Final Report

Monitoring Traffic in Work Zones:
The iCone System

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Office of Traffic, Safety, and Technology

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EXECUTIVE SUMMARY

Work zone traffic delays are often unpredictable and can cause significant safety and mobility problems. While many technology-driven concepts have been used to manage work zone traffic, they have generally been expensive or require protection from live traffic, such as behind Jersey barriers. The iCone System breaks from traditional methods by putting the traffic sensor and communication electronics inside a typical traffic barrel. This integral solution makes the iCone a safer alternative for the travelling public.

The iCone System’s core function is to detect traffic speeds and relay the data to a central server. The central server can load the data to a web page that is publicly visible (or can require a password if desired). The web page uses a Google Map interface to display the physical location of the iCones, providing a simple and effective tool for traffic management personnel.

This project first tested the iCone to determine the device’s speed accuracy and to better understand the underlying technologies. These tests found that the aggregated speed data was within about three percent of actual speeds. This accuracy was observed across a wide range of traffic speeds.

The first iCone deployments were in work zones on Hennepin County road construction projects. The iCone data revealed that the primary times of excessive vehicle speeds were outside of construction activities, resulting in no need for additional enforcement efforts.

After the County work zone projects, the iCones were set up in Mn/DOT work zones. The primary goal for most of these deployments was to monitor queued traffic and identify congestion. The deployment in Owatonna on I-35 found that there was little congestion and the existing static signage was sufficient to notify drivers of the work zone and possible queues. During this deployment, Mn/DOT added a link to the iCone website that could be seen by travelers that clicked on the Owatonna work zone icon on www.511mn.org. This demonstrated a user friendly approach that directly allowed the iCone data to be integrated into the 511 system.

Another deployment on I-35, this time in Moose Lake, found that traffic queuing was not as bad as expected, allowing the District Traffic Engineer to remove unnecessary signage upstream of the work zone. The final deployment, on TH 100, was a “before and after” study for a HEAT (Highway Enforcement of Aggressive Traffic) effort. The iCones were able to detect and report speed data that fit Mn/DOT’s need for data in 5 mph speed bins. This data was directly comparable to data from other sources, making it a valuable tool for traffic study applications as well.

The iCone System performed its stated capabilities and offered the flexibility to meet many of Mn/DOT’s functionality requests. This flexibility allows Mn/DOT and other transportation agencies to integrate the iCone into other work zone traffic control strategies, such as dynamic queue warning systems.
1. INTRODUCTION

*Monitoring Traffic in Work Zones: The iCone System* is a project funded by the Minnesota Department of Transportation’s (Mn/DOT) ITS Innovative Idea Program. This project deployed and tested the iCone traffic sensor, a portable, low-cost monitoring system that can withstand the challenging environment found within work zones and that can be rapidly deployed by field personnel with no specialized training.

Hennepin County and Mn/DOT were key participants in this project, making staff and resources available to deploy the units on several County and State construction projects. On the private sector side, SRF partnered with Street Smart Rental (SSR), the local iCone distributor, to conduct the project. SSR coordinated with the manufacturer for data collection and system modifications, and deployed and maintained the iCones at site locations, as needed, over the course of the project.

This report presents findings from a series of deployments over a two year period, including key findings and recommended next steps.

2. BACKGROUND

Delay and travel time variability due to traffic congestion are a significant concern for many motorists. In particular, work zones impact both traveler delay and safety due to their dynamic nature. In 2009, there were 667 fatalities resulting from work zone crashes.

Traffic management technology used in work zones, also referred to as “smart work zones,” has been successfully deployed for many years. Traditionally, these devices have typically been deployed on roadside trailers or in permanent roadside locations. The iCone implements this technology in a standard roadside channelizing drum. This section addresses the use of channelizing drums for smart work zone applications and summarizes several “smart work zone” projects implemented by Mn/DOT and others transportation agencies.

