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Office of Policy Analysis, Research & Innovation

Minnesota Local Agency Pavement Marking Practices Phase I

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Research Project
Final Report #2010-05

LRRB
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Pavement marking is an essential component of roadway construction and safety. The markings need to be visible (day and night) so that drivers can quickly identify where the markings are and determine what message is being defined. Good pavement marking provides critical elements to guide drivers on correct road paths, complement road signs that inform and warn drivers, and improve night driving conditions.

This project's objective was to review existing pavement marking practices by local agencies in Minnesota (material selection, installation, specifications, and contracting procedures) to provide guidance for maintaining good pavement markings, thereby saving money and increasing road safety. The two specific objectives were as follows:

1. Review existing pavement marking practices in local agencies.
2. Develop recommendations for better management of pavement marking through the use of pavement marking management tools and coordination with the Minnesota Department of Transportation (Mn/DOT).

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Minnesota Local Agency Pavement Marking Practices—Phase I

Final Report

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Tom Behm	(Mn/DOT)
Mitch Bartelt	(Mn/DOT)
Kenneth Johnson	(Mn/DOT)
Alan Rindels	(Mn/DOT)

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Executive Summary

Pavement marking is an essential component of roadway construction and safety. Markings, which are critical for helping guide drivers, need to be visible at all times. Because of weather and wear, pavement markings become less visible over time and need to be replaced periodically. The main factors used to determine the quality of pavement markings are how much of the marking is remaining on the road and how well the marking reflects light at night.

The primary objective of this project was to review the existing pavement marking practices of Minnesota local agencies. The results of this project will help provide guidance for maintaining pavement markings, which can help save money and increase road safety. Two specific objectives were to review the existing pavement marking practices in local agencies and develop recommendations for better pavement marking management

An initial email survey was sent to all Minnesota cities and counties; 48 local agencies responded with information about what materials they use for certain pavement surfaces and how they place pavement markings. From these responses, nine counties and six cities were selected to participate in a phone survey to learn more about their practices. The responses are summarized as follows: approximately half of the agencies use no assessment to determine their annual paint program, the majority of agencies either use their in-house crews for latex markings or contract out all pavement marking work, and most of the agencies use Minnesota Department of Transportation (Mn/DOT) standard specifications for materials and application.

This project found that to determine the condition of the pavement markings, the best existing practice is conducting an annual nighttime survey for pavement marking retroreflectivity and a daytime survey for presence. Storing this information within a GIS database allows for easier review and decision making and serves as a tool to communicate striping needs. Local agencies would benefit from a pavement marking management tool, such as a Web-based tool that is being developed for Mn/DOT.

Based on the results from this project, there are several recommendations for future needs, including developing guidance for selecting pavement marking material based on the pavement type and condition, developing a methodology that incorporates retroreflectivity measurements to help local agencies create their annual plan, and developing practices to help local agencies monitor the quality of their pavement markings.

Chapter 1
Introduction

Pavement marking is an essential component of roadway construction and safety. The markings need to be visible (day and night) so that drivers can quickly identify where the markings are and determine what message is being delivered. Good pavement marking provides critical elements to guide drivers on correct road paths, complement road signs that inform and warn drivers, and improve night driving conditions.

The key factor in determining marking quality is its presence (a measure of how much marking is remaining on the road) during the day and retroreflectivity (the ability of markings to reflect light and thus be visible to the driver) during the nighttime. Presence and retroreflectivity are based on the markings used (typically paint, epoxy, or thermoplastic), type and quality of beads, and how are they applied, as well as how they degrade over time.

This project's objective was to review existing pavement marking practices by local agencies in Minnesota (material selection, installation, specifications, and contracting procedures) to provide guidance for maintaining good pavement markings, thereby saving money and increasing road safety. The two specific objectives were as follows:

1. Review existing pavement marking practices in local agencies.
2. Develop recommendations for better management of pavement marking through the use of pavement marking management tools and coordination with the Minnesota Department of Transportation (Mn/DOT).

The project consisted of four specific tasks, which will be discussed in the next chapter.

Chapter 2
Tasks

2.1 Task 1

Review existing pavement marking practices by cities and counties in Minnesota.

The review will focus on material selection, application process, and quality control processes. The researchers will work with the Local Road Research Board (LRRB) and Mn/DOT to identify cities and counties that should be included in the review.

To accomplish this task, the research team met with the project Technical Advisory Panel (TAP), identified potential local agencies to review, conducted the reviews, and developed a report outline. This effort required reviewing existing pavement marking practices in Minnesota cities and counties, with a focus on pavement marking material selection, application process, contracting procedures, specifications, and quality control processes.

2.2 Task 2

Compile the results from the review (Task 1) and investigate different pavement marking material performance as applied by the local agencies.

Pavement marking performance will be measured using both durability and retroreflectivity. The analysis of current practices will also include defining key problematic issues and identifying potential solutions, strategies, or alternative methods. The team will also work with Mn/DOT to supplement the information gathered from cities and counties.

The research team provided information from existing national research and discussed the potential minimum retroreflectivity standards to be developed by Federal Highway Administration (FHWA) and methods to measure pavement marking quality.

2.3 Task 3

Work with the LRRB staff to develop key recommendations for local agencies in Minnesota to adopt pavement marking management practices to improve the quality and life expectancy of marking lines.

Mn/DOT currently has a pavement marking management tool that could be functionally extended in future efforts to interested local agencies in order to address anticipated FHWA rulemaking and to make more informed and consistent pavement marking maintenance decisions. This new tool would have to be customized to meet the local agencies needs and practices and a separate research effort would be necessary to address tool development, storage requirements, and maintenance and support.

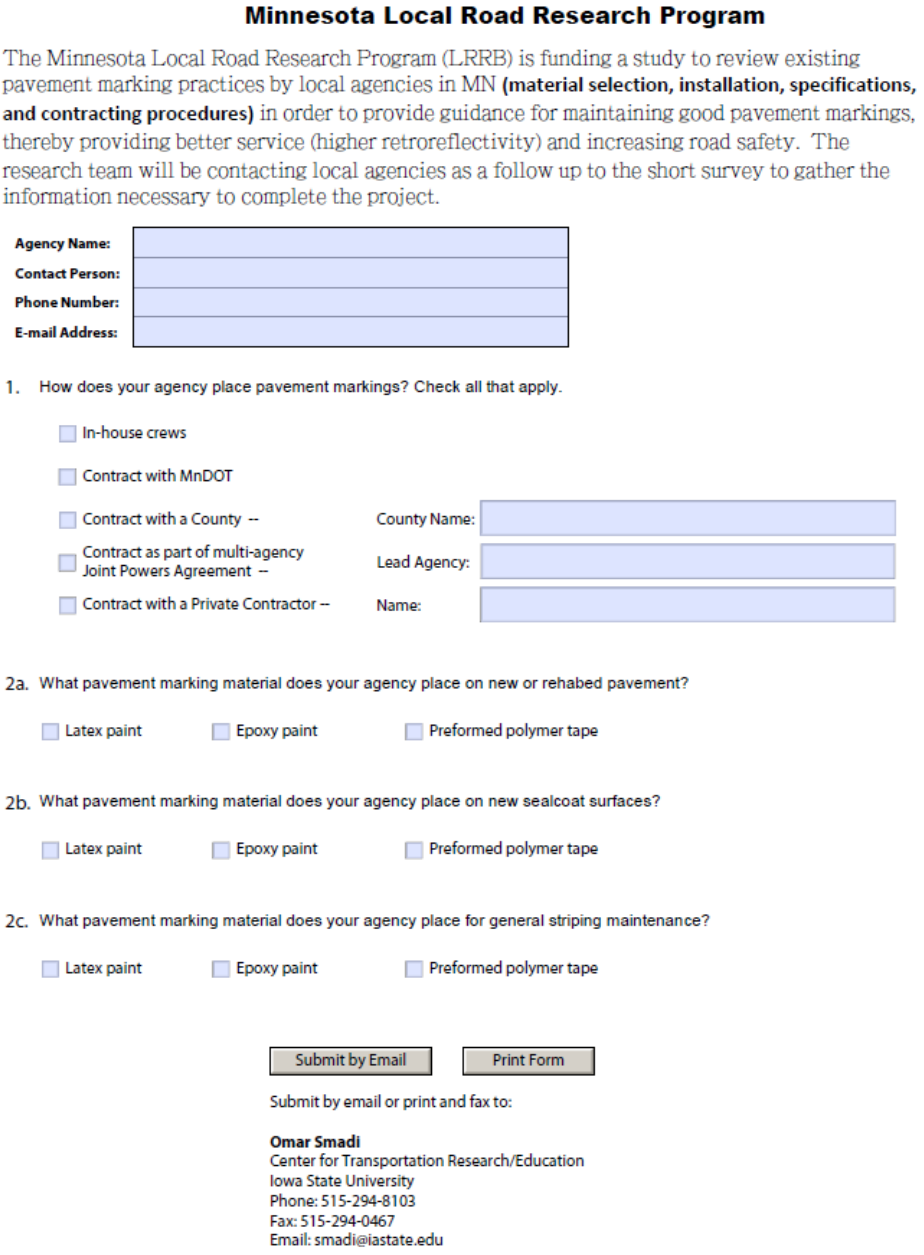
2.4 Task 4

Develop a final report that discusses the project findings.

Chapter 3
Survey

3.1 Statewide Survey

A survey was conducted to determine the methods and materials that Minnesota cities and counties use for pavement markings. Figure 3.1 shows the email survey that was distributed to all Minnesota cities and counties. Figures 3.2 through 3.9 summarize the information received from 48 local agencies.



Minnesota Local Road Research Program

The Minnesota Local Road Research Program (LRRB) is funding a study to review existing pavement marking practices by local agencies in MN **(material selection, installation, specifications, and contracting procedures)** in order to provide guidance for maintaining good pavement markings, thereby providing better service (higher retroreflectivity) and increasing road safety. The research team will be contacting local agencies as a follow up to the short survey to gather the information necessary to complete the project.

Agency Name:
Contact Person:
Phone Number:
E-mail Address:

1. How does your agency place pavement markings? Check all that apply.

- ☐ In-house crews
- ☐ Contract with MnDOT
- ☐ Contract with a County -- County Name:
- ☐ Contract as part of multi-agency Joint Powers Agreement -- Lead Agency:
- ☐ Contract with a Private Contractor -- Name:

2a. What pavement marking material does your agency place on new or rehabed pavement?

☐ Latex paint ☐ Epoxy paint ☐ Preformed polymer tape

2b. What pavement marking material does your agency place on new sealcoat surfaces?

☐ Latex paint ☐ Epoxy paint ☐ Preformed polymer tape

2c. What pavement marking material does your agency place for general striping maintenance?

☐ Latex paint ☐ Epoxy paint ☐ Preformed polymer tape

Submit by Email Print Form

Submit by email or print and fax to:

Omar Smadi
Center for Transportation Research/Education
Iowa State University
Phone: 515-294-8103
Fax: 515-294-0467
Email: smadi@iastate.edu

Figure 3.1. Email survey form

Figures 3.2 and 3.3 show the distribution of counties and cities in terms of how pavement markings are installed. As can be seen in both figures, the majority of both cities and counties use private contractors to install their pavement markings.

