

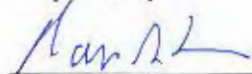
**Activated Approach Flasher System
Final Report**

October 2009

**Report 2009 - 11
Reporting on Work Plan No. WP 2006-R-1**

State of Vermont
Agency of Transportation
Materials and Research Section

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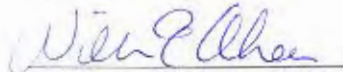


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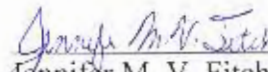


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16. Abstract This report documents the evaluation of a flashing beacon system to warn side road motorists stopped at an intersection with limited corner sight distance of oncoming traffic. The system evaluated was installed at the intersection of VT 30, South St, and Rice Willis Rd in Castleton in October 2007. A before and after conflicts study was performed to evaluate the effectiveness of the system.			
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1. INTRODUCTION

Drivers familiar with the intersection of VT Route 30, Rice Willis Road and South Street in Castleton, Vermont, know the difficulty of observing oncoming traffic. Specifically, vehicles proceeding onto or across VT 30 from Rice Willis Rd and South Street must adhere to stop signs and ensure that there is no oncoming traffic prior to turning onto the main route. However, due to the vertical grade, it is often difficult to survey oncoming traffic traveling southerly along VT Route 30.

Intersections with such visibility limitations do not provide motorists entering an intersection from a side road enough time to join main road traffic or to clear the intersection if attempting to cross the road. On highly traveled roads, intersections with this geometric deficiency are hazardous to motorists because of the higher likelihood of a crash. At these intersections, removing the vertical crest is often the preferred alternative.

On the other hand, at an intersection such as the one at VT Route 30, Rice Willis Road and South Street, which has relatively low traffic volumes (average annual daily traffic of 4600) and very few crashes (5 in the period of 2001 to 2007), the high cost of a major reconstruction project is often difficult to justify.

The purpose of this project was to determine how well a traffic conflict can be avoided at a sight-distance obstructed intersection if side road vehicles are forewarned of approaching mainline vehicles using an activated approach flasher system and associated cost effectiveness.

2. SITE DESCRIPTION

Locally known as Brown's Four Corners, the intersection of VT Route 30, Rice Willis Road, and South Street is located at mile marker (MM) 0.46 on VT Route 30. At this location, VT Route 30 is considered a major collector that runs south to north. Rice Willis Road is located on the west side and South Street on the east side of the intersection. This intersection is controlled by two-way stop signs that are placed on Rice Willis Road and South Street.

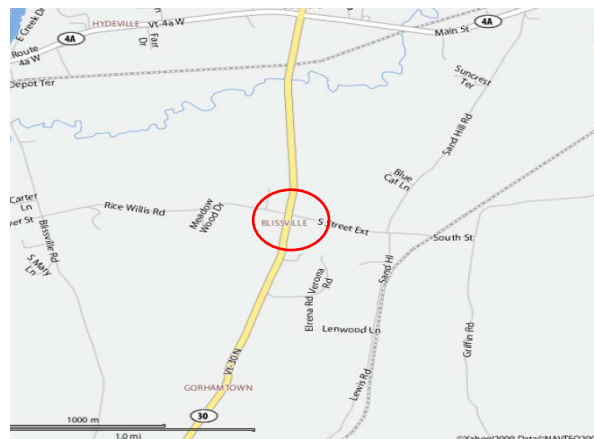


Figure 1: Location map (Source: Yahoo).

2.1 Surrounding Land Use

The land use at this intersection consists of a country store on the southeast corner, a house on the northeast corner, a barn on the northwest corner, and a field which is part of a residential property on the southwest quadrant.

A wide open entrance, approximately 100 feet in length, provides access to the country store from the south approach of VT Route 30. The country store is also accessible from South Street. The house on the northeast corner has a drive on South Street as well as another one on VT Route 30 about midway between the intersection and the crest. The barn on the northwest corner is accessible from any direction. House



Figure 2: Surrounding land use (looking North on VT Route 30).

2.2 Traffic Data

The 2006 estimated average daily traffic (ADT) on VT Route 30 south and north of the intersection was 3,800 and 4,600 vehicles respectively. The average traffic flow sorted by time of day on VT Route 30 in both directions is shown in Figure 3.

