JOINT TRANSPORTATION RESEARCH PROGRAM

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Snow and Ice Performance Standards

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16. Abstract

Performance standards are used extensively at INDOT to establish and measure performance in many different operations. One area that extensively uses standards is in Maintenance Operations. Currently INDOT has defined three Level of Service(LOS) standards for winter operations. These standards describe pavement conditions during winter weather events and are subjective in nature. A more quantifiable standard would improve the evaluation of winter operations.

This project produced a performance standard based on vehicle speeds during a storm impact period. The period is defined as the time between the beginning and end of a winter storm. The performance standard is modeled after the INDOT mobility standard and applies to interstate routes. It is easily implementable and can be used to identify ineffective snow and ice removal efforts and provides real time feedback.

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EXECUTIVE SUMMARY

SNOW AND ICE PERFORMANCE STANDARDS

Introduction

Performance standards have been developed by the Indiana Department of Transportation (INDOT) for most maintenance activities (e.g., mowing, crack sealing, and so forth). These standards provide guidance with regard to the amount of required effort, which correlates with costs. Currently there are three level of service (LOS) standards for winter operations. These LOS standards describe performance from a pavement condition perspective and are subjective. A more appropriate standard is one that utilizes a quantifiable measure, e.g., traffic speeds.

Findings

Storm Impact Period

Data analysis reveals that once a winter event starts there is a time lag of reduced traffic speeds at the start and end of the event. This time interval is called the "storm impact period." Since this study focused on interstate routes where the posted speed limit is 70 mph, the impact period interval is when speeds are lower than 55 mph. Data analysis also revealed that 27% of storm-related crashes occurred during the storm impact period.

Storm Index

INDOT uses the weather hour approach to define winter severity. A weather hour is defined as an hour that experiences winter precipitation. An individual storm can have different levels of intensity and severity, making the weather hour value inappropriate to use. Several storm indices have been developed and were evaluated. A recommended storm index is described in Table 2.1 of the report.

Performance Standard

After researching various measures for determining snow and ice performance and reviewing the current INDOT mobility standard, vehicle speed was chosen as the performance measure. The researchers then collected speed data during two winter seasons and performed statistical analyses.

During the first winter, 2010–2011, 21 monitoring stations were used. These stations were geographically spaced around Indiana and all were at interstate locations. During this winter there were 25 measureable winter weather events in which traffic speeds were recorded.

For the 2011–2012 winter season the study advisory committee requested that the speed analysis only include Marion County sites. The reason for this was to focus on operations in the Indianapolis metro area and validate the standard. There are six sites in this area, and there were 16 weather events in this area during this winter.

Based upon the data collected during the winter seasons 2010–2011 and 2011–2012, the following winter storm performance standard is proposed for adoption by INDOT.

ADT in vehicles per day (VPD)	% of traffic speeds less than 45 mph during storm impact period
≤65,000	No more than 25
>65,000*	No more than 60

*Exception: During the weekday hours of 6 AM to 6 PM, no more than 40% (*example only*) of the total traffic speeds are less than 45 mph per storm event.

Another proposed performance measure is to limit the amount of time during which traffic speeds are less than 45 mph to 30 minutes during a storm impact period.

LOS Grade

Another standard used in transportation agencies to measure performance is an LOS value. This is a subjective scale, but in this case the scale that follows is based on speed values collected over the two-year winter period.

Traffic speed (70 mph posted)	LOS grade
55+	Very good
45–55	Good
35–45	Fair
25–35	Poor
<25	Very poor

Implementation

Implementation will occur at the unit level where snow and ice operations occur. Managers can easily implement and use this standard since it is based on vehicle speeds. It provides immediate feedback to evaluate the effectiveness of winter operations during differing weather conditions. If this standard proves effective for interstate routes, standards for other route types can be patterned after this one. Operations will be involved in implementation.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

Performance standards have been developed by INDOT for most maintenance activities (e.g., mowing, crack sealing, etc.). These standards provide guidance as to the amount of required effort which correlates to costs. Currently there are three Level of Service (LOS) standards for Winter Operations and these are shown in Appendix A. These LOS standards describe performance from a pavement condition perspective and are subjective. A more appropriate standard is one that utilizes a quantifiable measure, e.g., traffic speeds.

Winter operations strive to maintain mobility during winter events. The current INDOT mobility standard describes a good day in terms of traffic speed. That standard is shown in Figure 1.1. The primary expected deliverable from this project will be a winter storm performance measure for Class I routes, using vehicle speed as the performance measure. With this initial performance measure, various winter operation strategies can be evaluated against a standard to provide direction to INDOT decision makers in future strategies to optimize winter resources, including allocation of resources (both capital and operational).

The process to develop a standard requires the analysis of various winter operations data sources consisting of weather, traffic speeds, and accidents. Analyzing these data will establish a proposed standard and through data mining will reveal facts about winter operations while also generating new questions and future directions for winter operations.

2. PROJECT ACTIVITIES

The project activities are listed below, along with their outcomes.

1. Produce a Summary of the Project NCHRP 6-17, Performance Measures for Snow and Ice

The objective of NCHRP Project 6-17 was to identify methods and measures for assessing agency and contractor performance in snow and ice control operations and to recommend measures for further development.

It was determined that agencies and contractors lack standard methods for measuring winter maintenance performance because it is difficult to benchmark and make both cost and efficiency comparisons between different maintenance programs. The importance for standard methods is rising due to limited resources and increased outsourcing of these activities. Performance measurement has not been considered by transportation agencies because (1) the focus has been on standards and specifications for physical conditions or level of service (LOS), and (2) expansion of technology has only recently made data collection easy. Budget and staff constraints also make it difficult for agencies to experiment with new technology.

MOBILITY

Performance Measures and Goals

Information:

Major metro area freeway mobility:

- A measure of congestion in Central Indiana and Northwest Indiana traffic corridors during peak AM and PM travel time hours. This is assessed by calculating the congested periods as a percentage of peak hour periods per month.
- Updated monthly.

Measures: Major metro area freeway mobility.

Goal: 18 or more good days per month, YTD.

Filters: Calendar year.

Definitions

Working day: Monday–Friday, excluding holidays.

Traffic day: Working day during peak hours.

Peak hours: Peak AM (6 AM–9 AM) & peak PM (3:30 PM–6:30PM)

Good day:A traffic day is considered to be good if the sensor data analyzed shows that at least 90% of the 15-minute analysis periods have an average traffic speed of 45 MPH or greater during peak AM and PM hours.

Calculations

Where available, data from urban Interstate speed detectors during rush hours are gathered and stored in 15-minute intervals during peak hours. A day is considered "good" if 90% of these intervals have an average traffic speed >45mph. A day is considered "bad" if <90% of these intervals have an average traffic speed >45mph. Rush hours include 6:00 AM–9:00 AM and 3:30 PM–6:30 PM Monday through Friday only.

Figure 1.1 Mobility performance standard.

Agencies currently use the following three factors to measure winter maintenance performance:

1. Inputs: resources utilized (fuel, labor, equipment use, materials).
2. Outputs: defines efficiency and input needed for physical accomplishments (lane-miles plowed or sanded, lane-miles that had deicing materials applied, level of accomplishments of other winter maintenance operations).
3. Outcomes: assesses effectiveness from customer perspective and measured in terms of pavement friction, number of crashes, bare pavement regain time, duration and frequency of closure, advanced warning time to customers, customer satisfaction via surveys.

Pavement friction has become acceptable in Finland, Sweden and Japan because it has been found to correlate to crashes and traffic speed and volume. In these countries, friction-measuring devices are sometimes mounted underneath maintenance vehicles. In the U.S., it is acceptable to measure time to bare pavement as a measure of performance. Less time is required to bare pavement in heavily congested areas. In general, comparisons among jurisdictions must use a common, repeatable performance measure and a stable method for collecting and reporting data.

A survey of winter maintenance practices in the U.S., Canada, Europe and Japan demonstrated that the preferred performance measures are related to money and management systems. For example, agencies in these countries used length of plowed roadway, personnel and overtime hours, material/equipment, cost of operations, time required to reach bare pavement, duration of lane closure, and customer satisfaction to measure performance. Some other findings include measuring degree of clear pavement by either manual or camera-assisted observation; measuring traffic flow by detectors of speed; measuring volume and occupancy by road closure; and measuring crash risk by friction or reported crashes.

There are many expectations for agencies and contractors to improve their assessment of performance measures. For one, agencies must place an emphasis on these performance measurement practices. It's important not to forget that the public will continue to expect clear roads and less harm to the environment. Agencies must also use programs such as Automated Vehicle Location (AVL), GPS, friction meters, road weather information systems (RWIS). The agencies must adopt target performance metrics to direct the maintenance activities. And, highway agencies must assess operational efficiency and extent of meeting expected goals in terms of safety, public satisfaction, and ability to control adverse impacts on the environment.

2. Perform Literature Review, Specifically Collecting Information on Performance Measures Developed and Used by Other Agencies

A summary of these measures is in Appendix B.

3. Evaluate Sensors and Install at Appropriate Locations

The office of Technical Services planned to issue an RFP (Development of Virtual Weigh Stations) to upgrade 10 (110 total stations) of its monitoring stations to include environmental sensors and data communications. This upgrade was scheduled to take about a year to complete, making the completion date for upgrading ten stations in the fall of 2008. The RFP states that a one station may be available for testing in the 2007–2008 winter. This station will be used to initially evaluate a proposed performance standard. The research team will coordinate these activities with this RFP.

Sensor data will be used to evaluate and rate pavement condition. Sensor data communications is a crucial part of this. Hourly data will be needed to determine and track performance.

Due to funding issues and purchasing approval delays these sensors were never purchased. At the same time, WIM station data was evaluated and determined to be an unreliable source of speed data. At the August 27, 2009 SAC meeting, the SAC decided to pursue another approach for measuring traffic speeds during winter events. The SAC recommended that for the 2009–2010 winter season utilize a Bluetooth traffic measurement device developed through JTRP and deploy it on I-65 to measure speeds between Lafayette and Frankfort. It was also recommended to use speed sensors in the Indianapolis area managed by the Traffic Management Center (TMC). These two speed data sources are documented in two publications developed by Brennan, Day, and others (*1,2*). See the reference section.

4. Develop a Winter Event Severity Index

The researcher developed a winter severity index for INDOT that calculates the severity of a winter season. This index is to be used for comparing and evaluating snow and ice removal expenditures in the different climatic regions of Indiana. Indices were developed for these areas and for the state. The indices were developed by using regression analysis of weather events and snow and ice expenditures.

On this project investigate similar approaches that can be used to calculate or categorize a winter storm. Weather factors that influence are: temperature, wind, solar radiation, precipitation type amount, rate and duration. Through a literature review storm indices have been developed and are reported in this section.

A snow and ice removal standard must consider the effect of weather. If a storm is severe then more resources and time will be required to mitigate its effects. This requires developing a relationship that correlates between weather and effort. Three winter event indices have been published.

One storm index was developed by Nixon and Qiu (*3*) and is shown below.

TABLE 2.1
Nixon Winter Storm Index (*3*)

	Storm Type	Storm Temperature	Early Storm Behavior	Wind Conditions During Storm	Post-storm Temperature	Post-storm Wind Conditions	Storm Severity Index
1	Heavy snow >6″ in 24 hours	Cold: <25° F	Starts as rain	Strong >15 mph	Cooling	Strong >15 mph	1.0
2	Freezing rain	Cold: <25° F	Starts as rain	Light <15 mph	Same	Light <15 mph	0.694
3	Heavy snow >6″ in 24 hours	Warm: >32° F	Starts as rain	Light <15 mph	Cooling	Strong >15 mph	0.664
4	Heavy snow >6″ in 24 hours	Warm: >32° F	Starts as snow	Light <15 mph	Cooling	Strong >15 mph	0.618
5	Heavy snow >6″ in 24 hours	Midrange 25–32° F	Starts as snow	Strong >15 mph	Cooling	Light <15 mph	0.609
6	Medium snow 2″–6″	Midrange 25–32° F	Starts as snow	Light <15 mph	Warming	Strong >15 mph	0.467
7	Freezing rain	Warm: >32° F	Starts as rain	Strong >15 mph	Warming	Light <15 mph	0.367
8	Medium snow 2″–6″	Midrange: 25–32° F	Starts as snow	Light <15 mph	Same	Light <15 mph	0.350
9	Light snow <2″	Midrange: 25–32° F	Starts as rain	Light <15 mph	Warming	Light <15 mph	0.30
10	Light snow <2″	Warm: >32° F	Starts as snow	Light <15 mph	Warming	Light <15 mph	0.00

$$SSI = [(1/b) * [(ST * ti * Wi) + Bi + Tp + Wp - a]]^\wedge 0.5$$

Index based on six factors:

1. Storm Type, ST (freezing rain, light snow, medium snow, heavy snow)
2. Storm Temperature, Ti (warm, midrange, cold)
3. Wind Conditions in Storm, Wi (light, strong)
4. Early Storm Behavior, Bi (starts as snow, starts as rain)
5. Post Storm Temperature, Tp (same, warming, cooling)
6. Post Storm Wind Conditions, Wp (light, strong)

Another equation was developed by Boselly and was used by Nixon (*3*) to develop the index reported in Table 2.1. The equation and terms are shown below.

$$WI = a(TI)^{0.5} + b\ \ln[(S/10) + 1] + c[N/(R + 10)]^{0.5} + d$$

Where:

WI = storm severity index
TI = temperature index
S = daily new snow (mm)
N = temperature average factor
R = temperature spread
a = $-$Weight TI/$[(TI_{cz})(R_{ct})]^{0.5}$
b = $-$Weight S/$\ln[(S_{ct}/10)+1]$
c = $-$Weight F/$[N_{cz}/(R_{cz}+10)]^{0.5}$
d = +50

Nixon and Qiu (*3*) developed a storm severity index using the above equation and created Table 2.1. The table describes ten different storm types and assigns a severity index. The index ranges 1.0 to 0.0, with 1.0 the most severe.

INDOT has been using weather hours as an indication of winter activity. A weather hour is when precipitation occurs and the temperature is 35° F or lower. Figure 2.1 shows the weather hours for the 2011–2012 winter season.

5. Develop a Performance Standard Based More on Objective Measures and Less on Subjective Analysis

This standard will use sensors at the monitoring stations to:

- Identify the start of an winter event
- Change in traffic flow/speed during the event and afterward
- The time when normal traffic flow and speed returns.

6. Develop a Reporting Tool that Reports Performance

For example, Minnesota uses a dashboard design that shows time to bare pavement in their districts. The reporting tool will report the winter event severity and the condition of traffic flow. The report type will be graphical in nature and most likely use INDOT GIS maps to show the results.

A web reporting tool was developed after the 2009–2010 winter season. The tool is available at http://ace.ecn.purdue.edu/Snow%20%26%20Ice%20Data/web/. An explanation of the tool is in the winter 2009–2010 section of this report.

