Wavetronix® Smart Sensor Matrix™

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STATE OF VERMONT
AGENCY OF TRANSPORTATION

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16. Abstract

According to the Federal Highway Administration (FHWA), negotiating intersections is one of the most complex and demanding tasks that a driver faces. Data shows that in 2007, approximately 2.4 million intersection-related crashes occurred, representing 40 percent of all reported crashes. Of the 37,435 total fatalities, 8,061 occurred at intersections, equaling 21.5 percent of total deaths (*1*). Many transportation agencies have developed solutions such as regulatory signs and electronic traffic control signals in an effort to reduce these alarming totals and decrease driver confusion.

The Wavetronix® Smart Sensor Matrix™, a radar stop bar detection system was installed at the intersection of VT 116 and Shelburne Falls Road/CVU Road located at mile marker 5.46 in the town of Hinesburg on June 15 and 16 of 2011. The purpose of this study is to evaluate the overall effectiveness of the proprietary Wavetronix SmartSensor Matrix™ system during varying weather and traffic stream conditions. Site visits were made and data was collected from before and after the installation in an effort to compare crash data and safety conditions. The following report summarizes the construction, performance and observations, and crash data analysis of the intersection.

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ABSTRACT

According to the Federal Highway Administration (FHWA) negotiating intersections is one of the most complex and demanding tasks that a driver faces. Data shows that in 2007, approximately 2.4 million intersection-related crashes occurred, representing 40 percent of all reported crashes. Of the 37,435 total fatalities, 8,061 occurred at intersections, equaling 21.5 percent of total deaths (*1*). Many transportation agencies have developed solutions such as regulatory signs and electronic traffic control signals in an effort to reduce these alarming totals and decrease driver confusion.

The Wavetronix® Smart Sensor Matrix™, a radar stop bar detection system was installed at the intersection of VT 116 and Shelburne Falls Road/CVU Road located at mile marker 5.46 in the town of Hinesburg on June 15th and 16th of 2011. The purpose of this study is to evaluate the overall effectiveness of the proprietary Wavetronix SmartSensor Matrix™ system during varying weather and traffic stream conditions. Site visits were conducted before and after the installation in an effort to compare traffic flow and overall effectiveness of the device. The following report summarizes the construction, performance, field observations, and crash data analysis of the intersection.

VTRANS EXECUTIVE SUMMARY

The installation of a non-induction remote sensing device for actuation of traffic signals is a promising technology. VTrans installed a radar-based sensing system on VT 116 to assess the performance of a non-visible light-based technique to identify vehicles in a queue for the light.

The importance of using a remote sensed system was demonstrated at this particular location because of damage to previously installed loop detectors. The existing pavement surface and structural characteristics of the pavement shifted repeatedly during the year as a function of seasonal and load-induced changes. The changes were so dramatic that the loop detector failed numerous times. Replacement of the loop detector causes traffic interruption and worker exposure to potential traffic accidents.

The proper actuation of the traffic signal system is essential both to the capacity and safety of the intersection. The Wavetronix® Smart Sensor Matrix™ traffic sensing system performed well in this trial. During the period of assessment the system continued to operate well with high reliability. There was a one period when the system failed to properly sense traffic in the intersection. The event was concurrent with a heavy storm event that included reported white-outs. Virtually all electro-magnetic sensing systems have this limitation whether they are radar or visible light based.

The use of the Wavetronix® Smart Sensor Matrix™ system worked very effectively as interim measure to improve intersection performance until the intersection can be rebuilt to eliminate the pavement distortion and risk of loop detector failure. The Wavetronix® Smart Sensor Matrix™ system may pose additional benefit if it can be reused after removal from this location. The system is well suited to existing intersections that have repeated failure of loop detection systems.

INTRODUCTION

In accordance with the 2009 Manual on Uniform Traffic Control Devices (MUTCD), Section 4B.03, Advantages and Disadvantages of Traffic Control Signals, "*When properly used, traffic control signals (TCS) are valuable devices for the control of vehicular and pedestrian traffic. They assign the right-of-way to the various traffic movements and thereby profoundly influence traffic flow*" (*2*). The MUTCD further notes that properly designed and well maintained TCS will provide the following advantages:

- Orderly traffic movement
- Reduce crash frequency and severity
- Provide continuous traffic flow along a route
- Interrupt heavy traffic volumes at specific intervals to allow other traffic including pedestrians to cross the roadway

The MUTCD notes that if TCS are not properly placed or maintained then they can result in (*2*):

