Cloud-Based Dynamic Warning System

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Horizontal curves account for more than 25% of highway fatal crashes and have a crash rate that is three times that of other highway segments. Transportation agencies employ dynamic warning systems that utilize roadside speed detection and warning equipment to provide drivers with a warning when they enter a curve at a speed that might be too high for safe travel. The goal of this project is to develop a system to expand the safety improvement potential of a dynamic curve speed warning system that can be implemented systemwide to all reduced speed curves without infrastructure investment. The system emulates a connected vehicle environment by utilizing a smartphone application to deliver dynamic, speed-based, directional warnings at locations in an online database. Transportation agencies are able to enter and manage the warning locations within their jurisdictions in the online warning database through a web-based tool, and it is envisioned that the warning data would be made available to navigation systems and vehicle manufacturers via the cloud.

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CLOUD-BASED DYNAMIC WARNING SYSTEM

FINAL REPORT

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LIST OF ABBREVIATIONS

API: Application Programming Interface

APK: Android Package

CAV: Connected and Autonomous Vehicles

CV: Connected Vehicle

CSW: Curve Speed Warning

GPS: Global Positioning System

GRIT: Geographical Roadway Inventory Tool

MUTCD: Manual for Uniform Traffic Control Devices

UGPTI: Upper Great Plains Transportation Institute

EXECUTIVE SUMMARY

Horizontal curves account for more than 25% of highway fatal crashes and have a crash rate that is three times that of other highway segments. To mitigate this problem of vehicles entering horizontal curves at speeds that may be too high for safe travel, transportation agencies employ a number of solutions including static reduced speed curve signs and dynamic systems that provide a warning to drivers when warranted based on their travel speed.

Dynamic curve speed warning systems consist of a detection component to capture vehicle speed and a warning component in the form of dynamic message signs or flashing beacons with static signs. They also require power and communications infrastructure and cost roughly $14,000 per site. Although research shows that dynamic systems are more effective at reducing vehicle travel speeds through horizontal curves, their deployment is limited to curves with historically high crash numbers due to the cost involved. The goal of this project is to develop a system to expand the safety improvement potential of a systemwide dynamic curve speed warning system that can deliver warnings to all reduced speed curves without infrastructure investment.

The developed system emulates a connected vehicle environment by utilizing a smartphone application to deliver dynamic, speed-based, directional warnings at locations that have been entered into an online database. The application captures the vehicle travel speed and direction from the smartphone's GPS and utilizes geo-fencing technologies to determine when the vehicle is approaching a reduced speed location. The application will generate an onscreen and audible warning when warranted based on the vehicle's travel speed and advisory speed data from the online warning database. While the smartphone application is used for proof of concept, the research team sees great value potential in the online warning database as a way for transportation agencies to enter and maintain reduced speed locations within their jurisdictions, where the data would be made available to navigation systems and vehicle manufacturers via the cloud. With the system in place, it could be utilized for situations other than horizontal curves that require a speed warning, including bumps and cracks due to seasonal changes, temporary maintenance and construction activities (work zones), special events, and approaching controlled intersections.

The project deliverables, in addition to this report, are access to the online warning location database and the smartphone warning application in Android distribution format and the application's source code.

CHAPTER 1: INTRODUCTION

1.1 HORIZONTAL CURVES

Curves represent a transition element in highway geometric design, while vertical curves are changes in the slope of the roadway, horizontal curves are changes in the alignment of the road that are necessary for gradual change in direction when a direct point of intersection is not feasible.

1.1.1 The Problem

Horizontal curves have been shown to be highway segments that require special attention from transportation agencies due to an overall increase in the rate and severity of crashes occurring at these locations. In fact, horizontal curves have a crash rate three times that of other highway segments and account for more than 25% of highway fatal crashes (Albin, et al., 2016).

Horizontal curves occur more frequently on rural two-lane roadways, which is a contributing factor resulting in the fatality rate on rural roads to be more than twice that of urban roadway segments (NHTSA, 2007-2016). Two-lane, two-way roadways, predominant in rural Minnesota, experience an elevated number of roadway departure crashes, resulting in the death of more than 70 people each year, or nearly 20% of annual roadway fatalities in Minnesota. Furthermore, more than 4,000 people are injured in these types of crashes every year. Horizontal curves were identified as a contributing secondary factor in 49% of fatal roadway departure crashes in Minnesota (Leuer, 2015).

1.1.2 Solutions

Transportation agencies have a wide array of countermeasures to mitigate the problem of vehicles entering horizontal curves at speeds that may be considered too fast for safe travel. Some of these countermeasures involve the use of basic treatments from the *Manual on Uniform Traffic Control Devices* (MUTCD) such as centerline and edge line pavement markings; enhanced basic treatments by improving the visibility of devices via an increase in sign size and by placing identical signs on both sides of the roadway; use of reflectors, panels, and chevrons; and rumble strips and other minor roadway improvements such as the elimination of shoulder drop-off and paving and widening shoulders.

The focus of this research is the mitigation method of utilizing dynamic curve speed warning (CSW) systems that only provide a warning when warranted to a vehicle that is approaching the curve at a speed higher than recommended. Dynamic curve speed warning systems consist primarily of two components: a detection component that measures the vehicle speed via inductive loops or a nonintrusive method such as radar detection; and a warning component that activates when warranted and can consist of a static sign with flashing beacons or a dynamic message sign. The system also requires power and communications for operation bringing the cost to roughly $14,000 per warning location (USDOT-ITS JPO, 2009).

Figure 1.1 Examples of horizontal curve warning signs: on the left a static sign, on the right a dynamic curve speed warning sign.

As shown in the literature review chapter, dynamic CSW systems are more effective than static signs at reducing the travel speed of approaching vehicles and reducing the crash rate at the warning location. However, due to their cost, they are typically deployed at locations with historically high crash rates.

1.2 CLOUD-BASED DYNAMIC WARNING SYSTEM

The goal of the system developed in this project is to extend the safety benefit potential of a dynamic CSW system to every reduced speed curve in the transportation network taking dynamic warning onboard the vehicle and removing the infrastructure cost per location associated with traditional dynamic CSW systems. The system consists of two components: an online database of warning locations and a warning application.

The warning database contains the coordinates of reduced speed curves. The database is built as an additional layer within an existing software system, the geographic roadway inventory tool (GRIT) developed by members of the research team at the Upper Great Plains Transportation Institute at North Dakota State University. The warning database is available online and is used by the warning application to determine when and where a warning should be generated.