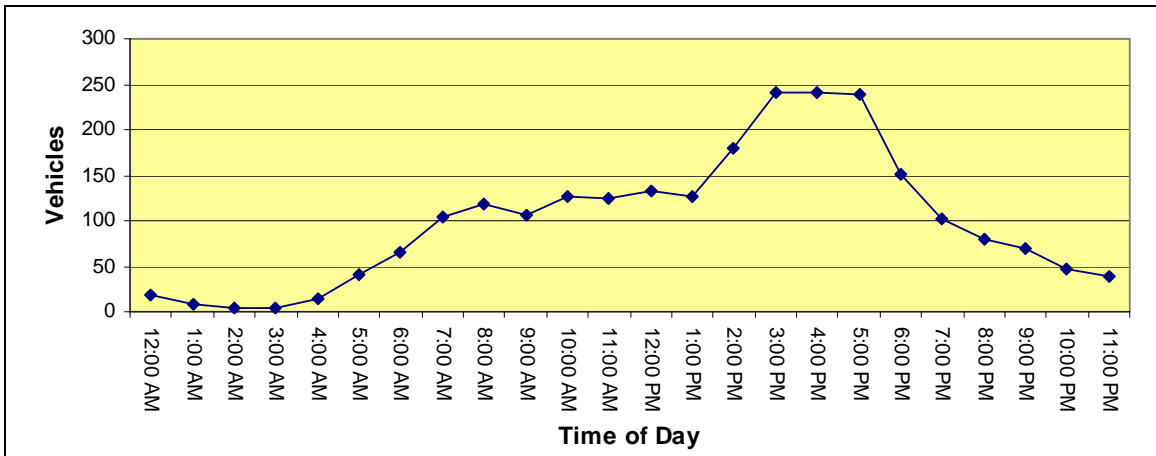


Figure 3: VT Route 30 traffic flow.

Turning movement counts performed in 2006 and 2008 show, for a ten-hour daytime period, about 1,200 vehicles traveling in each direction along VT Route 30. For the same ten-hour period, there are approximately 300 vehicles approaching the intersection from South Street, and about 200 vehicles approaching the intersection from Rice Willis Road. Throughout the day, 56% of the traffic along Rice Willis Road travels through the intersection and onto South Street. Conversely, the majority of traffic along South Street (40%) turns left onto VT Route 30 while only 31% travels through the intersection onto Rice Willis Road.

According to the turning movement counts, traffic entering this intersection is the heaviest during the afternoon peak period between 3:00 pm and 5:00 pm. Figure 4 displays the peak hour traffic volumes between 3:30 pm and 4:30 pm.

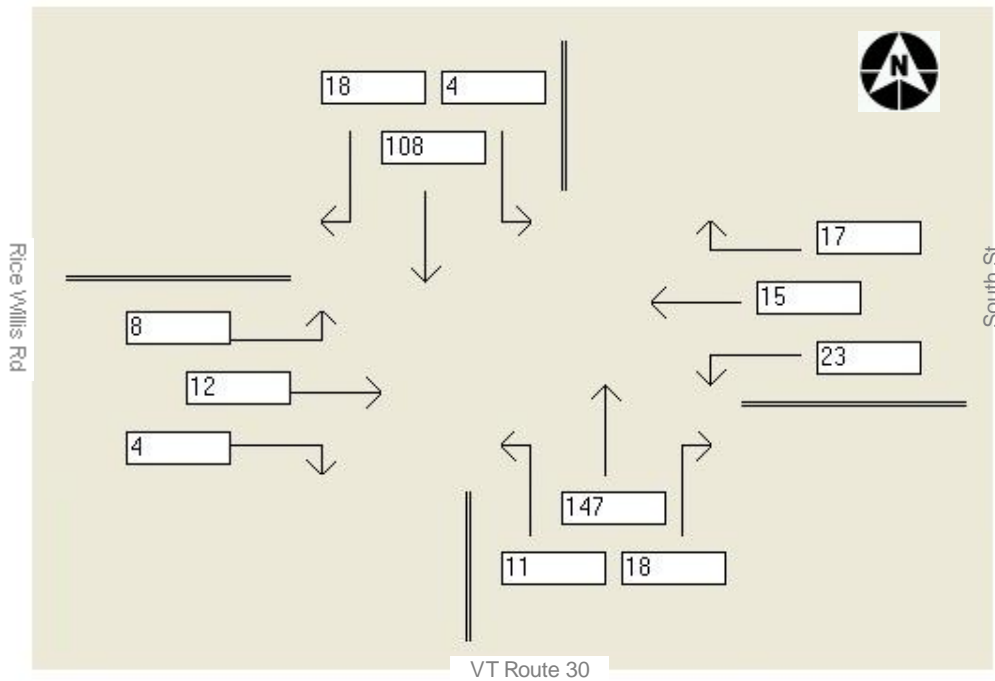


Figure 4: PM peak hour volumes (3:30 pm to 4:30 pm).