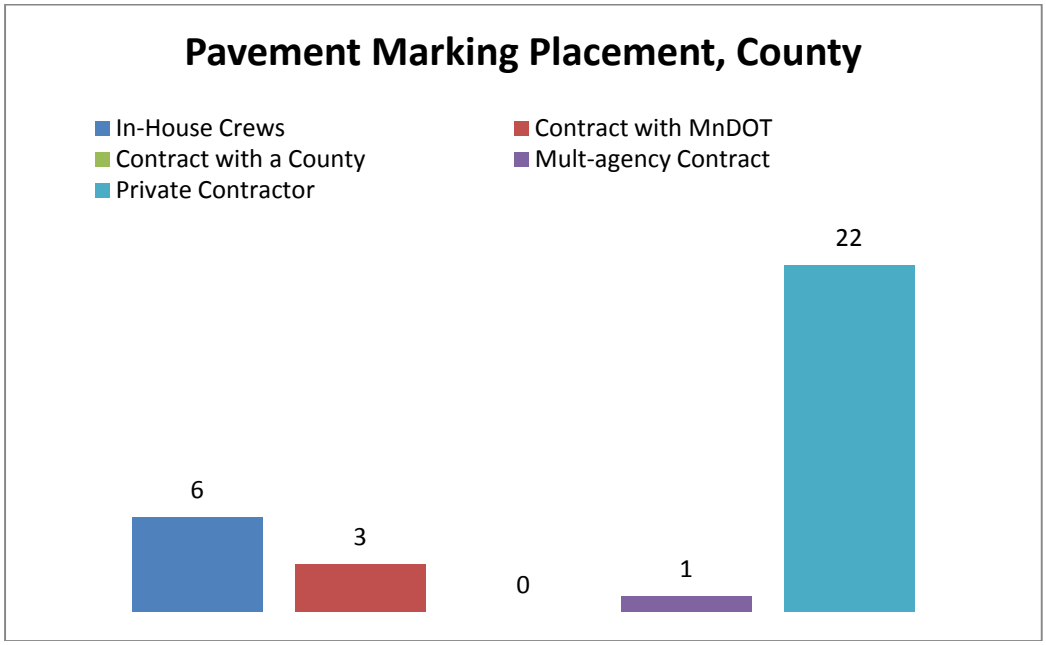


Figure 3.2. County pavement marking placement

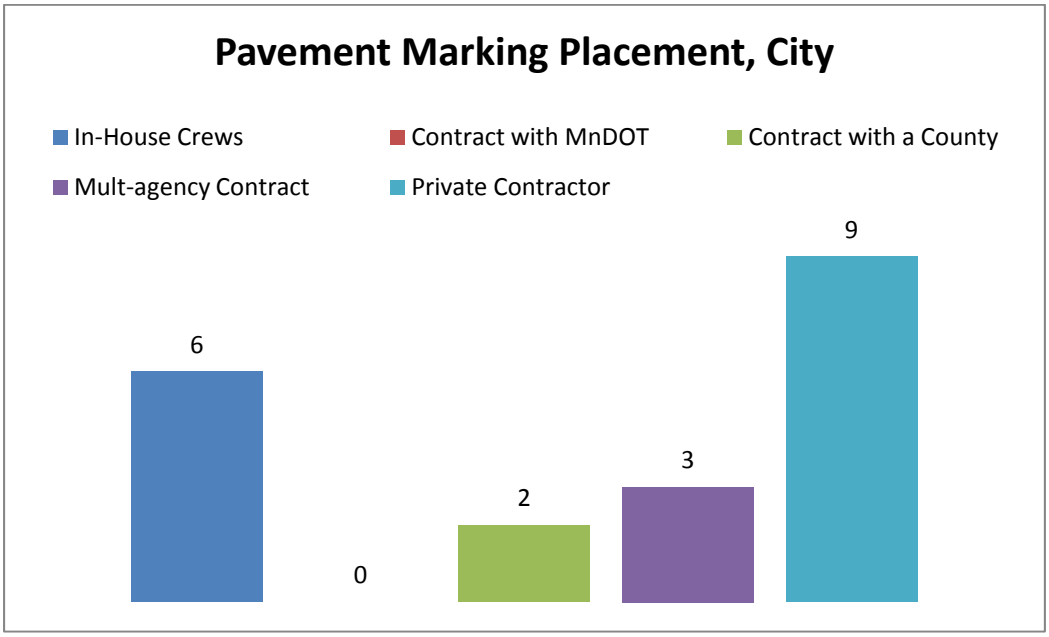


Figure 3.3. City pavement marking placement

Figures 3.4 and 3.5 show the distribution of counties and cities in terms of what type of pavement marking material is used for striping new and overlaid pavement segments. The

majority of counties and cities use either latex or epoxy paint. Two counties and two cities use preformed tape on new roadway surfaces.

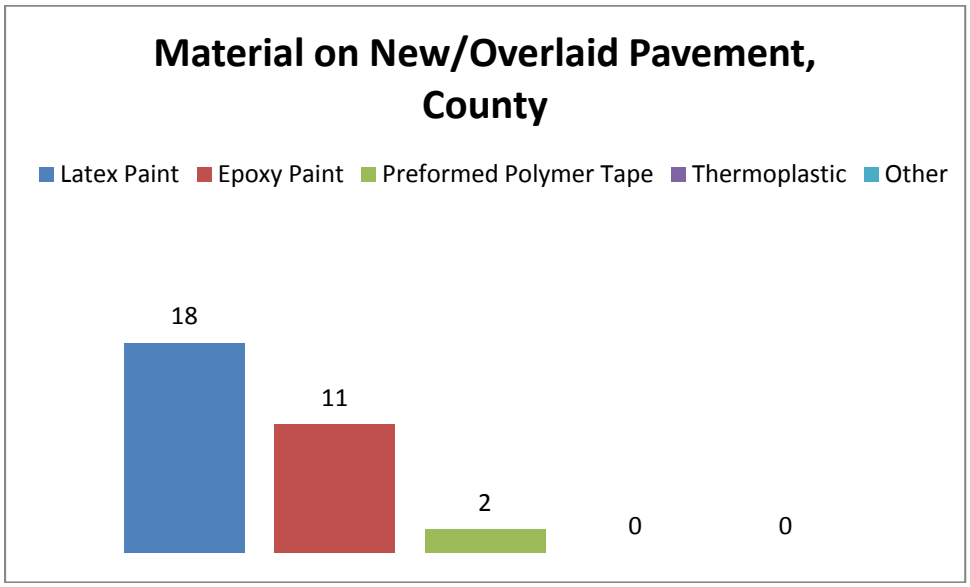


Figure 3.4. County material selection on new/overlaid pavement

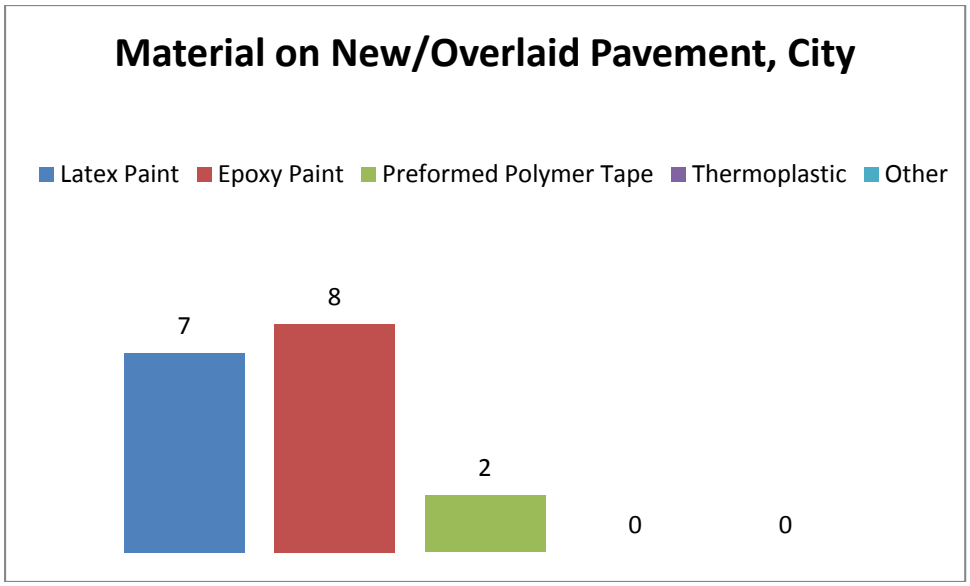


Figure 3.5. City material selection on new/overlaid pavement

Figures 3.6 and 3.7 show the distribution of counties and cities in terms of what type of pavement marking material is used for striping new sealcoat surfaces. As can be seen in both figures, the majority of counties and cities use latex paint as the primary material. Only one county and four cities from the survey indicated that they use something other than latex paint.

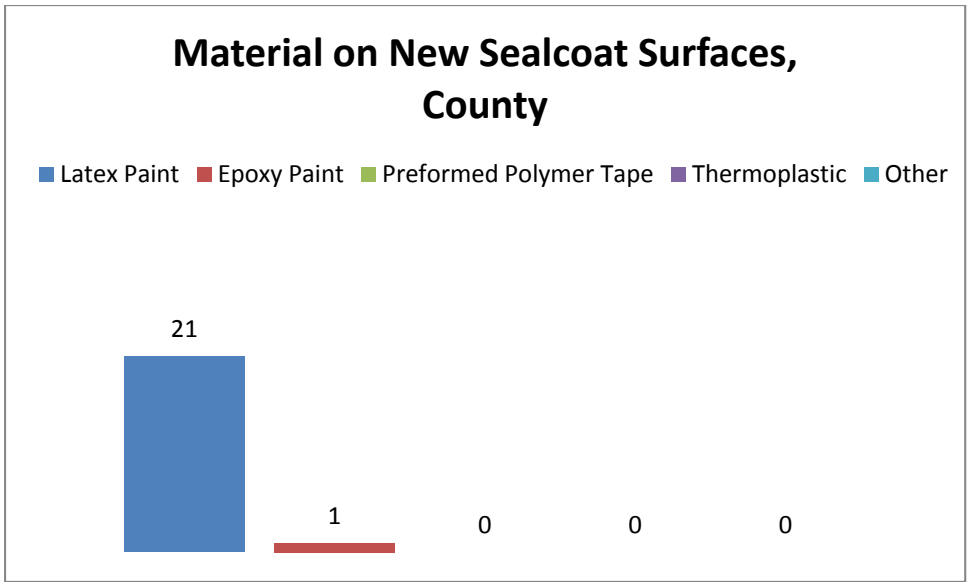


Figure 3.6. County pavement marking material for sealcoat surfaces

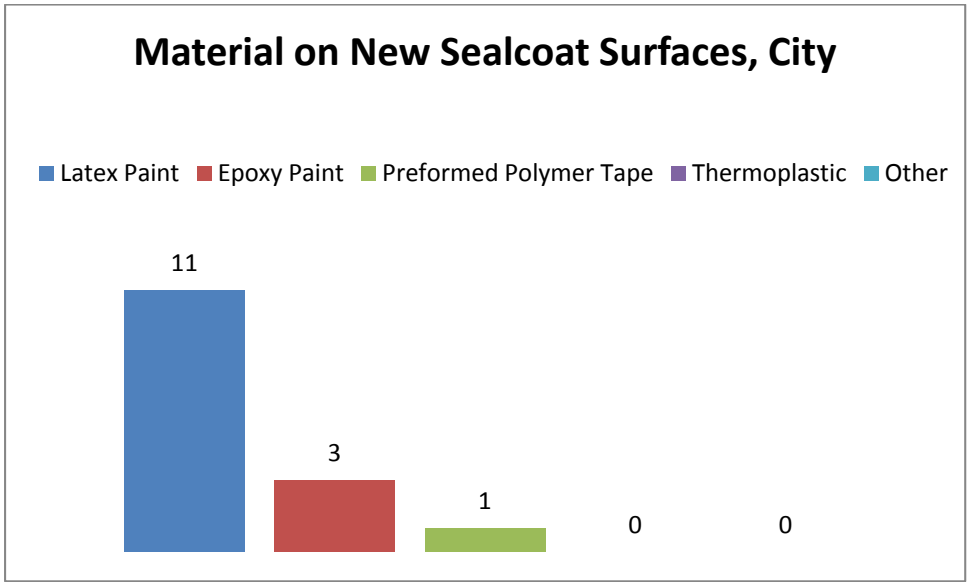


Figure 3.7. City pavement marking material for sealcoat surfaces

Figures 3.8 and 3.9 show the distribution of counties and cities in terms of what type of pavement marking material is used for general maintenance (in-service roads). The majority of counties and cities from the survey use latex paint as the primary pavement marking material. Only two counties and three cities indicated that they use something other than latex paint.

