	246.60	-0.10	0.95	229.00	0.21	0.22		112.08	9.53
asphalt	1c	13W1	White	s	2013	217.86	-0.01	0.07	213.00	1.20	0.69		206.08	0.50
asphalt	1c	13W2	White	s	2013	358.04	-0.09	0.96	353.00	0.31	0.18		170.00	8.94
asphalt	1c	VP13-W3	White	s	2013	329.01	-0.02	0.80	351.00	0.73	0.53		260.00	2.24
asphalt	1c	WHITE WB 982321	White	s	2013	682.36	-0.10	0.94	645.00	0.33	0.15		313.58	9.49
asphalt	1c	13W1	White	w	2013	262.38	-0.05	0.90	269.00	0.39	0.26		161.50	4.98

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	1c	13W2	White	w	2013	525.38	-0.19	0.97	494.00	0.06	0.05		162.08	17.55
asphalt	1c	VP13-W3	White	w	2013	356.01	-0.05	0.95	380.00	0.40	0.28		219.08	5.05
asphalt	1c	WHITE WB 982321	White	w	2013	698.27	-0.13	0.97	680.00	0.18	0.14		278.25	12.29
asphalt	1c	13Y1	Yellow	s	2013	174.53	-0.01	0.46	175.00	0.98	0.70		156.08	1.02
asphalt	1c	13Y2	Yellow	s	2013	309.90	-0.07	0.99	304.00	0.44	0.19		168.42	6.68
asphalt	1c	VP13-Y6	Yellow	s	2013	235.44	-0.06	0.93	236.00	0.47	0.28		135.17	6.04
asphalt	1c	YELLOW WB 982322	Yellow	s	2013	536.99	-0.12	0.95	490.00	0.24	0.11		218.25	11.65
asphalt	1c	13Y1	Yellow	w	2013	222.11	-0.10	0.96	217.00	0.18	0.13		99.00	9.77
asphalt	1c	13Y2	Yellow	w	2013	403.59	-0.18	0.97	374.00	0.07	0.05		127.92	16.70
asphalt	1c	VP13-Y6	Yellow	w	2013	281.64	-0.14	0.98	280.00	0.12	0.10		107.17	12.96
asphalt	1c	YELLOW WB 982322	Yellow	w	2013	544.83	-0.17	0.98	514.00	0.11	0.09		184.08	15.88

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	3a	Ozark Materials LLC White Alkyd Thermoplastic	White	s	2013	464.13	-0.05	0.71	458.00	0.50	0.41		283.58	5.33
asphalt	3a	WHITE HD THERMO	White	s	2013	687.00	-0.03	0.63	649.00	0.90	0.31		510.25	2.85
asphalt	3a	Ozark Materials LLC White Alkyd Thermoplastic	White	w	2013	358.72	-0.08	0.58	488.00	0.24	0.30		190.58	7.69
asphalt	3a	WHITE HD THERMO	White	w	2013	769.45	-0.12	0.95	718.00	0.22	0.18		323.58	11.21
asphalt	3a	Ozark Materials LLC Lead-Free Yellow Alkyd Thermop	Yellow	s	2013	207.71	-0.05	0.72	199.00	0.55	0.41		130.08	4.97
asphalt	3a	YELLOW HD THERMO	Yellow	s	2013	334.62	-0.03	0.73	332.00	0.81	0.46		252.50	2.72
asphalt	3a	Ozark Materials LLC Lead-Free Yellow	Yellow	w	2013	145.70	-0.07	0.57	197.00	0.25	0.34		83.67	6.35

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
		Alkyd Thermop												
asphalt	3a	YELLOW HD THERMO	Yellow	w	2013	406.57	-0.12	0.91	385.00	0.23	0.26		173.75	11.29
asphalt	3b	HotTape - White	White	s	2013	717.79	-0.05	0.86	678.00	0.69	0.20		439.67	5.04
asphalt	3b	Ozark Materials LLC White Preformed Thermoplastic	White	s	2013	437.83	-0.03	0.86	392.00	0.86	0.43		317.83	3.11
asphalt	3b	PreMark - White	White	s	2013	373.96	-0.01	0.28	370.00	1.02	0.63		337.58	0.93
asphalt	3b	Swarco Preformed Thermoplastic - White - 125 mil	White	s	2013	412.05	-0.09	0.84	365.00	0.36	0.17		194.08	8.96
asphalt	3b	Swarco Preformed Thermoplastic - White - 90 mil	White	s	2013	606.63	-0.15	0.90	529.00	0.13	0.05		210.00	14.19
asphalt	3b	HotTape - White	White	w	2013	692.13	-0.09	0.95	641.00	0.44	0.15		334.67	8.21