The warning application is a smartphone application developed on the Android platform. It tracks the speed, location, and direction of travel of the vehicle; crosschecks that information against data within the online warning database; and generates warnings as warranted when a vehicle approaches a location at a speed that may be too high for safe travel.

CHAPTER 2: LITERATURE REVIEW

The research team reviewed a variety of materials related to curve speed warning (CSW) under the following three main areas: information from the Federal Highway Administration (FHWA) on CSW Connected Vehicle applications and pilot deployment; literature articles related to dynamic warning applications utilizing both instrumented vehicles and smart devices; and literature articles on the benefits of dynamic vs static CSW applications. A summary of the literature review is provided below.

2.1 CONCEPT AND CONNECTED VEHICLE APPLICATION

CSW is an application where alerts are provided to the driver who is approaching a curve at a speed that may be too high for safe travel through that curve (FHWA, 2017). Using equipment such as basic radar detection sensors or a combination of multiple types of sensors such as radar and environmental sensors, the infrastructure application component collects available infrastructure and vehicle data. In a Driver Infrastructure Interface (DII) scenario where the vehicles are not equipped, the driver sees the alert via a roadway device. If the vehicle is equipped with a Driver Vehicle Interface (DVI), the available data are processed and the vehicle will display an appropriate advisory message, alert, and/or warning for the driver on the in-vehicle DVI providing the driver of the connected vehicle with a real time warning unique to the driver and the vehicle.

Based on the available data and complexity of the algorithm used to evaluate safe speed thresholds, the message sent to drivers varies. Different operational policies and constraints have been discussed in this document. These systems have been installed in Michigan, Georgia, and Oregon and are operational right now.

Michigan Department of Transportation (DOT) Metro Region anticipates improved motorist safety and a reduction in crashes. In Oregon, the evaluation of the system indicates an effective reduction in the mean speeds of passenger cars and trucks by around 3 mph for the southbound direction and 2 mph for the northbound direction. However, this system has its own disadvantages. For example, even if a driver is traveling at a lower speed than what the roadway signage indicates, due to different conditions such as weather, it may issue a warning to drivers for high speed which may end up with some confusion for the driver (Stephens, Timcho, Young, Klein, & Schroeder, 2012). CSW is an especially useful concept for drivers in unfamiliar surroundings or in adverse weather conditions (Sayer, LeBlanc, Mefford, & Devonshire, 2007).

There are different methods for warning the driver in an instrumented connected vehicle including auditory by use of headrest speakers, haptic using brake pulse, and visual using an interface inside the vehicle with varying degrees of effectiveness (Green, et al., 2008).

2.2 UTILIZING SMART DEVICES (PHONES AND TABLETS)

In a study, researchers utilized a smartphone-based application equipped with Bluetooth Low Energy (BLE) technology and a head-up display. In this system, messages can be wirelessly communicated from

the GPS-equipped smartphone to a receiving unit through BLE technology, and then displayed by head-up display on the vehicle's front windshield. Drivers can receive alerts without looking away from their usual line of sight and the relative accuracy of the model appeared to be high. The authors suggest that this application can be used for other locations such as work zones and highway-rail grade crossings (Qin, Zhang, & Wang, 2015).

In a report on connected commercial vehicles, it is shown that CSW could appear on an iPad that is used as part of the commercial vehicle's instrument panel. When an alert is warranted, a warning can be generated as a caution of the upcoming curve or a warning with audible tones (LeBlanc, Bogard, & Goodsell, 2014).

2.3 SAFETY BENEFITS

A 5% to 7% reduction in crashes was observed in a study in a national demonstration project depending on crash types and direction of travel when the crash occurred (Hallmark, Hawkins, & Smadi, 2015). A speed reduction of 3 mph was recorded at a dynamic curve warning sign on I-5 in Myrtle Creek, OR (Bertini, Monsere, & Nolan, 2006). Average speed reduction of between 1 and 8.8 mph at three low-volume rural highways in Meeker and McLeod counties MN (Knapp & Robinson, 2012). 68% of drivers reduced their speed on 5 dynamic curve warning locations on I-5 in Northern California (Tribbett, McGowen, & Mounce, 2000).

2.4 WARNING ENHANCEMENT: PREDICTION AND VEHICLE ASSISTED ACTIONS

In a summary report for a pilot study that tested warning systems, it was noted that improvements were needed to reduce unwarranted warnings. Further, driver behavior indicated the application of the brakes varied among driver groups and situations (LeBlanc, Buonarosa, Blankespoor, & Sayer, 2009).

In a study by (Machiani, Jahangiri, Balali, & Belt, 2017), a model was suggested to improve CSW system performance through activating the warning using the point of curvature speed instead of approaching speed. The real world connected vehicle dataset used in this study was a part of the Safety Pilot Model Deployment from over 2700 vehicles equipped with connected vehicle technology. The results of the proposed model that considers a driver behavior risky when vehicle approaching speed exceeds the advisory speed, showed an improvement in false alarms for all the monitoring periods.

CHAPTER 3: CLOUD-BASED DYNAMIC WARNING SYSTEM

The Cloud-Based Dynamic Warning system created through this project takes dynamic CSW onboard the vehicle and negates the need for roadside devices traditionally used for the speed detection and warning components of a CSW system. The infrastructure expenditure per site that is required for the deployment of CSW systems limited their deployment to locations with historically high crash rates. Eliminating the need for roadside devices and their cost allows for the safety improvement potential of dynamic CSW to be available at every reduced speed curve in the transportation network.