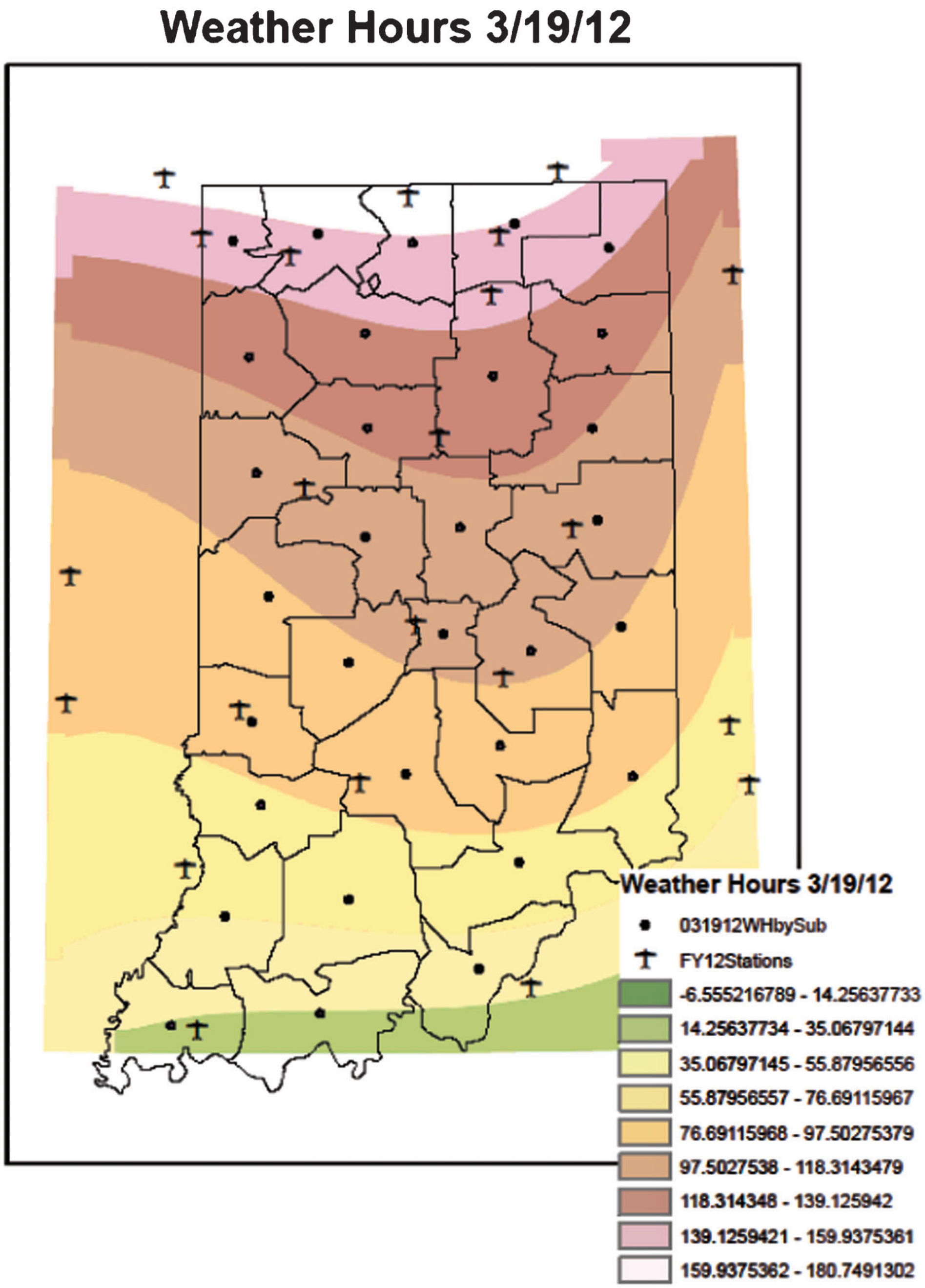

Figure 2.1 2011–2012 winter hours.

3. DATA COLLECTION AND ANALYSIS

3.1 Introduction

Three different winters (2009–2010, 2010–2011, 2011–2012) data was used to create and validate the proposed winter standard. Data used to develop the standard consisted of weather, traffic speed and accidents.

3.2 Winter 2009–2010

Two sources of speed data were tried; a Bluetooth station along I-65 between Lafayette and Frankfort and TMC stations in the Indianapolis metro area. The Bluetooth station was not deployed until January 2010 and in February it was determined that adequate data was not being collected.

Ten Indianapolis TMC stations were selected and data collected. Data consisted of traffic speed and volume before, during, and after a particular event. This data was converted to graphical format and displayed on a web site at the address http://ace.ecn.purdue.edu/Snow%20%26%20Ice%20Data/web/.

Figures 3.1, 3.2, and 3.3 describe the reporting tool. Figure 3.1 is a map showing the type of route the traffic

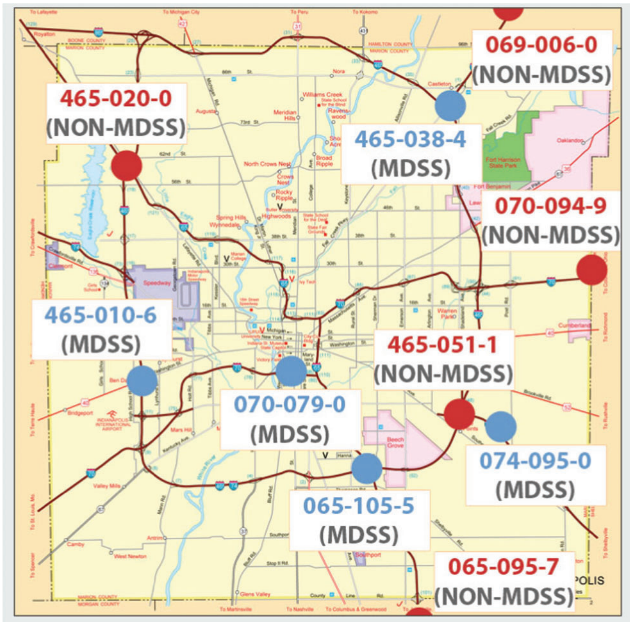

Figure 3.1 Indianapolis monitoring stations.

sensor is located on, and either weekday or weekend when the event occurred. Clicking a station causes a popup to appear (Figure 3.2) that displays weather dates and event type. Selecting one of the dates opens speed and volume charts (see Figure 3.3). There are also traffic data charts for non-winter weather days that were used for comparison purposes. The data suggests "specialty" routes (e.g., MDSS routes) performed comparable to typical routes in terms of traffic speed and flow. However, various data such as the quantity of deicing material used and localized weather data from RWIS sites were generally not available; furthermore adequate sites for statistical sampling were not available in the 2009–2010 winter season evaluation.

Because this sample size is not adequate to produce a performance standard that is statistically based, a scope and time expansion was requested and approved.

3.3 Winter 2010–2011

Due to inconsistent data being recorded at ATR and WIM stations and that installations planned for Covington and Earl Park never came on-line, the study turned to private speed data sources. JTRP had previously purchased speed data from INRIX, a private company that collects speed data across Indiana. Speed data was purchased from INRIX during the months December through February, March had no winter weather events so speed data was not obtained. The map in Figure 3.4 shows locations of INRIX speed data availability, it includes all interstate and some US routes.

Another data set not collected in 2009–2010 was that from Muncie and storm images. It is possible to retrieve Muncie data through MDSS. Storm images collected from the snow plow or stationary cameras can be useful in establishing and verifying performance standards. Combined together, this information will improve the development of a performance standard and at the same time evaluate the use of MDSS. The following activities expanded the project scope.

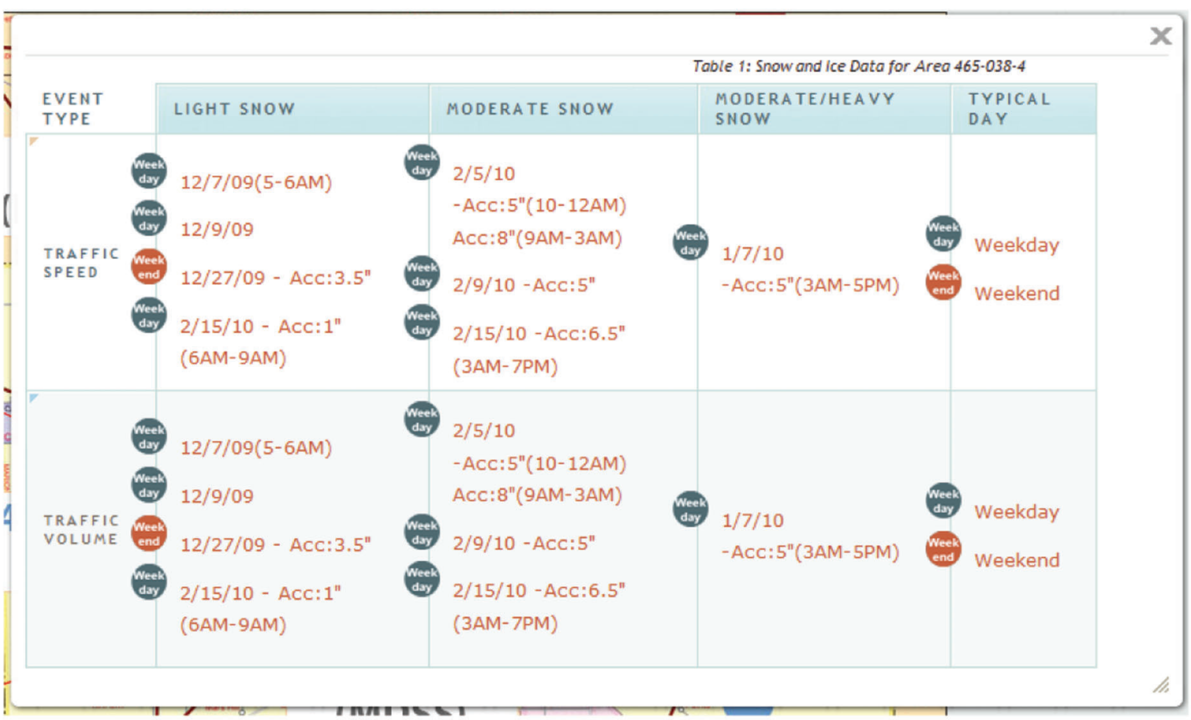

Table 1: Snow and Ice Data for Area 465-038-4

EVENT TYPE	LIGHT SNOW	MODERATE SNOW	MODERATE/HEAVY SNOW	TYPICAL DAY
TRAFFIC SPEED	Week day 12/7/09(5-6AM) Week day 12/9/09 Week end 12/27/09 - Acc:3.5" Week day 2/15/10 - Acc:1" (6AM-9AM)	Week day 2/5/10 -Acc:5"(10-12AM) Acc:8"(9AM-3AM) Week day 2/9/10 -Acc:5" Week day 2/15/10 -Acc:6.5" (3AM-7PM)	Week day 1/7/10 -Acc:5"(3AM-5PM)	Week day Weekday Week end Weekend
TRAFFIC VOLUME	Week day 12/7/09(5-6AM) Week day 12/9/09 Week end 12/27/09 - Acc:3.5" Week day 2/15/10 - Acc:1" (6AM-9AM)	Week day 2/5/10 -Acc:5"(10-12AM) Acc:8"(9AM-3AM) Week day 2/9/10 -Acc:5" Week day 2/15/10 -Acc:6.5" (3AM-7PM)	Week day 1/7/10 -Acc:5"(3AM-5PM)	Week day Weekday Week end Weekend

Figure 3.2 Winter activity reporting tool.

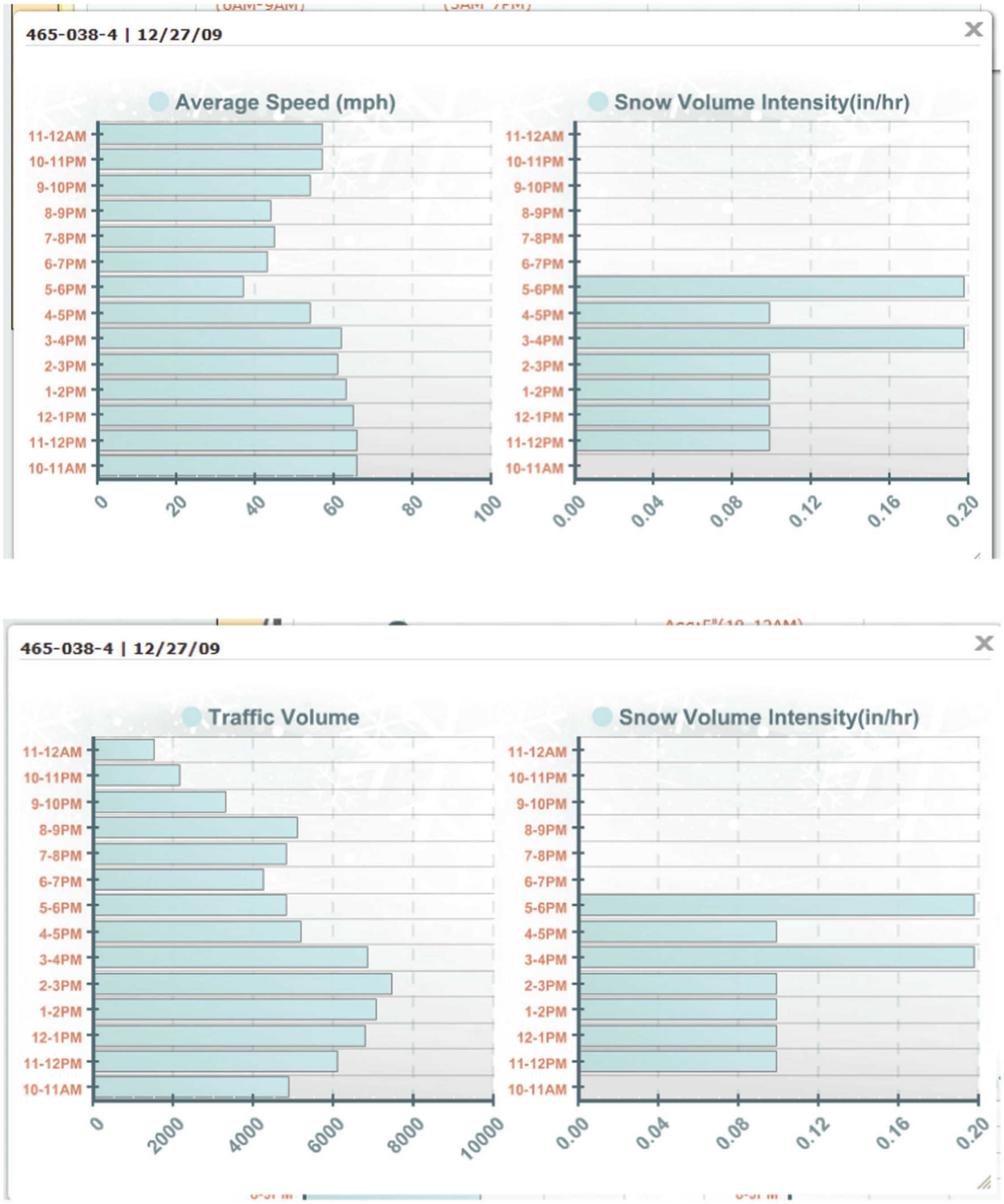

Figure 3.3 Traffic and weather graphs.

Activities

1. INDOT is completing the analysis of snow routes which has resulted in consolidation. This analysis changed some of the routes. In the analysis areas (Indianapolis, NW Indiana, and I-74 and US 41) these routes need to be identified as to the route type, MDSS or not.
2. For the 2010–2011 winter season, select a combination of stations that represent both MDSS and non-MDSS routes. For each winter event that affects traffic except for frost events; record weather, traffic, MDSS, and Muncie data. Work with Meridian to collect the MDSS and Muncie data before it is purged.
3. Provide performance data feedback to Operations by storm event and location.
4. Develop a statistical data analysis plan.
5. Perform a MDSS analysis.

This expanded scope will provide more data analysis covering a wider range of weather events and locations. The data will be used to better define a performance standard.