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	3b	Ozark Materials LLC White Preformed Thermoplastic	White	w	2013	426.77	-0.08	0.90	412.00	0.24	0.32		217.00	7.94
asphalt	3b	PreMark - White	White	w	2013	541.26	-0.07	0.87	551.00	0.33	0.43		293.75	6.94
asphalt	3b	Swarco Preformed Thermoplastic - White - 125 mil	White	w	2013	457.70	-0.08	0.93	458.00	0.25	0.16		227.75	7.90
asphalt	3b	Swarco Preformed Thermoplastic - White - 90 mil	White	w	2013	570.33	-0.13	0.97	545.00	0.19	0.13		223.17	12.50
asphalt	3b	HotTape - Yellow	Yellow	s	2013	483.74	-0.16	0.94	413.00	0.15	0.04		161.58	14.96
asphalt	3b	Ozark Materials LLC Lead-Free Yellow Preformed The	Yellow	s	2013	397.95	-0.09	0.94	350.00	0.43	0.18		188.92	8.76
asphalt	3b	PreMark - Yellow	Yellow	s	2013	139.92	-0.01	0.22	132.00	1.11	0.54		124.17	1.10

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	3b	Swarco Preformed Thermoplastic - Yellow - 125 mil	Yellow	s	2013	312.51	-0.18	0.89	255.00	0.06	0.06		96.50	16.63
asphalt	3b	Swarco Preformed Thermoplastic - Yellow - 90 mil	Yellow	s	2013	368.38	-0.18	0.88	302.00	0.05	0.05		112.83	16.65
asphalt	3b	HotTape - Yellow	Yellow	w	2013	493.14	-0.17	0.95	428.00	0.11	0.10		165.00	15.75
asphalt	3b	Ozark Materials LLC Lead-Free Yellow Preformed The	Yellow	w	2013	341.33	-0.13	0.96	342.00	0.17	0.18		140.33	11.78
asphalt	3b	PreMark - Yellow	Yellow	w	2013	166.56	-0.05	0.85	160.00	0.54	0.58		106.25	4.62
asphalt	3b	Swarco Preformed Thermoplastic - Yellow - 125 mil	Yellow	w	2013	311.95	-0.21	0.93	280.00	0.04	0.05		89.42	18.94
asphalt	3b	Swarco Preformed	Yellow	w	2013	360.91	-0.16	0.93	303.00	0.11	0.05		122.92	14.88

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
		Thermoplastic - Yellow - 90 mil												
asphalt	4a	Deltaline XRP (Extended Reflective Performance) Wh	White	s	2013	1570.09	-0.17	0.95	1344.00	0.08	0.02		499.08	16.02
asphalt	4a	Deltaline XRP-R (Extended Reflective Performance--	White	s	2013	1303.06	-0.20	0.91	1076.00	0.01	0.01		360.50	18.52
asphalt	4a	Deltaline XRP™ White	White	s	2013	1594.17	-0.21	0.92	1324.00	0.01	0.01		436.25	18.79
asphalt	4a	Deltaline XRP (Extended Reflective Performance) Wh	White	w	2013	1477.57	-0.19	0.95	1288.00	0.07	0.06		451.58	17.39
asphalt	4a	Deltaline XRP-R (Extended Reflective Performance--	White	w	2013	1282.02	-0.16	0.96	1159.00	0.12	0.10		445.17	14.79

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	4a	Deltaline XRP™ White	White	w	2013	1421.33	-0.18	0.96	1257.00	0.11	0.03		455.92	16.24
asphalt	4a	3M Stamark High Performance Tape 381I ES - Yellow	Yellow	s	2013	607.64	-0.05	0.83	600.00	0.57	0.31		380.00	4.91
asphalt	4a	Deltaline XRP (Extended Reflective Performance) Y	Yellow	s	2013	806.02	-0.21	0.94	685.00	0.03	0.02		227.25	18.67
asphalt	4a	Deltaline XRP-R (Extended Reflective Performance-W	Yellow	s	2013	810.56	-0.20	0.93	681.00	0.04	0.02		230.67	18.27
asphalt	4a	Deltaline XRP™ Yellow	Yellow	s	2013	938.73	-0.21	0.92	787.00	0.02	0.02		260.08	18.78
asphalt	4a	3M Stamark High Performance Tape 381I ES - Yellow	Yellow	w	2013	753.56	-0.05	0.93	704.00	0.61	0.49		475.33	4.70

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	4a	Deltaline XRP (Extended Reflective Performance) Y	Yellow	w	2013	351.00	-0.22	0.95	319.00	0.04	0.04		97.83	20.05
asphalt	4a	Deltaline XRP-R (Extended Reflective Performance-W	Yellow	w	2013	745.35	-0.21	0.95	654.00	0.04	0.05		213.92	18.70
asphalt	4a	Deltaline XRP™ Yellow	Yellow	w	2013	831.27	-0.23	0.96	737.00	0.02	0.02		221.83	20.50
asphalt	5a	HPS 2 WHITE	White	s	2013	479.01	-0.06	0.73	483.00	0.40	0.40		277.58	6.12
asphalt	5a	MARK-55 WHITE	White	s	2013	307.29	-0.06	0.64	314.00	0.39	0.38		182.17	5.84
asphalt	5a	White Epoxy Traffic Paint	White	s	2013	631.30	-0.06	0.85	637.00	0.49	0.37		378.83	5.50
asphalt	5a	HPS 2 WHITE	White	w	2013	514.71	-0.08	0.88	515.00	0.31	0.37		270.25	7.47
asphalt	5a	MARK-55 WHITE	White	w	2013	361.74	-0.06	0.83	395.00	0.33	0.38		211.92	5.88