The system consists of an online database of warning locations and a smartphone application that provides a warning when warranted utilizing the concept of geo-fences to determine when the vehicle enters a warning location.
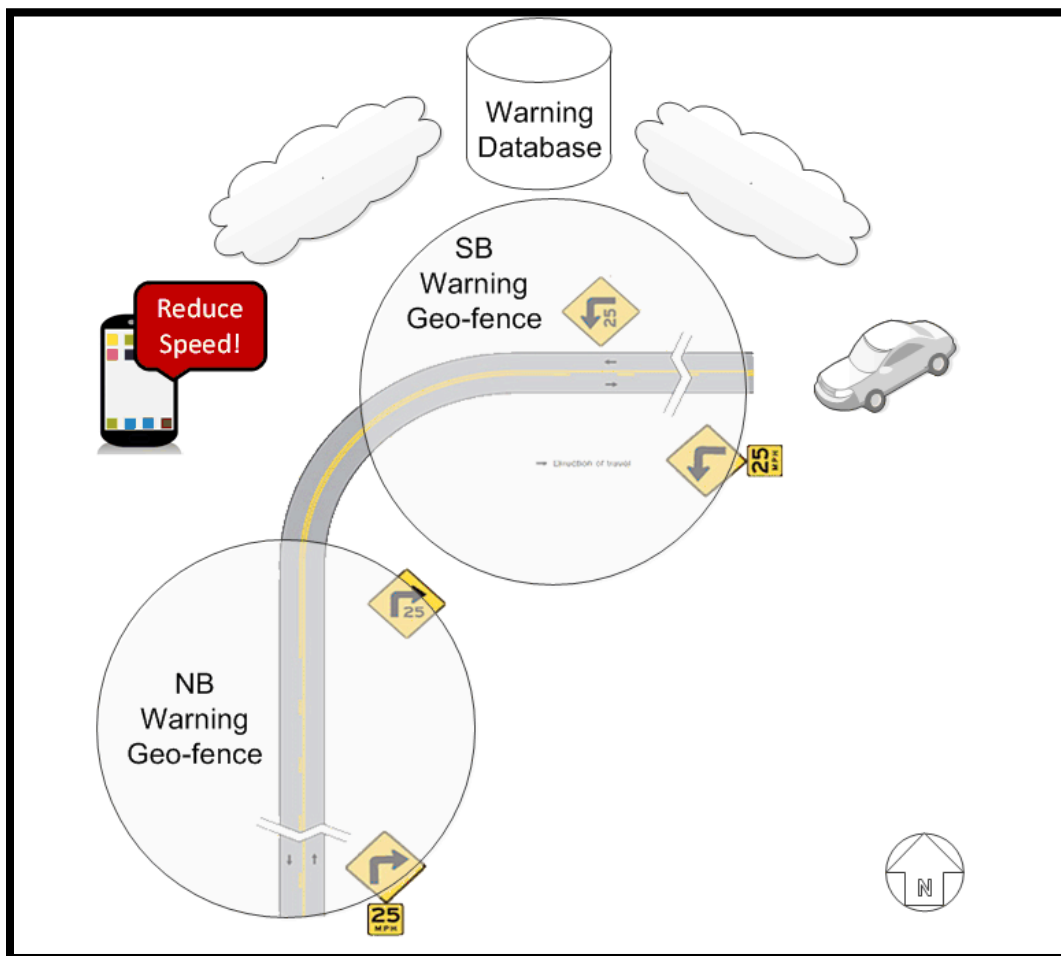

Figure 3.1 System overview.

3.1 ONLINE WARNING DATABASE

The warning location database component of the system satisfies the following objectives:

- Provides transportation agencies with a secure and easy to use method for entering and maintaining warning locations within their jurisdictions;
- Makes the database available online for use in the warning application;
- Creates a process for sharing the warning data with third parties such as vehicle and safety system manufactures, and navigation system developers.

In order to achieve this, the research team utilized a software system already developed by the Upper Great Plains Transportation Institute called the Geographic Roadway Inventory Tool (GRIT). GRIT is a web application with a map and graphical user interface, and a SQL database server backbone that allows agencies to manage an inventory of their transportation assets. Ten Minnesota counties already use GRIT to manage their data within layers for construction history, owner/load limits, minor structures, and construction planning. For the purpose of this project a new GRIT layer was created for curve speed warning.
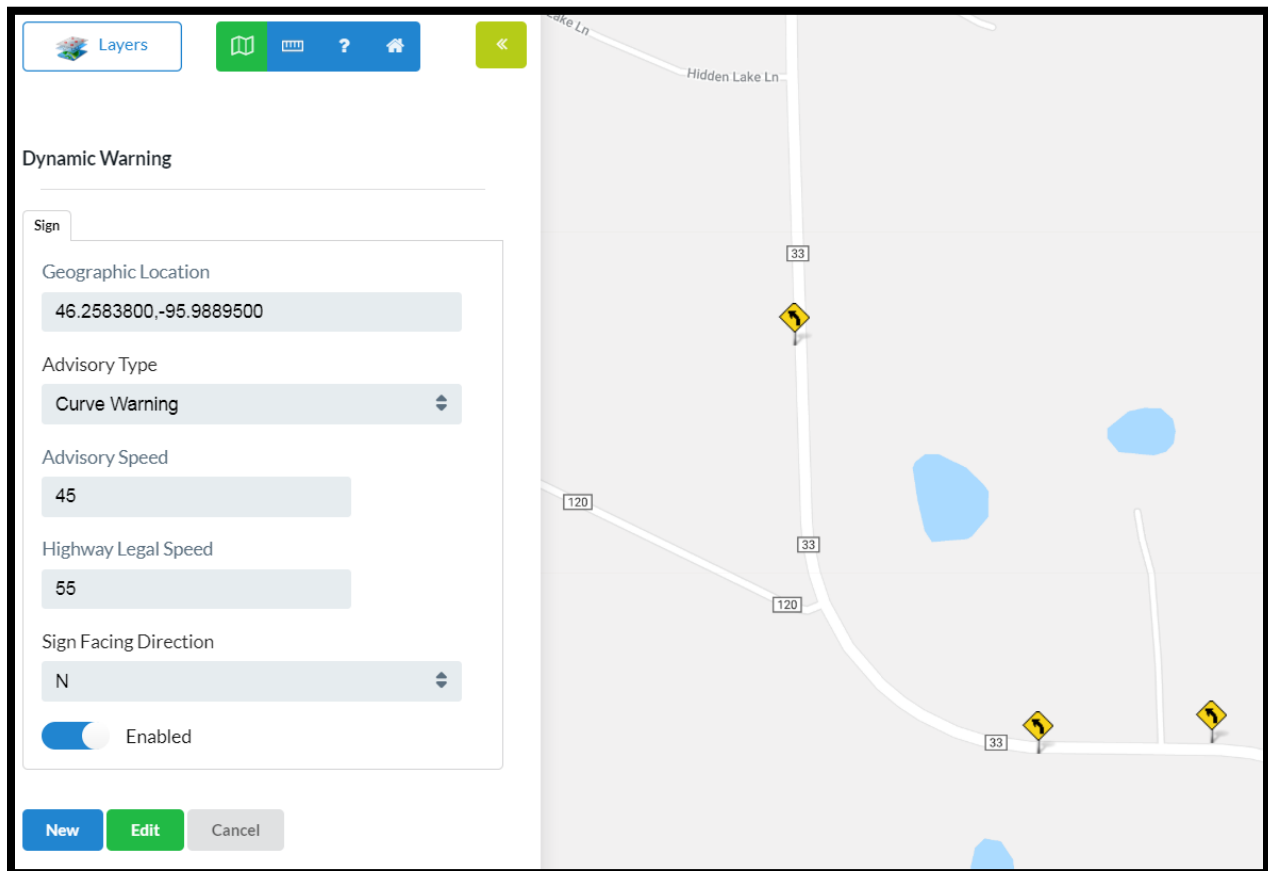

Figure 3.2 Dynamic Warning layer in GRIT.