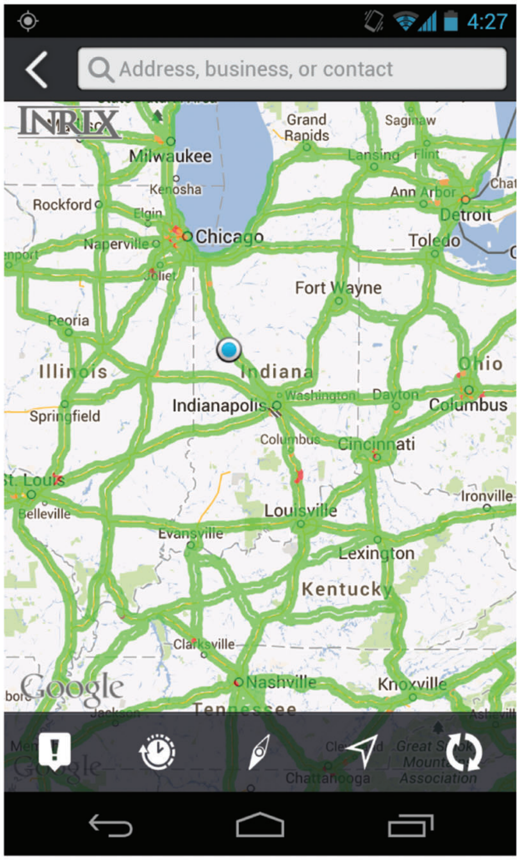

Figure 3.4 INRIX speed values locations.

Data Collection

Sample size and data availability increased significantly for the 2010–2011 winter season because National Weather Service (NWS) recording stations increased from four (Evansville, Indianapolis, Fort Wayne, South Bend) to 24. NWS data, while valuable for post evaluation of a winter storm event, is not available in real time for INDOT personnel to use during the storm event. Generally, NWS data is not available until a month after the storm event.

Currently, 29 RWIS stations are now on-line in Indiana with 9 of the RWIS sites hosting cameras that provide a visual picture of the weather/road condition of the site. Weather data collected at an RWIS station include the following:

- Pavement condition (wet/dry)
- Pavement temperature
- Air temperature
- Dew point temperature
- Precipitation (Y/N)
- Wind speed
- Wind direction
- Subsurface temperature
- Visual image (9 locations)

One important weather data element missing is hourly accumulation which is an indication of storm intensity. This information can be obtained through NOAA at the address http://www7.ncdc.noaa.gov/CDO/dataproduct. There are 24 weather stations providing this information in Indiana. Weather data from the Louisville and Cincinnati NWS can also be used for those adjacent areas in Indiana.

Figure 3.5 is a map showing the location of the following sensors: WIM, ATR, RWIS, and National Weather Service (NWS) stations, daily and hourly sites. Using this map, locations were identified which have RWIS and NWS stations (weather) data as well record traffic data.

After analyzing data source locations shown in Figure 3.5, Table 3.1 lists the proposed sites which match with the most sensors used for data collection and analysis. All locations are on interstate routes.

INRIX data is reported by road segment locations, called TMC, which is not to be confused with Traffic Monitoring Center sensor locations as shown in Table 3.1. INRIX TMC segments were identified to match the locations in Table 3.1 by using ArcMap. Figure 3.6 and Table 3.2 describe these segment locations. These segments are colored blue on the map.

Another map version is provided in Figure 3.7 that shows these locations in more clarity.

Multiple segments were used at Fort Wayne, Indianapolis, and Birdseye. These multiple segments made a total of 21 monitoring segments which are shown in Table 3.3.

For each winter event, except frost events, the following data was collected during the 2010–2011 winter season: RWIS data, NWS data, traffic volume and speed, AVL, visual image data (where available) and accident data. Image data is recorded at certain RWIS stations, truck mounted cameras or stationary cameras operated by the INDOT TMC. RWIS image data is kept for 24 hours and image retrieval requires Visalia interaction. A procedure that extracts images from TMC cameras was previously executed and station locations have been provided to the TMC to archive these images for this study.

Data types and sources are summarized below.

- AVL data: collected from AVL data string that is currently being archived
- Visalia: RWIS data and visual images (where available)
- INDOT: Traffic data from TMC stations; ATR and WIM stations; INRIX – private speed data
- NWS: Weather data; weather events must be adequately described and start and end times recorded.
- INDOT/State Police: Accident data

More specifically, the following data sources were used.

Traffic data. TMC Traffic sensors: http://archive-1.trafficwise.org/archive/. This archive contains traffic data (speed and volume) in CSV format for sensors in Northwest Indiana and Indianapolis metro. These sensors are on I-94 and I-65 in northwest Indiana and I-65, I-70, I-69, I-465, I-74 in the Indianapolis area.

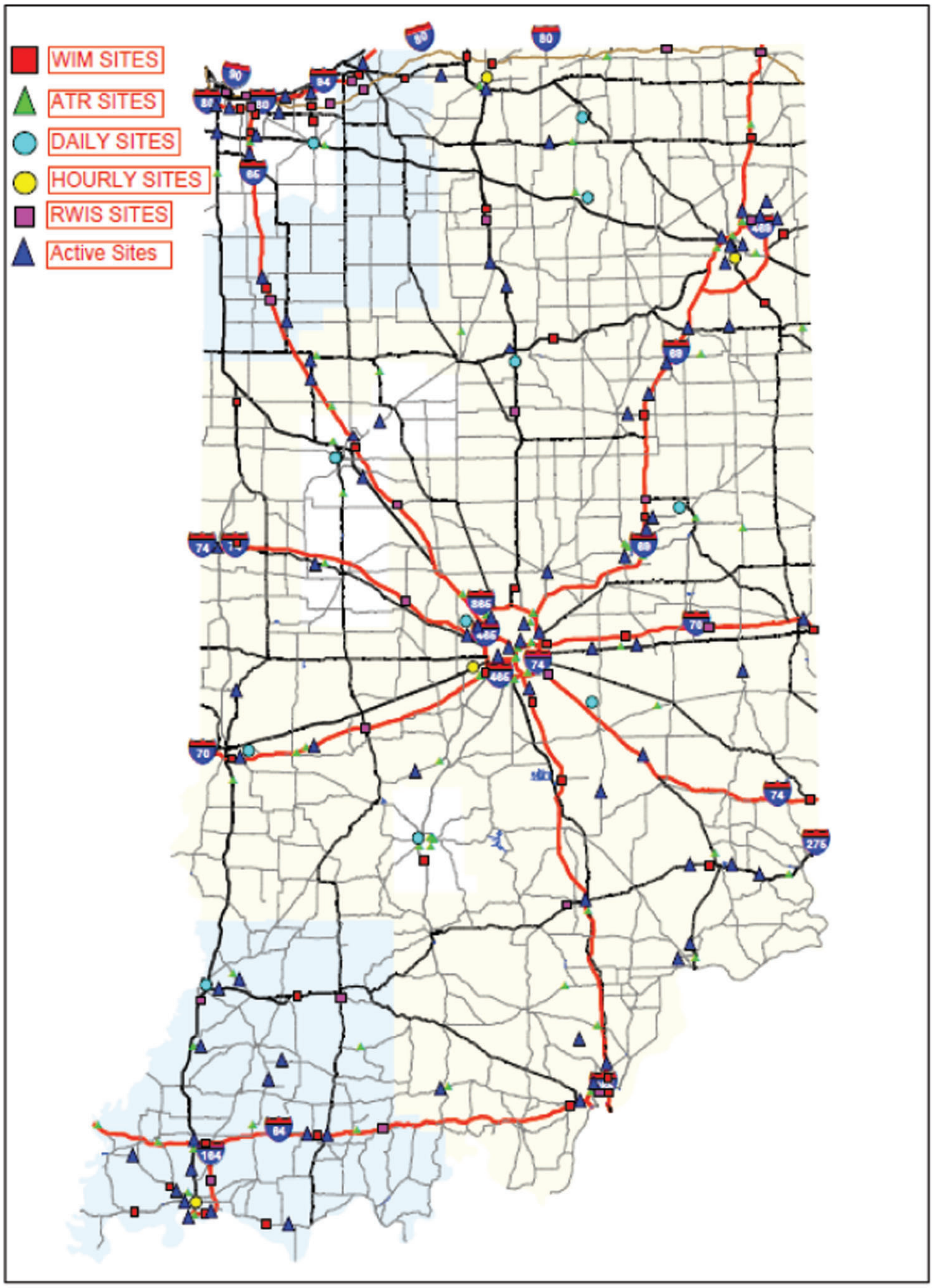

Figure 3.5 Sensor locations.

WIM and ATR sites: This data is collected and managed by INDOT. The accuracy of speed data is questionable. Volume data will be used. Therefore, INRIX private sector speed data was used. INRIX does not record traffic volume. Data analysis will be limited to interstate locations shown in Figure 3.7.

Weather data. National Weather Service Data (NOAA): http://www7.ncdc.noaa.gov/CDO/dataproduct. Twenty-four Indiana stations collect this data. Also, weather stations in Louisville and Cincinnati can be used for these areas of the state. The data is posted on the above NOAA website in the following month. For example, December data is available in January.

RWIS data. Visalia provided the following instructions on how to obtain data: The link to access the Scanweb page is http://ssiweather.indot.in.gov/. Click on INDOT under Summaries on the left side of the page and then click on the site name you wish to view. This will bring up the current weather data, and then you can click on any of the histories to bring up historical data. Historical atmospheric data (e.g., 12 hr., 24 hr. or 48 hr.) is available for the site you are

TABLE 3.1
Data Collection Locations

Route Location	Posted Speed Limit	RWIS Station Location	AVL Segment #	Traffic Monitoring Stations (TMC, WIM, ATR stations, INRIX)*	Truck #**	Road Condition (visual image, driver input)	Accident Data (location, cause, severity,# accidents/VMT)
I-80/I-94 and I 65 area (Borman)	70	West Point	IN-96-1	094-004-5 094-009-5		TMC camera images	***
I-80/94	70	I-94 and US 421	IN-158-1	954300*			***
I-69 @ FW – Route # 24-3-201	70	Fort Wayne	IN-160-1 IN-106-1	991211* 990204*	62275		***
I-65 @ Lafayette	70	Rensselaer	IN-81-1	Bluetooth			***
I-65 @ Frankfort	70	Frankfort	IN-82-1	Bluetooth			***
I-69 @ Gas City – Route # 26-4-201	70	Gas City	IN-119-1	952300*	62682		***
Indianapolis Area	60	Indianapolis	IN-08-1 (I-65) IN-142-3(I-65) (missing) IN-141-1(I-465) IN-140-1(I-465) IN-142-1(I-70) IN-139-1(i-74)	065-105-5 465-038-4 465-010-6 070-079-0 074-095-0		TMC camera images	***
Columbus	70	Columbus	IN-02-1	Private data		RWIS images	***
I-65 @ Seymour	70	Seymour	IN-28-1	990507*			***
I-65 south of Indy – Amity	70	Amity	IN-09-1	Private data		RWIS images	***
I-64	70	Birdseye	IN-56-1	956200*			***
I-64 @ Griffin	70	Griffin	IN-51-1	990611*		RWIS images	***
I-65 N. of Louisville	60	Scottsburg	IN-27-1	955600*		RWIS images	***

*Traffic monitoring stations (WIM and ATR) speed data is unreliable, private data is more accurate and will be used. Traffic volume collected by WIM and ATR stations. TMC stations collect speed and volume data. Speed data will be obtained from a private data source, INRIX.

**Truck data can be collected through the AVL vendor (IWAPI).

***Accident data will be obtained from State Police data.

Figure 3.6 INRIX TMC locations.

viewing by clicking on Atmospheric history on the right side of the screen.

Data is kept for 6 months; images are archived for 24 hours. To harvest storm images requires Visalia interaction at a quoted price of $1200 per event. At this cost it was decided not pursue the collection of these images. Below is an image of historical weather data recorded on 12-4-10.

This image is generated by selecting data types to plot. In Figure 3.8, air and surface temperatures and indicated by the green and purple lines for a 24 hour period. The top bar (green) shows the type and when precipitation occurred within the time period. The bottom bar indicates the road surface status. On the right are the legends for precipitation and road surface condition.

MDSS Analysis—IWAPI Data Source

Over 100 INDOT trucks are equipped with IWAPI AVL equipment. When data is collected in the truck it is sent to the AVL vendor (IWAPI) and then

TABLE 3.2
INRIX TMC Locations

TMC	Location	Highway #	Segments
107+05411	I-94/US 421	I-94/US 421	US 20 (Burns Harbor) to Michigan State Line (Right Lane)
121+04751	Griffin	I-64	IN Line to Jct. SR 165 (Poseyville)
121+04741	Birdseye	I-64	Jct. SR37 to Jct. SR66
121+04745	Birdseye	I-64	Jct. US 231 to Jct. SR162
107+05761	Fort Wayne	I-69	MM 158 to MM 139.7
107+05767	Fort Wayne	I-69	SR-4 to MM 125.3
107+04807	Indianapolis	I-465	MP 2.2 to 17.2
107+04550	Indianapolis	I-69	MM 14 to 8
107+04785	Indianapolis	I-465	MP 30.8 to 45.6
107-04872	Indianapolis	I-865	MM 17 (I-465) to MM 130 (I-65) and I-865
107+04709	Indianapolis	I-74	MP 92.8 to 101
107+04652	Indianapolis	I-70	MP 78.5 (Harding St.) to 80.8 (south split)
107+05706	Columbus	I-65	Exit 68 to Exit 76
107−05330	Amity	I-65	Exit 80 to Exit 99
107+05749	Gas City	I-69	MM 93.4 to MM 72.4
121+04791	Scottsburg	I-65	Exit 19 to Exit 34

Figure 3.7 Road segment locations.

TABLE 3.3
Segment Locations

Segment	Location	Highway #	Description
107+05411	I-94/US 421	I-94/US 421	US 20 (Burns Harbor) to Michigan state line (right lane)
121+04751	Griffin	I-64	IN Line to Jct. SR 165 (Poseyville)
121+04741	Birdseye	I-64	Jct. SR37 to Jct. SR66
121+04745	Birdseye	I-64	Jct. US 231 to Jct. SR162
107+05761	Fort Wayne	I-69	MM 158 to MM 139.7
107+05767	Fort Wayne	I-69	SR-4 to MM 125.3
107+04807	Indianapolis	I-465	MP 2.2 to 17.2
107+04550	Indianapolis	I-69	MM 14 to 8
107+04785	Indianapolis	I-465	MP 30.8 to 45.6
107-04872	Indianapolis	I-865	MM 17 (I-465) to MM 130 (I-65) and I-865
107+04709	Indianapolis	I-74	MP 92.8 to 101
107+04652	Indianapolis	I-70	MP 78.5 (Harding St.) to 80.8 (south split)
107+05706	Columbus	I-65	Exit 68 to Exit 76
107−05330	Amity	I-65	Exit 80 to Exit 99
107+05749	Gas City	I-69	MM 93.4 to MM 72.4
121+04791	Scottsburg	I-65	Exit 19 to Exit 34
107+05705	Seymour	I-65	Mile post 55 to mile post 68
107+05698	Rensselaer	I-65	Mile post 205 to mile post 215
107+05688	Frankfort	I-65	Mile post 148 to mile post 158
121+04747	Evansville	I-64	Mile post 29 to mile post 39
107+04444	Hammond	I-80	Mile post 2 to mile post 3

transferred to Meridian for use in MDSS. Automatic archiving of this data was established by INDOT on February 8, 2010 and continues. The address for this data is http://purdue-1.trafficwise.org/~jwasson/harvest/. Data is recorded in XML format and a sample record is shown in Figure 3.9.

IWAPI serial numbers need to be matched with truck numbers to identify routes. This data is obtained from INDOT Units where the trucks are originating.