2.3 Speed Limits and Travel Speeds

The posted speed limit along VT Route 30 is 50 mph, and 35 mph on both South Street and Rice Willis Road at this location.

A spot speed study using pneumatic road tubes was conducted in October 2005 on the southbound approach of VT Route 30. The pneumatic road tubes were placed at the location of the current intersection warning sign near MM 0.63. To ensure that only free flowing traffic was considered, measurements taken during the morning off peak period were used for further evaluation. The study revealed that the 85th percentile traffic speed, or the speed below which 85 percent of traffic stream travels, was 55 mph and that the average speed was 49 mph. The study further showed that 80 percent of the traffic was

traveling between 43 mph and 59 mph representing the limits of the 15th and 95th percentile speeds, respectively.

2.4 Corner Sight Distance

The vertical grade from the intersection warning sign along the shoulder of the southbound lane of VT Route 30 to MM 0.56 is 6.1%. This grade slightly decreases to 5.2% until it levels off near the intersection.

The available corner sight distance, or length of roadway a driver can see at any particular time, was measured in the field to be 228 ft when looking to the north from Rice Willis Road and 250 ft when looking north from South Street as shown in Figures 5 and 6.



Figure 5: Intersection site distance – looking North from Rice Willis Road.



Figure 6: Intersection site distance – looking North from South Street.

In accordance with the 2004 edition of the “Geometric Design of Highways and Streets”, “intersection sight distance criteria for stop-controlled intersections are longer than stopping sight distance to ensure that the intersection operates safely.” As shown in Case B1, recommended intersection sight distance is provided for traffic approaching from either the right or the left for left turns from the minor road onto the major road for intersections with stop control on the minor road. As shown within the guidance, an intersection sight distance of 660 ft and 610 ft along the major road is recommended when passenger cars travel at speeds of 59 mph and 55 mph along the major road, respectively. These speeds represent the 95th and 85th percentile speeds along VT Route 30. Therefore, the current intersection sight distance for passenger cars making a left hand turn onto VT Route 30 is not acceptable.

2.5 Crash Data

From January 1, 2001 to the time the beacon system was installed in October 2007, five crashes were reported to the Vermont Department of Motor Vehicles. One crash was reported in 2003, 2006 and 2007. Two crashes were reported in 2005. Over this period of six years and nine months, the crash rate per year was 0.72, and the crash rate per million entering vehicles was approximately 1.40.



Figure 7: Reported crashed (January 2001 through September 2007).

The five crashes reported during this period are shown in the collision diagram presented in Figure 6 (in this diagram, the numbers next to the arrow symbols represent the number of crashes for that crash type). As shown in Figure 6, the five crashes were all right-angle crashes. Four of these crashes involved vehicles traveling southbound along VT Route 30 and traffic approaching from Rice Willis or South Street. All five crashes took place in the afternoon, between 2:30 pm and 6:00 pm, and mostly on a weekend (80%). From the statements taken at the scenes, the motorists on the side roads had stopped at the stop signs prior to proceeding, indicating that the amount of corner sight distance may have been inadequate to accurately warn traffic of oncoming traffic.

3. SYSTEM DESIGN

Given the lack of adequate intersection sight distance per the “Geometric Design of Highways and Streets” and associated number and type of crashes reported from 2001 and 2007, an activated approach flasher system was installed in 2007. The basis of the

system is a detector loop buried in the pavement on the north approach of the intersection on VT Route 30. The system senses the presence of approaching vehicles and activates beacons to warn drivers waiting on the side roads that traffic is approaching the intersection.

Two beacons were installed at the intersection. These beacons were installed above a warning sign and face the motorists found to have inadequate intersection sight distance. One beacon faces Rice Willis Road and the other one faces South Street. When stopped on Rice Willis Road, the sign informs motorists that vehicles from the left (or traffic traveling south along VT Route 30) are coming when the beacon is flashing. Similarly, when stopped on South Street and if the beacon is flashing, the sign informs motorists that vehicles are coming from the right (or traffic traveling south along VT Route 30).