- Excessive delay
- Excessive disobedience of the signal indications
- Increased use of less adequate routes as road users attempt to avoid TCS
- Significant increases in the frequency of collisions

Capacity is the maximum rate at which vehicles can pass through a given point in an hour under prevailing conditions; it is often estimated based on assumed values for saturation flow. Capacity accounts for roadway conditions such as the number and width of lanes, grades, and lane use allocations, as well as signalized conditions. The volume-to-capacity ratio, also referred to as degree of saturation, represents the sufficiency of an intersection to accommodate the vehicular demand. A volume-to-capacity ratio less than 0.85 generally indicate that adequate capacity is available and vehicles are not expected to experience significant queues and delays. As the volume-to-capacity ratio approaches 1.0, traffic may become unstable, and delay and queuing conditions may occur. Once the demand exceeds the capacity (a volume-to-capacity ratio greater than 1.0), traffic flow is unstable and excessive delay and queuing is expected (*3*).

Delay is the additional travel time experienced by a driver, passenger, or pedestrian. The primary factors that affect control delay are lane group volume, lane group capacity, cycle length, and effective green time. Factors are provided that account for various conditions and elements, including signal controller type, upstream metering, and delay and queue effects from oversaturated conditions (*3*).

An important element of developing an appropriate traffic profile is distinguishing between traffic demand and traffic volume. For an intersection, traffic demand represents the arrival pattern of vehicles, while traffic volume is generally measured based on vehicles' departure rate. For the case of overcapacity or constrained situations, the traffic volume may not reflect the true demand on an intersection (*3*).

The intention of TCS is to improve traffic flow and minimize crashes at intersections, common driver errors at these locations still occur. Some of the most common are underestimating the time it takes to reach the intersection or smooth stop and whether or not they have time to clear the intersection when approaching a yellow signal indication (*1*). Modeling driver behavior and excursions that are created by driver frustration are beyond the scope of this research. TCS that have high reliability and continuous availability contribute to reduction in excursions. Different technologies have been employed to increase safety at signalized intersections. A technology, developed by Wavetronix, named "SmartSensor Matrix™" is a radar stop bar presence detector. The system uses frequency modulated continuous wave (FMCW) radar to detect and report vehicle presence in as many as 10 lanes simultaneously. Measures of traffic demand were not measured or projected as a function of the TCS improvement. Future assessment of these parameters may help define deployment strategies for improved traffic sensing techniques across the state.

Vermont Agency of Transportation (VTrans) installed one Wavetronix SmartSensor Matrix™ system at an existing intersection located along VT Route 116 in Hinesburg, VT. The purpose of this study was to evaluate the overall effectiveness of the proprietary Wavetronix SmartSensor Matrix™ system during varying weather and traffic stream conditions.

PROJECT LOCATION SUMMARY

The Wavetronix SmartSensor Matrix™ was installed at an existing span wire intersection located at mile marker 5.46 along Vermont Route 116 and Town Highways 1 and 7 in the town of Hinesburg, VT as part of the Hinesburg-Richmond improvement project, STPG SGNL (38). The average annual daily traffic (AADT) at this intersection during the evaluation period was 8,500. This location was selected due to the demand at the intersection and frequent signal repairs due to broken loop detectors as a result of poor pavement conditions.

MATERIAL DESCRIPTION

According to product literature, the SmartSensor Matrix™ system is comprised of four radar detection units. Ideally they would be installed in two corners of an intersection to allow for 90º field of view so that when vehicles enter the user-defined zones the controller will detect their presence. Each detection box measures 13.2 in. x 10.6 in. x 3.3 in., weighs 4.2 lbs, and is resistant to corrosion, fungus, moisture deterioration, and ultraviolet rays. Based on manufacturing techniques, the system is considered to be extremely low maintenance. Battery replacement, recalibration, cleaning, and readjustments are not necessary. The purpose of the system is to detect vehicles and extend the green light if the system detects the speed at which a vehicle is travelling would cause a conflict if they were to stop abruptly. This overhead system is also not susceptible to damage induced by frost heaves, rutting, and other pavement structure deformations as is the case for standard loop detection systems (*4*). The device is shown in Figure 1 and Figure 2 below.

Figure 1: Traffic facing side of sensor.

Figure 2: Pole facing side of sensor.

CONSTRUCTION

The system was installed on June 15 and June 16, 2011. Research personnel were onsite to document the installation.

Cabinet

Because the existing components within the controller cabinet are typically positioned close to each other, the existing equipment was arranged and modified so the new components could fit into the controller cabinet. This included drilling out new and old hardware and remounting them to keep things organized within the controller cabinet. The control box is shown in Figure 3 below.