Figure 3.10 shows all dates when a weather event occurred (indicated by yellow) and AVL data was recorded (indicated with an x). This table shows

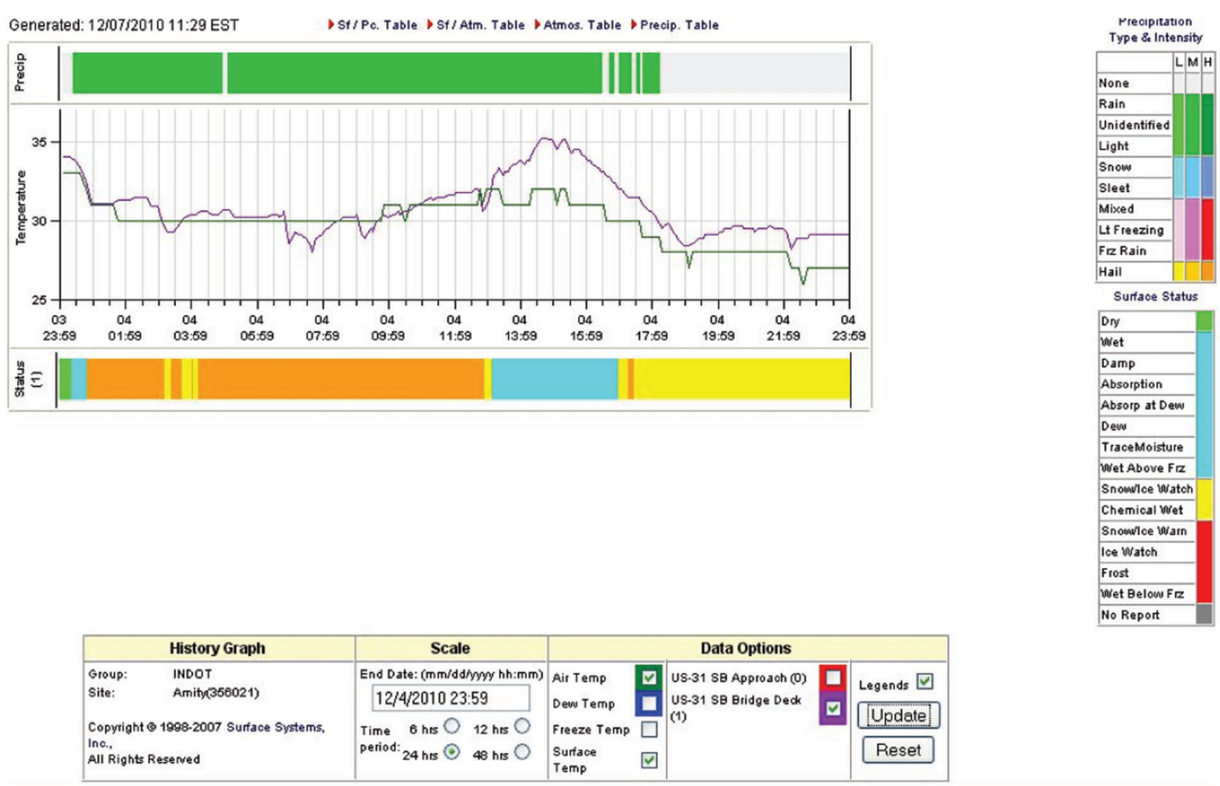

Figure 3.8 RWIS data log.

<INDOT.dbo.gps_last_locationUTC_date_time_of_fix="2010-02-10 06:38:50.0" latitude="40.937004" longitude="-86.77643" speed_over_ground="18.9" course_over_ground="180.9" gps_unit_status="A" serial_number="iwapi070685">

<INDOT.dbo.mdss_last_reportedserial_number="iwapi070685" lane="0" lane_ts="2010-02-10 06:31:23.0" material_type="SALT" material_rate="300" material_ts="2010-02-10 05:01:36.0" liquid_type="N/A" liquid_rate="0.0" liquid_ts="2010-02-10 05:01:36.0" road_condition="SNOW PACKED" road_ts="2010-02-09 23:32:02.0" weather="SNOW" weather_ts="2010-02-09 23:32:07.0" snow="1" snow_ts="2010-02-09 23:32:30.0" total_snow="3" total_snow_ts="2010-02-10 04:04:39.0" status="TRUCK STARTED" status_time_stamp="2010-02-09 05:32:02.0" driver_id="64676" driver_ts="2010-02-09 11:31:31.0" blade_status="BLADE UP" blade_ts="2010-02-10 06:00:13.0" air_temperature="21" surface_temperature="21" temperature_timestamp="2010-02-10 06:32:57.0" last_entry_timestamp="2010-02-10 06:38:59.81"/></INDOT.dbo.gps_last_location>

Figure 3.9 Sample XML data record.

inconsistency in AVL data. There were no locations where AVL was reported for all events and most locations had few AVL records. This indicates that AVL data is not reliable and therefore no analyses were performed.

For the season there were 25 official storm days. A storm day is defined as when winter weather occurs. With the 21 possible sites and 25 storm days, multiplying these two numbers means there are $21 \times 25 = 525$ TMC sites storm days. With speed measures available every minute there are 1440 per day. So theoretically there are $1440 \times 525 = 756{,}000$ possible speed measures for analysis. Pulling the INRIX speed data revealed there were actually 671,919 speed values because some were lost in data collection. These speed values were used in the statistical analysis.

Table 3.4 tabulates the results of the speed data analysis.

The 21 location numbers are the total minutes where speed values are less than the speed category. For example, at the first location I-465 mm 30.8 to 45.6, traffic speeds were less than 35 mph a total of 1688

Weather Date	194/US421	Birdseye	Griffin	Fort Wayne	Gas City	Indianapolis	Columbus	Scottsburg	Amity
12/4/2010	x	x				x	x		
12/9/2010									
12/12/2010		x	x	x	x	x	x		
12/16/2010		x		x		x		x	
12/20/2010						x			
12/21/2010	x					x		x	
12/24/2010						x			
12/25/2010	x	x				x	x	x	
1/6/2011				x		x	x		
1/7/2011				x	x	x			
1/11/2011				x		x	x		
1/12/2011				x		x	x		x
1/20/2011				x		x	x		x
1/24/2011				x		x	x		
1/25/2011									
1/27/2011				x		x			
1/31/2011				x		x	x		
2/1/2011				x		x		x	
2/2/2011				x		x	x	x	
2/5/2011				x		x	x	x	x
2/7/2011				x		x	x	x	
2/8/2011				x					
2/20/2011									
2/21/2011				x		x			
2/22/2011						x			
2/25/2011									

= weather event; X = AVL data collected.

Figure 3.10 AVL data.

TABLE 3.4
2010–2011 Winter Speed Analysis

No.	TMC	Less Than 35 mph	Less Than 40 mph	Less Than 45 mph
1	107+04785 (I-465 MM 30.8–45.6)	1688	2111	2730
2	107+04444 (I-80 – Borman)	1366	1627	1870
3	107+04652 (I-70 Harding to south split)	922	1209	1766
4	107-04872 (I-865)	569	787	923
5	107+05411 (I-94 US 20 to MI line)	522	850	1215
6	107+04807 (I-465 MM 2 to 17)	439	595	1749
7	107+05698 (I-65 Rensselaer)	471	716	906
8	107+04550 (I-69 MM8 to 14)	253	507	772
9	107+05688 (I-65 Frankfort)	218	543	751
10	107+04709 (I-74 MM 92 to101)	121	359	594
11	107+05705 (I-65 Seymour)	45	107	158
12	107+05706 (I-65 Columbus)	79	139	260
13	107+05749 (I-69 Gas City)	120	334	426
14	107+05761 (I-69 Fort Wayne)	99	206	368
15	107+05767 (I-69 Fort Wayne)	29	105	192
16	107-05330 (I-65 Amity)	150	195	298
17	121+04741 (I-64 Birdseye)	31	74	134
18	121+04745 (I-64 Birdseye)	33	62	82
19	121+04747 (I-64 Evansville)	10	44	82
20	121+04751 (I-64 Griffin)	7	28	31
21	121+04791 (I-65 Scottsburg)	3	12	32
Total minutes in the 25 storm days		**7175**	**10610**	**15339**
Probability during storm impact period		**10%**	**15%**	**25%**
Allowable minutes per snow day		**15**	**20**	**30**
Allowable total minutes in 25 snow days		**375**	**500**	**750**

minutes during the 25 storm days. The row, "total minutes in the 25 storm days," is the summation of 21 site numbers. The next row, "probability during storm impact period," is the percentage of the total speed values below that speed value. So 10% of the values were less than 35 mph, 15% of the values were less than 40 mph, and 25% of the values less than 45 mph. The last table row, "allowable total minutes in 25 snow days," is the average minutes in each speed range. The next to last row, "allowable minutes per snow day," is the last row value divided by the number of events, 25.

Since the speed analysis occurred on Interstate routes, a performance measure was developed for Class I routes. This standard will use traffic speed values to evaluate performance. Table 3.5 indicates proposed initial speed ranges and associated LOS grades. These ranges are based on setting a level of service of very good if the operating speed is at the 85th percentile speed occurring at normal operating conditions. Traffic operating speeds at 50% of the posted speed usually occur when the operation is at or near capacity and hence speeds below that level are considered unsatisfactory in terms of operating capacity. Minimum winter operation performance measures will be designed to meet and exceed the 50% of the posted speed. As the data permits, traffic speeds will be identified and correlated to the effectiveness of a strategy, including materials and quantities used. The concept may be applicable to other classes given the posted speed.

TABLE 3.5
Proposed Initial Speed Ranges and Associated LOS Grades

Traffic speed (70 mph posted)	LOS grade
55+	Very good
45–55	Good
35–45	Fair
25–35	Poor
<25	Very poor

Figure 3.11 graphically shows the results of the statistical analysis in terms of storm impact period. The storm impact period is the time where traffic speeds are influenced by the weather event.

Figure 3.11 shows the three speed ranges (30, 40, 45) and the percentage of total speed values below those ranges. So 10% of all speed values were below 35 mph, 15% of all speed values were below 40 mph, and 25% of all speed values were below 45 mph.

Accident Data

Accident data was collected from the Indiana State Police (ISP). This data was used to qualify site accident data (location, cause, type, number) and to determine whether accidents affected traffic speed during winter events. The relationship between winter events, LOS provided by INDOT winter operations, accidents and the resulting traffic speeds were examined.

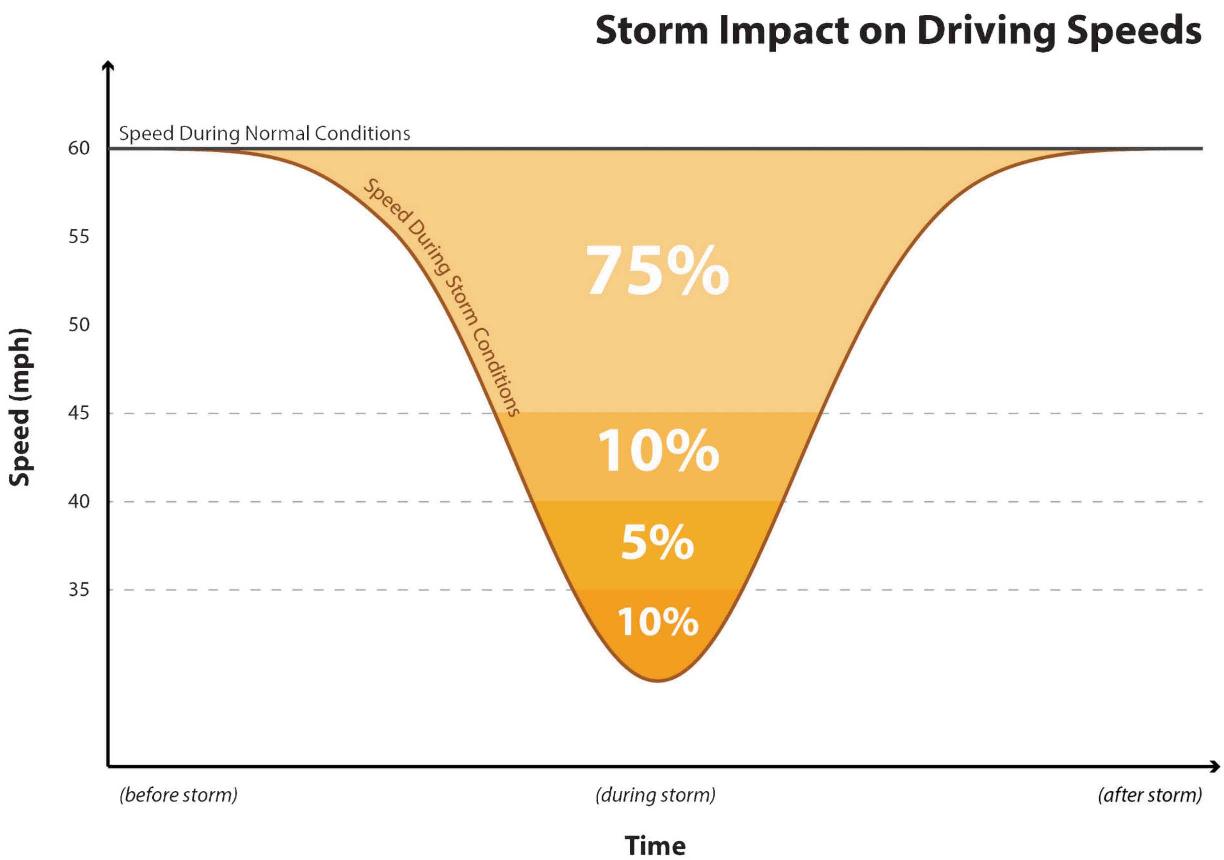

Figure 3.11 Storm impact period.

Figure 3.12 shows the locations of the middle state speed sites. Those circled in red are those sites with red numbers in Table 3.4. Those circled in green had no red numbers meaning speed values were the average and exceeded the proposed performance standard. The red sites had average speed values less than the performance standard. The blue numbers are the number of accidents that occurred at the locations during the 25 winter days.

There are four red segments all in the Indianapolis metro area where higher traffic volumes occur. The segment 107+04785 had 13 accidents on these 25 winter days. On the other side, segment 107+04872 had no accidents. Both segments have similar volumes which will be discussed in the next section. Segment 107-5330, a green segment, had 13 accidents. Also green segment 107+05706 had 5 accidents which is more than two of the four red segments.

Using the speed values from this winter, it is difficult to make a relationship between speeds and accidents. What about traffic volume?

Traffic Volume

Table 3.6 contains the average daily traffic volumes for Figure 3.12 locations.

The two I-465 segments have similar traffic volumes but significantly different accident numbers. One segment had 13 accidents and the other zero. The segment at Amity had 13 accidents and significantly lower volumes than all the four red segments in Indianapolis. The Columbus segment had 5 accidents and the Seymour segment zero accidents, both segments have similar volumes. There appears to be no strong correlation between volume and accidents during winter events.

3.4 Winter 2011–2012

For the 2011–2012 winter season the SAC requested the speed analysis only include Marion County sites. The reason for this request is to focus on operations in the Indianapolis metro area and validate the standard. These sites are shown in Table 3.7.

At these locations there were 16 weather events between November 29, 2011 and March 5, 2012. Each of these events speed values are shown in graphical form for each of these 16 dates in Appendix C.