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	5a	White Epoxy Traffic Paint	White	w	2013	634.47	-0.09	0.88	705.00	0.26	0.29		318.42	8.23
asphalt	5a	HPS 2 YELLOW	Yellow	s	2013	310.03	-0.08	0.83	310.00	0.37	0.31		163.58	7.51
asphalt	5a	MARK-55 Non-Lead Yellow	Yellow	s	2013	158.73	-0.04	0.68	166.00	0.59	0.45		109.33	3.78
asphalt	5a	Yellow Epoxy Traffic Paint	Yellow	s	2013	475.94	-0.07	0.83	492.00	0.45	0.31		269.00	6.36
asphalt	5a	HPS 2 YELLOW	Yellow	w	2013	284.35	-0.07	0.89	290.00	0.41	0.37		153.25	7.02
asphalt	5a	MARK-55 Non-Lead Yellow	Yellow	w	2013	176.84	-0.05	0.82	190.00	0.38	0.44		110.08	5.03
asphalt	5a	Yellow Epoxy Traffic Paint	Yellow	w	2013	468.75	-0.08	0.87	507.00	0.33	0.34		246.33	7.45
asphalt	5c	3M Liquid Pavement Marking 5001B - White	White	s	2013	505.26	-0.04	0.81	497.00	0.68	0.43		352.17	3.60
asphalt	5c	MFUA-12 White	White	s	2013	351.58	-0.08	0.86	306.00	0.37	0.24		176.42	8.09

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
		Polyurea Two-Component Pavement Mark												
asphalt	5c	3M Liquid Pavement Marking 5001B - White	White	w	2013	521.23	-0.06	0.93	505.00	0.43	0.44		306.50	5.67
asphalt	5c	MFUA-12 White Polyurea Two-Component Pavement Mark	White	w	2013	371.46	-0.08	0.92	363.00	0.30	0.34		187.00	8.04
asphalt	5c	3M Liquid Pavement Marking 5001B - Yellow	Yellow	s	2013	336.90	-0.03	0.81	330.00	0.67	0.47		238.50	3.43
asphalt	5c	MFUA-12 Yellow Polyurea Two-Component Pavement Mar	Yellow	s	2013	122.99	-0.05	0.72	118.00	0.46	0.47		76.67	5.04

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	5c	3M Liquid Pavement Marking 5001B - Yellow	Yellow	w	2013	376.63	-0.07	0.94	360.00	0.35	0.36		205.42	6.72
asphalt	5c	MFUA-12 Yellow Polyurea Two-Component Pavement Mar	Yellow	w	2013	148.56	-0.09	0.87	141.00	0.26	0.33		71.67	8.90
asphalt	5d	EVEX-13-1	White	s	2013	447.84	-0.07	0.91	415.00	0.57	0.10		237.25	6.92
asphalt	5d	EVPF-13-1	White	s	2013	658.53	-0.12	0.95	632.00	0.27	0.06		269.17	11.33
asphalt	5d	EVSP-13-1	White	s	2013	407.48	-0.02	0.42	348.00	1.00	0.55		322.33	2.23
asphalt	5d	M13W1	White	s	2013	644.02	-0.10	0.92	629.00	0.39	0.05		292.92	9.40
asphalt	5d	MMA EXT WHITE	White	s	2013	478.02	0.00	0.00	383.00	1.69	1.04		472.83	0.10
asphalt	5d	MMA STR WHITE	White	s	2013	1268.18	-0.09	0.87	1163.00	0.51	0.09		596.00	8.74

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	5d	EVEX-13-1	White	w	2013	519.48	-0.10	0.97	556.00	0.23	0.17		234.08	9.86
asphalt	5d	EVPF-13-1	White	w	2013	501.46	-0.09	0.91	574.00	0.24	0.24		248.83	8.39
asphalt	5d	EVSP-13-1	White	w	2013	482.87	-0.05	0.90	388.00	0.54	0.44		288.50	5.35
asphalt	5d	M13W1	White	w	2013	547.83	-0.09	0.93	614.00	0.25	0.21		268.83	8.51
asphalt	5d	MMA EXT WHITE	White	w	2013	534.01	-0.07	0.86	441.00	0.45	0.24		294.92	6.36
asphalt	5d	MMA STR WHITE	White	w	2013	1343.25	-0.08	0.97	1328.00	0.33	0.23		694.58	7.49
asphalt	5d	EVEX-13-2	Yellow	s	2013	359.22	-0.11	0.93	320.00	0.30	0.12		155.08	10.44
asphalt	5d	EVPF-13-2	Yellow	s	2013	346.15	-0.09	0.93	361.00	0.39	0.12		169.17	8.32
asphalt	5d	EVSP-13-2	Yellow	s	2013	295.54	-0.10	0.88	251.00	0.37	0.08		129.50	9.84
asphalt	5d	M13W2	Yellow	s	2013	404.51	-0.04	0.64	336.00	0.74	0.30		265.67	4.28
asphalt	5d	M13Y1	Yellow	s	2013	369.65	-0.12	0.94	377.00	0.27	0.05		150.00	11.53