Sensor Anchoring

The brackets to attach the sensors were mounted on the utility poles. Each bracket was mounted at least 17 feet up the pole to avoid the power lines in place. Two brackets were mounted to each pole and were secured by two metal bands, one tightened on the bottom and one on the top. Two electrical boxes were mounted next, one over each bracket. These were also secured with metal bands. The brackets and electrical boxes are shown in Figure 4 and Figure 5 below.

Figure 3: Control box.

Figure 4: Mounting brackets.

Figure 5: Mounting brackets and electrical boxes.

The sensors were then anchored on each mount. Each sensor is responsible for regulating a lane so they must be properly positioned to the correct lane. This is shown in Figure 6, Figure 7 and Figure 8.

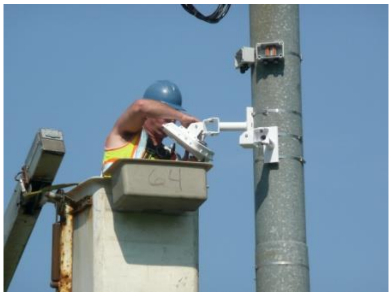

Figure 6: Anchoring sensor.

Figure 7: Positioning sensor.

Figure 8: Sensors after positioning.

Wire Installation

All wiring for the system was fed through the main traffic pole, and connected to the controller cabinet. The length of the wire stretching across the intersection was determined. Once measured, the wire was stretched across the intersection on the ground from a spool and was then raised and fixed to the correct positions. Once everything was wired, a programmer prepared the controller cabinet. The wire installation is shown in Figure 9, Figure 10 and Figure 11.

Figure 9: Measuring wire.

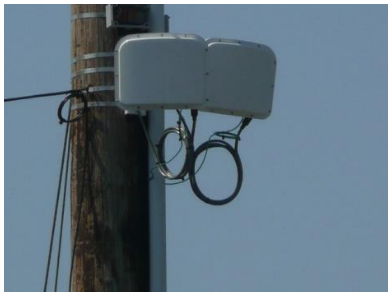

Figure 10: Connecting wire to sensor.

Figure 11: Running the wire across intersection.

PERFORMANCE AND OBSERVATIONS

The site was visited in both dry and wet conditions. The system and control box was checked and the system appeared to be operating properly. Since this installation there have been two more installations of the Wavetronix® Stop Bar Detection system in Vermont. One is located at the intersection of US Route 7 and Bostwick Road in Shelburne and the other is at the intersection of VT 104 and St. Albans State Highway off from Interstate 89 Exit 19 in St. Albans. There were two reported incidents where the system failed due to the amount of wind and snow causing temporary white out conditions, leading to the radar device losing track of the moving vehicles through the intersection, effectively maximizing green cycle time. The first incident occurred at the St. Albans location in the winter months of 2011. The second was at the Hinesburg location in December 2014. For both instances a signal technician was dispatched to the sites and the signals were reset and restored to proper working conditions.

On December 18th, 2014, research personnel traveled to the intersection site to evaluate and observe the function of the Wavetronix® system while traffic approached the intersection. The control box was monitored during traffic flow to ensure the system hardware was working properly. No errors were reported during the final visit. Figure 12, Figure 13, Figure 14 and Figure 15 capture the system hardware at the time of this visit. Through approximately one hour of observation of the midday traffic stream, no issues were noted, as the system appeared to allow appropriate timings for approaching and stopping vehicles. The observations were consistent with the lack of complaints on the system.

Figure 12: Intersection traffic and lights.

Figure 13: Traffic sensors on pole.

CRASH DATA ANALYSIS

The function of a traffic light signal is to reduce the risk of accidents where roads meet and cross each other. FHWA states that the different approach and crossing movements by motorists, bicyclists and pedestrians make at-grade intersections one of the most complex traffic situations that people encounter. Intersections represent a disproportionate share of traffic safety issues and are a national, state and local priority. Crashes can occur at intersections for several reasons and can be categorized as angle (broadside) crashes, rear end crashes, sideswipes, single vehicle accidents, head on crashes, and other (*1*).

Figure 14: Control box in the winter.

Figure 15: Inside of the control box.

For the purpose of this analysis, VTrans 2000-2014 crash data was utilized to perform a cross sectional analysis of the VT 116 and Shelburne Falls Road/CVU Road intersection prior to and following the installation of the Wavetronix® Smart Sensor Matrix™. Various potential explanatory variables for each crash including weather conditions, time of day, time of year, type of crash, and reason for each crash was examined to determine any changes in the number of crashes, injuries and fatalities before and after the Wavetronix® system installation.