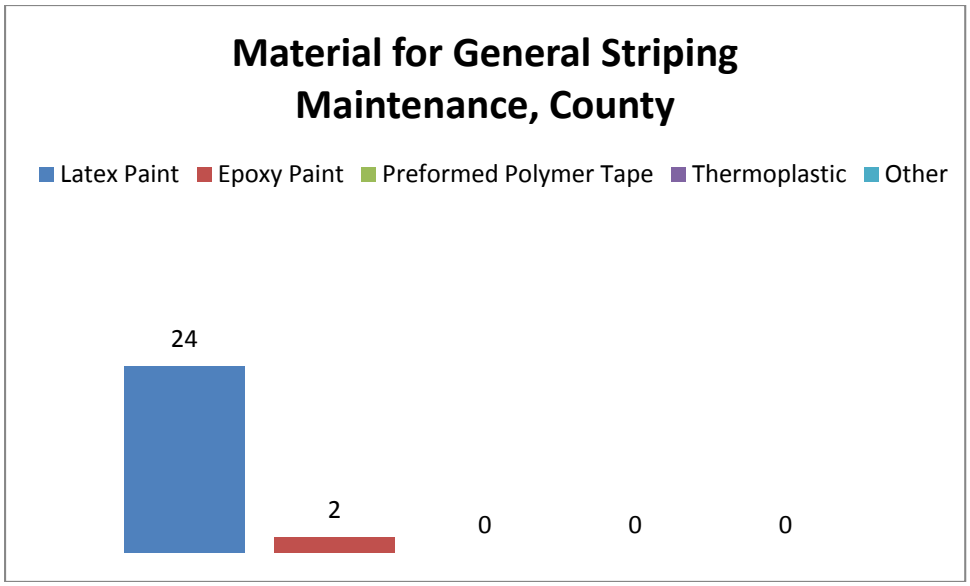


Figure 3.8. County pavement marking material for general maintenance

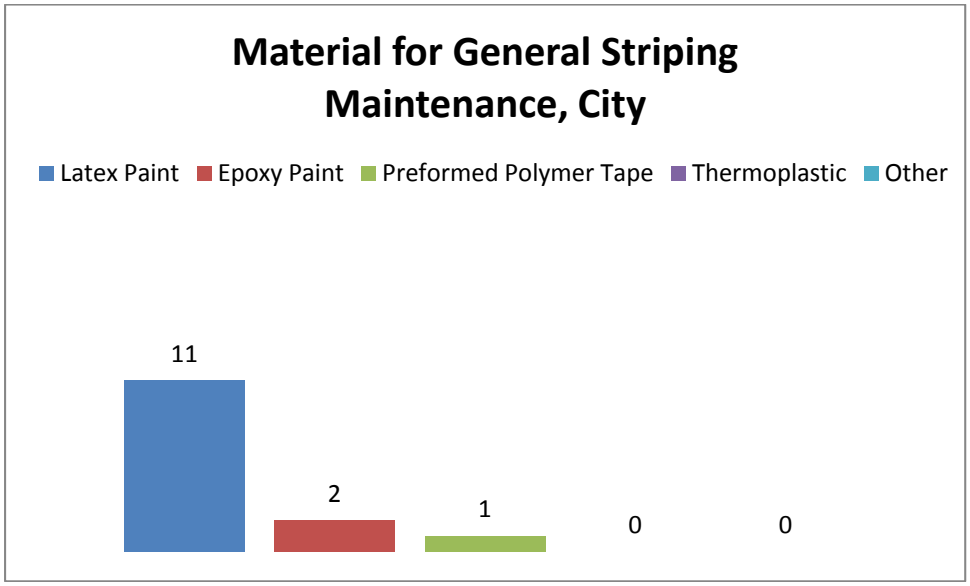


Figure 3.9. City pavement marking material for general maintenance

The research team analyzed the results from the survey and recommended further investigation (by phone interview) of certain cities and counties, as shown in Table 3.1.

Table 3.1. Local agencies considered for further investigation

Agency	County or City	Category
Olmsted	County	Contracts with Mn/DOT for striping
Washington	County	Uses in-house crews
Rice	County	Uses in-house crews
Wright	County	Contracts with a private contractor
Lincoln	County	Contracts with a private contractor
Lake	County	Contracts though a multi-agency agreement (St. Louis County)
Hennepin	County	Uses in-house crews
Otter Tail	County	Contracts with a private contractor
St. Louis	County	Administers a multi-agency agreement
Roseville	City	Contracts with Ramsey County
St. Paul	City	Uses in-house crews
Burnsville	City	Administers a multi-agency contract
Rochester	City	Uses in-house crews
Eden Prairie	City	Contracts with a private contractor
North Mankato	City	Contracts with a private contractor

Figure 3.10 shows the geographic distribution of the agencies listed in Table 3.1; Figure 3.11 shows more detail within the metro area. A Google Map link of these sites with the pertinent information can be accessed using the following address: http://maps.google.com/maps/ms?ie=UTF8&hl=en&msa=0&msid=103671225846464728138.00046ceef7077cf16d469&z=4.

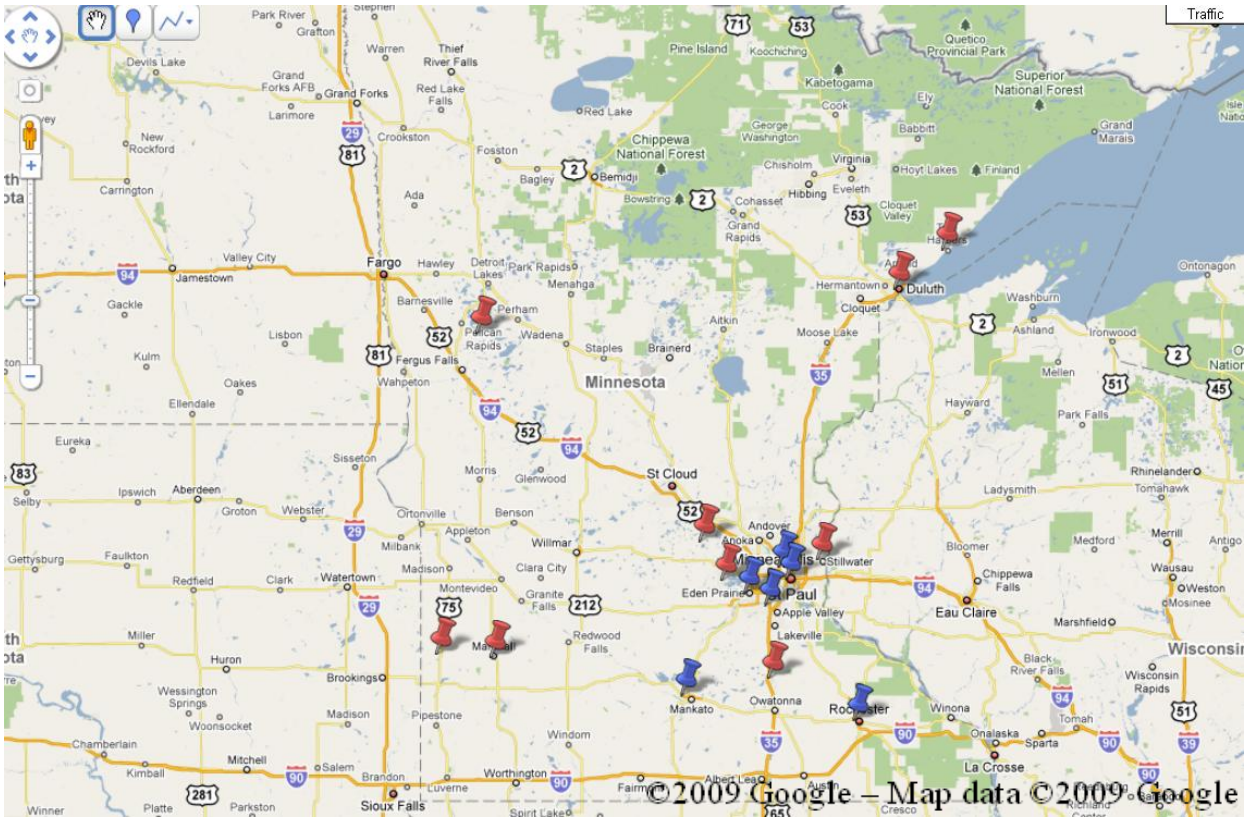


Figure 3.10. County (red) and city (blue) locations for follow-up phone surveys

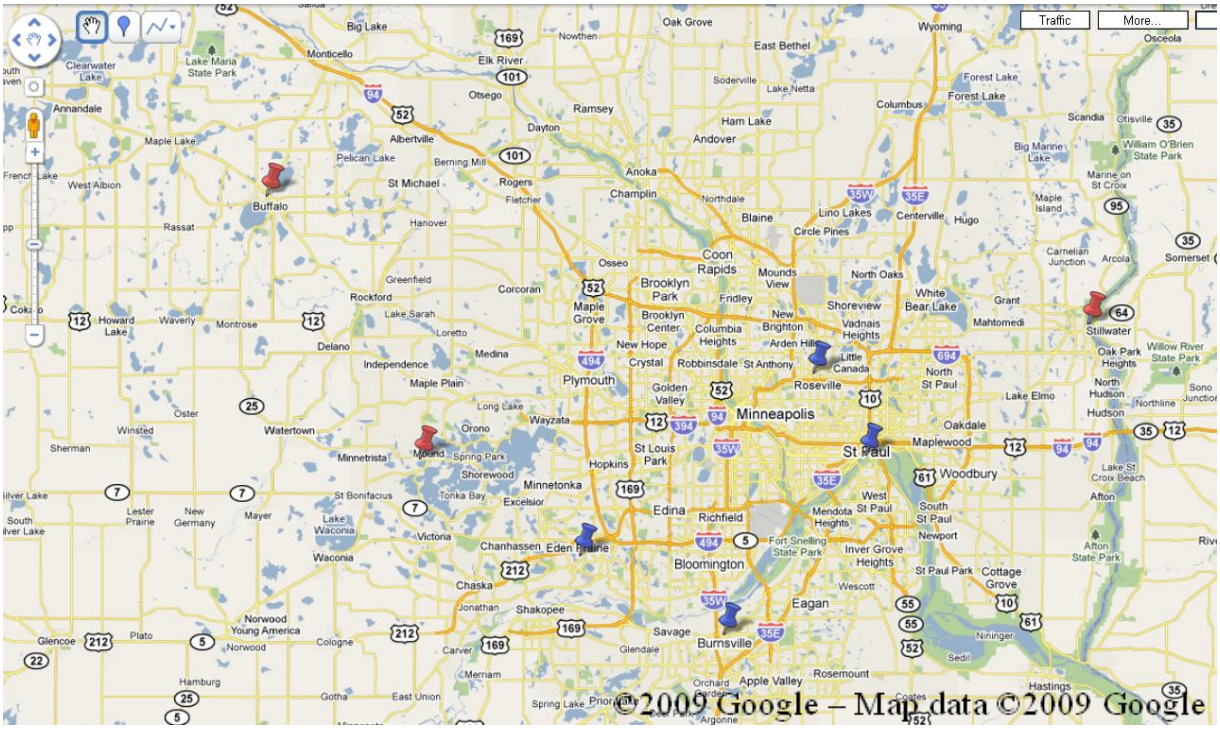


Figure 3.11. Phone survey sites within metro area

3.2 Follow-Up Phone Surveys (Agency-Specific Discussions)

Based on the results of the statewide survey, specific agencies (nine counties and six cities; see Table 3.1) were contacted to further document existing pavement marking practices. The specific questions addressed during each phone discussion were

1. What determines your annual paint program, and what is your budget?
2. How is this work performed?
3. What specifications do you use (beads and paint)?
4. What are your quality control practices?
5. How many miles do you maintain (paved, painted)?
6. Other comments?