A schematic of the system is illustrated in Figure 8.

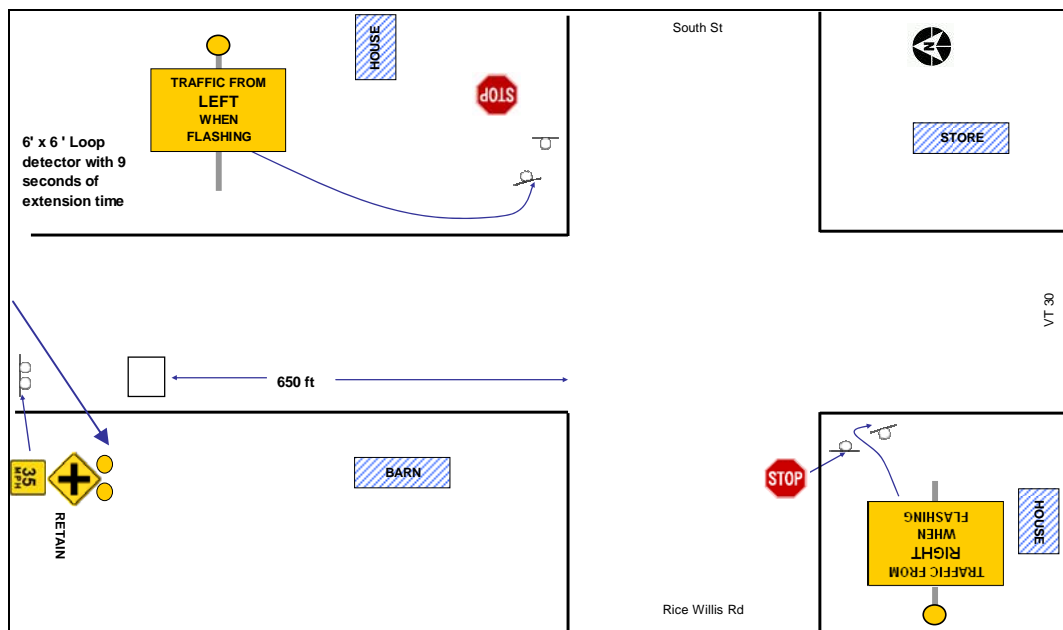


Figure 8: System layout.

3.1 Equipment & Installation

A 6 ft x 6 ft inductive loop was installed, 650 ft from the intersection, in the southbound lane on VT Route 30. Once a vehicle or motorcycle passes over the loop, the beacons are activated for a duration of nine seconds. If a vehicle passes over the loop while the beacons are already activated, the flashing duration is reset for an additional nine seconds.

To determine the length of time the beacons are on flash mode, the 50th percentile speed was used. For a 49 mph travel speed, the duration the beacons must remain flashing is nine seconds. Using this approach means that the beacons flash for a longer duration than is necessary for vehicles traveling above 49 mph and continue to flash after these

vehicles have traveled through the intersection. Conversely, for vehicles traveling below the 50th percentile speed, the beacons stop flashing prior to reaching the intersection. However, the slower vehicles are visible at that time.

Two 30" x 24" warning signs were developed as shown in Figure 8. Two different legends, depending whether a vehicle is waiting on South Street or Rice Willis Road, are used to alert drivers of approaching traffic on from VT 30 north. The signs simply say "traffic from right when flashing" (for traffic facing South Street) or "traffic from left when flashing" (for traffic facing Rice Willis Road).



Figure 9: Example of warning sign.

The signs were made of fluorescent yellow sheeting type IX with three-inch capital letters (four-inch letters were used for the words "left" and "right"). As designed, the signs are legible for approximately 99 ft to 120 ft based on the letter height to legibility distance ratio recommended in the "Manual of Uniform Traffic Control Devices." Each sign was installed on a tubular post with a slip base to reduce the likelihood of the beacons being knocked down by large trucks.

The lenses of the beacons are twelve-inch yellow light emitting diode (LED) lenses. To improve the fail safe nature of the system, the LED lenses used are of the type for which failure of a single LED results in the loss of light from only that LED.

To further increase reliability, an eight-hour battery back up system was installed inside the cabinet. In addition, if the loop is broken and cannot detect vehicles, the beacons are set to go on continuous flash.