Summary of Data Analysis

All the weather events were light and medium snow events. The proposed performance standard has 45 mph as the minimum average speed. Most of the 2011–2012 events, speeds were above 55 mph. At some locations speeds went below the 45 mph value. Some of the days where speeds dropped below 45 was due to

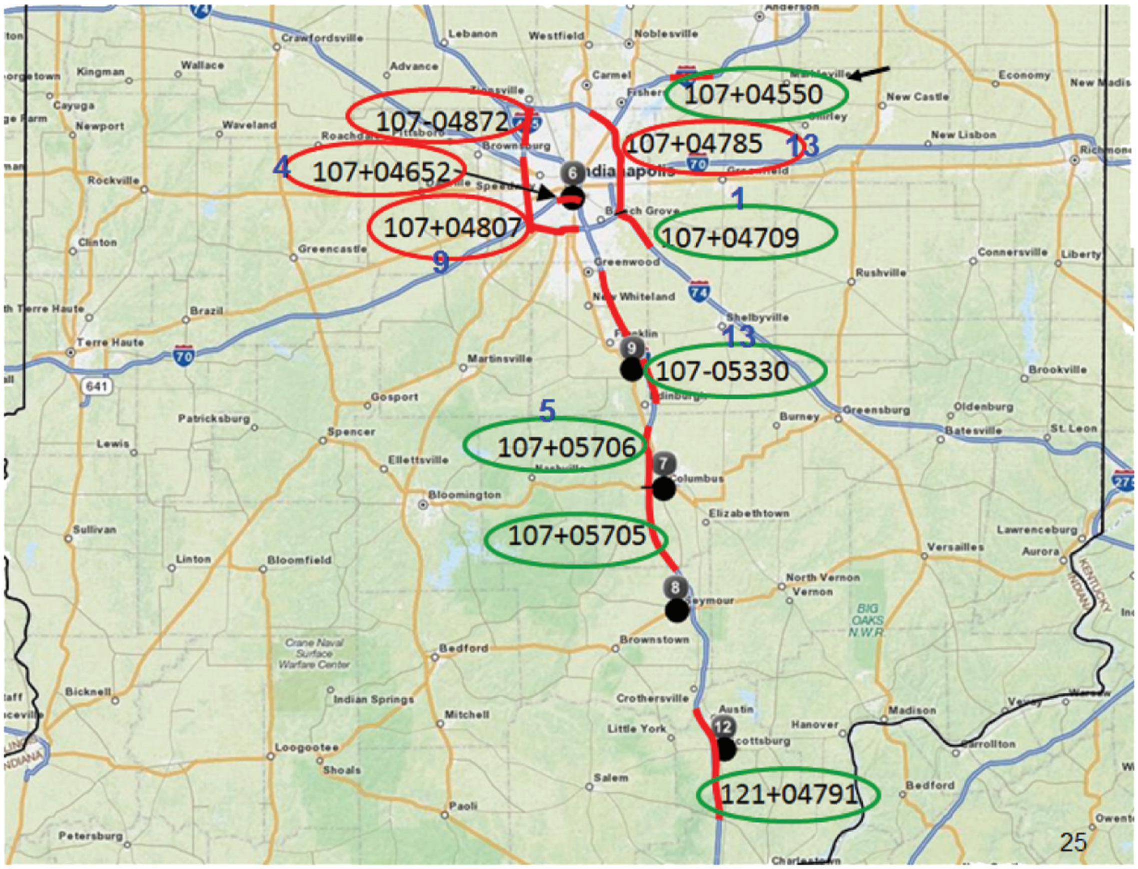

Figure 3.12 Accident data (2010–2011).

TABLE 3.6
Traffic Volume

Location	Highway #	Description	Car AADT	Truck AADT
Indianapolis	I-465	MP 2.2 to 17.2	120000	19000
Indianapolis	I-69	MP 8 to 14	55000	11000
Indianapolis	I-465	MP 30.8 to 45.6	113000	18000
Indianapolis	I-865	MP 17 (I-465) to MP 130 (I-65) and I-865	26000	6000
Indianapolis	I-74	MP 92.8 to 101	38000	8000
Indianapolis	I-70	MP 78.5 (Harding St.) to 80.8 (south split)	96000	16000
Columbus	I-65	Exit 68 to Exit 76	40000	16000
Amity	I-65	Exit 80 to Exit 99	63000	16000
Scottsburg	I-65	Exit 19 to Exit 34	37000	16000
Seymour	I-65	Mile post 55 to mile post 68	31000	14000

TABLE 3.7
2011–2012 Analysis Sites

INRIX Segment	107+04550	107+04652	107+04709	107+04785	107+04807	107−04872
Location	I-69, 14 to 8	I-70, Harding to south split	I-74, 92.8 to 101	I-465, 30.8 to 45.6	I-465, 2.2 to 17.2	I-865, 465 to 65
Route Numbers	35-A-4-1, 35-B-4-1	31-J-2-1	31-1-2-BR, 31-J-1-1, 31-K-1-1	31-4-3-BR	31-1-1-BR	31-1-3-1

TABLE 3.8
2011–2012 Indianapolis Locations Where Speeds <45 mph

Date	Location(s)	Accident	Notes
11-29-11	I-70	No	
1-2-12	I-70	Yes	
1-2-12	I-465	Yes	
1-19-12	I-69	Yes	
1-19-12	I-465	No	
1-21-12	All	No	Early morning hours
1-28-12	I-69	No	Early morning hours
2-8-12	I-465	No	
2-10-12	I-70	No	
3-5-12	I-70	No	
3-5-12	I-465	No	

accidents. Table 3.8 summarizes dates and locations where speeds were below 45 mph.

Three locations had multiple events where speeds were less than the proposed performance standard of 45 mph. These locations are I-70 (Harding St. to south split), I-465 (30.8 to 45.6), and I-69 (8 to 14). This may indicate these locations may have some operational issues and should be considered for further review.

4. SUMMARY AND CONCLUSIONS

Storm Index

INDOT uses the weather hour approach to define winter severity. A weather hour is defined as one that experiences winter precipitation. An individual storm can have different levels of intensity and severity making the weather hour value inappropriate to use.

The storm index developed by Nixon (*3*) and described in Table 2.1 is recommended to INDOT. It covers a wide range of storm characteristics and is easy to use and implement.

Proposed Standard

Common performance measures used with traffic are:

- Volume/Capacity (V/C) Ratio
- Space Mean Speed
- Travel Time
- Crash Frequency

Using the V/C ratio, capacity can change during an event making this measure difficult to calculate. However Travel time is equivalent to speed. Crash frequency was analyzed and the data indicates a poor correlation with traffic performance (speed) during winter weather events. Therefore, a performance measure that uses speed range values was the one chosen.

One influencing factor on speed is volume. A typical relationship is as volume increases from zero, speed increases until it reaches a maximum value and then decreases until volume reaches the traffic jam state. Therefore traffic volume will influence performance and should be a part of the measure.

Based upon the data collected during the winter seasons 2010–2011 and 2011–2012, the following winter storm performance standard is proposed for adoption by INDOT.

- For interstate roads with an ADT of less than or equal to 65,000 VPD, during a storm impact period, no more than 25% (*example only, based on current data*) of the total traffic speeds less than 45 mph per storm event.
- For interstate roads with an ADT greater than 65,000 VPD, during a storm impact period, no more than 60% (*example only based on current data*) of the total traffic speeds less than 45 mph per event. **Exception:** During the weekday hours of 6 AM to 6 PM, no more than 40% (*example only*) of the total traffic speeds are less than 45 mph per storm event.

This standard should be utilized to gauge performance during winter events. Currently there is a month lag in getting INRIX speed data. Since this standard is based on traffic speed and for this standard to be useful in evaluating performance and analyzing operations; it is recommended that INDOT work with JTRP traffic engineers to develop a methodology that collects speed data close to real time making it useful in winter operations.

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3. Nixon, W., and L. Qiu. Developing a Storm Severity Index. *Transportation Research Record, Journal of the Transportation Research Board*, No. 1911, Transportation Research Board of the National Academies, Washington, D.C., 2005, 143–148.

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APPENDIX A. WINTER OPERATIONS LOS

Road Classes

Three classes of INDOT roads are identified to prioritize allocation of INDOT resources and to outline INDOT's snow and ice control service objectives.

The three classes of INDOT roadways are identified as follows:

Class I

Interstate routes and roadways with Average Daily Traffic (ADT) volumes over 10,000 vehicles per day, as well as other high priority roadways, including but not limited to those serving hospital facilities and other emergency service providers.

Class II

Routes with traffic volumes between 5,000 and 10,000 ADT.

Class III

Routes with traffic volumes of less than 5,000 ADT.

Service Objectives

The following snow and ice control service objectives are identified for each of the three roadway classifications:

Class I

INDOT shall provide service to mainline pavements, ramps, and turn lanes to remove snow and ice from pavement surfaces by plowing and chemical applications to achieve bare pavement conditions. Once bare pavement conditions are achieved, minimal plowing of shoulders should commence. All other cleanup will be deferred to normal working hours. Class I routes should be serviced approximately every 2 hours.

Class II

INDOT shall provide service to mainline pavements, ramps, and turn lanes to remove snow and ice from pavement surfaces by plowing and chemical applications to achieve bare pavement conditions. All other cleanup will be deferred to normal working hours. Class II routes should be serviced approximately every 2.5 hours.

Class III

INDOT shall provide service to remove snow and ice from mainline pavements to provide partial bare pavement. Final cleanup will generally be deferred to normal working hours. Class III routes should be serviced approximately every 3 hours.

APPENDIX B. STATE AGENCIES WINTER PERFORMANCE MEASURES

Idaho DOT

Interstates and roads that have the highest volume of traffic are cleared first. Workers continue to clear roads with top priority placed on the most-traveled roads down to areas with lower volumes of traffic. Some routes, because of concerns for public safety, high difficulty and cost of winter maintenance, may be closed for short durations until manpower and equipment resources are available for snow removal.

Minnesota DOT

See Table B.1 for Minnesota current and target clearance times for snow and ice removal.

Missouri DOT

Priority 1: Roads with the highest traffic volumes are cleared or treated first. These include interstate and other major routes, which receive continuous treatment throughout a storm.

Priority 2: Lower-volume lettered and numbered routes are cleared next. Traffic on these routes may be impeded until higher-volume routes are open and clear.

After all roadways are as clear as possible, continued work is applied to clean up shoulders, bridge edges, and interchanges accumulations. Priority 1 routes are to be returned to wet or dry condition as soon as possible after the storm ends, and to plow and treat critical area of other routes as soon as possible after the storm ends.

Montana DOT

Interstates and roads that have the highest volume of traffic are cleared first. Workers continue to clear roads with top priority placed on the most-traveled roads down to areas with lower volumes of traffic. Some routes, because of concerns for public safety, high difficulty and cost of winter maintenance, may be closed for short durations until manpower and equipment resources are available for snow removal.

New Hampshire DOT

Traffic volume and posted speed are the primary factors in determining the level of winter maintenance service with the highway grade also being an important factor. The Interstate System, Turnpike System and other heavily traveled highways are maintained in such a manner that bare pavement is produced as soon as practical after termination of a storm. On State highways with low traffic volumes, the NHDOT attempts to provide some bare pavement, but not necessarily from shoulder to shoulder, within a day or two after a storm ends. The winter maintained State highway system is comprised of four roadway types defined as follows:

- **Type 1A:** Highways in the Interstate and Turnpike Systems and those highways carrying 15,000 vehicles or more daily (green) should have full width bare pavement as soon as practical after a winter storm terminates.
- **Type 1B:** Highways on the State system and carrying 5,000 to 15,000 vehicles daily (blue) should have full width bare pavement as soon as practical after a winter storm terminates.
- **Type 2:** Highways on the State system carrying 1,000 to 5,000 vehicles daily (orange) should have some bare pavement as soon as practical after a winter storm terminates.
- **Type 3:** Highways in the State highway system carrying less than 1,000 vehicles daily (red) should have bare pavement in left wheel tracks near the center of the highway as soon as practical after the winter storm. Included in this classification are highways carrying less than 500 vehicles daily for which snow-covered pavement is deemed acceptable.

See Table B.2 for Recommended snow and ice treatments per lane mile and Table B.3 for Snow and ice management planning criteria.

The NHDOT will evaluate the feasibility of establishing low or no salt section on selected low volume roadways following a written request from the local governing body. To facilitate this program two additional highway types are specified:

- **Type 4:** Highways on the State highway system carrying less than 2,500 vehicles daily for which all municipal officials, including all selectman, the police chief, the fire chief, the chief of ambulance service, and the superintendent of schools or the school board, have signed and submitted a written request to establish low (minimum) salt section on existing Type 2 highways (orange routes).
- **Type 5:** Highways on the State highway system carrying less than 1,000 vehicles daily for which all municipal officials, including all selectman, the police chief, the fire chief, the chief of ambulance service, and the superintendent of schools or the school board, have signed and submitted a written request to establish no salt section on existing Type 3 highways (red routes).

See Table B.4 for recommended snow and ice treatments per lane mile for reduced winter maintenance areas.

Vermont DOT

See Table B.5 for Vermont DOT snow and ice performance standards.

Vermont DOT Snow and Ice Control Plan: 3 Tiered LOS

- **Green Roads:** Snow will be removed continuously and salt, salt/sand mixtures or sand will be used as needed during the storm to keep the roads open for traffic and provide a good surface on which to operate. After the storm has subsided, a bare pavement, shoulder to shoulder, will be provided as soon as practicable.
- **Yellow Roads:** Snow will be removed continuously and salt, salt/sand mixtures or sand will be used as needed during the storm to keep the roads open to traffic and provide a good surface on which to operate. After the storm has subsided, one-third bare pavement, in the middle of the road, will be provided as soon as possible. During the next regular working day, a bare pavement condition will be obtained.
- **Red Roads:** Snow will be removed continuously and sand will be applied to curves, hills, and intersection as needed to keep the road open for tragic and provide a good surface on

TABLE B.1
Minnesota Current and Target Clearance Times for Snow and Ice Removal

Road Class	Current Clearance Times (hours)	Target Clearance Time (hours)
Overall system	N/A	10
Super commuter	2.2	1–3
Urban commuter	5.0	2–5
Rural commuter	7.0	4–9
Primary collector	9.2	6–12
Secondary collector	18.1	9–36

TABLE B.2
Recommended Snow and Ice Treatments per Lane Mile

Conditions	Temperature	Types 1A and 1B	Types 2 and 3
Sleet/freezing rain	Variable	Salt 300 lbs. per lane mile and/or abrasive as needed	Salt 300 lbs. per lane mile and/or abrasive as needed (2)
Snow	20° F and up	Salt 250 lbs. per lane mile (1)	Salt 250 lbs. per lane mile (2)
Snow	Below 20° F	Salt 250 lbs. per lane mile (2 and 3)	Abrasive-chemical mix

(1) For exceptionally high volume roads where traffic will enhance the action of the salt, this rate may be decreased to 200 lbs. per lane mile.
(2) Abrasive-chemical mix may be needed at extremely low temperatures or on very lightly traveled highways.
(3) An alternative low temperature treatment is to use a chemical mix of 2 pars salt to 1 part calcium chloride at 200 lbs. per lane mile.

TABLE B.3
Snow and Ice Management Planning Criteria

Highway Type	Planned Plowing Frequency	Planned Allowable Snow Accumulation	Average Max. Allow Accumulation
Type 1A	1.5 hours	1½″	3″
Type 1B	2 hours	2″	4″
Type 2, 4	2.5 hours	2½″	5″
Type 3, 5	3.5 hours	3½″	6″

TABLE B.4
Recommended Snow and Ice Treatments per Lane Mile for Reduced Winter Maintenance Areas

Conditions	Temperature	Type 4	Type 5
Sleet/freezing rain	Variable	Salt 250 lbs. per lane mile and/or abrasives as needed	Abrasives only
Snow	20° F and up	Salt 250 lbs. per lane at beginning and/or end of storm only	Abrasives only
Snow	Below 20° F	Abrasives only except salt 250 lbs. per lane mile at end of storm	Abrasives only

NOTE: Emphasis areas include hills, bridges, curves, intersections, and known problem areas.