A total of 34 crashes were reported at the intersection of VT 116 and Shelburne Falls Road prior to the installation of the Wavetronix® system from January 1, 2000-June 14, 2011 averaging 2.83 crashes annually. Of the 34 crashes, there were 18 injuries but no fatalities reported. Since the installation 17 crashes resulting in 3 injuries and no fatalities have been reported, averaging 4.25 crashes per year. The small crash totals make it difficult to assess the effectiveness of the detection system with regards to safety; single incidents are skewing the dataset resulting in no statistical significance. A longer timeframe of crash data analysis should be considered to determine if the number of crashes is reduced at this location. It should also be noted that although crashes do not appear to have been reduced at this location, no public concerns have been raised or reported signifying that the device increased or decreased accessibility of the intersection. Table 1 below summarizes the annual number of crashes, injuries, and fatalities at the traffic intersection of VT 116 and Shelburne Falls Road in Hinesburg. Notice in Table 1, that there is a dramatic reduction in annual injury rate reported. It is beyond the scope of this research to assign causal factors to the improvement. As such time dependency or weather dependency of events has not been assessed.

Table 1: Totals and Averages of the Number of Crashes, Injures, and Fatalities per Year

Year	# of Crashes	# of Injuries	# of Fatalities
Before			
2000	2	3	0
2001	5	6	0
2002	2	0	0
2003	2	1	0
2004	4	0	0
2005	2	2	0
2006	2	0	0
2007	6	5	0
2008	3	0	0
2009	2	0	0
2010	3	0	0
2011	1	1	0
TOTALS	**34**	**18**	**0**
Avg. Per Year	**2.83**	**1.50**	**0.00**
After			
2011	2	1	0
2012	3	0	0
2013	5	1	0
2014	7	1	0
TOTALS	**17**	**3**	**0**
Avg. Per Year	**4.25**	**0.75**	**0.00**

SUMMARY AND RECOMMENDATIONS

The experimental SmartSensor Matrix™ system was monitored from installation in June 2011 through December 2014. Site visits were made bi-annually during the evaluation period.

Crash data before and after the installation was analyzed with particular attention to the type and cause of crash and time of day, however due to the limited number of crashes, the dataset is not statistically significant. A longer timeframe of crash data analysis should be considered to determine if crashes were reduced at this location statistically.

Since this installation there have been two more installations of the Wavetronix® Stop Bar Detection system in Vermont. Out of the three installations, two reports of system failures have occurred, once in St. Albans and once in Hinesburg. In both failures there were white-out conditions which then caused the system to lose track of traffic and shut down. VTrans supports the use of sophisticated vehicle stop bar detection. Due to the successes noted since installation, a construction specification for use on new intersection projects along with signal equipment upgrade projects that incorporates three different types of detection technology, the Wavetronix® Smart Sensor Matrix™ being one of those has been developed and enacted. Selection of one of these detection systems is dependent by contractor preference and is usually based on vendor pricing. Installations to date have shown little maintenance issues and at this time no evidence has been reported suggesting that one system is better or worse than the other two systems approved for use and the systems at this time should be considered equal.

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Prepared By: Wendy Kipp
Date: 12-22-2010

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH SECTION

WORK PLAN FOR RESEARCH INVESTIGATION
Wavetronix® SmartSensor Matrix™
Radar Stop Bar Detection
Work Plan No. WP 2011-2

OBJECTIVE OF STUDY:

According to the Federal Highway Administration (FHWA) negotiating intersections is one of the most complex and demanding tasks that a driver faces. Data shows that in 2007, approximately 2.4 million intersection-related crashes occurred, representing 40 percent of all reported crashes. Of the 37,435 total fatalities, 8,061 occurred at intersections, equaling 21.5 percent of total deaths (*1*). Many transportation agencies have developed solutions such as regulatory signs and electronic traffic control signals in an effort to reduce these alarming totals and decrease driver confusion.

In accordance with the 2009 Manual on Uniform Traffic Control Devices (MUTCD), Section 4B.03, Advantages and Disadvantages of Traffic Control Signals, "When properly used, traffic control signals (TCS) are valuable devices for the control of vehicular and pedestrian traffic. They assign the right-of-way to the various traffic movements and thereby profoundly influence traffic flow" (*2*). The MUTCD further notes that properly designed and well maintained TCS will provide the following advantages: 1) orderly traffic movement, 2) reduce crash frequency and severity, 3) provide continuous traffic flow along a route, and 4) interrupt heavy traffic volumes at specific intervals to allow other traffic including pedestrians to cross the roadway. The MUTCD notes that if TCS are not properly placed or maintained then they can result in: 1) excessive delay, 2) excessive disobedience of the signal indications, 3) increased use of less adequate routes as road users attempt to avoid TCS, and 4) significant increases in the frequency of collisions (*2*).