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	5d	M13Y2	Yellow	s	2013	227.87	-0.08	0.82	190.00	0.53	0.21		118.83	7.34
asphalt	5d	MMA EXT YELLOW	Yellow	s	2013	323.09	-0.05	0.81	299.00	0.75	0.37		201.42	4.85
asphalt	5d	MMA STR YELLOW	Yellow	s	2013	1355.98	-0.19	0.92	1151.00	0.08	0.01		405.58	17.04
asphalt	5d	EVEX-13-2	Yellow	w	2013	245.80	-0.14	0.94	264.00	0.16	0.17		98.75	12.69
asphalt	5d	EVPF-13-2	Yellow	w	2013	244.06	-0.09	0.91	266.00	0.24	0.25		118.83	8.72
asphalt	5d	EVSP-13-2	Yellow	w	2013	319.01	-0.12	0.96	289.00	0.18	0.16		131.67	11.33
asphalt	5d	M13W2	Yellow	w	2013	477.76	-0.06	0.93	426.00	0.47	0.43		277.50	5.81
asphalt	5d	M13Y1	Yellow	w	2013	258.59	-0.11	0.91	290.00	0.21	0.21		117.17	10.18
asphalt	5d	M13Y2	Yellow	w	2013	233.75	-0.09	0.96	232.00	0.28	0.27		115.17	8.32
asphalt	5d	MMA EXT YELLOW	Yellow	w	2013	413.70	-0.04	0.90	371.00	0.66	0.50		287.50	3.60
asphalt	5d	MMA STR YELLOW	Yellow	w	2013	1317.04	-0.15	0.97	1186.00	0.16	0.08		468.67	14.28

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	5e	Cem/Stripe	White	s	2013	203.91	-0.01	0.28	219.00	0.84	0.77		182.50	1.02
asphalt	5e	MARK-55.9 WHITE	White	s	2013	382.84	-0.04	0.77	401.00	0.55	0.44		255.08	4.16
asphalt	5e	MARK-65.5 WHITE	White	s	2013	590.15	-0.05	0.85	590.00	0.55	0.40		379.75	4.57
asphalt	5e	MFUA-10 White Modified Polyacrylate Two-Component	White	s	2013	290.39	-0.03	0.59	304.00	0.59	0.63		217.50	2.84
asphalt	5e	Cem/Stripe	White	w	2013	211.75	-0.04	0.85	215.00	0.65	0.21		136.67	4.38
asphalt	5e	MARK-55.9 WHITE	White	w	2013	351.40	-0.06	0.87	382.00	0.33	0.37		212.42	5.37
asphalt	5e	MARK-65.5 WHITE	White	w	2013	578.93	-0.08	0.97	588.00	0.34	0.23		290.58	8.00
asphalt	5e	MFUA-10 White Modified Polyacrylate Two-Component	White	w	2013	234.03	-0.05	0.73	272.00	0.32	0.47		142.92	5.35

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
asphalt	5e	MARK-55.9 Non-Lead Yellow	Yellow	s	2013	353.50	-0.08	0.84	357.00	0.34	0.29		185.42	7.56
asphalt	5e	MARK-65.5 Non-Lead Yellow	Yellow	s	2013	430.56	-0.08	0.85	417.00	0.36	0.29		225.25	7.55
asphalt	5e	MFUA-10 Yellow Modified Polyacrylate Two-Component	Yellow	s	2013	283.98	-0.05	0.77	280.00	0.49	0.43		173.33	5.32
asphalt	5e	MARK-55.9 Non-Lead Yellow	Yellow	w	2013	263.27	-0.08	0.87	304.00	0.24	0.28		135.92	7.75
asphalt	5e	MARK-65.5 Non-Lead Yellow	Yellow	w	2013	414.91	-0.10	0.96	426.00	0.28	0.19		194.92	9.19
asphalt	5e	MFUA-10 Yellow Modified Polyacrylate Two-Component	Yellow	w	2013	180.03	-0.06	0.76	204.00	0.45	0.44		103.42	6.19
concrete	1a	White Waterborne PA Spec	White	s	2013	565.43	-0.09	0.96	528.00	0.32	0.19		268.17	8.85

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	1a	White Waterborne PA Spec	White	w	2013	596.63	-0.20	0.97	556.00	0.06	0.04		179.92	17.92
concrete	1a	Yellow Waterborne PA Spec	Yellow	s	2013	355.55	-0.09	0.94	330.00	0.32	0.21		173.00	8.48
concrete	1a	Yellow Waterborne PA Spec	Yellow	w	2013	332.92	-0.16	0.97	308.00	0.12	0.07		114.00	15.21
concrete	1b	VP13-W1	White	s	2013	283.91	-0.05	0.98	279.00	0.56	0.35		181.08	4.61
concrete	1b	VP13-W2	White	s	2013	382.66	-0.04	0.95	390.00	0.56	0.41		258.75	3.94
concrete	1b	White WB 982301 / MNW21M1	White	s	2013	415.06	-0.02	0.96	411.00	0.81	0.61		337.50	1.95
concrete	1b	WHITE WB RG1	White	s	2013	457.59	-0.06	0.96	440.00	0.50	0.30		265.67	5.82
concrete	1b	WHITE WB RG2	White	s	2013	456.72	-0.05	0.95	437.00	0.56	0.38		288.00	4.76
concrete	1b	VP13-W1	White	w	2013	372.87	-0.18	0.97	343.00	0.08	0.08		122.42	16.13
concrete	1b	VP13-W2	White	w	2013	492.22	-0.15	0.99	481.00	0.12	0.07		176.50	14.19