The warning database contains the following fields:

Geographic Location: the user may enter coordinates for the warning location or select the location on the map and the coordinates will be populated automatically.

Advisory Type: this dropdown field allows the selection of speed advisory types other than curve speed warning. Such advisories may include construction, seasonal speed restrictions, etc.

Advisory Speed: the user enters the reduced speed for the warning location.

Highway Legal Speed: this input is for the regular speed limit for that highway section outside of the warning location.

Sign Facing Direction: the user may select the facing direction for the warning from this dropdown field. The direction options include the four cardinal directions of North, South, East, and West; and the four primary inter-cardinal directions of Northeast, Northwest, Southeast, and Southwest.

Enabled: this checkbox indicates whether this is an activated warning location or not.

The GRIT application can be accessed through this link: http://dotsc.ugpti.ndsu.nodak.edu/grit-app-test/. Warning locations can be viewed by anyone, but in order to add new or edit existing locations a password protected login to the website is required. Both Otter Tail and Pope counties were provided with logins in this project.

3.2 WARNING APPLICATION

To prove the concept that dynamic curve speed warning can be achieved onboard the vehicle without roadside infrastructure, the research team developed an Android smartphone application that utilizes Google Maps API. The application captures the vehicle's location, heading, and speed from the smartphone's global positioning system (GPS) in real-time which are crosschecked against locations from the warning database to determine whether a speed warning is warranted.

At initialization, the warning application pulls warning locations from the online database that are within a 20-mile radius from the current location and creates geo-fences around each point, this process is repeated every 12 minutes. Each geo-fence serves as a virtual boundary surrounding a warning location, this allows the application to track when the vehicle enters a warning area and generate warranted warnings at the appropriate time and location. The warnings are directional in nature based on the vehicle's heading and "sign facing direction" field in the warning database to assure that warnings are generated correctly for the direction of travel.

During development, the warning application underwent iterative parameter refinement and testing to assure that warnings are only generated when warranted, at the appropriate location, and in a timely manner that allows for corrective action to be taken by the driver.

The warning application has two levels for warnings provided to the driver based on their travel speed. The initial warning is a caution for approaching a reduced speed curve that displays the curve's advisory speed along with the vehicle's current speed in a green circle if traveling at or below the advisory speed, or in a yellow circle if exceeding the advisory speed for the curve.


Figure 3.3 Initial warning display for traveling at or below the advisory speed (left) and above the advisory speed (right).

If speed is not reduced, the secondary warning is triggered which displays a message to slow down along with the curve's advisory speed and the vehicle's travel speed in a red circle, the secondary warning also includes an audible warning of three successive beeps.

After initialization, the warning application runs in the background and is not required to be the active screen on the phone to function properly. If there is a different application active on the screen, the warning application will preempt the active application and display warnings when warranted. Furthermore, warnings are still generated even if the phone's screen has timed out and gone into sleep mode.

It is important to note that the warning application was developed solely for proof of concept, the application is not intended to be distributed to the general public. Therefore, the application design and the visual and audible warnings were put in place for the research team to be able to test and

demonstrate the system effectively, particularly whether the phone's GPS would be accurate enough for warnings to be generated in a timely manner. As such, human factors were not a consideration in the design of the application, the warning messages, or the testing process.
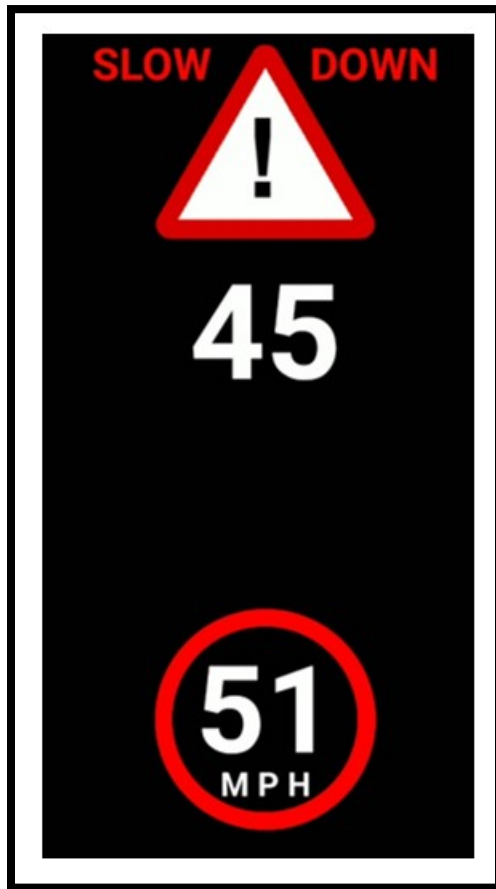
Figure 3.4 Secondary warning.

The warning application is part of the project deliverables and is provided in Android Package (APK) distribution format which allows the application to be installed on Android phones. The counties were provided a copy of the APK file for field testing. Additionally, the warning application source code is also provided as a project deliverable.

CHAPTER 4: SYSTEM TESTING

Two participating Minnesota counties, Otter Tail and Pope, entered their reduced speed curves into the warning database utilizing the GRIT interface and that data were used in system testing. The field testing was conducted under the following parameters:

- Condition 1: Approaching the curve at a speed that is at or below the posted advisory speed – expected outcome: initial warning for approaching a reduced speed curve is displayed with travel speed in a green circle.
- Condition 2: Approaching the curve at a speed that exceeds the posted advisory speed then slowing down to at or below the advisory speed – expected outcome: initial warning for approaching a reduced speed curve is displayed with travel speed in a yellow circle, changing to a green circle after speed reduction occurs.
- Condition 3: Approaching the curve at a speed that exceeds the posted advisory speed limit and not slowing down through the curve – expected outcome: secondary warning is displayed and the audible warning of three beeps is played in its entirety.
- Condition 4: Slowing down to or below the advisory speed after the secondary warning was triggered – expected outcome: revert back to initial warning and stop playing the audible warning.