2.1 Reasons for Collecting Work Zone Data

Work zone data can be used to aid traffic engineers in understanding the performance of a work zone. Data can then be used to provide a basis for decision making to increase the performance and safety of work zones. Smart work zones aid agencies in complying with the Work Zone Safety and Mobility Rule (FHWA 23 CFR 630 Subpart J). The prevailing goal of the rule is to better understand and manage work zone impacts. Three related provisions of the rule include the impact assessment area, use of data, and the area of process reviews. The impacts assessment area recommends that agencies develop and implement procedures to manage safety and mobility during project implementation. Data from other work zones can be used to predict the performance of a work zone during the design phase and the design can be adjusted to meet work zone performance metrics. The data provisions section of the work zone rule requires that agencies use work zone data at both the project and process levels to manage and improve work zone safety and mobility on individual projects as well as improvements over an extended period of time. The rule also requires agencies to perform a process review every two years. Smart work zone data collection devices can provide data for these reviews.
2.2 Mn/DOT Smart Work Zone Efforts

Mn/DOT has experience with several smart work zone deployments. One successful endeavor has been the Minnesota Intelligent Work Zone Toolbox (IWZ Toolbox); a system of documented guidelines used as a tool for selecting technologies appropriate to manage work zone traffic issues. Because most of the technologies recommended by the IWZ Toolbox may be implemented in several ways, the document gives schematic ideas/suggestions of how to integrate these techniques into a system.

The IWZ Toolbox suggests several ways to manage work zone traffic through the use of examples. This approach allows for broad interpretation that can be used in different applications instead of prescribed placement instructions. Examples of applications that the IWZ Toolbox includes are:

- Travel Time Information (Trip Time or Estimated Delay)
- Speed Advisory Information
- Congestion Advisory
- Stopped Traffic Advisory
- Dynamic Merge (Late or Early)
- Traffic Responsive Temporary Signals
- Temporary Ramp Metering

Most of these applications require accurate speed data. The iCone is capable of being located near traffic and obtaining very accurate results that could be used to feed data into these systems.

A recent application of the smart work zone concept was Mn/DOT’s ITS During Major Urban Reconstruction (IDMUR) project deployed for the I-35W/TH 62 Crosstown Commons Reconstruction. One system detected vehicles exceeding the provisional warning speed as they approached the construction area. Once activated, a portable changeable message sign (PCMS) would encourage users to slow down. Another aspect of the project detected vehicle speeds as a replacement to detector stations that were disrupted by the construction activities. These systems were deployed by a specialized contractor. The iCone concept differs from these systems by being a very simple and ruggedized device that can be deployed by construction personnel with minimal training.

Other Mn/DOT projects have used radar traffic detection to determine vehicle speeds in work zones. For example, Mn/DOT’s Dynamic Late Merge System used an RTMS™ radar sensor to detect vehicle speeds. When speeds were high, the system advised drivers via a PCMS to merge early. When vehicles began to queue, lower speeds were detected and drivers were advised to wait to merge until a preset merge point. The project found that the detector did not report accurate speed data when traffic volumes were low.
2.3 Literature Review

A literature review was conducted using the Transportation Research Information Services (TRIS) database and Internet searches. The literature search found several applications that use detection data to perform various traffic-information-related tasks, but only one project that specifically examined detection techniques for work zones. In addition, these prior efforts have been deployment-related rather than research-related. Thus, little information was uncovered by the literature search. However, a large amount of studies have looked at the smart work zone concept and show that smart work zone technologies are an effective method of managing traffic and enhancing safety.

3. ICONE CAPABILITIES

The core capability of the iCone is to measure average speeds of traffic and report them to iCone's central server for display and download on a secure website. Most iCone deployments use a cellular modem, although iCones also have a satellite modem that can be used in locations where there is no cellular coverage.

3.1 iCone System Components

Traffic Barrel. The iCone is a standard channelizing drum (aka traffic barrel) that houses specialized electronic components. Because the iCone resembles a conventional traffic control barrel, it is able to observe traffic unobtrusively. Also, vandalism and driver distraction is less of a risk compared to other temporarily mounted devices like sensors mounted on work zone trailers. However, when viewed close up, the iCone is easily distinguishable from other traffic barrels because an arrow is imprinted on the top of the unit. This arrow shows the direction in which to point the iCone to properly detect oncoming traffic. The iCone was accepted to be a crashworthy traffic control device by the FHWA in 2008 (WZ-272). Figures 1 and 2 show an image and schematic of the iCone.

Electronic Components. The iCone’s electronic components are housed within the traffic barrel. These components consist of a GPS antenna, radar controller, radar transducer, modem, antenna, mounting plate, sealing plate and a controller board. The main component of the iCone is the circuit board which is environmentally sealed and contains the radar components. The circuit board also has ports for the GPS receiver and cellular antenna.