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	1b	White WB 982301 / MNW21M1	White	w	2013	432.46	-0.06	0.97	429.00	0.39	0.30		243.00	6.26
concrete	1b	WHITE WB RG1	White	w	2013	535.25	-0.16	0.98	485.00	0.17	0.05		184.75	14.63
concrete	1b	WHITE WB RG2	White	w	2013	546.23	-0.16	0.98	492.00	0.13	0.06		187.25	14.76
concrete	1b	VP13-Y7	Yellow	s	2013	258.94	-0.05	0.96	252.00	0.56	0.38		165.42	4.61
concrete	1b	YELLOW WB 982302 / MNY21M1	Yellow	s	2013	273.62	-0.06	0.94	261.00	0.48	0.29		156.08	6.09
concrete	1b	YELLOW WB RG1	Yellow	s	2013	276.52	-0.07	0.96	262.00	0.44	0.28		153.92	6.40
concrete	1b	YELLOW WB RG2	Yellow	s	2013	249.95	-0.07	0.96	234.00	0.48	0.24		139.58	6.31
concrete	1b	VP13-Y7	Yellow	w	2013	305.01	-0.18	0.98	283.00	0.11	0.09		101.00	16.26
concrete	1b	YELLOW WB 982302 / MNY21M1	Yellow	w	2013	302.97	-0.17	0.97	273.00	0.11	0.10		103.17	15.41
concrete	1b	YELLOW WB RG1	Yellow	w	2013	313.72	-0.17	0.98	288.00	0.13	0.08		105.17	15.82

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	1b	YELLOW WB RG2	Yellow	w	2013	275.13	-0.15	0.96	244.00	0.14	0.09		97.75	14.17
concrete	1c	13W1	White	s	2013	319.32	-0.04	0.98	308.00	0.65	0.42		220.50	3.68
concrete	1c	13W2	White	s	2013	663.48	-0.15	0.93	569.00	0.15	0.09		239.00	13.82
concrete	1c	VP13-W3	White	s	2013	410.76	-0.03	0.97	414.00	0.71	0.53		311.83	2.65
concrete	1c	WHITE WB 982321	White	s	2013	653.35	-0.12	0.95	593.00	0.25	0.13		270.50	11.22
concrete	1c	13W1	White	w	2013	384.22	-0.13	0.96	359.00	0.19	0.10		150.42	12.13
concrete	1c	13W2	White	w	2013	704.10	-0.21	0.97	626.00	0.06	0.04		207.08	18.54
concrete	1c	VP13-W3	White	w	2013	425.47	-0.08	0.97	442.00	0.30	0.24		217.75	7.65
concrete	1c	WHITE WB 982321	White	w	2013	710.06	-0.20	0.98	646.00	0.09	0.05		216.25	18.08
concrete	1c	13Y1	Yellow	s	2013	231.86	-0.05	0.95	222.00	0.49	0.34		143.67	4.98
concrete	1c	13Y2	Yellow	s	2013	429.11	-0.12	0.95	387.00	0.23	0.12		177.92	11.14

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	1c	VP13-Y6	Yellow	s	2013	302.65	-0.09	0.94	293.00	0.31	0.22		147.67	8.50
concrete	1c	YELLOW WB 982322	Yellow	s	2013	497.28	-0.14	0.95	443.00	0.20	0.10		190.33	12.73
concrete	1c	13Y1	Yellow	w	2013	283.13	-0.16	0.96	256.00	0.13	0.13		100.17	14.61
concrete	1c	13Y2	Yellow	w	2013	489.04	-0.21	0.97	452.00	0.06	0.06		144.33	18.74
concrete	1c	VP13-Y6	Yellow	w	2013	307.13	-0.20	0.98	290.00	0.09	0.07		94.50	18.48
concrete	1c	YELLOW WB 982322	Yellow	w	2013	476.65	-0.22	0.98	435.00	0.07	0.05		138.92	19.53
concrete	3a	Ozark Materials LLC White Alkyd Thermoplastic	White	s	2013	507.93	-0.06	0.90	512.00	0.46	0.34		298.00	5.76
concrete	3a	WHITE HD THERMO	White	s	2013	759.33	-0.05	0.91	695.00	0.72	0.30		483.17	4.54
concrete	3a	Ozark Materials LLC White Alkyd Thermoplastic	White	w	2013	301.77	-0.06	0.47	456.00	0.27	0.32		181.83	5.63

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	3a	WHITE HD THERMO	White	w	2013	821.30	-0.14	0.97	777.00	0.13	0.14		320.75	12.71
concrete	3a	Ozark Materials LLC Lead-Free Yellow Alkyd Thermop	Yellow	s	2013	185.82	-0.05	0.84	163.00	0.66	0.42		117.75	4.69
concrete	3a	YELLOW HD THERMO	Yellow	s	2013	375.99	-0.07	0.93	341.00	0.59	0.14		196.83	7.03
concrete	3a	Ozark Materials LLC Lead-Free Yellow Alkyd Thermop	Yellow	w	2013	117.40	-0.05	0.41	184.00	0.28	0.33		77.08	4.41
concrete	3a	YELLOW HD THERMO	Yellow	w	2013	401.37	-0.13	0.94	373.00	0.16	0.18		163.67	11.95
concrete	3b	HotTape - White	White	s	2013	620.97	-0.09	0.94	553.00	0.37	0.05		284.50	8.82
concrete	3b	Ozark Materials LLC White Preformed Thermoplastic	White	s	2013	602.17	-0.05	0.76	505.00	0.83	0.04		353.08	5.33