The installation of the system was completed on October 22, 2007.



Figure 10: Installed beacon system (view is from South Street).

4. EVALUATION

Before and after traffic conflict studies were utilized as the primary evaluation method of the enhanced beacon system. These studies provide a surrogate measure for the likelihood of crashes.

In addition to the conflict studies, crash data was also considered, but a longer term evaluation period is needed to solidify results.

4.1 Traffic Conflict Studies

A traffic conflict is defined as a traffic event involving the interaction of two or more road users where one or both drivers take evasive actions such as braking or swerving to avoid a collision.¹

There are several types of traffic conflicts. The principal conflicts of interest for the application of the enhanced beacon system are related to cross traffic movements such as a through southbound vehicle along VT Route 30 and a through westbound or eastbound

¹ Traffic Conflict Techniques for Safety and Operations, Observers Manual, Publication, FHWA-IP-88-027, January 1989

vehicle from the minor roads, or a through southbound vehicle and a left turning westbound or eastbound vehicle.

The methodology used to record and quantify traffic conflicts was adapted from one suggested in “Traffic Conflict Procedure Manual,” by Dr. Tarek Sayed, of the University of British Columbia².

4.2 Data Collection

Data was collected on June 7, 2006, for a period of 10 hours between 9:00 am and 7:00 pm. Following the installation of the system, a second set of data was collected on April 8, 2008, for the same number of hours between 8:30 am and 6:30 pm.

For both data collection sessions, one observer was used. The same observer performed both collection events to ensure consistency. After reviewing the site, the best position for observing traffic was determined to be in the parking lot of the country store, on the southeast quadrant of the intersection. However this position was limited due to the ability of the observer to record low evasive actions related to braking, especially for vehicles traveling southbound along VT Route 30.

The observer recorded the conflicts, as well as the number of vehicles entering the intersection. For each conflict, the observer quantified the severity of the conflict by estimating two elements as suggested in the methodology proposed by Dr. Sayed: the time to collision and the risk of collision. The time to collision is the time before a collision would have occurred while the risk of collision is dependent on the nature of the evasive actions taken. Both of these elements were determined in the field for each conflict. The time to collision was measured subjectively based on a three-point scale with the following ranges of times in seconds: 2 to 1.6, 1.5 to 1, 0.9 to 0. The risk of collision was characterized as being low, medium or high.

The data collection form used is shown in Appendix A. The conflicts recorded during the before and after periods are listed in Appendix B.

4.3 Results

4.3.1 Conflict Diagrams

Figure 11 presents conflict diagrams for the before and after periods.

An analysis of these diagrams confirms that cross traffic conflicts are the primary types of conflicts at this intersection. There are four types of conflicts that are predominant in both the before and after periods. These are 1) a southbound through vehicle with a westbound left turning vehicle, 2) a southbound through vehicle with a westbound

² Sayed, T, Traffic Conflict Procedure Manual, Department of Civil Engineering, University of British Columbia

through vehicle, 3) a southbound through vehicle with an eastbound left turning vehicle, and 4) a southbound through vehicle with an eastbound through vehicle.

A comparison of the diagrams further indicates that the proportions of conflicts for most conflict types remained the same in the after period. The conflict involving a through southbound vehicle on VT Route 30 and a through vehicle on South Street is the only conflict for which the proportion of conflicts was reduced by a large percentage. While the relative proportion of each major conflict type remained approximately the same, the number of occurrences for each type was found to be lower than the before study.