The information obtained is summarized below.

3.2.1 Washington County

1. What determines your annual paint program, and what is your budget?

   In the past, unless it was recent construction where tape or epoxy was used, then everything would be striped with latex each year. In 2009, the county initiated a new method that prioritizes and ranks all markings using a night survey method, which has a subjective rating of 1 to 4 (with 4 being the best quality). The night surveys are conducted after the lines are cleaned by good spring rains. Any segment (defined by major intersections) that gets a 1 or 2 is made part of the annual paint program. This information is put into a spreadsheet for estimating and budgeting purposes. The typical annual budget is approximately $90,000 for materials only.

   Materials used: Tape or epoxy on new construction/overlays and latex on everything else.

2. How is this work performed?

   In-house crews for latex paint. New construction and rehabilitation projects are striped with either tape or epoxy as part of the construction contract.

3. What specifications do you use (beads and paint)?

   Mn/DOT specifications for both materials and application.

4. What are your quality control practices?

   None, given that they are using in-house crews and Mn/DOT specifications.

5. How many miles do you maintain (paved, painted)?

   281 centerline miles, which are all paved and painted.

6. Other comments?
   - Since the county has begun using the night survey method, they have striped 23% less than in 2008 (1.1 million feet).
   - The county paint crew does some striping (by work order) for small adjacent municipalities.
   - Feel that durability of epoxy and tape depends on the annual average daily traffic (AADT) (five- to seven-year life).

3.2.2 Otter Tail County

1. What determines your annual paint program, and what is your budget?

   If the budget allows, the centerline on higher volume roads (1,500 to 2,000 average daily traffic [ADT]) are striped annually, with the edge lines striped every other year. All other roads are striped on a three-year cycle. In addition to this, the county relies on three maintenance area foremen who rank all pavement markings on a 1 to 3 scale (1 = restripe, 2 = restripe if budget available, 3 = don't restripe). Given the annual budget and condition rankings, the engineering technicians establish the annual paint program. The typical annual budget is approximately $250,000 for latex restriping.

   Materials used: Epoxy on new construction/overlays and latex on everything else.

2. How is this work performed?

   Standard low bid with no pre-qualifications. Using private contractors (usually get two to three bids each year).

3. What specifications do you use (beads and paint)?

   Mn/DOT specifications for both materials and application.

4. What are your quality control practices?
   - Take samples for both paint and beads.
   - Verify marking length and width.
   - Verify material quantities (gallons per mile).
   - A county employee is with the contractor each day of restriping..

5. How many miles do you maintain (paved, painted)?

   1,050 centerline miles, which are all paved and painted.

6. Other comments?
   - County prefers that all striping be completed by June 30, but this ends up being the end of July. Next year the county will put an August 15 deadline on the contract.
   - Experimenting with durable grooved-in products (tape).
   - Moving to 6 in. edge lines widths in 2009 for maintenance and construction.

3.2.3 Olmsted County

1. What determines your annual paint program, and what is your budget?

   Each spring the county rates pavement condition, which includes pavement markings. The rating is based on three categories (good, fair, and poor). The county crews will further assess the "fair" category and then build the annual striping program from all the "poor" and the selected "fair" segments. Typically, the annual program includes about half of the total miles (edge line and centerline). The typical annual budget is approximately $235,000.

   Materials used: Epoxy on new construction/overlays with latex on everything else.

2. How is this work performed?

   Mn/DOT crews.

3. What specifications do you use (beads and paint)?

   Mn/DOT specifications for both materials and application.

4. What are your quality control practices?

   None, given that they are using Mn/DOT.

5. How many miles do you maintain (paved, painted)?

   374 centerline miles, which are all paved and painted.

6. Other comments?
   - Going with Mn/DOT saved time for county crews as well as storage requirements for materials.
   - Give Mn/DOT a map of sections needing to be painted and this is usually completed by the end of June.
   - Get at least one year from latex and three years from epoxy.
   - Experimenting with rumble stripes (edge line only).

3.2.4 Wright County

1. What determines your annual paint program, and what is your budget?

   The county restripes all roads with latex paint each year. Roads striped with epoxy are evaluated each year and considered for latex restriping (two to four years performance for the epoxy). The typical annual budget is approximately $260,000 for latex only.

   Materials used: Epoxy on new construction/overlays with latex on everything else.

2. How is this work performed?

   Using contractors (usually get two bids each year). Bid by the gallon under a seasonal contract. The contract is flexible so the contractor can come in up to ten times over the season. The county provides a "striping" map on roads that need new markings. Once the contractor receives the map, they must start striping within seven days (no set completion time; the intent is that once started, they will complete the work on each map).

3. What specifications do you use (beads and paint)?

   Mn/DOT specifications for both materials and application.

4. What are your quality control practices?

   Compare quantities billed versus estimates for a 4 in. line at 15 mm thickness.

5. How many miles do you maintain (paved, painted)?

   537 centerline miles, which are all paved and painted.

6. Other comments?
   - Prefer majority of work on first map to be done in early May. The second map is fairly large, too. Third and fourth maps typically include a few roads and end of season striping, etc.
   - Converting to 6 in. edge lines on reconstruction (epoxy).

3.2.5 Rice County

1. What determines your annual paint program, and what is your budget?

   The county maintenance director evaluates existing markings in a subjective manner and decides pavement marking needs each year. On average, the county paints roughly 35 percent of its total miles each year. Traffic is a consideration when deciding pavement marking needs. The typical annual budget is approximately $80,000 for latex only.

   Materials used: Majority is latex with some epoxy used on new construction/overlays.

2. How is this work performed?

   Annual bids (usually get three bids each year). All work is required to be done by July 4.

3. What specifications do you use (beads and paint)?

   Mn/DOT specifications for both materials and application.

4. What are your quality control practices?

   None; however, the county is familiar with the contractor.

5. How many miles do you maintain (paved, painted)?

   350 centerline miles, which are all paved and painted.

6. Other comments?
   - Budget is a constraint, and the county would like to do more painting each year.
   - Higher ADT (>10,000) get painted twice every three years.
   - Experimenting with 6 in. edge line stripes (using federal funds)

3.2.6 Lake County

1. What determines your annual paint program, and what is your budget?

   Centerlines on all county roads are striped annually, while edge lines are striped every other year. The typical annual budget is approximately $100,000 for both signs and pavement markings.

   Materials used: Latex.

2. How is this work performed?

   Use a multi-agency contract through St. Louis County.

3. What specifications do you use (beads and paint)?

   Established by St. Louis County.

4. What are your quality control practices?

   County staff monitor paint operations (contractor output).

5. How many miles do you maintain (paved, painted)?

   380 centerline miles, which are all paved and painted.

6. Other comments?
   - In the last couple of years through a federal safety program, the county has upgraded edges from 4 to 6 inches.
   - Considering using epoxy because the county is within a tourist area.
   - Desired window of implementation is June through July.
   - Experimenting with edge line rumble stripes on roughly 50 miles starting in 2011.
   - With a minimum federal requirement on retro, the county would have to reconsider priorities as well as what to do on major routes.

3.2.7 Lincoln County

1. What determines your annual paint program, and what is your budget?

   The maintenance foreman reviews the pavement marking condition in July/August and makes a map by condition (good, fair, and poor). Pavement marking needs are coordinated with the seal coat program. The county paints all of the poor and some of the fair pavement markings but not the good markings. Everything is usually painted on a three- to four-year cycle. The typical annual budget is approximately $25,000 for latex only.

   Materials used: Latex.

2. How is this work performed?

   In July and August the county evaluates the pavement marking needs and issues a quote in September for work to be completed by the end of October. A map is produced to show the location of the installed pavement marking and these locations are coordinated with the seal coat program. The county invites two contractors to bid (provide a quote) based on gallons.

3. What specifications do you use (beads and paint)?

   Mn/DOT specifications for both materials and application.

4. What are your quality control practices?

   County staff does visual observation but does not monitor line width or mm thickness.

5. How many miles do you maintain (paved, painted)?

   235 centerline miles, which are all paved and painted.

6. Other comments?
   - Will be involved with safety striping around curve (6 in.) edges in 2010.
   - On new seal coat roads, the county only stripes the centerline because the edge lines do not perform well the first year.

3.2.8 St. Louis County

1. What determines your annual paint program, and what is your budget?

   The centerline is striped each year, with edge lines striped on a two-year cycle. The typical annual budget is approximately $410,000.

   Materials used: Epoxy on new construction/overlays with latex on everything else.

2. How is this work performed?

   The county manages a multi-agency pavement marking agreement. It solicits to all townships and cities within St. Louis County. Once the agreement is executed, the agencies provide their quantities, which are combined within the bid documents. The contract specifies that the contractor must contact local agencies for details on where to paint and the begin/end calendar dates. Lake County is also included in this agreement.

3. What specifications do you use (beads and paint)?

   Mn/DOT specifications for both materials and application.

4. What are your quality control practices?

   Specific to St. Louis County, the county does random inspections of the contractor's work. A certificate of compliance with Mn/DOT specifications is also required.

5. How many miles do you maintain (paved, painted)?

   1,400 centerline miles, which are all paved and painted. On average, less than 100 miles have epoxy.

6. Other comments?
   - Experimenting with 6 in. edge lines. Will be involved with safety striping around curve (6 in.) edges in 2010.
   - Applied for and received two rumble strip projects.
   - Do not have any seal coat roads.

3.2.9 Hennepin County

1. What determines your annual paint program, and what is your budget?

   The county paints the entire road system each year with latex. Some areas are painted twice (based on need). No formal process is used for deciding when to paint over durables; the county relies on visual inspection. The typical annual budget is approximately $450,000 for both materials and installation.

   Materials used: Epoxy and tape on new construction/overlays with latex on everything else.

2. How is this work performed?

   County crews complete annual latex striping between April 15 and November 1.

3. What specifications do you use (beads and paint)?

   Mn/DOT specifications for both materials and application. Materials are purchased using the state contract.