Figure 1. iCone Image
Battery. The largest electrical component of the iCone is the battery. The Absorbed Glass Mat (AGM) battery is a type of Valve Regulated Lead-Acid (VRLA) battery. This type of battery is sealed, allowing it to be turned on its side with no adverse effects. The iCone requires the battery to be recharged every 14 to 17 days, typically by connecting the iCone to an electrical outlet. Recharging takes between 12 to 20 hours. For this project, it was found that larger aftermarket batteries allow the system to function for an additional four to six days. Furthermore, configuring the iCone’s radar for continuous operation and report data every minute caused a minimal change in battery performance. Although the iCones were tested in a variety of environmental conditions, no definitive relationship between the battery performance and temperature was observed. Although batteries usually do not perform as well in cold weather, other issues, such as communications dropouts, made it difficult to directly compare the data.

3.2 iCone Deployment

While the process for deploying the iCone is straightforward, iCone has developed guidelines to assist with setup. The diagram shown in Figure 3 shows the offset and distance upstream that the iCone should be angled to get the optimal speed detection performance. The rule of thumb that is recommended is to aim the iCone 30 feet upstream (“y” in the diagram) for each foot the iCone is from the edge of the travelled lane (“x” in the diagram).
Due to curves or other line-of-sight obstacles, it may not be possible to always/regularly follow this guideline. In those cases, the iCone could be placed such that the iCone is pointed as close as possible to the target distance. In practice, when the iCones are set up, it is not always possible to measure distances, so approximate aiming is acceptable. The iCone may be pointed further upstream if the site conditions allow it, however, iCone gives a guideline that the distance should be within 25 percent of the recommended distance.

3.3 XML Data Feed

The iCone reports its exact location determined by its onboard GPS. From this location, it collects near real-time traffic data. Using a cellular connection to the internet, the iCone relays data to a website (www.iconetraffic.com) where current traffic conditions can be viewed publicly if desired. Password access to the site allows for agencies to download historic records of iCone data. If desired, the Extensible Markup Language (XML) data feed is provided by the iCone central server. The XML data feed can also be sent directly to agencies for use in traveler information systems, such as 511 or the Condition Acquisition and Reporting System (CARS).

3.4 Web Interface Capabilities

Throughout the project, iCone was asked to provide additional functionality that allowed Mn/DOT to obtain more useful information and avoid additional time consuming data manipulation. A key request that iCone was able to accommodate was to make the interface default to a two-mile view of iCone locations. This allowed the public to be directed to a website to see where the I-35 iCones were deployed.

The iCone System successfully provided the following web interface capabilities:

- Data is available from the iCone website.
- Historical data can be password protected.
- Website provides a mapping function that pictorially illustrates the location of the iCones and displays speed data in a color-coded format.
- Website provides historical data in graphical and tabular format.
- Website produces an XML feed that can be parsed by Mn/DOT’s traffic management software.

3.5 iCone Operation

The basic mode of operation is that the iCone turns on for 30 seconds, detects vehicles, and then turns off to conserve battery power. This is considered to provide sufficient data so the iCone does not need to operate continuously. In general, all the data recorded within this 30-second period is aggregated and reported as one-minute binned data. As with many other elements of the system, this period can be configured to better suit a particular application.

The iCone met the following functional requirements:

- Detects speed of vehicles traveling towards the sensor.
• Detects the volume of vehicles traveling towards the sensor. However, the iCone system approximates volume by counting the number of times a speed measurement is made, which does not always directly correlate with the number of vehicles. The iCone could be oriented perpendicular to traffic to get a more accurate count for a single lane of traffic, but would then not be able to collect speed data. The iCones were not tested in this configuration.

• Communicates with iCone’s central server by cellular modem (or satellite modem when cellular service was not available).

• Reports speeds within three miles per hour of actual speeds.

• Reports data once per minute.

The iCone met the following data requirements:

• Reports data in real time. The real-time data was available on iCone’s website.

• Configurable to report 85th percentile speed data.

• Configurable to report 50th percentile speed data.

• Provides binned speed data.

• Historical data is available in Microsoft Excel format.

Sample data is provided in Table 1. Each data parameter must be downloaded separately, but may be compiled as shown in the sample data. All data downloads include the latitude and longitude of the iCone where the data was recorded (not shown in the table). The data is available in a comma separated values (CSV) file that may be opened in spreadsheet or text editor software.