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	3b	PreMark - White	White	s	2013	582.77	-0.14	0.91	495.00	0.21	0.05		216.33	12.85
concrete	3b	Swarco Preformed Thermoplastic - White - 125 mil	White	s	2013	630.78	-0.18	0.86	525.00	0.04	0.04		190.42	16.70
concrete	3b	Swarco Preformed Thermoplastic - White - 90 mil	White	s	2013	582.62	-0.18	0.85	481.00	0.04	0.04		178.17	16.40
concrete	3b	HotTape - White	White	w	2013	473.00	-0.09	0.94	491.00	0.29	0.16		228.08	8.49
concrete	3b	Ozark Materials LLC White Preformed Thermoplastic	White	w	2013	487.60	-0.11	0.94	501.00	0.21	0.20		220.42	10.06
concrete	3b	PreMark - White	White	w	2013	664.70	-0.17	0.97	630.00	0.17	0.08		228.25	15.65
concrete	3b	Swarco Preformed Thermoplastic - White - 125 mil	White	w	2013	423.92	-0.21	0.94	364.00	0.04	0.05		122.58	18.59

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	3b	Swarco Preformed Thermoplastic - White - 90 mil	White	w	2013	358.06	-0.12	0.85	280.00	0.47	0.06		145.00	11.07
concrete	3b	HotTape - Yellow	Yellow	s	2013	442.76	-0.16	0.92	373.00	0.07	0.06		146.42	15.10
concrete	3b	Ozark Materials LLC Lead-Free Yellow Preformed The	Yellow	s	2013	389.74	-0.10	0.94	332.00	0.40	0.08		172.25	9.53
concrete	3b	PreMark - Yellow	Yellow	s	2013	265.23	-0.17	0.90	221.00	0.10	0.09		88.17	15.41
concrete	3b	Swarco Preformed Thermoplastic - Yellow - 125 mil	Yellow	s	2013	303.55	-0.17	0.85	251.00	0.08	0.08		99.42	15.38
concrete	3b	Swarco Preformed Thermoplastic - Yellow - 90 mil	Yellow	s	2013	413.50	-0.18	0.88	352.00	0.06	0.06		129.33	16.37
concrete	3b	HotTape - Yellow	Yellow	w	2013	344.33	-0.13	0.98	331.00	0.17	0.08		134.50	12.24

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	3b	Ozark Materials LLC Lead-Free Yellow Preformed The	Yellow	w	2013	308.78	-0.13	0.96	314.00	0.19	0.15		127.08	11.75
concrete	3b	PreMark - Yellow	Yellow	w	2013	301.58	-0.23	0.97	275.00	0.06	0.06		86.17	20.53
concrete	3b	Swarco Preformed Thermoplastic - Yellow - 125 mil	Yellow	w	2013	206.57	-0.14	0.85	151.00	0.27	0.11		76.75	13.14
concrete	3b	Swarco Preformed Thermoplastic - Yellow - 90 mil	Yellow	w	2013	325.68	-0.17	0.92	274.00	0.13	0.06		105.33	15.92
concrete	4a	Deltaline XRP (Extended Reflective Performance) Wh	White	s	2013	1610.72	-0.16	0.94	1401.00	0.15	0.08		562.17	14.49
concrete	4a	Deltaline XRP-R (Extended	White	s	2013	1407.90	-0.20	0.91	1173.00	0.02	0.02		395.17	18.34

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
		Reflective Performance--												
concrete	4a	Deltaline XRP™ White	White	s	2013	1583.19	-0.21	0.92	1330.00	0.02	0.02		437.92	18.69
concrete	4a	Deltaline XRP (Extended Reflective Performance) Wh	White	w	2013	1410.28	-0.22	0.97	1263.00	0.06	0.03		396.00	20.03
concrete	4a	Deltaline XRP-R (Extended Reflective Performance--	White	w	2013	1269.75	-0.20	0.98	1140.00	0.10	0.02		385.67	17.85
concrete	4a	Deltaline XRP™ White	White	w	2013	1460.72	-0.24	0.96	1286.00	0.01	0.01		378.75	21.18
concrete	4a	3M Stamark High Performance Tape 381I ES - Yellow	Yellow	s	2013	654.93	-0.07	0.87	596.00	0.38	0.28		349.25	7.07
concrete	4a	Deltaline XRP (Extended Reflective Performance) Y	Yellow	s	2013	679.05	-0.22	0.97	598.00	0.04	0.04		188.83	19.88