4.2 FIELD TESTING

The initial field test was conducted on 10/15/2018 on Otter Tail County Road 33 which includes a segment with 15 reduced speed curves. The team drove the segment four times in each direction resulting in 100% accuracy for the warning application behaving in the expected manner based on the test conditions outlined above.

The second field test was conducted on 11/29/2018 in Pope County with participation of county engineer Brian Giese and MnDOT Research videographer Charles Ombati. The team drove on a number of different Pope County highways and through a large number of reduced speed curves while observing the warning application's behavior under the same conditions outlined above. The warning application behaved as expected with the exception of not providing a warning at one particular curve. After concluding the test, the research team examined the record for that curve in the warning database and found that the "sign facing direction" field was entered as South while it should have been East based on the roadway geometry.
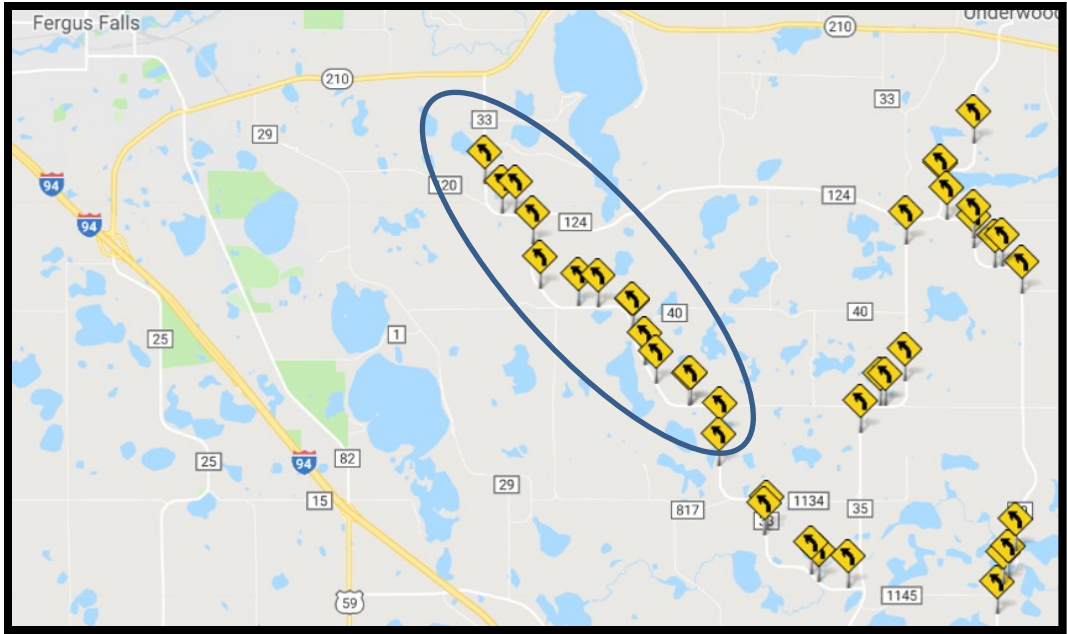
Figure 4.1 A portion of reduced-speed curves in Otter Tail County with County Road 33 test segment highlighted.
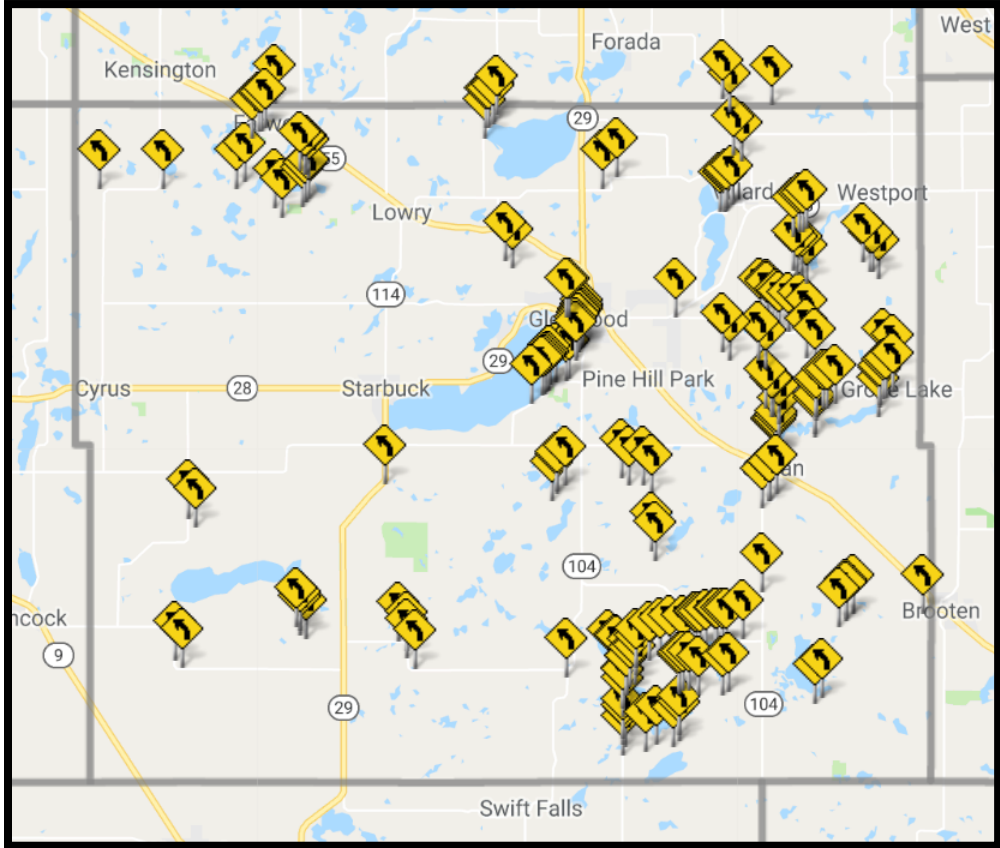

Figure 4.2 Curve speed warning locations in Pope County.

CHAPTER 5: BENEFITS AND CONCLUSIONS

5.1 RESEARCH BENEFITS

The benefits of the Cloud-Based Dynamic Warning system are twofold: improved safety and cost reduction over traditional dynamic CSW systems.