**Table 1. Sample iCone Data**

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<th>count</th>
<th>fahrenheit</th>
<th>celsius</th>
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<th>voltage</th>
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<td>12.58</td>
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4. OPERATIONAL SCENARIOS

Four main types of operational scenarios were considered in this project. They included mobility measurement, enforcement, closure restrictions/traffic control modification and traffic responsive systems as per the IWZ Toolbox.

4.1 Closure Restrictions and Traffic Control Modifications

This concept uses iCone data to determine if any modifications should be made to a construction project’s traffic control plan, such as any changes to lane closure restrictions or the location of signing. By using the iCone speed data in this manner, it is possible to improve the traffic control plans throughout the construction project.

Project engineers could check iCone data on a weekly basis, or whenever they receive a report of heavy congestion. From the data, they could tell where and how often congestion is occurring. Then they could look for opportunities to improve mobility in the work zone, such as by modifying the traffic control plans.

4.2 Enforcement

The iCone collects data at regular intervals and then wirelessly transmits all the data to the iCone website. On the website, the data is presented in both tabular and graphical formats. Under this scenario, law enforcement could access this data to determine specific time periods when speeding tends to occur, and target enforcement accordingly.

Similarly, law enforcement personnel rarely have any means of determining the effectiveness of enforcement efforts because they do not have before and after data. Law enforcement officials could use iCone data to track speeds before and after enforcement periods.

4.3 Mobility Measurement

Mobility measurement consists of capturing speed data in a work zone to monitor traffic flow. For the purposes of this study, mobility was defined as either the change in travel time through the work zone, or delay through the work zone as compared to when the segment is not under construction. The iCone has the ability to approximate mobility by capturing traffic speeds at the iCone’s location. This information could be used to improve work zone mobility by modifying the traffic control plan, such as adding additional signage.

For construction projects, project engineers could examine the iCone data on a regular basis in order to track mobility efficiency in the work zone. A significant reduction in speeds would be an indicator that delays are increasing and that steps need to be taken to improve mobility.

4.4 Traffic Responsive Systems

iCone data can be integrated into traffic management and traveler information systems, such as 511. The data would provide another input into an existing network of traffic sensors. Additionally, iCone data could be used to actively manage traffic, by integrating iCone data with
a PCMS to warn drivers of queued traffic ahead. These signs could communicate directly with the iCones, allowing for the displayed information to be real-time and accurate. For example, the iCone could be placed anywhere within a work zone and could communicate information to a PCMS at the beginning of the work zone. The PCMS could provide delay information or warn drivers of queued traffic ahead.

4.5 Non-Work Zone Applications

The iCone can be used in applications beyond work zones. For example, an iCone could be used to warn motorists they are approaching the back of a queue. Unexpected traffic queue situations can result in rear end crashes. If an iCone were placed in advance of where the backups occur, it could transmit information to a PCMS or blank-out sign upstream of the backup to alert drivers motorists of a queue ahead.

Traditionally, speed studies focus on determining the 85th percentile speeds. The iCone does not record per-vehicle speeds, but was found to provide a valid approximation of 85th percentile speeds, making it a candidate for traditional speed studies.

Traffic control during special events creates unique challenges. The iCone could be used as a flexible, low-cost, and inconspicuous means of capturing traffic flow data, attributes that are suited to the short-term nature of special events.

The detection component for the applications listed above can be provided by a variety of traffic sensors. However, the iCone would be a good sensor choice if any of the following are important: self-powered, inconspicuous, or easy to deploy.

5. ACCURACY TEST RESULTS

An evaluation of data accuracy was performed using three iCones. The iCones were placed in the following locations:

- The NIT Test Site on I-394 at Penn Avenue detecting eastbound traffic.
- Northbound I-35W in Lino Lakes at the junction with I-35E.
- Northbound I-35W in Lino Lakes near the Main Street overpass.

All three iCones were evaluated for speed data accuracy. The data collection time interval for each of these tests was set to one minute.