4. What are your quality control practices?

   None, because the county does its own work.

5. How many miles do you maintain (paved, painted)?

   The county has 9 million lineal feet of lines.

6. Other comments?
   - Experimenting with 6 in. edge lines (roughly 200,000 lineal feet).
   - On new construction, epoxy is used for the white lines and grooved-in tape is used for all yellow lines.

3.2.10 City of North Mankato

1. What determines your annual paint program, and what is your budget?

   The city paints 80 percent of all roadways each year, with the remaining 20 percent included on an as-needed basis. The typical annual budget is approximately $17,000.

   Materials used: Epoxy on new construction/overlays with latex on everything else.

2. How is this work performed?

   Using contractors (usually get three to four bids each year). Typically have no problems getting all of the work completed by the end of June.

3. What specifications do you use (beads and paint)?

   Mn/DOT specifications for both materials and application (purchased using the state contract).

4. What are your quality control practices?

   None.

5. How many miles do you maintain (paved, painted)?

6. Other comments?
   - The city has a list of lineal feet of striping by street and line type, which is used to provide estimated gallons to the contractor.

3.2.11 City of Eden Prairie

1. What determines your annual paint program, and what is your budget?

   A list of pavement marking needs (by segment) is identified based on visual inspection. Overlay and seal coat segments are then added to this list. The typical annual budget is approximately $85,000.

   Materials used: Epoxy on everything except for roadways getting a seal coat or overlay within the next two years.

2. How is this work performed?

   Using contractors (usually get three to five bids each year). The contract includes multiple completion dates.

3. What specifications do you use (beads and paint)?

   The city references Mn/DOT specifications but has developed its own.

4. What are your quality control practices?

   City staff monitors contractor work and identifies paint locations.

5. How many miles do you maintain (paved, painted)?

   223 centerline miles, of which less than 20 percent (40 miles) are painted.

6. Other comments?
   - Use epoxy on new seal coat surface but get shorter life.
   - Started inputting pavement marking location, type, condition, and maintenance history into pavement management system.

3.2.12 City of St. Paul

1. What determines your annual paint program, and what is your budget?

   The city completes an initial list of pavement marking needs based on the traffic engineer's and shop supervisor's visual inspection. The final marking plan is developed from this initial list, considering budget constraints. The typical annual budget is approximately $1.1 million (annual signs and marking budget).

   Materials used: Epoxy or tape (grooved-in) on new construction with latex on everything else.

2. How is this work performed?

   City crews for latex only.

3. What specifications do you use (beads and paint)?

   The city has developed its own specifications.

4. What are your quality control practices?

   None, because the city does its own work.

5. How many miles do you maintain (paved, painted)?

   Roughly 1.3 million lineal feet (4 in. lines) are painted each year.

6. Other comments?
   - Residential roads are not typically marked.
   - Maintain county roads within their jurisdiction (get reimbursed).

3.2.13 City of Roseville

1. What determines your annual paint program, and what is your budget?

   The city restripes critical routes (state-aid and >1,000 ADT roads) each year. All roads are listed in a spreadsheet and are tracked for when they are striped and when to stripe next. The typical annual budget is approximately $10,000 to 15,000 for latex only.

   Materials used: Epoxy (on new construction) with latex on everything else.

2. How is this work performed?

   Using contractors (typically have contracted with Ramsey County, but this year going with a private contractor).

3. What specifications do you use (beads and paint)?

   The city has developed its own specifications.

4. What are your quality control practices?

   None.

5. How many miles do you maintain (paved, painted)?

   Roughly 120 miles, of which 25 miles are striped annually on average.

6. Other comments?
   - Have a geographic information system (GIS) database that tracks when stripes were placed and when to stripe next.
   - New road surfaces get epoxy. After five years, restripe with latex.

3.2.14 City of Burnsville

1. What determines your annual paint program, and what is your budget?

   The city paints everything annually with latex and typically bids 12,000 gallons (this includes quantities for nine other cities).

   Materials used: Epoxy on new construction/overlay with latex on everything else.

2. How is this work performed?

   The city manages a multi-agency agreement for pavement marking (between 9 and 12 cities participating). The work is performed by a contractor, who typically bids by the gallon.

3. What specifications do you use (beads and paint)?

   Mn/DOT specifications for both materials and application.

4. What are your quality control practices?

   Monitor contractor progress and traffic control. Burnsville city staff will offer technical help to other cities if needed.

5. How many miles do you maintain (paved, painted)?
   No response.

6. Other comments?
   - Each city gives the contractor a map of where to paint and is responsible for its own inspection and payment (minimizes administrative needs for Burnsville).
   - Have administered a multi-agency contract for ten years.

3.2.15 City of Rochester

1. What determines your annual paint program, and what is your budget?

   All latex markings are restriped annually. The goal is to develop a striping management program to show what is painted by type. The typical annual budget is approximately $100,000 for durable markings only.

   Materials used: Epoxy, which is mostly grooved-in on new construction/overlay, with latex on everything else.

2. How is this work performed?

   All latex markings are placed by in-house crews. All epoxy work is contracted out (typically three bids per year).

3. What specifications do you use (beads and paint)?

   Mn/DOT specifications for both materials and application.

4. What are your quality control practices?
   No response.

5. How many miles do you maintain (paved, painted)?
   No response.

6. Other comments?
   - Developing a GIS system to track pavement marking (90 percent complete).
   - Residential streets are not painted. Non-residential roads with less than 6,000 ADT are striped with latex, and those with more than 6,000 ADT are striped with grooved-in epoxy.
   - The city has old striping equipment and is leaning toward contracting out the latex work in the future.

3.3 Additional Documentation

The following section contains some of the additional information provided by various cities and counties as a result of the phone surveys. Figure 3.12 shows how St. Louis County is using GIS technology to create its annual pavement marking plan.

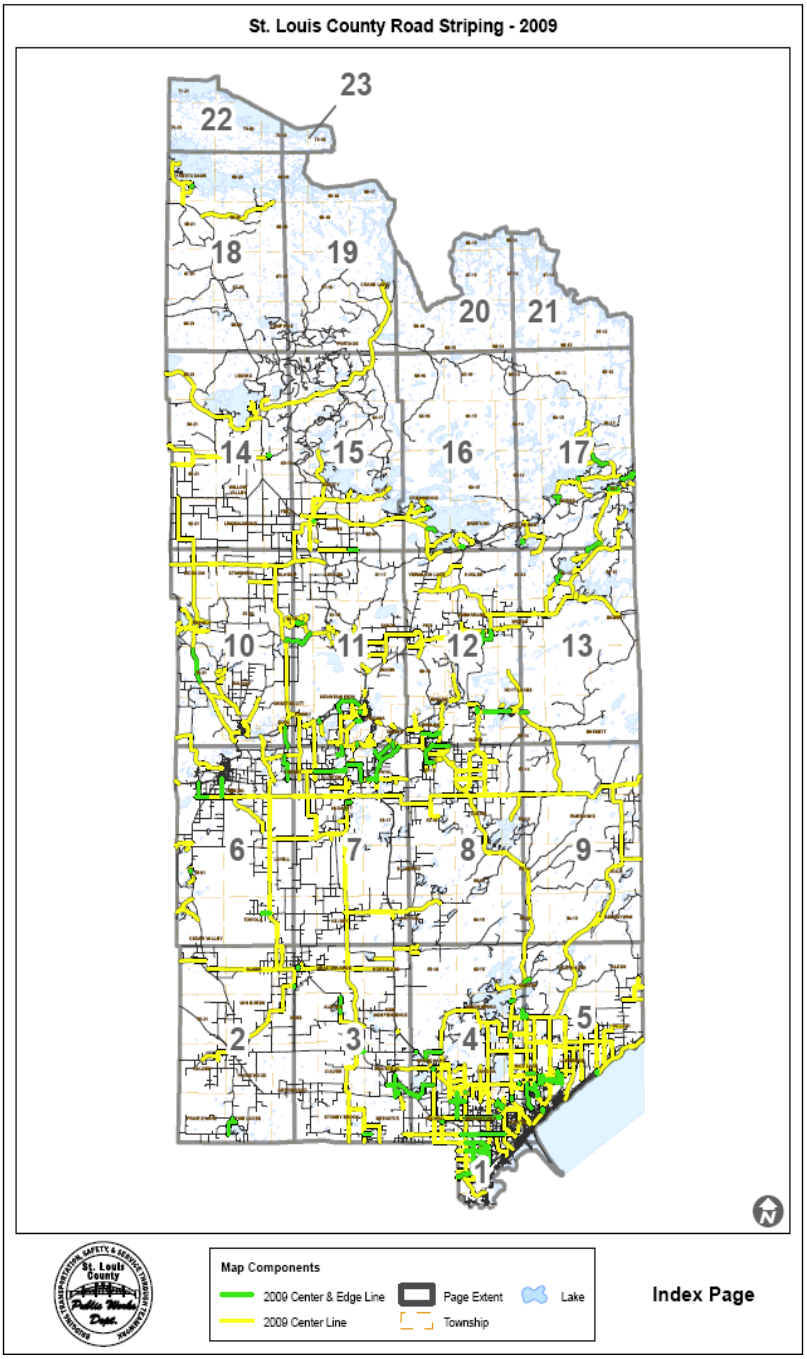


Figure 3.12. GIS used to identify the annual pavement marking plan in St. Louis County

Figure 3.13 shows an example of a pavement marking specification and quote used by Lincoln County.

LINCOLN COUNTY, MINNESOTA
2009 HIGHWAY STRIPING/PAVEMENT MARKINGS
SPECIFICATIONS/QUOTE
August 26, 2009

Prepared by Lee E. Amundson, PE
Lincoln County Engineer

This work shall consist of furnishing and applying reflectorized pavement markings for control and guidance of traffic in accordance with the following specifications on County State Aid Highways and County Highways at the unit price bid per gallon of paint applied and at the cost each for railroad grade crossing pavement markings.

The 2005 Edition of the Minnesota Department of Transportation "Standard Specifications for Construction" shall govern.

All materials and equipment furnished by the Contractor shall meet MN/DOT Specifications and shall be furnished at the unit price quote bid item. Materials shall consist of:

Reflectorized Latex Paint, Yellow or White, as specified
Glass beads – Drop on and/or premixed types for additional reflectorizing on traffic paint: included in paint price at a rate of 8 pounds of beads per gallon of paint.

All pavement striping shall be 4 inches wide. Skip lines shall be applied in lengths of 10 feet, separated by gaps of 40 feet on pavements where existing markings are still visible. All pavement striping shall be a minimum of 15 mils thick (wet thickness).

Work can be performed on this project as the seal coat and construction projects are completed, or as directed by the Engineer.

The unit price quote per gallon for each type of striping and pavement marking quote shall be compensation in full for all costs of controlling and protecting traffic, sweeping and surface preparation, and maintaining work, together with any other expenses incurred in completing the work that is not specifically included for payment under other quote items.

A three (3) working day notice shall be given to the County prior to the Contractor commencing striping. Coordination will be necessary related to completion of fog seal on seal coat roads.

MN/DOT Specification 1903, increased or decreased quantities of work, or material, shall not apply to this quote.

All work shall be completed as provided for in the specifications, before October 30, 2009.

Quotes will be received until 10:30 AM, September 2, 2009.

Striping requirements include:

Approximately 26 miles of yellow centerline and white edge line striping & 34 miles of yellow centerline on seal coat roads (without edgelines) and municipal routes.