5.1.1 Safety

The safety benefits come in the form of reduction in travel speed when a driver is traversing a horizontal curve. Existing in-car safety features such as adaptive cruise control and lane departure warning systems are fast becoming standard features for many manufacturers. While these features create many safety improvements, there are some safety concerns with the inability to identify and adjust to hazards such as reduced speed curves, bumps, and construction and maintenance activities. The online warning database component of this system could provide a potential basis for transportation agencies to provide this information to vehicle and safety systems manufacturers. For evaluating the potential safety benefits, the research team relies on existing literature regarding the benefits of dynamic CSW systems. These benefits are typically expressed in the amount of reduction in travel speed when utilizing dynamic vs. static warning or by the reduction of the percentage of vehicles traveling at a certain threshold above posted or advisory speed, or by performing a crash analysis on the roadway comparing crash rates before and after a dynamic system is installed.

We hypothesize that the safety benefits of the Cloud-Based Dynamic Warning system will be similar to levels achieved in traditional roadside dynamic warning systems. The following is a summary of safety benefits of dynamic speed warning systems from various literature publications.

Crash reduction: 5% to 7% reduction in crashes depending on crash types and direction of travel when the crash occurred (Hallmark, Hawkins, & Smadi, 2015).

Speed reduction: a speed reduction of 3 mph at a dynamic curve warning sign on I-5 in Myrtle Creek, OR (Bertini, Monsere, & Nolan, 2006).

Speed reduction: average speed reduction of between 1 and 8.8 mph at three low-volume rural highways in Meeker and McLeod counties, MN (Knapp & Robinson, 2012).

Speed reduction: 68% of drivers reduced their speed on 5 dynamic curve warning locations on I-5 in Northern California (Tribbett, McGowen, & Mounce, 2000).

5.1.2 Cost Saving

Roadside dynamic warning systems consist of a detection component to capture vehicle speeds and a warning component to relay a message to drivers. The detection component may include technologies such as in-pavement inductive loops, or non-intrusive applications such as radar and cameras. The warning component may be in the form of a dynamic message sign or a static sign with flashing beacons.

To operate these devices, roadside warning systems require power and communication at the warning location. The cost is roughly $14,000 per warning location (USDOT-ITS JPO, 2009).

Whereas existing dynamic warning systems rely on roadside infrastructure and thus are only deployed at high crash locations (typically greater than or equal to 10 crashes in a 24-month period and greater than or equal to 7 crashes in a 12-month period), the proposed system eliminates the need for any roadside devices and takes the warning system entirely onboard the vehicle, resulting in cost savings and the advantage of spreading the potential safety benefits systemwide to all reduced speed curves regardless of crash history. A new warning location in the proposed system requires only an additional entry into the warning location database.

To express the cost savings benefit, we perform a break-even calculation. The research project cost at under $80,000 would fund 6 traditional dynamic CSW sites. The cost to maintain the warning application software and the online warning location database is offset by the cost to maintain the infrastructure of traditional dynamic CSW systems. Considering that Otter Tail County roadways have over 400 reduced speed curves, the potential cost-savings benefit is great.

5.2 CONCLUSIONS

The research team developed successfully a system for providing curve speed warnings onboard the vehicle without utilizing roadside devices and infrastructure. The Cloud-Based Dynamic Warning system consists of a smartphone warning application and an online warning database managed through a web application.

The purpose of the smartphone warning application is for proof of concept and was utilized for testing the system; the application will not be available to the general public. However, the online warning location database is potentially valuable for implementing an in-vehicle CSW system. For managing the warning locations, the team utilized GRIT and created a layer for the Cloud-Based Dynamic Warning system. Both Otter Tail and Pope counties entered their reduced speed curves into the system and that data was utilized for field testing. For any future implementation, the participating transportation agencies would be responsible for using the GRIT tool to populate the database with the desired warning locations within their jurisdiction.

CSW is a planned vehicle to infrastructure (V2I) connected vehicle (CV) application. In a CV environment, the vehicle would take the role of warning a driver who is traversing a curve at an unsafe speed through different measures such as audible warnings, or haptic feedback through vibrating the seat or steering wheel. In a connected and autonomous vehicle (CAV) environment, it is perceived that the vehicle would also take corrective actions automatically, such as slowing down and steering assist to keep the vehicle on the road, which could greatly improve the safety potential of systems such as CSW. For these safety systems to function correctly, it is important that transportation agencies are able to communicate their needs and maintain an inventory of warning locations as they know their roadways best. The GRIT Dynamic Warning layer can be the tool used for that purpose and for sharing the data with vehicle and safety system manufacturers and other interested third parties.

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APPENDIX A: INDUSTRY CONTACT LETTER

For part of the project's Task 2: Literature Review and Automobile Manufacturer Contact, the research team contacted members of the industry for possible interest in the project and in the online warning database in particular. The following entities were contacted:

- Alliance of Automobile Manufacturers. The Auto Alliance is an advocacy group for the auto industry representing 70% of all car and light trucks in the US including the BMW Group, Fiat Chrysler Automobiles, Ford Motor Company, General Motors Company, Jaguar Land Rover, Mazda, Mercedes-Benz USA, Mitsubishi Motors, Porsche, Toyota, Volkswagen Group of America and Volvo Car USA.
- Honda – Ohio State University Automotive Proving Grounds
- HERE Maps
- Google
- Clemson University International Center for Automotive Research
- Easy Mile Driverless Busses

The contact letter is provided in the following page.

Upper Great Plains Transportation Institute – Advanced Traffic Analysis Center
North Dakota State University Dept 2880
P.O. Box 6050
Fargo, ND 58108-6050

Dear Automobile and Navigation System Manufacturer:

I am writing to inform you of a research project for a vehicle **Cloud Based Dynamic Warning System** conducted by our center and sponsored by the Minnesota Local Road Research Board that could be of benefit to your vehicle/navigation system safety applications.