5.1 NIT Test Site Results

**Speed Accuracy Testing.** At the NIT Test Site, iCone was compared against two loop detectors set in a speed trap configuration for each of the three eastbound lanes. The iCone was compared to loop speed data for all three lanes at the same time as well as loop speed data for only the lane closest to the iCone. The absolute percent difference between iCone speeds and loop detector speeds was four percent when comparing the iCone to only the closest lane of I-394 for about nine hours. The absolute percent difference between iCone speeds and loop
detector speeds was five percent when comparing iCone speeds with loop detector speeds for all three lanes of I-394 for seven hours and 25 minutes.

Figures 4 and 5 show a graphical representation of the iCone and loop detector recorded speeds for two different days. Each of these figures display loop detector data for only the closest lane to the iCone.

![Figure 4. NIT Test Site iCone and Loop Detector Comparison (August 17, 2009)](image)

![Figure 5. NIT Site iCone and Loop Detector Comparison (September 2, 2009)](image)

5.2 I-35W at I-35E Results

The I-35W iCones were compared against loop detector stations with single loops in each lane. Historically, single loop detectors do not provide an accurate per-vehicle speed measurement, but are more accurate with aggregated trends as detector errors balance.
**Speed Accuracy.** Figure 6 displays speed data comparing iCone and the single loop detectors for both lanes of northbound I-35W at the I-35E junction. The loop detector speeds represent a per-minute average of both northbound lanes. Although the single loop detector speeds are erratic and tend to be about eight to twelve miles per hour higher than the iCone speed, the graph shows that the iCone and loop detectors report similar trends in traffic speed.

![Figure 6. I-35W at I-35E iCone and Loop Comparison (August 15, 2009)](image)

**5.3 I-35W at Main Street Results**

**Speed Accuracy.** Figure 7 displays speed data, comparing iCone and the two loop detectors for northbound I-35W at the Main Street overpass. Similar to the I-35W at I-35E site, the loop detector speeds represent a per-minute average of both northbound lanes. Again, the loop detector speeds are erratic and are an average of 13 mph higher than the iCone speeds. A trend can be clearly seen from 11:00 to 14:00 where both the iCone and loop detectors reported that traffic speeds greatly reduced at approximately 11:30 and then increased to normal speeds at approximately 13:45. The iCone reported speeds between 65 and 70 mph during free flow conditions.

![Figure 7. I-35W at Main Street iCone and Loop Detector Comparison (August 15, 2009)](image)
5.4 Accuracy Summary

The mean absolute percent difference in speed data between the iCone and loop detector baseline was compared. The dual loop detector baseline at the NIT Test Site provided accurate per-vehicle speed data. The average difference was two to three miles per hour or four to five percent lower than speeds reported by the iCone. The iCone confirmed that this result has been seen in other tests and is due to the sensor being placed adjacent to the roadway where traffic is not traveling, directly toward the unit. The I-35W test was compared to single loop detectors which are not as accurate as dual loop detectors or the iCone, so the average percent difference was much higher than what would be expected with a more accurate baseline. A summary of the results of the tests are shown in Table 2.

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<th>Test Date</th>
<th>Test Time of Day</th>
<th>Average Difference (mph)</th>
<th>Speed Standard Deviation</th>
<th>Average Percent Difference</th>
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</thead>
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<td>3.6</td>
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</tr>
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<td>11</td>
<td>8.2</td>
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</tr>
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</table>

6. DEPLOYMENT RESULTS

The iCones were deployed at several locations around Minnesota. The locations were selected to maximize their benefit to Mn/DOT and Hennepin County stakeholders. The following deployments were conducted:

- CSAH 101 in Plymouth (Hennepin County)
- CSAH 1 in Eden Prairie (Hennepin County)
- I-35 in Owatonna (Mn/DOT)
- TH 10 in St. Cloud (Mn/DOT)
- I-35 near Moose Lake (Mn/DOT)
- TH 100 in Golden Valley (Mn/DOT)

This section gives a brief description of the deployments and the associated findings.
6.1 CSAH 101 in Plymouth

Three iCones were deployed at the intersections of CSAH 101 and 12th, 26th and 30th Avenues. These locations are shown in Figure 8.

![Figure 8. CSAH 101 in Plymouth Work Zone Deployments](image)

The initial iCone placements were on horizontal curves where excessive speeding was not observed. The placement was adjusted, but again, no speeding issues were observed. The County staff concluded that the original traffic control was effective in deterring drivers from speeding and that specific enforcement efforts were not necessary.