Although the intention of TCS is to minimize crashes at intersections, common driver errors at these locations still occur. Some of the most common is underestimating the time it takes to reach the intersection or smooth stop and whether or not they have time to clear the intersection when approaching a yellow signal indication (*1*). Different technologies have been employed to increase safety at signalized intersections. A new technology, developed by Wavetronix, named "SmartSensor Matrix™" is a radar stop bar presence detector. The system uses frequency modulated continuous (FMCW) radar to detect and report vehicle presence in as many as 10 lanes simultaneously.

In an effort to increase safety the Vermont Agency of Transportation will install one Wavetronix SmartSensor Matrix™ system at an existing intersection located along VT Route 116 in Hinesburg, VT. The purpose of this study is to evaluate the overall effectiveness of the proprietary Wavetronix SmartSensor Matrix™ system during varying weather and traffic stream conditions.

LOCATION:

The Wavetronix SmartSensor Matrix™ system will be installed at an existing span wire intersection located at mile marker 5.46 along Vermont Route 116 and Town Highways 1 and 7 in the town of Hinesburg, VT as part of the Hinesburg-Richmond improvement project, STPG SGNL (38). The average annual daily traffic (AADT) at this intersection is 9,200. From 2000 to 2009 there have been 55 crashes, 27 injuries, and 0 fatalities. This location was selected due to the high rate of damage and subsequent repair of the existing loop detection system.

PRODUCT:

According to product literature, SmartSensor Matrix™ system is comprised of four radar detection units. Ideally they would be installed in two corners of an intersection to allow for 90º field of view so that when vehicles enter the user-defined zones the controller will detect their presence. Each detection box measures 13.2 in. x 10.6 in. x 3.3 in., weighs 4.2 lbs, and is resistant to corrosion, fungus, moisture deterioration, and ultraviolet rays. Based on manufacturing techniques, the system is considered to be extremely low maintenance. Battery replacement, recalibration, cleaning, and readjustments are not necessary. The purpose of the system is to detect vehicles and extend the green light if the system detects the speed at which a vehicle is travelling would cause a conflict if they were to stop abruptly. This overhead system is also not susceptible to damage induced by frost heaves, rutting, and other pavement structure deformations as is the case for standard loop detection systems (*3*).

COST:

All product material and installation costs will be paid for through the improvement project. The estimated cost will be $5,000 per approach, and $5,000 for incidental items, totaling $25,000.

SURVEILLANCE AND TESTING:

The experimental SmartSensor Matrix™ system will be monitored during placement in accordance with our Standard Specifications as well as with the manufacturer's specifications.

Research personnel will monitor the installation of the system and visually inspect the detection units at varying times during the year for the duration of the study. It will be imperative to conduct site visits during different weather events including: snow, rain, and clear conditions and during different times of day to account for changes in daylight and peak travel times. Research personnel will be present for any significant maintenance activities involving the materials to evaluate the ease repair and associated cost of those activities. Surveillance shall include the following:

1) Ease of installation of system hardware.
2) Visibility at installation and delineation performance under various light and weather conditions (daytime and nighttime performance).
3) Photographic documentation of product performance.
4) Field evaluations conducted over the first two years of service will entail evaluating the system during varying conditions as previously mentioned. These will include: snow, rain, and clear conditions and different times of day such as morning peak and non-peak, afternoon peak and non-peak, and evening peak and non-peak. A stop watch will be utilized to determine whether or not the system is engaged and if so if it is operating as intended.
5) Crash data will be analyzed with particular attention to the type and cause of crash and time of day. Analysis of this data will aid in successful determination of whether or not the radar stop bar detection system is a beneficial safety addition to our roadways.
6) Staff from Traffic Operations will be polled at least annually to obtain their observations.

STUDY DURATION:

The duration of this study will be no more than five years or until final conclusions can be drawn from the field observations and crash data analysis.

REPORTS:

An initial report will be prepared once installation and the post-construction pedestrian crossing examination is complete. A final report will be published once the evaluation is complete.

Agency of Transportation
Materials and Research Section

Reviewed By:

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William Ahearn P.E.
Materials and Research Engineer
Date:

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