TABLE B.5
VDOT Snow and Ice Performance Standards

Conditions	High Volume Roads Are Treated/Plowed	Residential Streets Are Treated/Plowed
Snow 0–2 inches	Up to 12 hours after storm ends	Sanding as needed
Snow 2–4 inches	Up to 18 hours after storm ends	Up to 36 hours after storm ends (plowing begins at 2 inches)
Snow 4–8 inches	Up to 36 hours after storm ends	Up to 38 hours after storm ends
Snow 8–12 inches	Up to 2 days after storm ends	Up to 3 days after storm ends
Snow 12–18 inches	Up to 3 days after storm ends	Up to 4 days after storm ends
Snow 18+ inches	Up to 4 days after storm ends	Up to 6 days after storm ends
Ice/freezing rain	12 hours after storm ends	Up to 18 hours after storm ends

which to operate. Road surface may be snow covered during following the storm.

- **All Levels:** If temperatures and precipitation conditions during a prolonged storm result in a snow packed or ice covered surface, causing unacceptable traveling conditions even at a reduced speed, applications of salt may be applied to restore acceptable driving conditions. Critical areas such as intersections, areas of extreme curvature and problem grades may have to be treated differently to retain proper mobility and safety regardless of the level of service assigned to the balance of the route. Between storms and of the pavement temperatures are favorable, salt will be applied to remove and y existing surface buildup of packed snow or ice to restore acceptable winter driving conditions.
- **Freezing Rain or Sleet:** ALL ROUTES – Salt or salt/sand blends shall be applied at the effective salt application rate of 250 lbs. per lane mile. Repeated applications will be required when the pavement temperatures are below freezing, if the storm continues.
- **General Application Procedures:** Salt shall be applied in a narrow strip along the centerline of the normal section of highway and as high as possible on banked curves. The rate of application shall be selected from the attached "Salt Application Rate" chart and will be based upon pavement temperature sensing and snow-ice conditions encountered. Generally, salt will be used when pavement temperatures are 20° F or higher. When pavement temperatures are less than 20° F, sand will be used. When the pavements are dry and snow is blowing off the pavement, no salt or sand is to be used because it will cause snow packing. In these cases, considerable judgment will be required on whether to use salt or sand.

TABLE B.6
WSDOT Road Condition Rating for Sand Treatment and Chemical Treatments

Road Condition Rating	Points	LOS Rating
Sand Treatment		
100% of roadway has sand present	3	C+
50% or more of roadway has sand present		C
All emphasis areas have sand present		D+
50% or more of emphasis areas have sand present		F+
50% or less of emphasis areas have sand present		F
Unable to evaluate	—	—
Chemical Treatment		
Bare pavement	1	A+
Patches of frost, black ice, slush, or compact	1.5	A
Wheel tracks bare, frost, snow, or ice encountered	2	B+
50% of roadway with compact snow and ice	3	C+
Entire roadway covered with compact snow and ice	4	D+
Unable to evaluate	—	—

TABLE B.7
Wisconsin DOT Winter Performance Measures

	Fiscal Year 2004	Fiscal Year 2005	Fiscal Year 2006	Fiscal Year 2007
Time to bare/wet pavement (after end of storm)	2 hours 38 minutes	2 hours 4 minutes	1 hour 55 minutes	1 hour 28 minutes
Cost per lane mile	$1279	$1374	$1400	$1549
Winter severity index	31.2	31.9	31.8	28.4
Cost per lane mile per WSI point	$40.99	$43.07	$44.03	$54.54
Winter weather crashes million VMT	26 per 100 million	25 per 100 million	24	23

Washington State DOT

See Table B.6 for the WSDOT road condition rating for sand and chemical treatments.

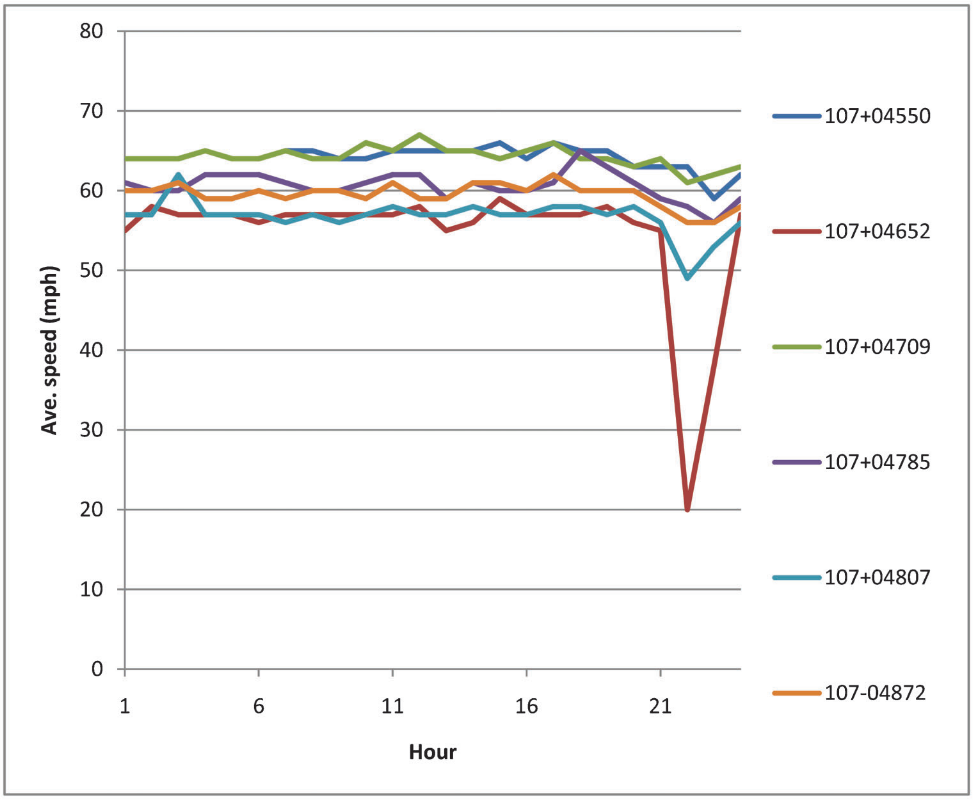
Wisconsin DOT

Table B.7 shows characteristics that Wisconsin DOT uses to evaluate winter performance. This table does not contain or describe performance standards.

Wyoming DOT

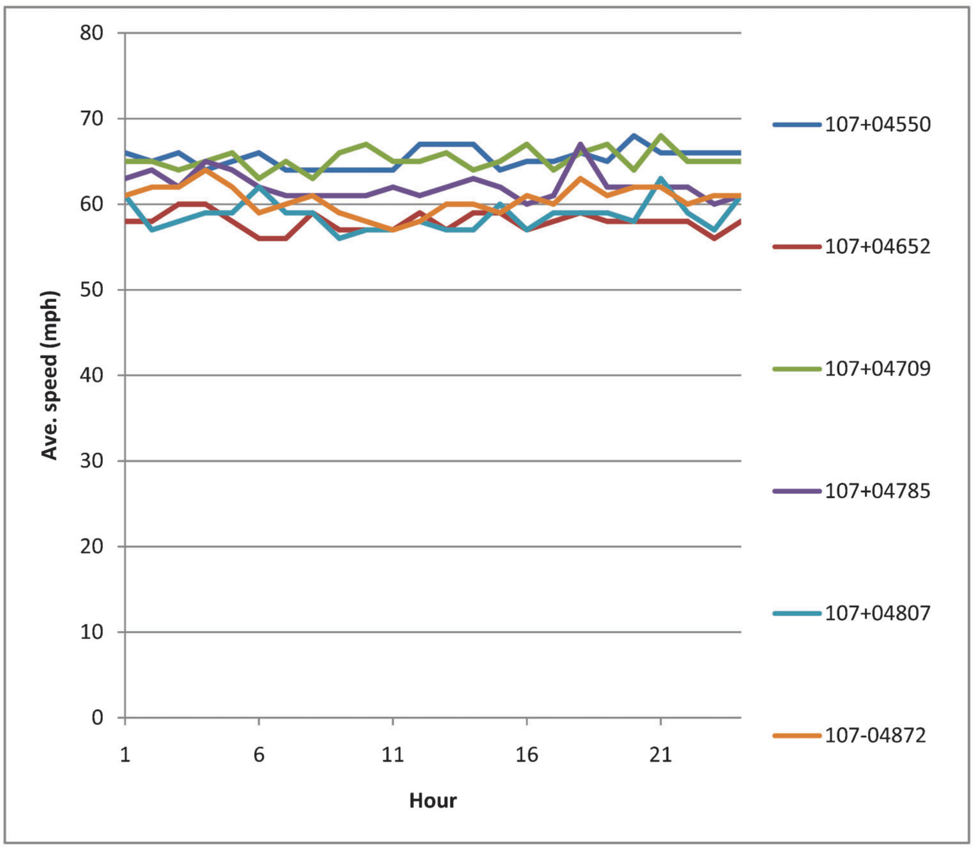
High volume service is provided on Interstates and principal arterial and urban routes. If necessary, crews will work up to 20 or 24 hours a day; the goal is to maintain a bare roadway for driving safely at reasonable speeds. Medium volume service is provided on lesser used minor arterial routes. The goal is to keep the roadway passable for drivers who are taking reasonable winter driving precautions, although with less emphasis on keeping the roadway bare. Low volume service generally involves other less busy minor arterial and collector routes and is provided after high-volume and medium-volume routes have been cleared, with exceptions sometimes made for school buses or similar traffic. Low-volume service is provided only during daylight hours. Level IIIB state highways receive minimum levels of service as resources become available. During severe storms, scheduling depends on available personnel and equipment. Roads tagged for high-volume service will be plowed first; medium and low-volume highways will be handled as soon as possible thereafter. As bad weather begins to clear, cleanup operations are undertaken only after all roads have been provided with their designated levels of service. Close service-level roads are the few that are allowed to close seasonally as snow accumulation dictates. For these roads, the cost of keeping them open through the winter overrides the benefits to the few travelers that might regularly use them.

Date and event type: November 29, 2011. A light snow event with total snow accumulation of 0.2 inches scattered throughout the day.



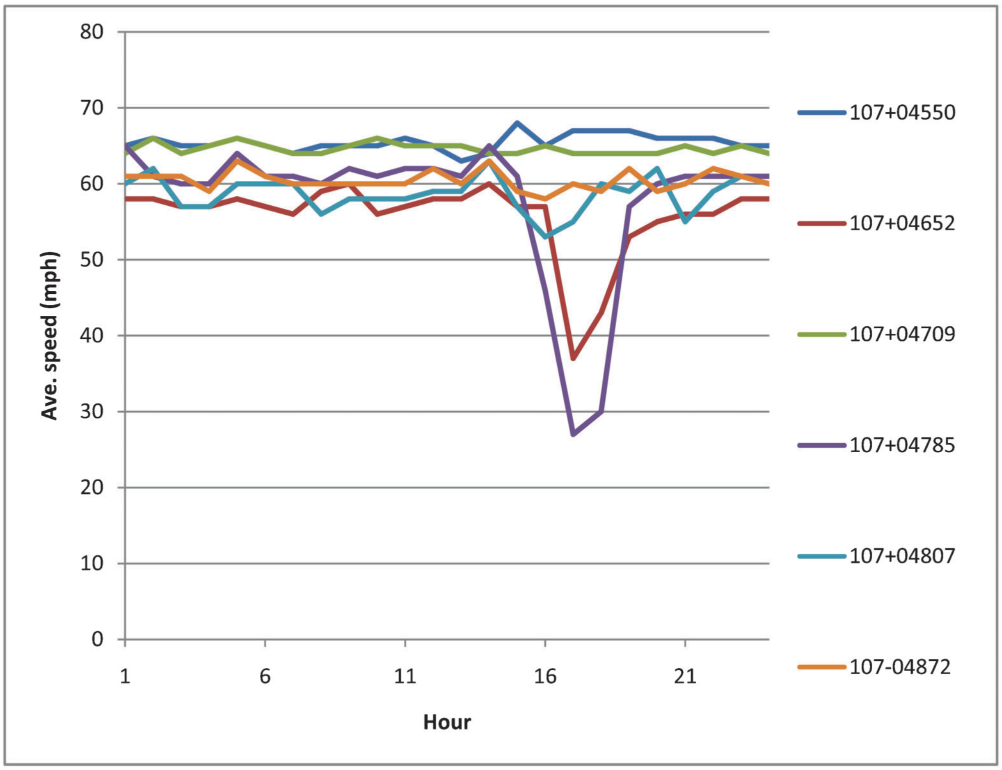
No accident occurred on 107+04652 and yet speeds dropped to 20 mph. This occurred over a 4-hour time period.

Date and event type: December 17, 2011.Medium snow event with total accumulation of 2.3 inches that occurred over 18 hours.



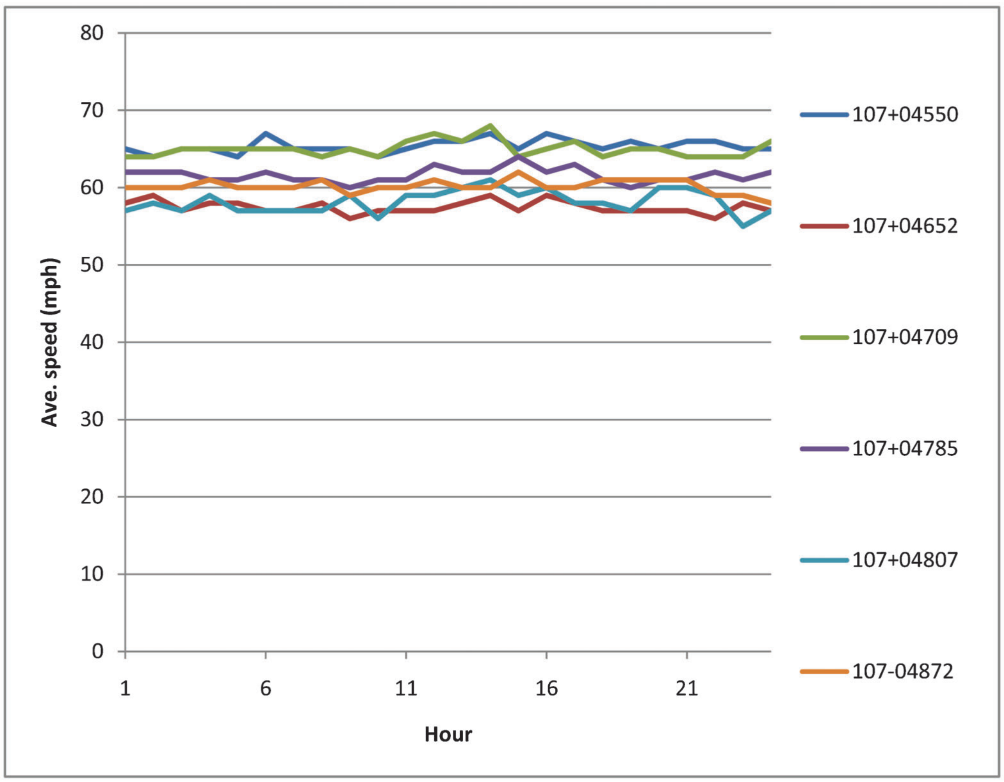
No large speed variations experienced during the storm and speed values above proposed standard.

Date and event type: January 2, 2012. Light snow event with total accumulation of 0.7 in. that occurred during the hours 00:00–20:00.