6.2 CSAH 1 (Pioneer Trail) in Eden Prairie

In parallel with the CSAH 101 deployment, three iCones were deployed on CSAH 1 in Eden Prairie. At this site, speeding was noted only at night, but was determined to not be a significant issue, so the data was not used to target enforcement. Volumes were low, so it was not cost effective to enforce the site at late hours. Also, the iCone data revealed that excessive traffic queues did not form as a result of the project. The two County work zone deployments served to justify the value of iCone data.

6.3 TH 169 at TH 13 in Shakopee

For this short-term evaluation, Mn/DOT desired to see whether additional channelizing barrels would mitigate congestion induced by early merges from TH 13 to TH 169. An iCone was placed in the study area and used to capture vehicle speeds before and after modifications were made to the merge area. An image of the channelizing barrel and traffic cone locations is shown in Figure 9.
A Mn/DOT Metro District Traffic Engineer was interviewed regarding this deployment. He reported that a variety of factors contributed to the iCone data not being used, however, the factors had nothing to do with the performance of iCone. Most of the factors were related to the weather and holiday traffic. Also, the iCone positioning was altered by a maintenance worker that did not realize that the iCone was a traffic sensor. As a result, the iCone was not pointed in the same direction for the "before" and "after" conditions, so the data could not be directly compared. However, the Mn/DOT spokesman said that he would like to have the iCone in his "toolbox" for future applications.

6.4 I-35 South of Owatonna

Several iCones were deployed during a major roadway construction project on I-35 south of Owatonna. The units were placed at key points throughout the work zone to track vehicle speeds and queuing in both directions of travel. Real time traffic conditions were also made available to
the public through a link from the 511mn.org website to the iCone website. This “integration” is further described in Section 8.3.

6.5 I-35 near Moose Lake

Three iCones were used to monitor the traffic through a work zone on I-35 near Moose Lake. The iCones were set up in the following locations (also shown as “barrel” icons in Figure 10):

1) At the 55 mph speed limit sign immediately after the taper
2) One mile from the taper at the PCMS
3) Five miles from the taper near Mile Post 211

![Figure 10. I-35 near Moose Lake Deployment](image)

The Mn/DOT District 1 Traffic Engineer reported that the iCone provided useful data and he was able to determine when and for how long backups lasted. He reported that he is using the data found during the iCone test to modify the plans for future I-35 construction. Based on the findings, he also reported that he was able to eliminate extraneous advance signing for a static late merge. Signing was every two miles in advance of the backup and was not as useful as expected. Overall, the iCone met his expectations and was beneficial.

6.6 TH 100 in Golden Valley

The final deployment of iCone was on TH 100 in Golden Valley. The iCone was setup for more than two weeks to monitor the effect of a speed enforcement effort. The iCones were placed in the right shoulder of both northbound and southbound TH 100. The specific site selected was problematic for communications. On the northbound side of the roadway, the cellular modem
did not have cellular communications access and the satellite modem was activated. This was likely in part due to the nearby retaining wall. The iCone was placed away from the wall as far as it could be without risking the iCone being hit by passing vehicles.

iCone provided the graph shown in Figure 11 that shows the percentile speeds throughout the test period.

![Figure 11. Percent Traffic in Speed Range by Time of Day, 30 minute aggregates, TH 100 NB from Duluth St. to 36th Ave., October 6 to October 15, 2010.]

7. LESSONS LEARNED

The following lessons learned will aid Mn/DOT in future work with the iCone System.

7.1 Volume Data

The iCone System can give an approximation of volume data, but cannot report accurate volume for multilane roads. If the iCone is placed so that the detection zone is perpendicular to the direction of traffic, it can better approximate volume, however, then it cannot detect speeds. Because speed was the primary parameter of interest in this project, the iCone was not tested for volume performance. Another parameter that affects volume performance is how long the sensor turns off after each detection. A typical value is a 2.5 second rest after each detection, but this parameter can be set to be smaller by the vendor to detect more vehicles. Originally, volume was included as a capability, however, the latest marketing material minimizes this capability.
7.2 Comparison with alternative traffic detection technologies

The iCone monitors traffic much differently than traditional non-intrusive technologies, such as the Wavetronix microwave radar sensor, or the TIRTL infrared sensor. Those technologies are designed to collect speed, volume and classification data. However, they require significantly more setup equipment and calibration time than the iCone. The iCone’s core capability is speed detection. The iCone was regarded as easy to set up by Mn/DOT and SSR. The ability to be ground-mounted and battery-powered allowed it to be placed on a roadway on short notice. Other traditional traffic detector devices would have required more planning and cost to deploy.