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	4a	Deltaline XRP-R (Extended Reflective Performance-W	Yellow	s	2013	853.56	-0.20	0.92	719.00	0.03	0.03		245.42	18.11
concrete	4a	Deltaline XRP™ Yellow	Yellow	s	2013	838.86	-0.22	0.96	727.00	0.03	0.03		233.08	19.48
concrete	4a	3M Stamark High Performance Tape 381I ES - Yellow	Yellow	w	2013	776.30	-0.09	0.91	691.00	0.30	0.21		363.42	9.04
concrete	4a	Deltaline XRP (Extended Reflective Performance) Y	Yellow	w	2013	307.23	-0.40	0.92	280.00	0.05	0.05		69.83	33.26
concrete	4a	Deltaline XRP-R (Extended Reflective Performance-W	Yellow	w	2013	745.95	-0.24	0.98	676.00	0.04	0.03		200.25	21.71

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	4a	Deltaline XRP™ Yellow	Yellow	w	2013	437.33	-0.37	0.94	396.00	0.03	0.04		99.75	30.67
concrete	5a	HPS 2 WHITE	White	s	2013	527.47	-0.06	0.76	533.00	0.39	0.42		312.08	5.76
concrete	5a	MARK-55 WHITE	White	s	2013	329.11	-0.02	0.74	335.00	0.69	0.66		261.50	2.19
concrete	5a	White Epoxy Traffic Paint	White	s	2013	727.06	-0.06	0.88	745.00	0.46	0.36		437.58	5.45
concrete	5a	HPS 2 WHITE	White	w	2013	513.55	-0.09	0.86	532.00	0.27	0.32		259.42	8.21
concrete	5a	MARK-55 WHITE	White	w	2013	367.45	-0.06	0.89	391.00	0.36	0.33		211.08	6.10
concrete	5a	White Epoxy Traffic Paint	White	w	2013	711.59	-0.11	0.91	767.00	0.23	0.21		320.25	10.26
concrete	5a	HPS 2 YELLOW	Yellow	s	2013	317.75	-0.04	0.81	325.00	0.51	0.48		211.58	4.17
concrete	5a	MARK-55 Non-Lead Yellow	Yellow	s	2013	170.18	-0.02	0.75	176.00	0.69	0.66		134.92	2.22
concrete	5a	Yellow Epoxy Traffic Paint	Yellow	s	2013	506.17	-0.06	0.90	537.00	0.40	0.31		289.42	6.15

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	5a	HPS 2 YELLOW	Yellow	w	2013	350.71	-0.08	0.87	371.00	0.32	0.35		186.42	7.32
concrete	5a	MARK-55 Non-Lead Yellow	Yellow	w	2013	173.26	-0.06	0.87	187.00	0.38	0.39		104.50	5.43
concrete	5a	Yellow Epoxy Traffic Paint	Yellow	w	2013	514.89	-0.10	0.88	538.00	0.25	0.27		241.25	9.53
concrete	5c	3M Liquid Pavement Marking 5001B - White	White	s	2013	587.41	-0.05	0.89	553.00	0.51	0.39		370.58	4.77
concrete	5c	MFUA-12 White Polyurea Two-Component Pavement Mark	White	s	2013	240.16	-0.09	0.68	129.00	0.58	0.32		113.42	8.86
concrete	5c	3M Liquid Pavement Marking 5001B - White	White	w	2013	605.78	-0.09	0.98	581.00	0.30	0.20		295.75	8.35
concrete	5c	MFUA-12 White	White	w	2013	337.49	-0.10	0.91	336.00	0.23	0.24		155.75	9.72

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
		Polyurea Two-Component Pavement Mark												
concrete	5c	3M Liquid Pavement Marking 5001B - Yellow	Yellow	s	2013	391.83	-0.04	0.93	360.00	0.67	0.42		261.42	4.06
concrete	5c	MFUA-12 Yellow Polyurea Two-Component Pavement Mar	Yellow	s	2013	235.23	-0.04	0.79	224.00	0.57	0.50		162.75	3.70
concrete	5c	3M Liquid Pavement Marking 5001B - Yellow	Yellow	w	2013	412.38	-0.09	0.97	399.00	0.29	0.20		202.67	8.22
concrete	5c	MFUA-12 Yellow Polyurea Two-Component Pavement Mar	Yellow	w	2013	232.29	-0.10	0.89	222.00	0.23	0.28		110.58	9.16

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	5d	EVEX-13-1	White	s	2013	470.46	-0.08	0.92	399.00	0.47	0.15		235.17	7.75
concrete	5d	EVPF-13-1	White	s	2013	535.41	-0.10	0.98	516.00	0.31	0.09		236.92	9.80
concrete	5d	EVSP-13-1	White	s	2013	515.17	-0.12	0.88	389.00	0.28	0.06		205.83	11.17
concrete	5d	M13W1	White	s	2013	620.43	-0.12	0.96	606.00	0.27	0.07		251.33	11.32
concrete	5d	MMA EXT WHITE	White	s	2013	529.78	-0.03	0.49	417.00	1.14	0.41		406.08	2.50
concrete	5d	MMA STR WHITE	White	s	2013	1156.81	-0.09	0.89	986.00	0.38	0.12		540.58	8.72
concrete	5d	EVEX-13-1	White	w	2013	553.27	-0.13	0.96	509.00	0.18	0.12		215.83	12.55
concrete	5d	EVPF-13-1	White	w	2013	479.42	-0.09	0.92	538.00	0.29	0.21		234.83	8.49
concrete	5d	EVSP-13-1	White	w	2013	541.17	-0.12	0.95	483.00	0.22	0.05		220.75	11.00
concrete	5d	M13W1	White	w	2013	552.24	-0.11	0.97	585.00	0.26	0.09		239.92	10.24
concrete	5d	MMA EXT WHITE	White	w	2013	577.28	-0.06	0.93	566.00	0.46	0.42		346.58	5.41