Four (4) railroad grade crossing sites (8 railroad grade crossing pavement messages). Quote includes paint and application.

STOP bars; 2 feet x 12 feet (quote includes paint and application)

STOP AHEAD pavement messages (quote includes paint and application)

Quote Items:	Unit	Quantity	Unit Price	Totals
Yellow Reflective Latex Paint	gallon	918	_____	_____
White Reflective Latex Paint	gallon	910	_____	_____
Pavement Messages (RR Grade Crossings)	each	8	_____	_____
STOP Bars	each	1	_____	_____
STOP AHEAD (pavement message)	each	1	_____	_____
		GRAND TOTAL		_____

NOTE: Attached county and municipal maps show striping/markings locations.

Remit Quote to:

Lee Amundson
Lincoln County Engineer
PO Box 97
221 N Wallace Avenue
Ivanhoe MN 56142
Ph. 507-694-1464
FAX 507-694-1101

Figure 3.13. Example pavement marking specification and quote for Lincoln County

Figure 3.14 shows an example of how CAD is used to determine the annual pavement marking plan in Lincoln County.

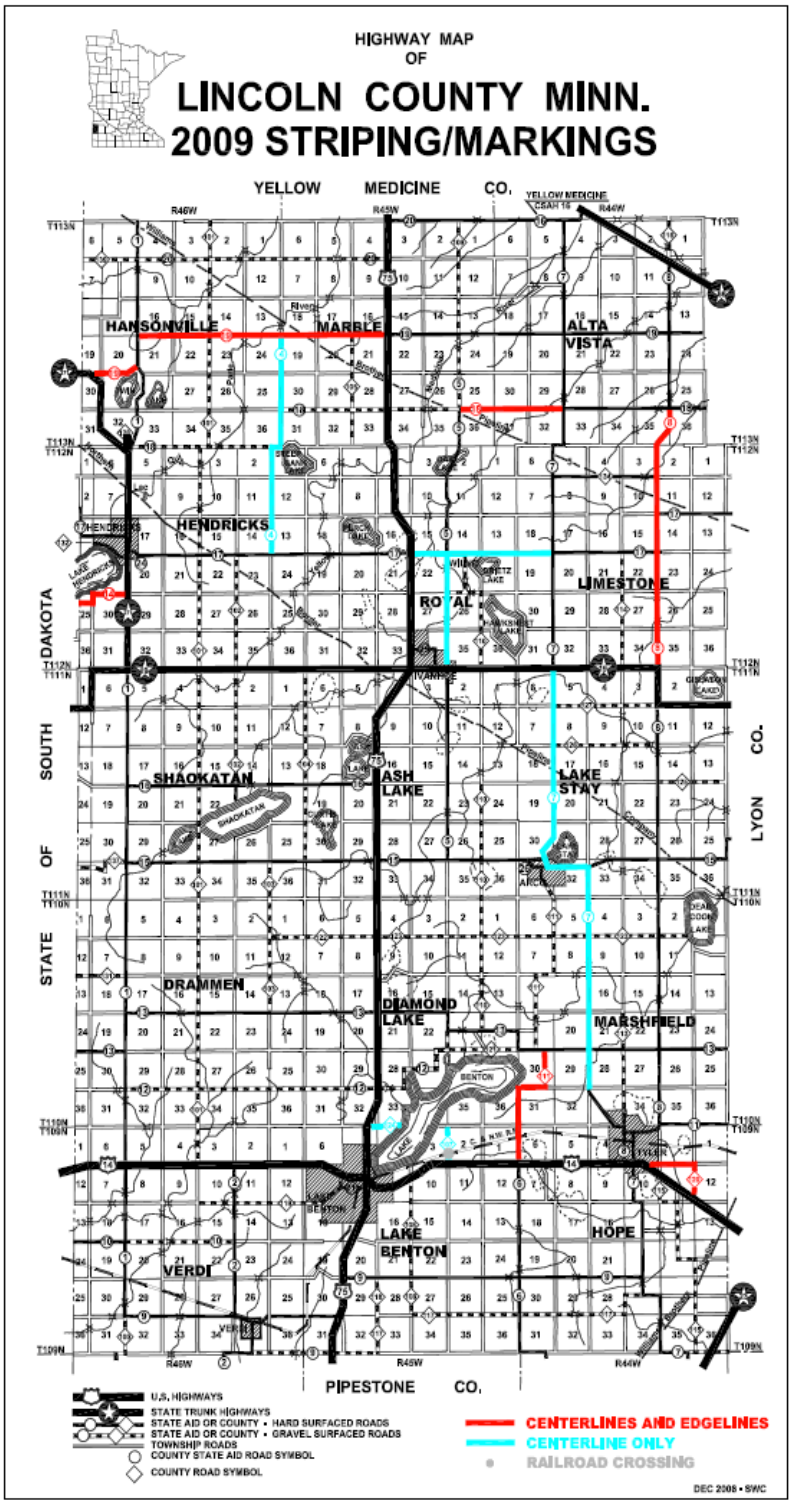


Figure 3.14. CAD used to create annual pavement marking plan (county-wide map)

Figure 3.15 shows how Lincoln County uses CAD to determine the pavement marking plan for a specific section, in this case, the town of Tyler.

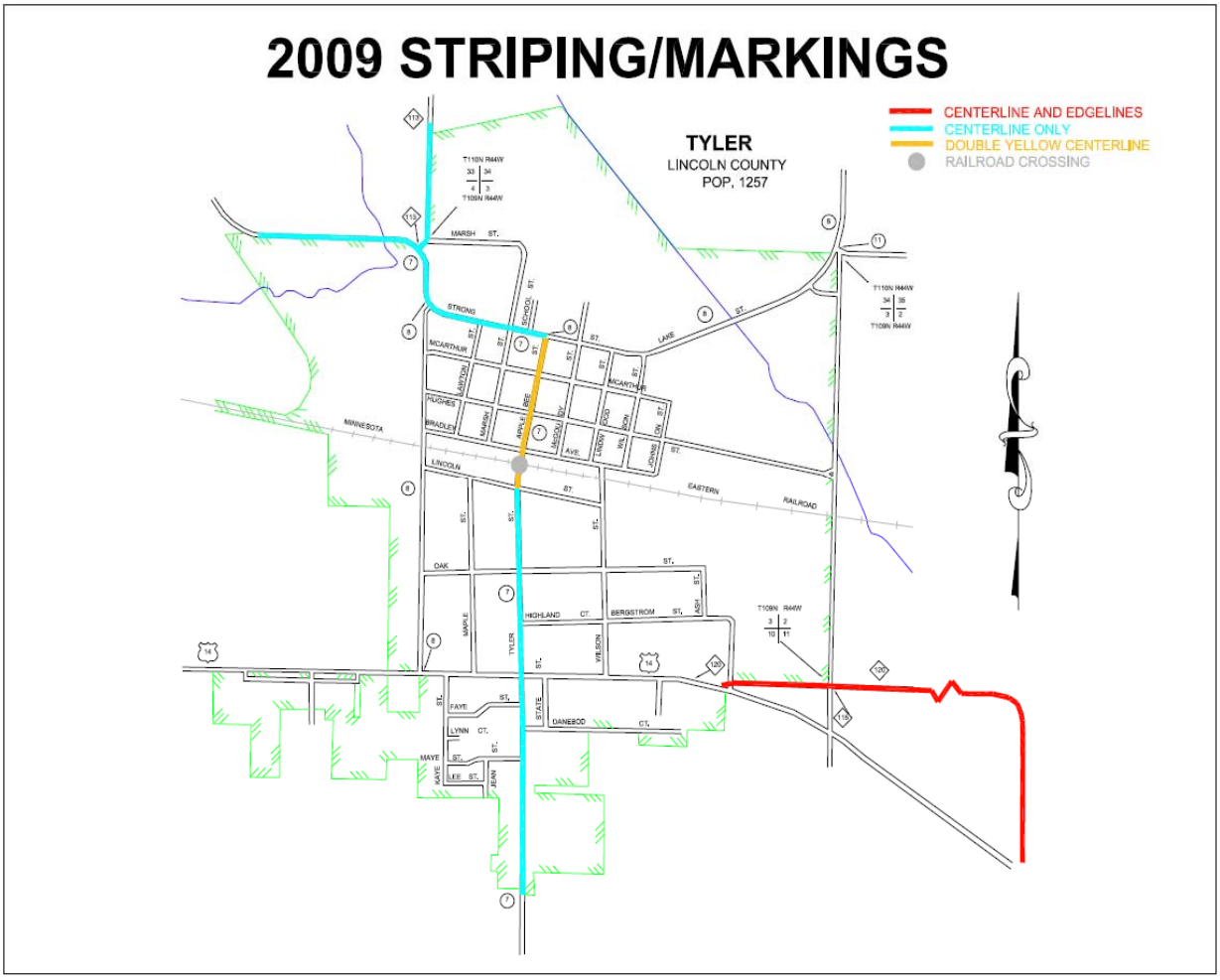


Figure 3.15. CAD used to identify annual pavement marking plan for Tyler in Lincoln County (specific section map)

Figure 3.16 represents how Wright County uses both a table (shown in Table 3.2) and a map to identify and create its annual pavement marking plan.

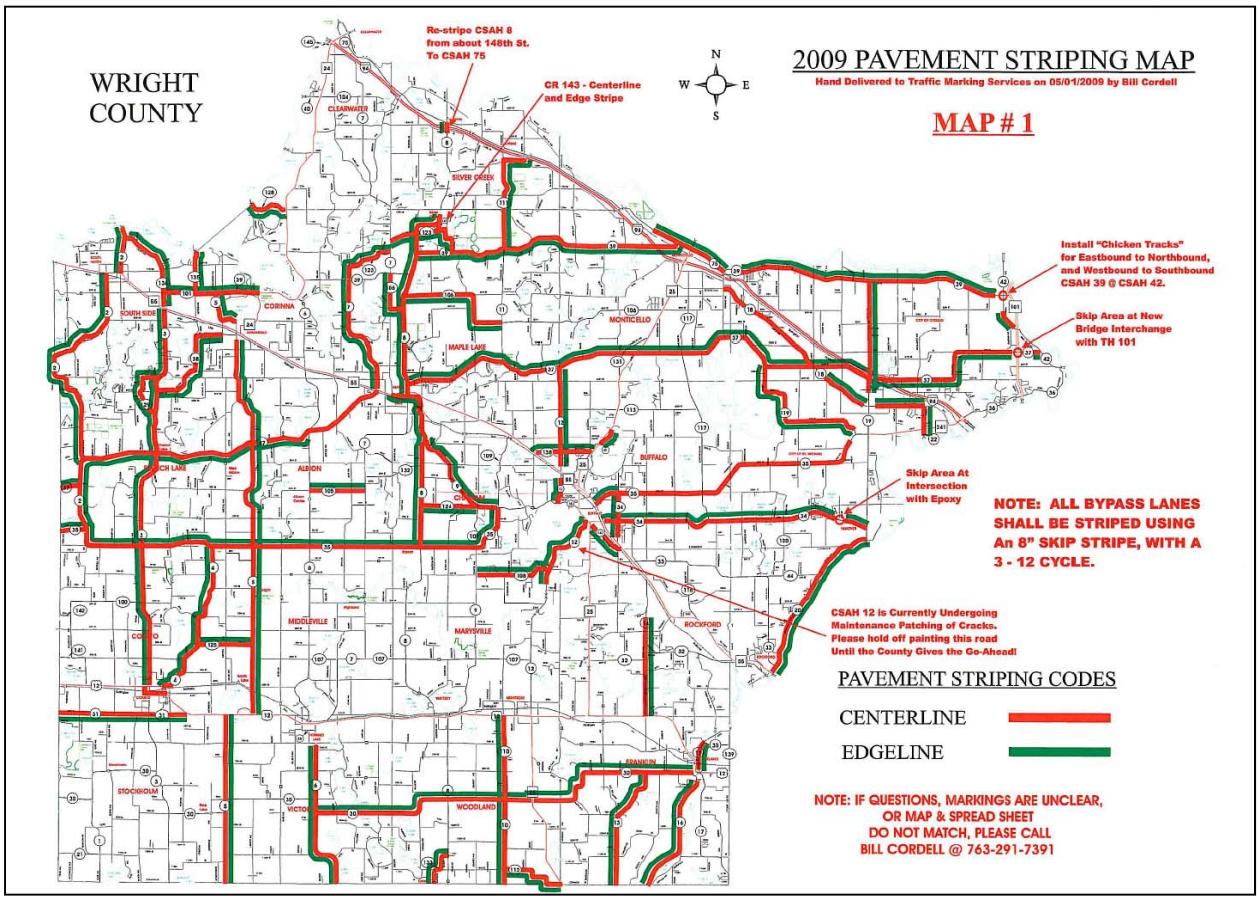


Figure 3.16. Wright County map used to identify annual pavement marking plan

Table 3.2. Wright County table to identify roads for annual pavement marking plan