8. COST

Street Smart Rental charges an iCone rental rate of $600.00 per week, plus a delivery charge that varies by location. Other rental terms are $1,800.00 per month or seasonal rentals of $1,500.00 per month (minimum 6 months).

9. NEXT STEPS/RECOMMENDATIONS FOR FUTURE DEPLOYMENT

A few areas of interest were developed throughout the project that would be worth additional exploration by Mn/DOT and other transportation agencies. A brief summary of each application is provided below.

9.1 Study Traffic Flow through a Work Zone

This concept would place several iCones at fixed spacings in a work zone to identify how long most drivers maintain the posted speed limits. The hypothesis is that as drivers travel through a long work zone, they tend to increase their speeds. iCones would provide the speed information to determine where these increases are most prevalent and a new signing plan that mitigates this effect could be developed. After instating the new signing plan, iCones could be again used to determine the effects of the new signing plan.

9.2 Additional 511mn.org Integration

For the Owatonna deployment on I-35, the iCone data was “linked" into the relevant page of 511mn.org. The link directed users to view traffic conditions on the iCone website. This simple step allowed travelers to see live traffic conditions and required little additional effort for Mn/DOT RTMC and 511 staff to establish. Additional deployments could be similarly integrated with existing traveler information resources with little additional effort. Figure 12 shows a screenshot of the 511mn.org interface. During the actual deployment on I-35, the pop-up dialog box had a link to the iCone website.
The iCone could be implemented in several scenarios listed in Mn/DOT’s Intelligent Work Zone (IWZ) Toolbox. The following scenarios are presented as potential opportunities to integrate the iCone System.

**Travel Time Information.** The iCone could be used as a non-intrusive detection device to determine vehicle speeds throughout the work zone. By factoring in the length of the work zone, travel times could be determined and displayed on an upstream PCMS.

**Travel Delay Information.** Similarly to the travel time information concept, current travel times could be compared to known travel times on the roadway segment to determine delay. The delay could then be displayed on a PCMS.

**Speed Advisory Information.** The iCone could detect speeds throughout the work zone and the average vehicle speeds could be shown to motorists so that they can adjust their speed to maximize safety and mobility.

**Congestion Advisory.** The iCone could detect speeds to determine the location of the back of the queue (where the vehicle speeds approach zero). This information could be used to alert motorists of stopped traffic on an upstream PCMS.
**Trucks Merging Traffic Warning.** The iCone could be used as a non-intrusive detection device to determine trucks merging onto the mainline from a haul road. When the iCone detects a vehicle, a PCMS could activate to warn motorists that a truck is merging. However, for proper operation, the iCone must be in a continuous operation mode to ensure that no vehicles are missed.

### 9.4 Integration with PCMS

An iCone representative reported that there is a trend toward iCones providing information for upstream PCMS. The data flows from the iCone to iCone's central control center. The control center remotely controls the PCMS and changes the PCMS message to show a message about backups ahead. The PCMS integration process is most effective if the agency already has a standard traffic control plan and a set of messages because there are differences in messages from agency to agency. The PCMS integration goes smoothly if these procedures are put in place. iCone already supports several PCMS types and is willing to write translation protocols if needed.

### 9.5 Suggested Improvements

Mn/DOT suggested the following modifications that would add value to the iCone System.

- Add more robust volume detection capabilities.
- Add a user-configurable gap time (time between detections—this is currently configurable on the iCone central server only).

**CONCLUSION**

The iCone System was tested to determine its utility and traffic speed reporting abilities. In general, the iCone device performed its stated abilities, and the traffic speed data was consistently within three percent of the actual speeds. Additionally, iCone has provided web tools that allow traffic managers and other stakeholders to easily obtain real time and historical iCone traffic speed data. If desired by the agency, the iCone traffic speed data can also be made available to the public. This could help in integration with existing traveler information tools as was done with the 511mn.org website. Another emerging application is to use iCone data to convey information to motorists, such as integration with PCMS to provide “stopped traffic ahead” warnings. The iCone system has potential to be used in several work zone and traffic study-related applications and is recommended for further use by Mn/DOT and other transportation agencies.