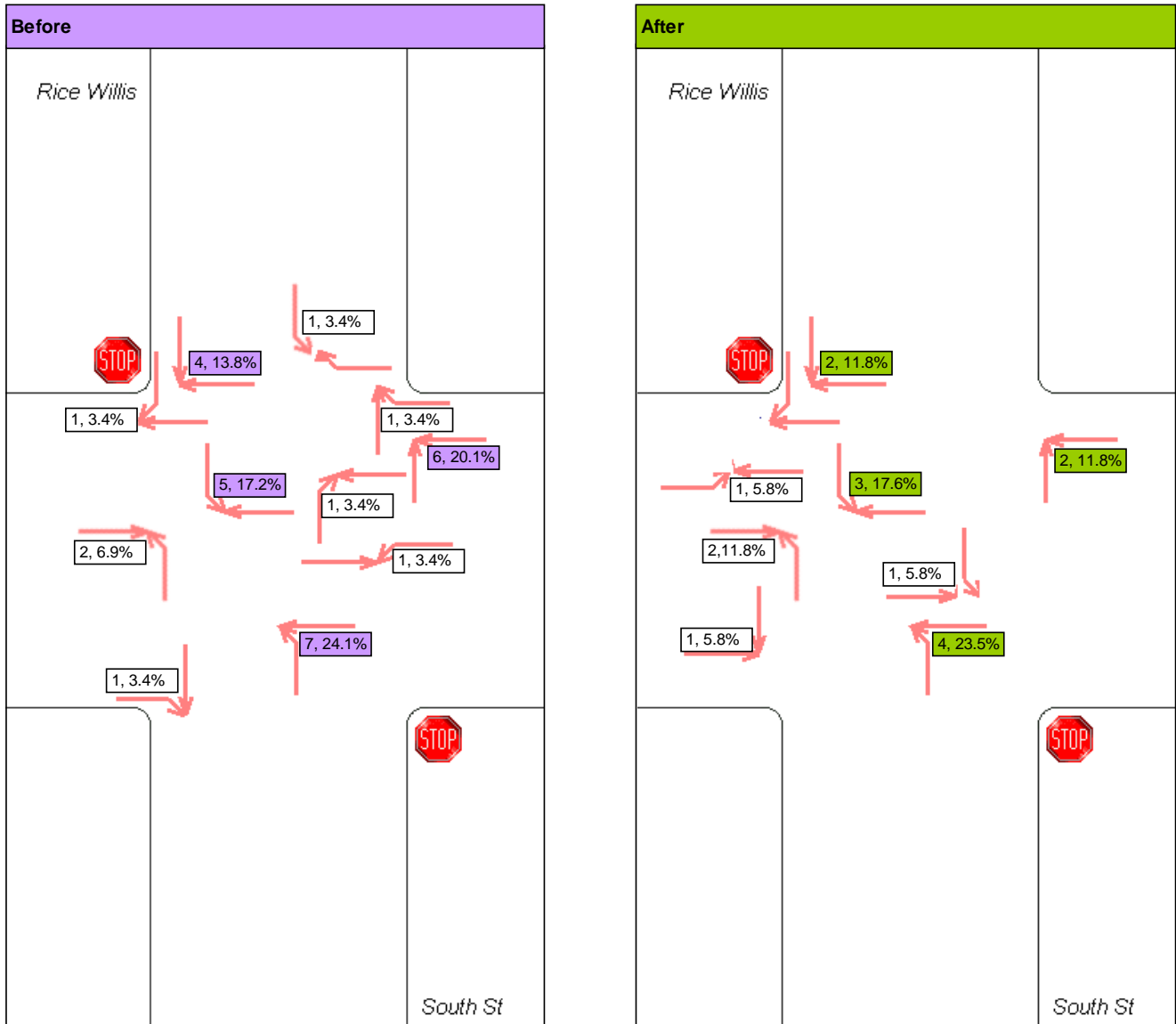


Figure 11: Before and after conflict diagrams.

4.3.2 Conflict Rates and Severity

The average number of conflicts per hour, the average number of conflicts per hour per 1000 entering vehicles, and the average severity score per conflict were calculated for the before and after periods. These results are displayed in Table 1.

Table 1: Summary of conflict rates and severity.

	Before	After	% Change
Average Number of Conflicts per Hour	3	1.9	36.6
Average Hourly Conflicts per 1000 Entering Vehicles	10.75	6.31	41.3
Average Severity per Conflict	2.6	2.2	15.3
Median Severity per Conflict	2	2	0
Mode (Severity per Conflict)	2	2	0
Maximum Severity Score	6	3	na

As shown in Table 1, a 36.6% reduction in the average number of conflicts per hour was observed. When considering entering traffic, a 41.3% reduction in the average number of conflicts per 1000 entering vehicles was experienced after the installation of the warning beacon system.

The average severity per conflict was calculated from the observations made in the field by converting the low-to-high scales used in estimating the time to collision and the risk of collision to 1-to-3 numerical scales. The severity score per conflict was determined by summing the numbers obtained for the time to collision and for the risk of collision. Given this, the lowest possible severity for a conflict is 2, while the largest possible score is 6. From the summations performed, it was found that the average severity per conflict prior to and following installation of the system was 2.6 and 2.2, respectively. This translates into a 15.3% reduction in severity.