WRIGHT COUNTY HIGHWAY DEPARTMENT 2009 PAVEMENT STRIPING			YELLOW CENTERLINE						WHITE EDGELINE			MAP # 1	
PAGE 1	MAP # 1		IN FEET			TOTAL	17.5 GALLONS PER MILE $9.99 PER GALLON			35 GALLONS PER MILE $9.43 PER GALLON			
ROUTE	DESCRIPTION	MILEAGE	SKIP X 0.2	SKIP SOLID X 1.2	DOUBLE SOLID X 2	FEET / MILES	ESTIMATED GALLONS	ACTUAL GALLONS	TOTAL MILES	ESTIMATED GALLONS	ACTUAL GALLONS	DIST./SEGMENT	TOTAL COST PER ROAD
CSAH 2	From CSAH 35 to the Bridge at the North County Line Centerline, Edge Stripe, Turn & Bypass Lanes	12.681	0	0	0	0.000	0.00	292.5		0	382.1		$6,525.28
CSAH 35	From the West County Line to Jct with CSAH 9 (west), CR 109 (north), CSAH 35 (east) Centerline, Edge Stripe and Turn Lane	17.334	0	0	0	0.000	0.00	379.1		0	573.6		$9,196.26
CSAH 3	From TH 12 (Cokato) to TH 55 Centerline, Edge Stripe, Turn & Bypass Lanes	13.945	0	0	0	0 0.000	0.00	219.7		0	491.9		$6,833.42
CR 153	From TH 12 (West Jct) to TH 12 (East Jct) in the City of Cokato Centerline Only (See City of Cokato Detail Map)	1.038	0	0	0	0 0.000	0.00	16.2		0	0		$161.84
CR 129	From the South Jct of CSAH 3 to the North Jct of CSAH 3 Centerline and Edge Stripe	2.066	0	0	0	0 0.000	0.00	52.9		0	66.6		$1,156.51
CSAH 4	From TH 12 to CSAH 35 Centerline and Edge Stripe	5.945	0	0	0	0 0.000	0.00	150.3		0	194.1		$3,331.86
CR 125	From CSAH 4 to CSAH 5 Centerline and Edge Stripe	1.942	0	0	0	0 0.000	0.00	22.2		0	64.3		$828.13
CSAH 31	From West County Line to TH 12 Centerline and Edge Stripe	4.642	0	0	0	0 0.000	0.00	66		0	154.1		$2,112.50
CSAH 5	From South County Line to Highland Street (City of Annandale) Centerline and Edge Stripe	19.875	0	0	0	0 0.000	0.00	353.7		0	711.4		$10,241.97
CSAH 5	From about 400' North of Candlestick Street (City of Annandale) to CSAH 39/CR 101 Centerline and Edge Stripe	1.530	0	0	0	0 0.000	0.00			0			$0.00
CSAH 38	From CSAH 3 to about 550 Feet East of Douglas Drive (City of Annandale) Centerline, Edge Stripe and Turn Lane	4.073	0	0	0	0 0.000	0.00	174.3		0	226		$3,872.44
CR 136	From TH 55 to CSAH 2 Centerline, Edge Stripe, Turn and Bypass Lanes	3.214	0	0	0	0 0.000	0.00	72.5		0	108		$1,742.72
	TOTAL MILEAGE →	88.285			TOTAL QUANTITIES →		EST. GALS 0.00	ACT. GALS. 1799.40		EST. GALS. 0.00	ACT. GALS. 2972.10		TOTAL COST PAGE 1
					TOTAL COST →		YELLOW $0.00	$17,976.01		WHITE $0.00	$28,026.90		$46,002.91

$0.00	TOTAL EST. COST
$46,002.91	TOTAL ACT. COST
1.00	% DIFFERENCE

Chapter 4
Analysis

4.1 Analysis of Findings

Based on the phone survey discussions with Minnesota agencies (nine counties and six cities), the following information summarizes current agency practice:

1. What determines your annual paint program?
   - 7 agencies—no assessment (paint all lines each year)
   - 3 agencies—subjective assessment of durable markings only
   - 4 agencies—subjective assessment (daytime only) of all markings
   - 1 agency—subjective assessment (nighttime) of all markings

2. How is this work performed?
   - 4 agencies use their in-house crews for latex markings
   - 7 agencies contract out all pavement marking work
   - 1 agency contracts directly with Mn/DOT
   - 3 agencies participate in a multi-agency agreement contract

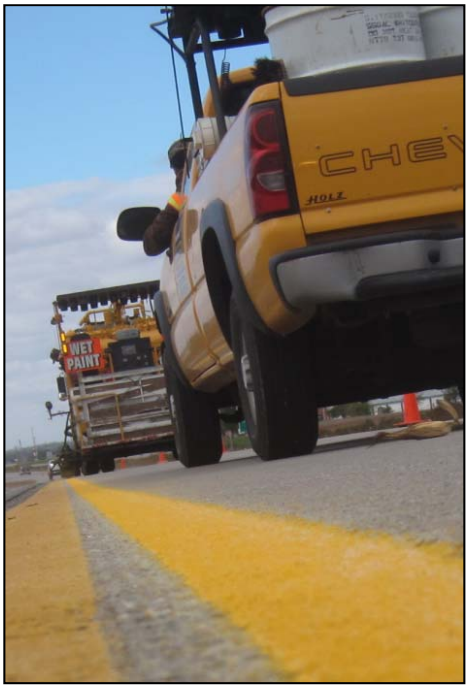
3. What specifications do you use (beads and paint)?
   - 4 agencies use their own (agency specific) specifications
   - 11 agencies use Mn/DOT standard specifications for materials and application

4. What are your quality control practices?
   - 4 agencies—none (agency uses in-house crews)
   - 1 agency—none (agency uses Mn/DOT)
   - 3 agencies—none (agency uses private Contractors)
   - 1 agency—minimal (agency only monitors quantities)
   - 5 agencies—moderate (agency employee monitors marking operations)
   - 1 agency—enhanced (agency employee monitors marking operations, quantity, and quality)

4.2 Challenges

Agencies face a number of challenges specific to annual pavement marking installation, such as equipment, materials, traffic control, operational skills, and weather. These issues were discussed during the phone surveys, and the following sections summarize the information.

4.2.1 Scheduling/Contracting



As with many northern U.S. states, Minnesota has a limited window for pavement marking installation because of weather (rain, ice, sleet, snow, and cold temperatures). The typical paint season within Minnesota begins in May and continues through October.

Most agencies reported that under normal seasonal conditions, they are able to install all of their intended miles of pavement markings.

Annual progress was less of a concern among the agencies using in-house crews because they were able to adjust schedules and work activities to take advantage of good weather days.

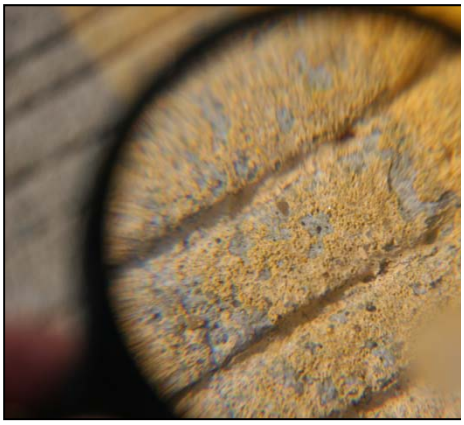
In contrast, of the ten agencies surveyed by phone that contract out their pavement marking work, seven of these had a unique approach in directing annual placement. Although the weather window stretches until October, many agencies prefer that their markings be placed early in the season (before July). Reasons cited included the desire to extend the useful life of the marking prior to winter, the need to get the work completed ahead of the annual busy tourist season, and the need for visibility and to fulfill user expectations within the community.

Pavement marking contracting practices by local agencies who responded to the email survey are listed in Table 4.1.

Table 4.1. Email survey results of local agency contracting practices

Contract Method	City	County
Private	11	27
Multi-Agency Agreement	3	1
County Crews	2	0
Mn/DOT	0	3
In-house	2	6

4.2.2 Annual Condition Assessment



Pavement markings are not required for every roadway, nor is there a national minimum retroreflectivity or presence standard. Agencies bear the annual burden of evaluating and determining which roads and, more specifically, which pavement marking lines along each road to include within their annual marking or striping program.

The complexity of each evaluation level can vary from none (simply re-stripe all lines annually) to advanced (using field reviews to document presence and costly equipment to document retroreflectivity for each line once or twice per year).

Pavement marking quality is typically measured in terms of nighttime retroreflectivity (millicandela/square meter/lux-mcd) and daytime presence. Retroreflectivity is typically measured using 30 m geometry with either a mobile van with lasers or a hand-held device. Regarding daytime presence, the most common approach is to do a visual assessment (windshield survey), or some recent research has developed image processing tools that allow agencies to measure presence in an automated fashion [1].

Choosing the right approach is not straightforward nor without consequences. For example, agencies who paint all of their lines each year run the risk of repainting markings that could have provided another season of service. Agencies using a subjective rating assessment typically set some cutoff limit, which may not cover all of the markings that could perform for another year. The assessment method used can have an impact on annual striping plans. For example, Washington County experienced a 23 percent reduction in striping needs once they began using nighttime surveys to evaluate their annual painting needs.

The variety of assessment methods reported among the agencies surveyed within Minnesota are as follows:

- No assessment (paint all lines each year)
- Subjective assessment of durable markings only
- Subjective assessment (daytime only) of all markings
- Subjective assessment (nighttime) of all markings

4.2.3 Material Selection

Within any agency, the roadways include a variety of pavement surface types, conditions, and traffic levels. Choosing a pavement marking material to compliment the roadway conditions will have a significant impact on both budget and marking durability.