Over 25% of roadway fatal crashes are associated with a horizontal curve. Research shows that dynamic curve speed warning systems are more effective than static signs in reducing vehicle speeds while traversing curves. Due to cost and operational limitations, dynamic warning systems deployment is limited to locations with historically high crash numbers. The goal of this research project is to expand the safety benefits of dynamic curve speed warning (CSW) to virtually all potentially dangerous curves within a jurisdiction by providing on-board dynamic warning to vehicles entering a horizontal curve at speeds that may be too high for safe travel. Further, safety benefits can also be achieved at any roadway segment requiring a reduction in travel speed for additional circumstances such as seasonal factors, special events, and incidents. The research team will be developing a software tool for local jurisdictions to enter and edit their reduced speed warning locations in an online database that can be provided to automobile and navigation system manufacturers for use in applications such as Adaptive Cruise Control and Lane Departure Warning.

The online warning database will at a minimum contain the following fields: coordinates of warning location; direction of travel the warning is meant for; and the advisory speed for that warning location.

Please let us know if this project is of interest to you or if you would like to be involved on discussions regarding the cloud based database and its integration potential with industry.

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APPENDIX B: NATIONAL RURAL ITS CONFERENCE 2018 PRESENTATION

For the project's Task 8: Out-of-State Conference Travel, the research team presented the Cloud Based Dynamic Warning System at the National Rural ITS Conference held October 21-24 2018 in Fort McDowell, AZ. The presentation was in a session titled: *Talking to Each Other: Connected Vehicle and Infrastructure Applications*. The slides from the presentation are provided below.

About UGPTI

- The Upper Great Plains Transportation Institute is a research and education center at North Dakota State University.
- Mission: Providing innovative transportation research, education, and outreach that promote the safe and efficient movement of people and goods.
- The institute has centers working on various transportation areas including traffic; transit; safety and security; and freight and logistics.

www.ugpti.org

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Project Sponsor

"*The mission of the LRRB is to serve local road practitioners through the development of new initiatives, the acquisition and application of new knowledge, and the exploration and implementation of new technologies.*"

Partners: *MnDOT, Otter Tail and Pope counties, MN*

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Synopsis

- Emulate a connected vehicle environment by utilizing a smartphone application to deliver dynamic, speed-based, directional warnings at locations in an online database

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The Problem

- Vehicles entering horizontal curves at speeds that may be too high for safe travel
- >25% of fatal crashes
- Crash rate 3X of other highway segments
- Vehicles with features such as adaptive cruise control and access to curve warnings
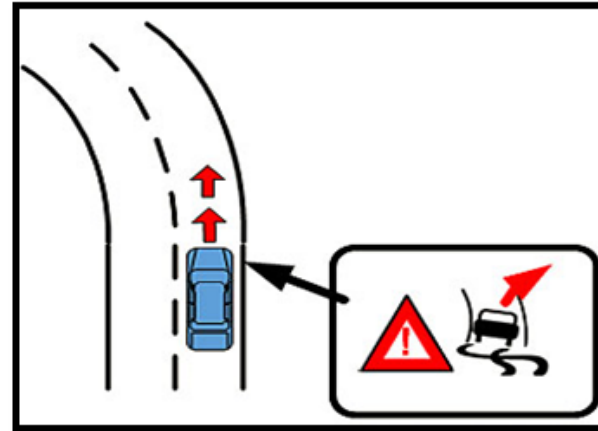
Existing Solutions

- Static Warning Signs
- Dynamic warning signs

Dynamic Systems

- Consist of a detection component, and a warning component, in addition to power and communications
- Cost: roughly $14,000
- Limited to high-crash locations
  - ≥10 crashes in a 24 month period and ≥ 7 crashes in a 12 month period
  - Research: dynamic systems are more effective at reducing vehicle speeds

Goals

- Expand safety improvement potential of dynamic CSW system-wide to all reduced speed curves

- No infrastructure investment

- Provide cloud database maintained by agency in charge of roadway

- Warning database flexibility for additional warning situations

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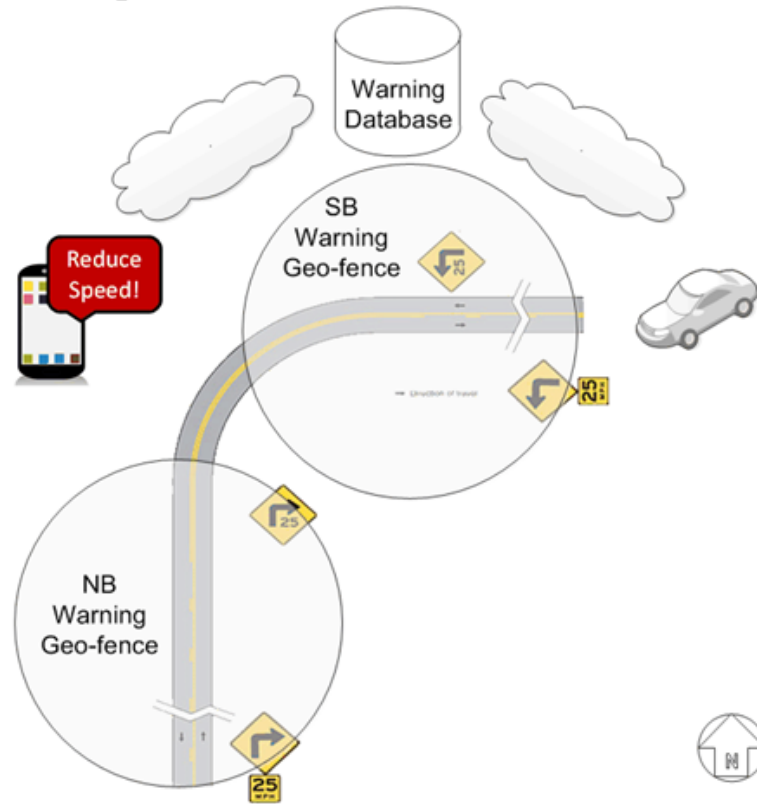
Warning Database

- Managed through an online tool created at UGPTI: Geographic Roadway Inventory Tool (GRIT)
- GRIT is a web application that allows agencies to manage an inventory of their transportation assets
- A layer within the application was created for managing speed warning locations