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	5d	MMA STR WHITE	White	w	2013	1456.27	-0.10	0.94	1506.00	0.26	0.21		680.58	9.30
concrete	5d	EVEX-13-2	Yellow	s	2013	375.79	-0.12	0.96	341.00	0.28	0.07		150.83	11.43
concrete	5d	EVPF-13-2	Yellow	s	2013	386.09	-0.13	0.98	388.00	0.23	0.07		154.00	11.81
concrete	5d	EVSP-13-2	Yellow	s	2013	259.83	-0.11	0.91	213.00	0.33	0.15		109.92	10.56
concrete	5d	M13W2	Yellow	s	2013	537.26	-0.11	0.88	412.00	0.37	0.06		222.08	10.55
concrete	5d	M13Y1	Yellow	s	2013	390.03	-0.12	0.97	383.00	0.24	0.13		163.42	11.03
concrete	5d	M13Y2	Yellow	s	2013	253.68	-0.07	0.90	210.00	0.55	0.26		139.42	6.48
concrete	5d	MMA EXT YELLOW	Yellow	s	2013	399.39	-0.03	0.74	343.00	0.97	0.46		298.08	2.80
concrete	5d	MMA STR YELLOW	Yellow	s	2013	1387.68	-0.18	0.91	1169.00	0.07	0.04		429.67	16.52
concrete	5d	EVEX-13-2	Yellow	w	2013	294.92	-0.14	0.95	306.00	0.17	0.13		114.83	13.31
concrete	5d	EVPF-13-2	Yellow	w	2013	300.19	-0.10	0.95	321.00	0.26	0.14		135.25	9.80

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	5d	EVSP-13-2	Yellow	w	2013	250.00	-0.14	0.97	225.00	0.18	0.09		93.67	13.15
concrete	5d	M13W2	Yellow	w	2013	496.36	-0.10	0.96	451.00	0.33	0.12		224.25	9.42
concrete	5d	M13Y1	Yellow	w	2013	331.24	-0.13	0.96	341.00	0.20	0.11		133.50	11.97
concrete	5d	M13Y2	Yellow	w	2013	246.86	-0.12	0.99	244.00	0.24	0.07		101.42	11.15
concrete	5d	MMA EXT YELLOW	Yellow	w	2013	459.68	-0.06	0.92	396.00	0.64	0.29		266.08	5.70
concrete	5d	MMA STR YELLOW	Yellow	w	2013	1322.30	-0.20	0.98	1216.00	0.10	0.03		402.42	17.99
concrete	5e	Cem/Stripe	White	s	2013	212.89	-0.02	0.85	208.00	0.84	0.61		170.83	2.08
concrete	5e	MARK-55.9 WHITE	White	s	2013	441.38	-0.03	0.89	452.00	0.62	0.52		315.00	3.33
concrete	5e	MARK-65.5 WHITE	White	s	2013	634.62	-0.07	0.90	598.00	0.41	0.33		339.58	7.05
concrete	5e	MFUA-10 White Modified Polyacrylate Two-Component	White	s	2013	384.38	-0.03	0.80	365.00	0.63	0.58		272.83	3.41

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	5e	Cem/Stripe	White	w	2013	171.12	-0.05	0.93	164.00	0.46	0.41		103.92	5.19
concrete	5e	MARK-55.9 WHITE	White	w	2013	440.97	-0.08	0.93	466.00	0.28	0.29		229.92	7.53
concrete	5e	MARK-65.5 WHITE	White	w	2013	588.60	-0.11	0.95	600.00	0.25	0.21		262.92	10.16
concrete	5e	MFUA-10 White Modified Polyacrylate Two-Component	White	w	2013	277.42	-0.06	0.69	324.00	0.32	0.44		168.67	5.44
concrete	5e	MARK-55.9 Non-Lead Yellow	Yellow	s	2013	300.30	-0.05	0.84	320.00	0.45	0.43		185.58	5.11
concrete	5e	MARK-65.5 Non-Lead Yellow	Yellow	s	2013	493.32	-0.11	0.92	467.00	0.27	0.19		219.25	10.10
concrete	5e	MFUA-10 Yellow Modified Polyacrylate Two-Component	Yellow	s	2013	244.72	-0.04	0.69	220.00	0.62	0.60		169.58	3.70

Surface	Type	Product	Color	Wheel	Year	β_0	β_1	R^2	R0	R1/R0	R2/R0	R3/R0	Average	β_2 (%)
concrete	5e	MARK-55.9 Non-Lead Yellow	Yellow	w	2013	259.00	-0.10	0.89	284.00	0.24	0.24		123.67	9.18
concrete	5e	MARK-65.5 Non-Lead Yellow	Yellow	w	2013	429.55	-0.13	0.97	432.00	0.18	0.14		172.58	12.27
concrete	5e	MFUA-10 Yellow Modified Polyacrylate Two-Component	Yellow	w	2013	148.93	-0.05	0.61	173.00	0.35	0.47		92.58	5.15