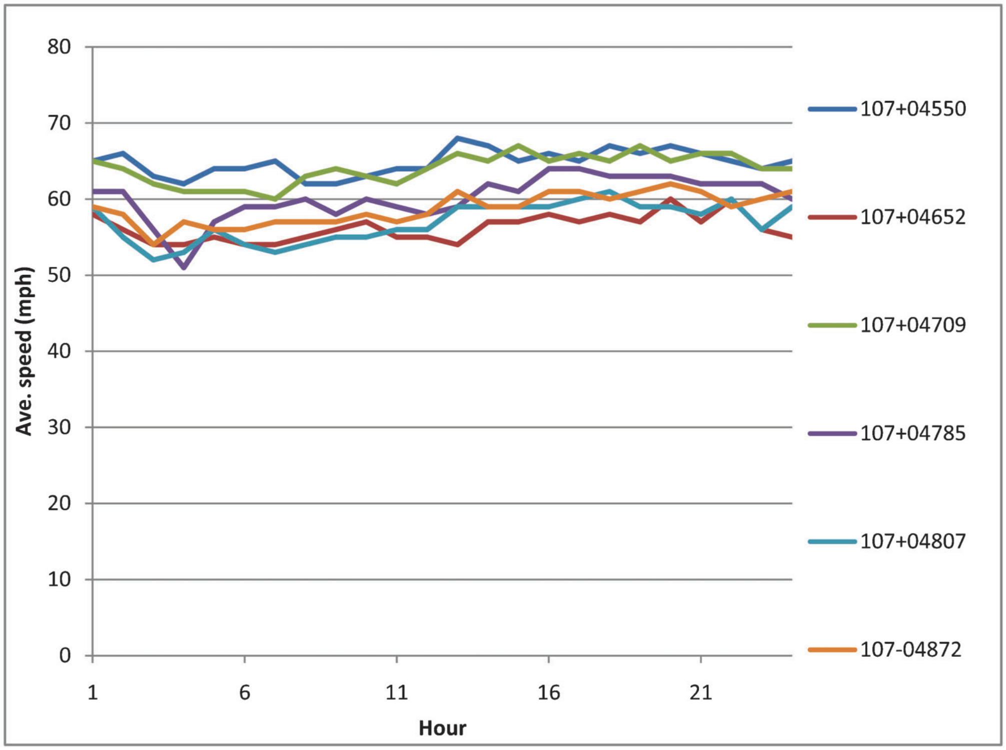
Accidents did occur on 107+04652 and 107+04785, which is most likely the contributing factor for lower speeds.

Date and event type: January 12, 2012. Light snow event with total accumulation of 1.2 inches that occurred over 14 hours (10:00–24:00).



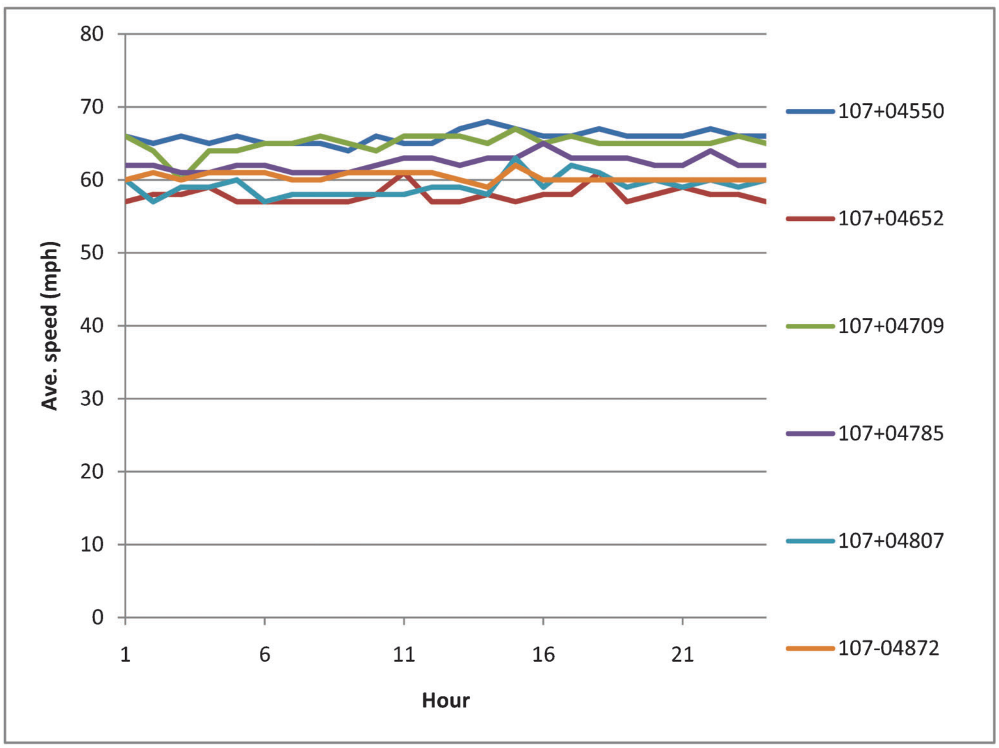
No large speed variations experienced during the storm and speed values above proposed standard.

Date and event type: January 13, 2012. Light snow event with total accumulation of 0.5 inches spread over the whole day (0:00–24:00).



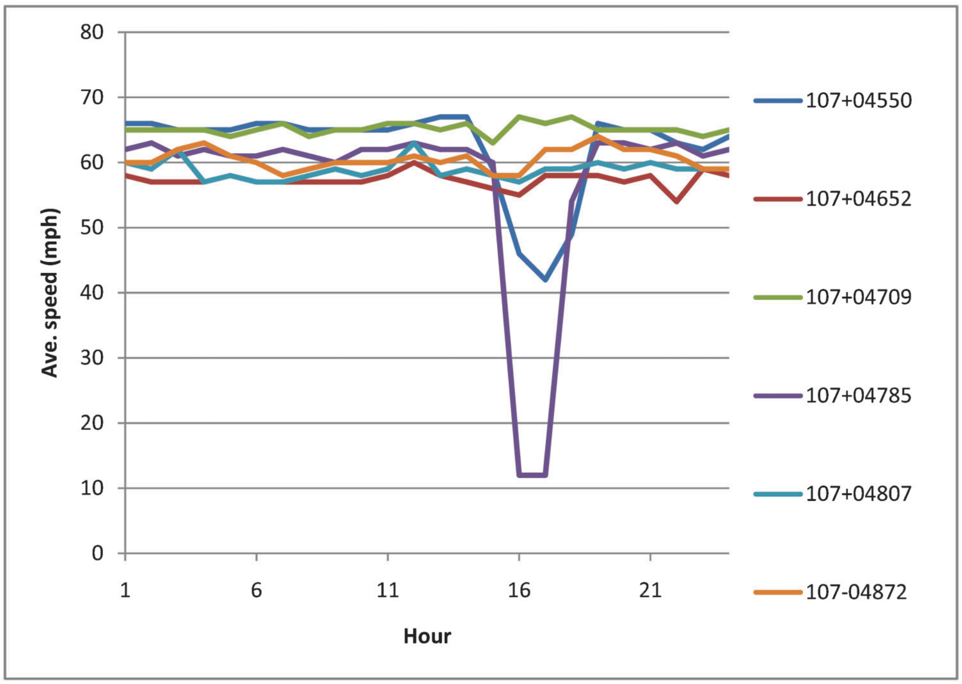
No large speed variations experienced during the storm and speed values above proposed standard.

Date and event type: January 18, 2012. Light snow event with total accumulation of 0.1 inches that occurred over 11 hours (0:00–11:00).



No large speed variations experienced during the storm and speed values above proposed standard.

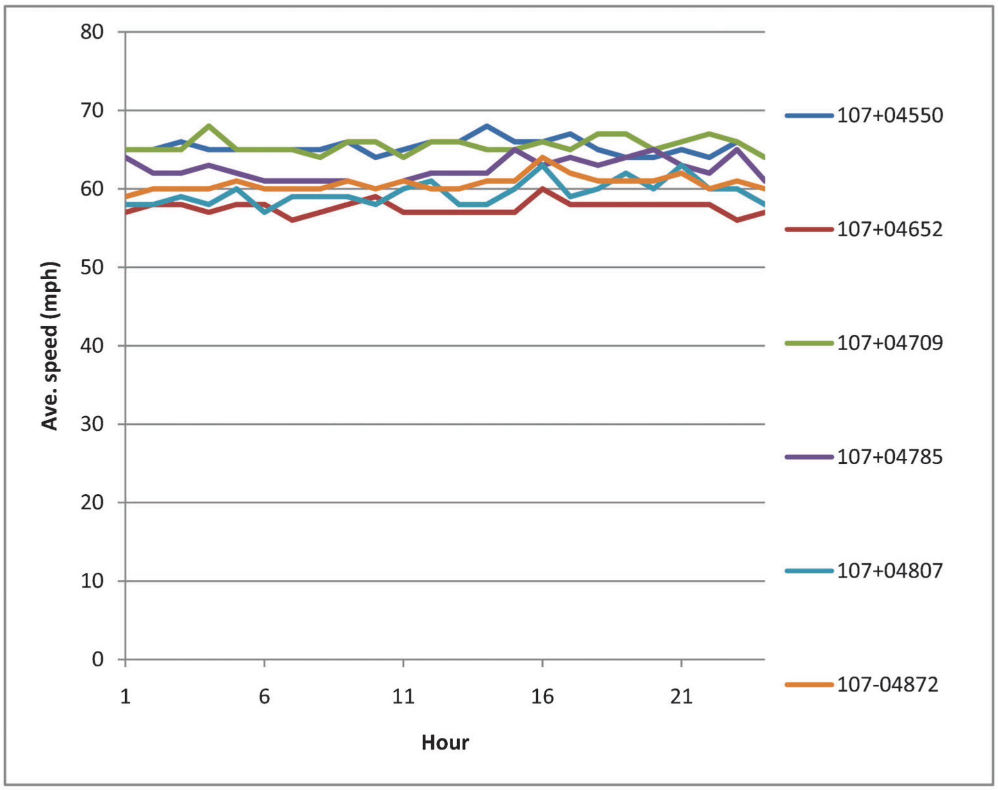
Date and event type: January 19, 2012. Light snow event with total accumulation of 0.6 inches that occurred during three different time intervals(9:00–12:00, 17:00–18:00,19:00–20:00).



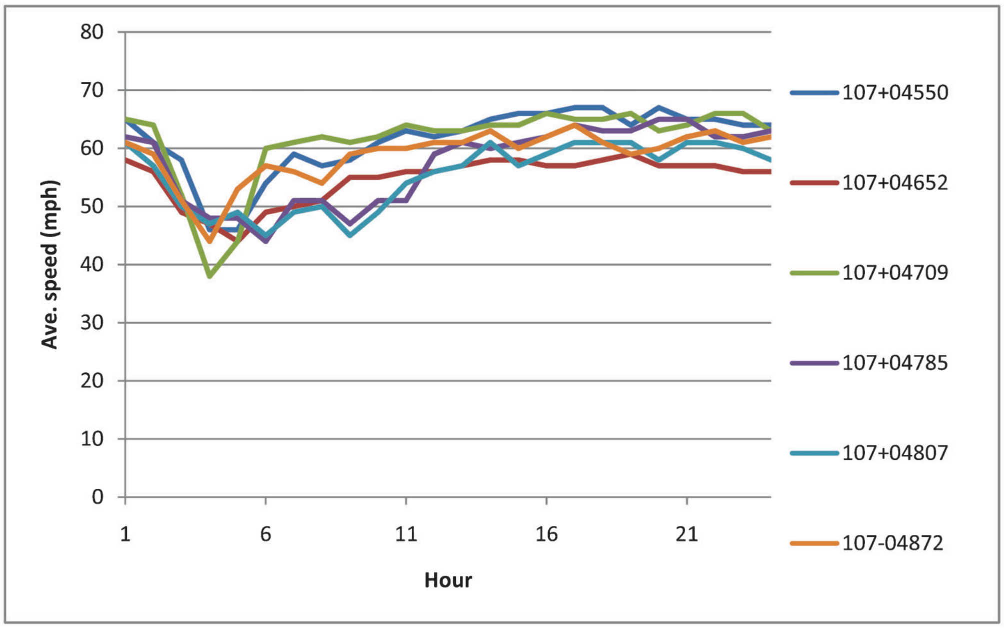
An accident occurred on 107+0455 which most likely contributed to the speed decrease.

Traffic speeds stayed above 55 except on two routes between the hours 14-19. I-69 location experienced an accident which most likely affected the traffic speeds shown on the above chart indicated by the blue line. The purple line (I-465 mm 30.8 to mm 45.6) had no reported accidents and the traffic speed dropped below 20 mph.

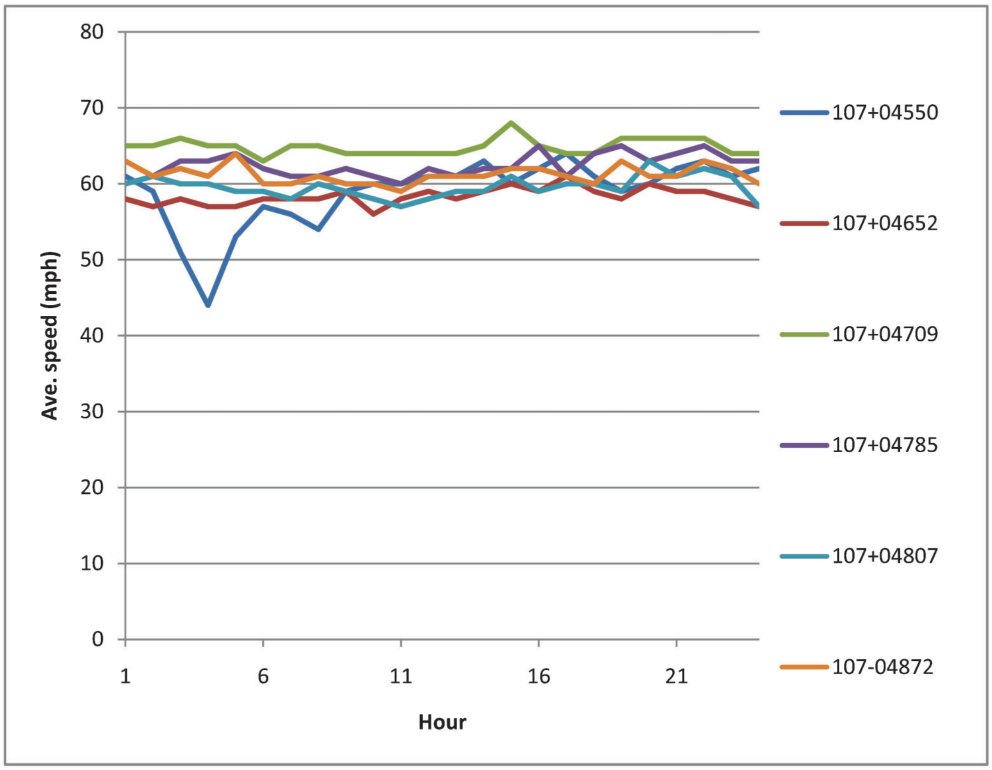
Date and event type: January 20, 2012. Light snow event with a total accumulation of 0.4 inches that occurred during the hours of 20:00–24:00.



No large speed variations experienced during the storm and speed values above proposed standard.