The research team discussed a 2002 study, "Long-Term Pavement Marking Practices," which documents the current best practices for managing pavement marking systems, identifies future needs, and addresses driver needs and methods of communicating information to drivers, selection criteria (e.g., reflectivity, pavement service life, wet weather performance), materials (e.g., color, durability, cost), specifications, construction practices, and inventory management systems. The report contains information derived from 61 transportation agency survey responses (state, province, county, and city). The report discusses the many different practices among agencies due to variations in structure, policies, and climate [2].

Mn/DOT provides material selection guidance to each district through a technical memorandum available at http://dotapp7.dot.state.mn.us/edms/download?docId=700101, as shown in Figure 4.1.

MINNESOTA DEPARTMENT OF TRANSPORTATION, Engineering Services Division,
Technical Memorandum No. 08-10-T-02, May 20, 2008

TWO LANE TWO WAY HIGHWAYS

Remaining Pavement Surface Life[1] (years)	ADT			
	<1,500		>1,500	
	Edgeline	Centerline	Edgeline	Centerline
0-2	Paint	Paint	Paint	Paint
2+	Paint	Paint	Epoxy	Epoxy

[1] Anticipated life of existing pavement is based on planned projects and anticipated life of surface is based on preventive maintenance plans. For the purpose of this tech memo the expected life of a seal coat is greater than 6 years. All marking materials used shall be on Mn/DOT's Qualified Products list.

Figure 4.1. Example of Mn/DOT technical memorandum

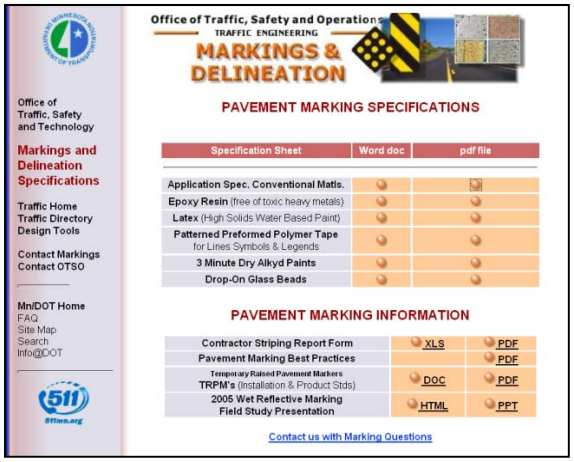
Table 4.2 shows the percent of pavement marking material used by local agencies who responded to the email survey. As shown, the majority of agencies are using latex paint for most of their pavement marking applications, with epoxy being the second choice, especially on new pavements.

Table 4.2. Local agencies material selection practices

Material	Latex	Epoxy	Other
General Maintenance	87%	8%	5%
New/Overlaid Pavement	58%	35%	7%
Seal Coat	75%	20%	5%

In a 2000 LRRB report [3], the authors indicated that for low-volume roads (AADT less than 10,000), a conventional product, such as paint, may be the most cost-effective material. For roadways with higher volumes (AADT of more than 10,000), a more durable product, such as epoxy or tape, may be more cost-effective and may reduce worker exposure to traffic. This AADT threshold needs to be examined considering available pavement marking material performance data (conventional or durable) and local agency practices.

4.2.4 Material Specification



Specifying, procuring, and handling pavement marking paint materials and glass spheres can be a challenge for agencies, particularly given the continual revision of products. Maintaining current specifications, testing procedures, and material handling requirements uses staff resources and can go beyond the staffing expertise of many local agencies. Of the 15 agencies included in the phone surveys, 11 rely on Mn/DOT for product specification and installation practice guidance. These specifications and guidance can be found at the following web address: http://www.dot.state.mn.us/trafficeng/products/markings-specs.html.

Chapter 5
Best Practices

As with any function performed by local agencies, budgetary limitations play a central role in agency planning, practices, and annual material placement. The best practices discussed within this section highlight the different methods agencies are using to adapt to their budget constraints and to stretch their dollars to provide the best pavement marking performance possible.

5.1 Scheduling/Contracting

- As part of an annual pavement marking contract, agencies can prioritize pavement marking placement by developing installation maps that are given priority throughout the paint season.
- Agencies can consider using in-house crews as a best practice because of the benefits of flexibility in scheduling, lack of need for contracting/monitoring, and minimized concerns for quality control. However, these benefits can be highly dependent on the size, budget, and operational conditions of each local agency.
- Multi-agency agreements provide agencies of all sizes the advantage of larger quantity pricing, consistent material and installation specifications, and ease of contracting and/or dispute resolution.
- Let agency staff monitor the quality and quantity of contractor-applied markings.

5.2 Annual Condition Assessment

- The best existing practice is conducting an annual nighttime survey for pavement marking retroreflectivity and a daytime survey for presence. Storing this information within a GIS database allows for easier review and decision making and serves as a tool to communicate striping needs.
- Track material installation by date, line, quantity, and type in a graphical format.

Chapter 6
Conclusions and Recommendations

6.1 Minimum Retroreflectivity

The FHWA is preparing to develop proposed language for the *Manual on Uniform Traffic Control Devices* (MUTCD) regarding pavement marking retroreflectivity. In 2007, FHWA held two pavement marking retroreflectivity workshops regarding the upcoming proposed rulemaking, which can be found at http://safety.fhwa.dot.gov/roadway_dept/night_visib/pavement_visib/fhwasa08003/fhwasa08003.pdf.

It is evident that pavement marking research is active and is delivering findings that demonstrate the effects of pavement markings and their characteristics. Despite the new and exciting findings, it also appears obvious that more work is needed but that opportunities exist to develop additional safety-based policies and performance-based specifications to improve the application of pavement marking for transportation agencies. This body of research should be utilized to guide the ongoing MUTCD activities to develop pavement marking warrants related to minimum retroreflectivity [4].

For Mn/DOT, once the rule making process is completed, striping operations across the state will be responsible for assuring that pavement markings meet or exceed these minimum-level criteria. Because of Minnesota's climatic extremes, a systematic approach to pavement markings (district and statewide striping plans) have been developed and implemented in order to attain Mn/DOT's mission. Over the past several years, Mn/DOT has emphasized efforts to increase the performance of pavement markings throughout the state. These efforts have focused on improving equipment, streamlining maintenance operations, evaluating new materials, retrofitting materials on existing surfaces, and investigating performance-based specifications to better deliver Mn/DOT's goal to “Provide an appropriate pavement marking on all highways, 365 days per year” [5].

This rulemaking will also impact local agency pavement marking practices, which will focus on pavement marking quality and management methods.

6.2 Mn/DOT Pavement Marking Management Tool

Mn/DOT is currently working with Iowa State University to develop a scalable, reliable, and practical tool for viewing, querying, understanding, and making consistent, objective, and cost effective decisions regarding pavement marking needs, durability, and quality. The tool graphically displays pavement marking retroreflectivity data, collected by either mobile or handheld devices, using a Web-based application that resides on Mn/DOT’s GIS Web server. Phase I of the above noted project provided Mn/DOT staff with the ability to map and query pavement marking retroreflectivity information and serves as a significant resource to both district and central office staff in developing short- and long-term pavement marking plans.

The research team worked with Mn/DOT staff to retrieve, sort, and analyze various pavement marking data sources to be included within the mapping tool. Data items, such as retroreflectivity, location (route and milepost), date, and line type, were integrated with geographic location (as established by Mn/DOT staff). A standard format was developed for retroreflectivity and paint data, which is compatible with the location component of Mn/DOT's GIS server. A screen shot of the Web-based tool is shown in Figure 6.1.

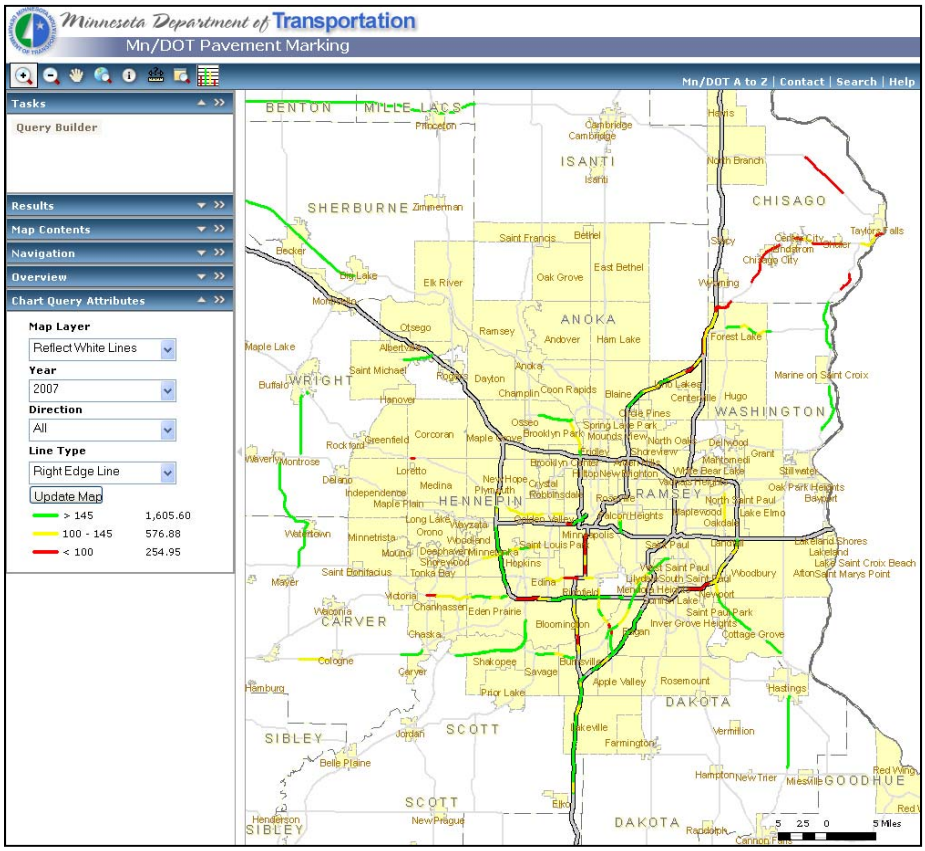


Figure 6.1. Example of Mn/DOT pavement marking tool

Future efforts could extend this Mn/DOT tool to interested local agencies as part of meeting the anticipated FHWA rulemaking and making more informed and consistent pavement marking maintenance decisions.

6.3 Pavement Marking on Challenging Surfaces

This report does not address local agency pavement marking practices on seal coat or micro-surfaced roadways. This information will be the subject of a related Center for Transportation Research and Education (CTRE) research project for Mn/DOT titled "Pavement Marking Compatibility with Chip Seals, Seal Coat, and Micro Surfacing." The project will document existing pavement marking practices on chip seal, seal coat, and micro-surfaced roadways within and outside of Minnesota; analyze these findings; and make recommendations specific to Mn/DOT needs and conditions.

6.4 Future Needs

Based on results from this project, the following list of future needs represents opportunities for local agencies to consider improvements to their pavement marking practices.

- Develop guidance on pavement marking material selection based on pavement type, condition, and traffic volume (long lines and legends).
- Develop practices to help local agencies monitor the quality of pavement markings during installation.
- Develop a methodology that incorporates retroreflectivity measurements to help local agencies determine annual pavement marking striping needs.
- Extend the functionality of the Web-based Mn/DOT pavement marking management tool to the local agency network.

References

[1] Smadi, O., El-Nasan, A., and Hawkins, N. “Image Processing: A Practical Approach to Assessing Pavement Marking Quality”. Proceedings of the Applications of Advanced Technologies in Transportation (AATT) 2008. Athens, Greece, 2008.

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