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Warning Locations – Otter Tail CO
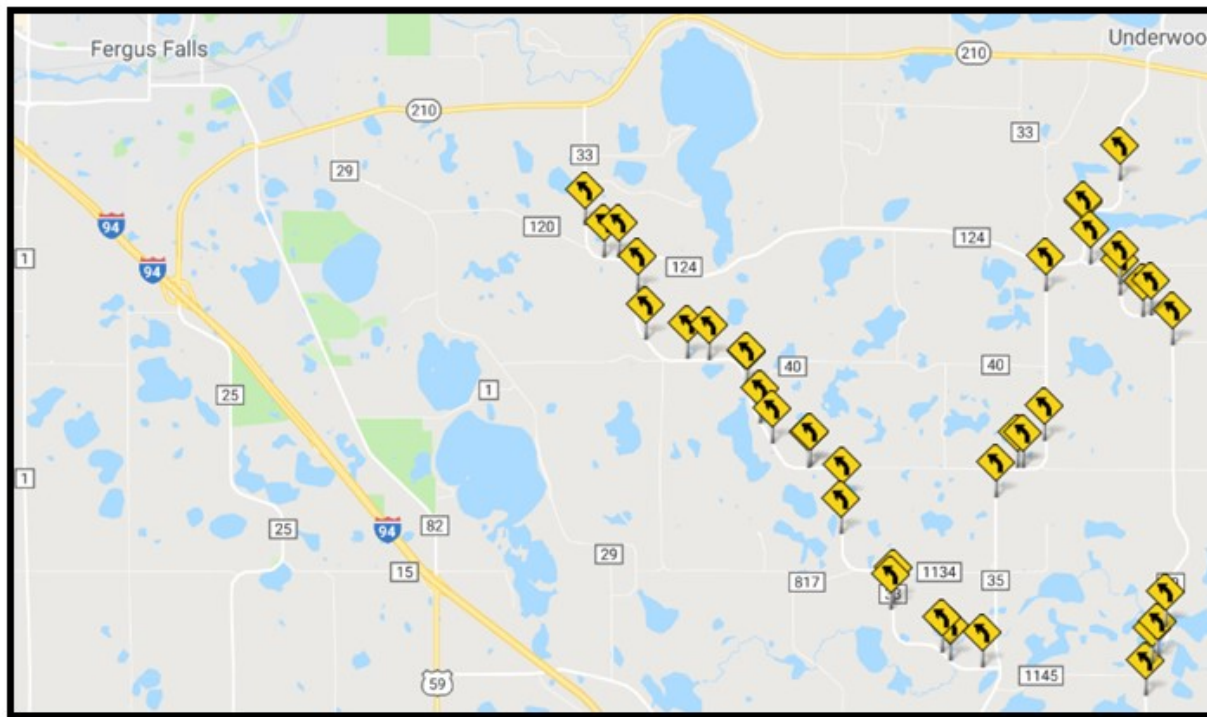
Warning Application

- Android smartphone app utilizing Google Maps API

- The app captures location, heading, and speed data from the phone (GPS) which are checked against the warning database

- The app pulls warning locations within a 20 mile radius with a 15 minute refresh to handle large volumes of data

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Warning Application

- The app applies geo-fencing technologies to determine when a vehicle enters a warning location
- The warnings are directional based on sign facing
- Warning levels:
  - The initial warning is a caution for approaching a curve
  - If speed is not reduced, an audible warning is applied

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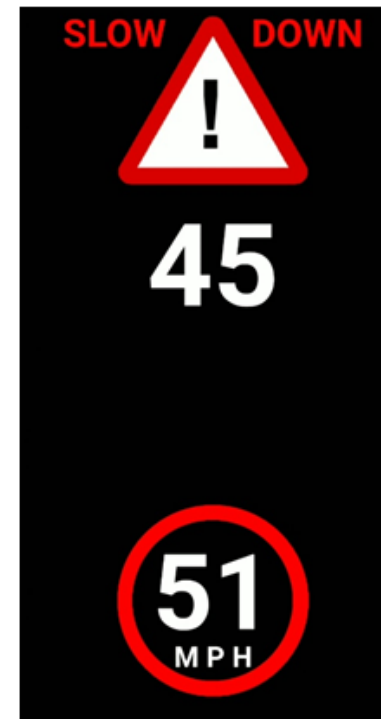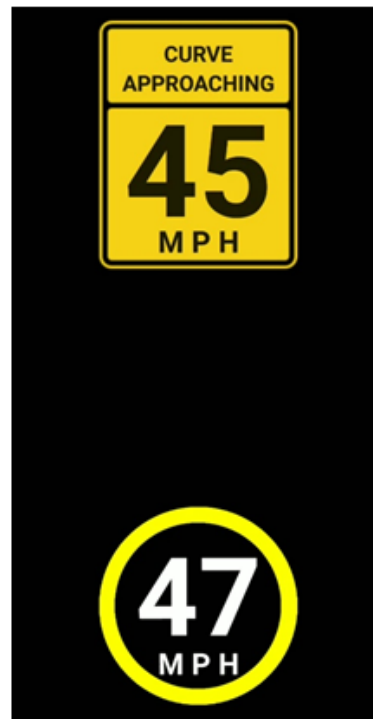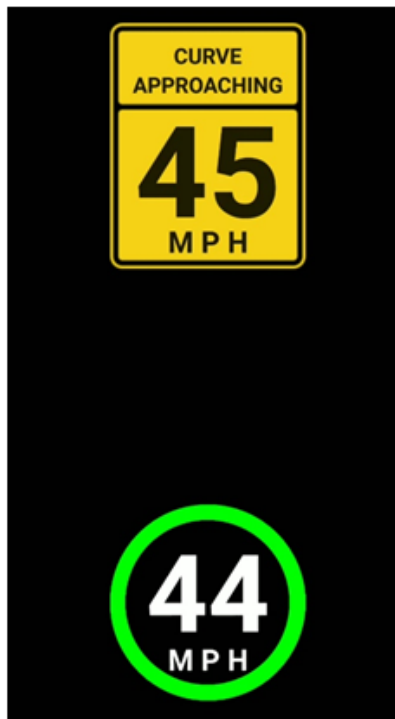
Testing

- Otter Tail County Road 33 – 15 CSW signs
- Drove 4 times each direction at varying speeds
- Results:
  - 100% accuracy picking up CSW sign
  - 100% accuracy in providing the audible warning only when warranted

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Wrap Up

- The warning app is a demo and proof of concept
  - CSW is a V2I CV application
  - Low hanging fruit/early implementation
- Value in the warning database
  - An easy way for agencies to manage data
  - Make data available to navigation systems and vehicle manufacturers

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Wrap Up

- System can be used for other situations requiring reduced travel speed:
  - Bumps and cracks (seasonal changes)
  - Maintenance and construction activities
  - Special events
  - Approaching a STOP sign
- Acknowledgements
  - Megan Bouret, IT Manager
  - Mostofa Ahsan, Student Programmer

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Questions?

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