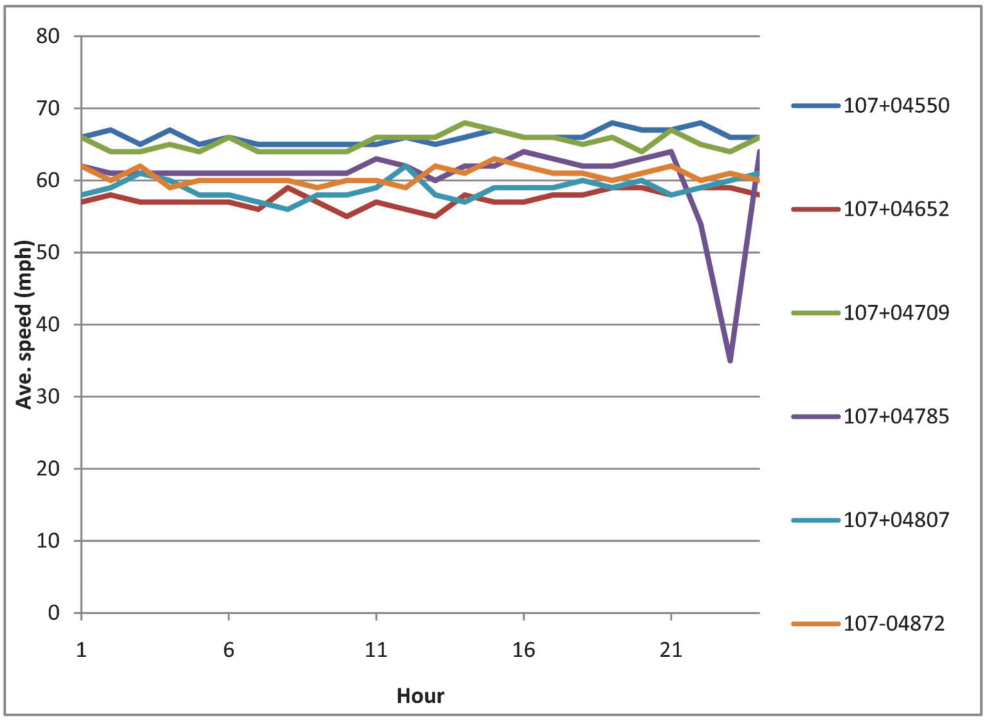
Date and event type: January 21, 2012. Light snow event with a total accumulation of 0.2 inches that occurred during three separate intervals (0:00–3:00, 17:00–18:00, 20:00–23:00) for a total of 7 hours.

No accidents at any locations. Speeds dropped in the early morning hours but stayed above the proposed standard with the exception of one (I-74) location.

Date and event type: January 28, 2012. Light snow event with a total accumulation of 0.6 inches that occurred during the hours of 4:00–8:00.



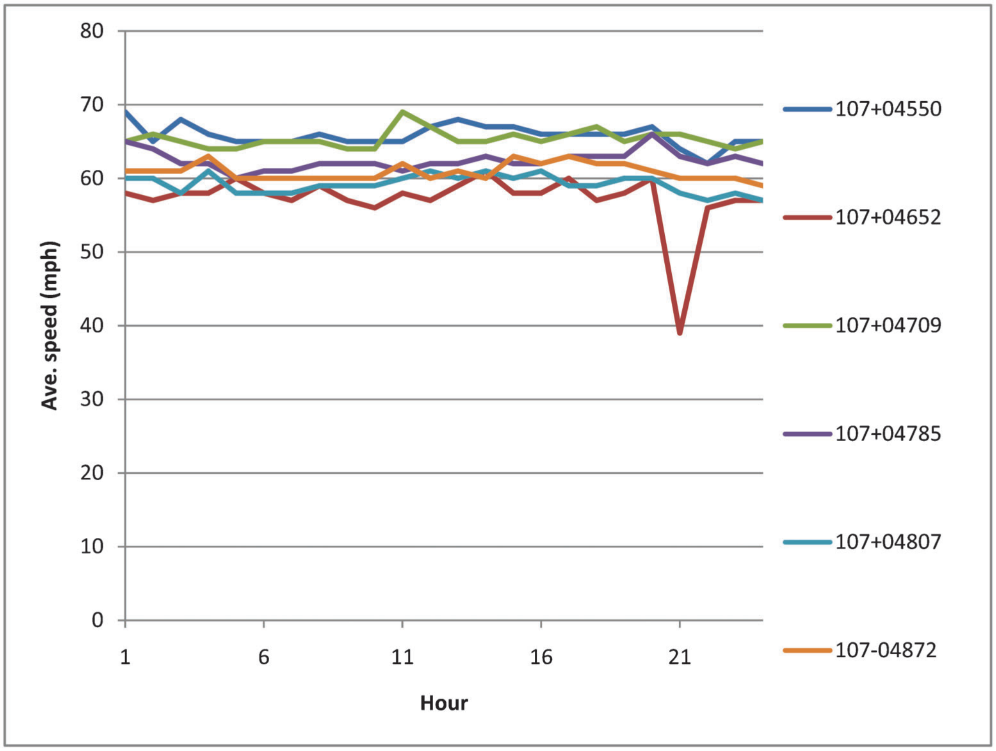
No accidents at any locations. No large speed variations experienced during the storm and speed values above proposed standard.

Date and event type: February 8, 2012. Light snow event with total accumulation of 0.2 in. that occurred during three intervals (3:00–10:00, 14:00–16:00, 18:00–23:00), for a total of 14 hours.



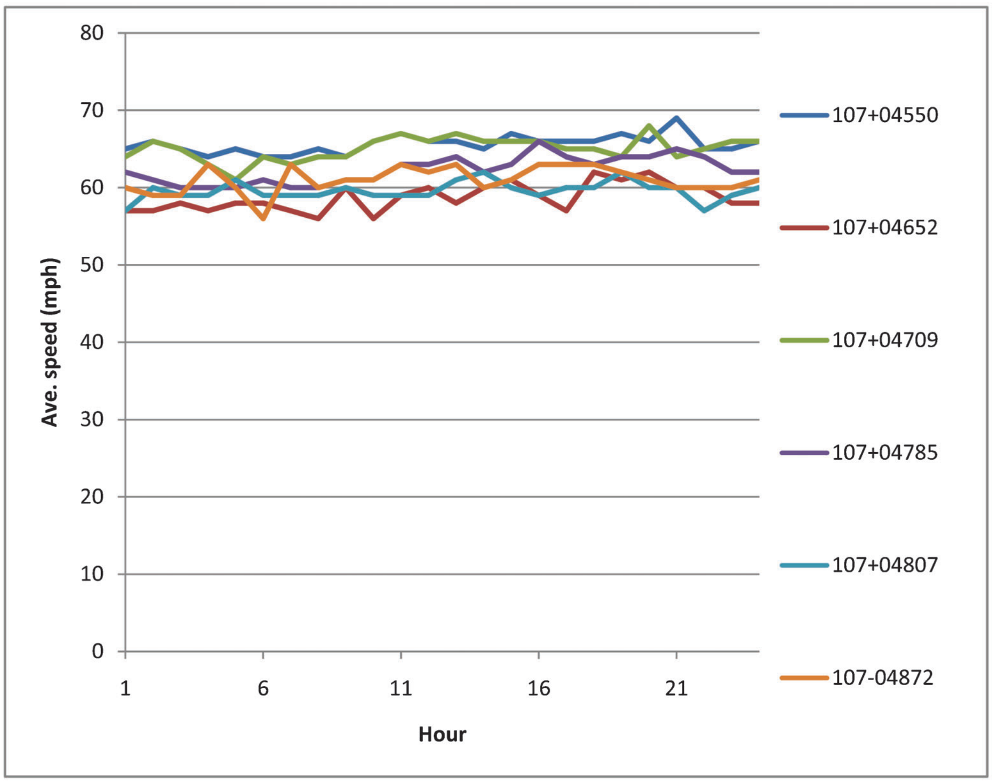
No accidents at any locations. Speeds stayed above 55 with the exception of I-465 site (30.8 to 45.6) where the speed dropped below 40 after 8 PM.

Date and event type: February 10, 2012. Light snow event with a total accumulation of 0.2 inches that occurred during the hours of 10:00–24:00, for a total of 14 hours.



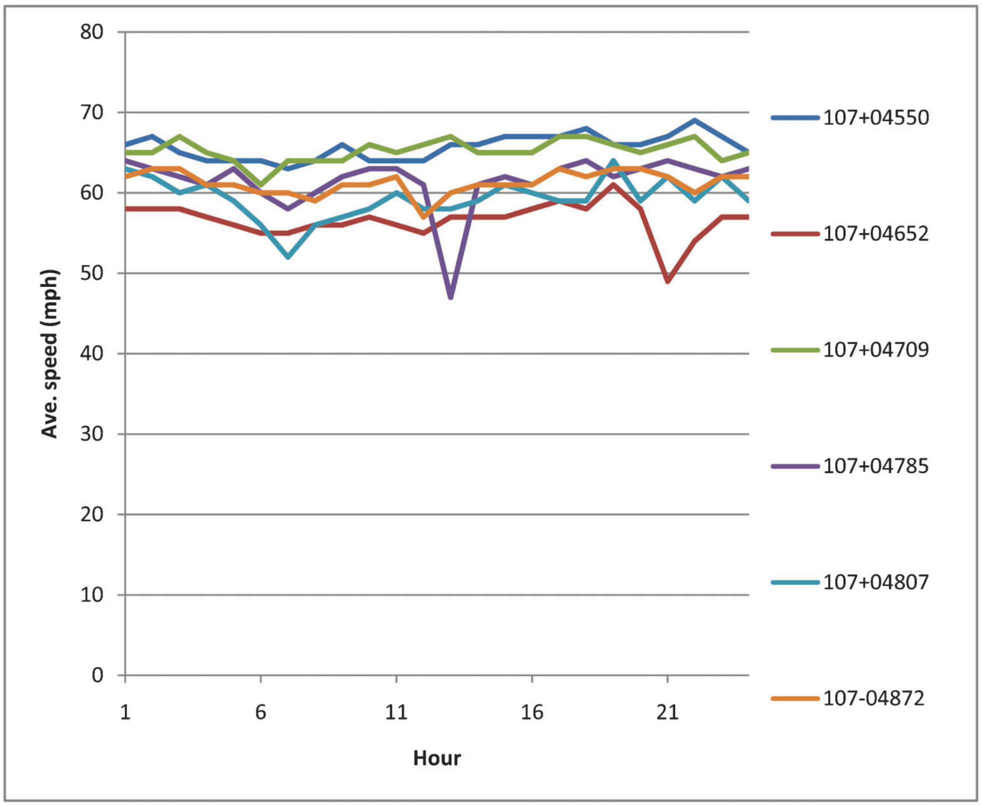
No accidents at any locations. Speeds were above 55 with the exception of I-70–Harding St. to south split, where the speed dropped below 40.

Date and event type: February 11, 2012. Light snow event with total accumulation of 0.1 inches that occurred during the hours of 0:00–3:00 and 8:00–13:00, for a total of 8 hours.

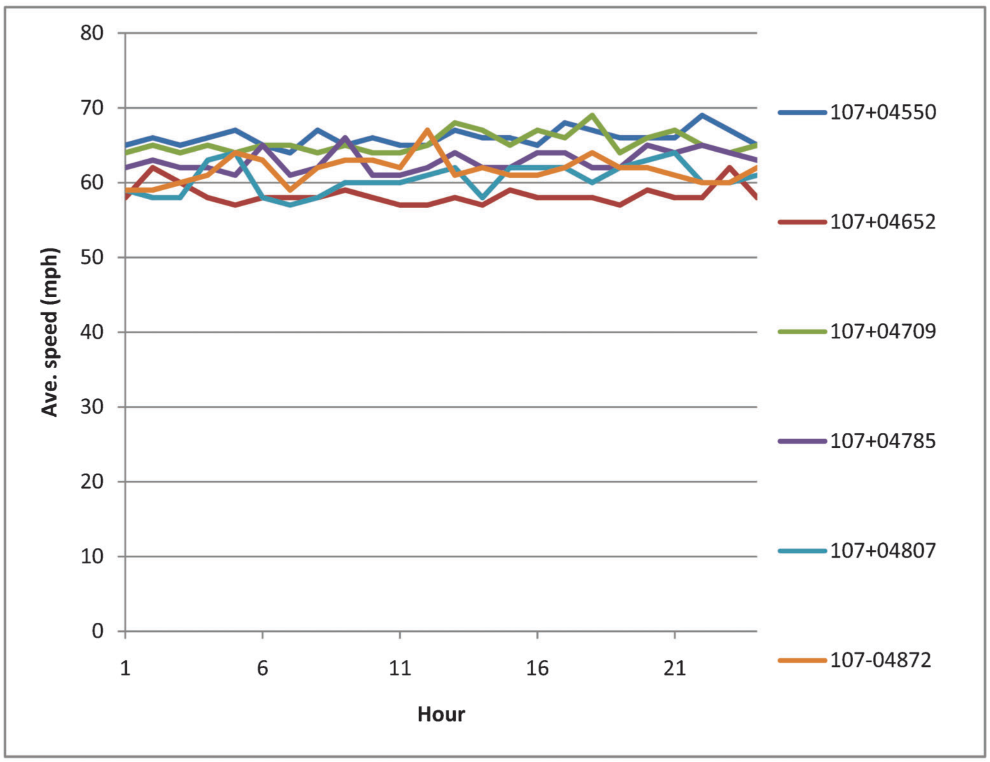


No large speed variations experienced during the storm and speed values above proposed standard.

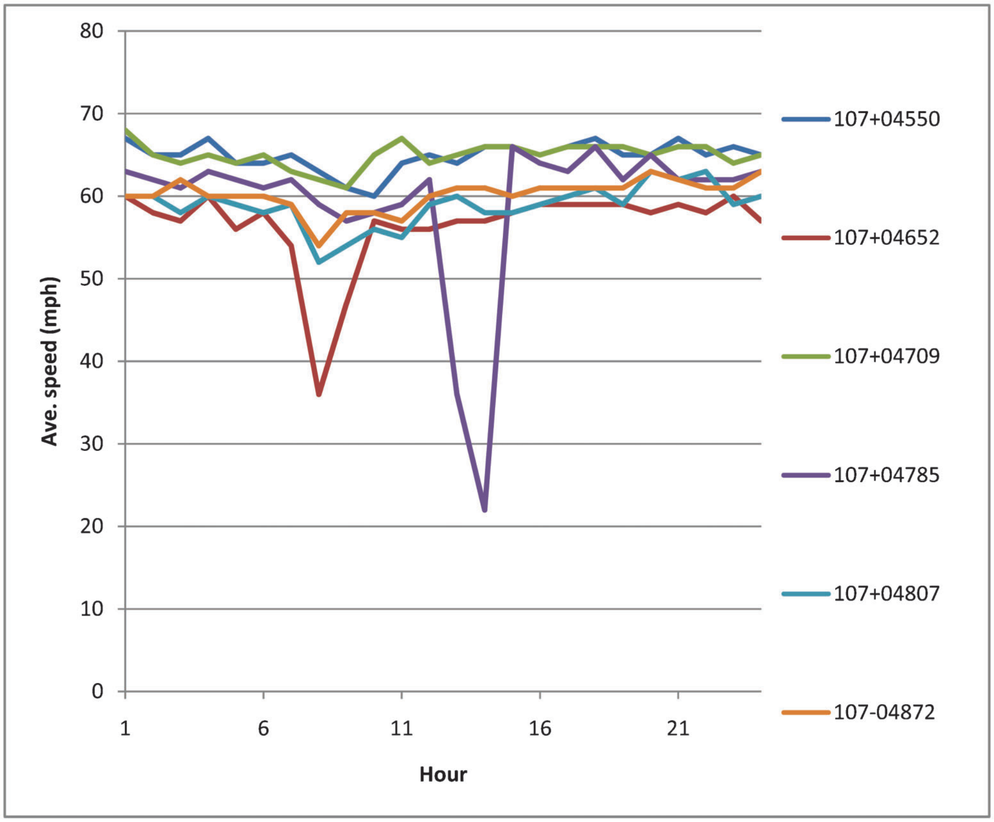
Date and event type: February 11, 2012. Light snow event with a total accumulation of 1.6 inches that occurred during the hours of 0:00–11:00.



Speed values stayed above the proposed standard.

Date and event type: March 4, 2012. Light snow event that occurred during the intervals of 9:00–15:00 and 23:00–24:00, for a total of 7 hours

No large speed variations experienced during the storm and speed values above proposed standard.

Date and event type: March 5, 2012. Light snow event with a total accumulation of 0.1 inches that occurred 0:00–9:00.



No accidents. Speeds at two locations: I-70 and I-465 (30.8 to 45.6) dropped below 40.

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,500 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at: http://docs.lib.purdue.edu/jtrp

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