The median and mode severity per conflict were also computed and were found to be 2 for both evaluation periods. On the other hand, examining maximum severity scores, scores above 3 were documented prior to installation of the beacon system, with the maximum score of 6. No conflict had a severity greater than 3 following installation.

4.3.3 Temporal Distribution

The before and after distributions of conflicts per time of day between the hours of 9:00 am and 6:30 pm, are shown in Figure 11. These distributions indicate that the number of conflicts observed between 9:00 am and 1:00 pm were approximately the same in both the before and after periods. From 1:00 pm to 5:30 pm, a larger number of conflicts were recorded prior to the installation of the beacon system. The number of conflicts is again about the same after 5:30 pm.

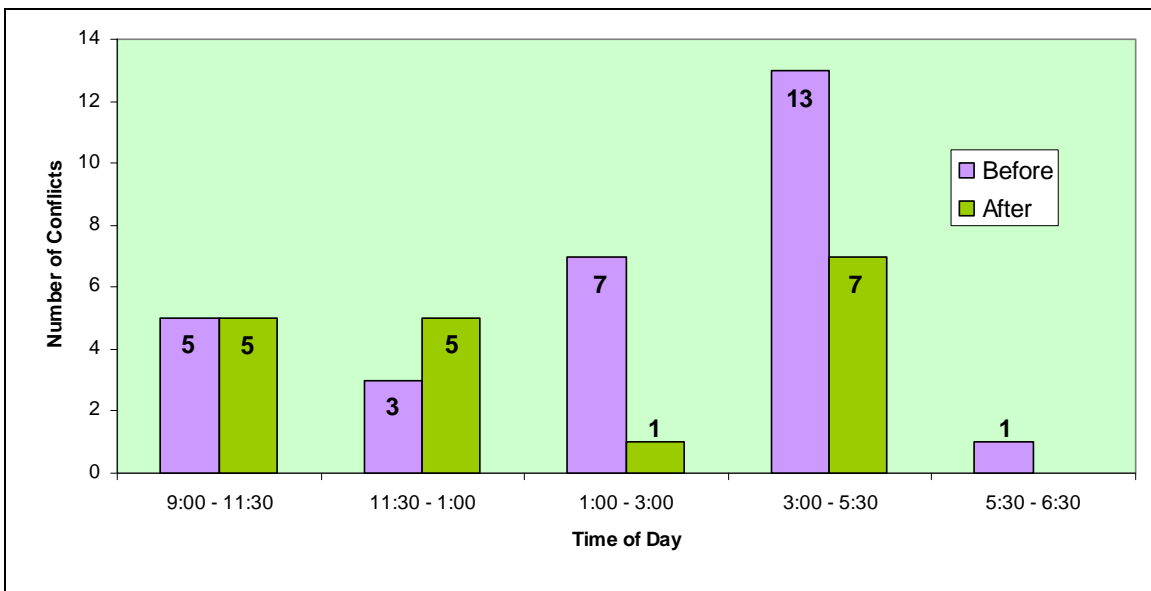


Figure 12: Temporal distribution of the observed conflicts.

4.4 Crash Data

Since the installation of the beacon system, two crashes of the type susceptible to be reduced by the system (i.e., right-angle crashes) have been reported to the Vermont Department of Motor Vehicles. One crash occurred in 2008 and one in 2009 (Overall, there were four crashes reported to be at this intersection but two were, in reality, away from the intersection).

These two right-angle crashes were caused by a motorist failing to yield the right of way in clear weather conditions. The two crashes were caused by vehicles travelling from Rice Willis Road. In the 2008 case, the driver at fault stated that the “caution light” was not flashing and that she did not see the other vehicle coming from the south. In the most recent instance, the motorist at fault (a resident of South Street) said that she stopped but did not see the other vehicle from the north. One of these crashes occurred in the

afternoon between 2:15 pm and 3:15 pm, while the other one was in the morning between 10:15 am and 11:15 am.

Over this period of two years and one month, the crash rate per year was 0.96 (compared to 0.72 for the previous six year and nine month period, and the crash rate per million entering vehicles was approximately 1.81 (compared to 1.40 for the six year plus period).

5. CONCLUSIONS AND RECOMMENDATIONS

The evidence provided indicates that the number of conflicts was reduced following the installation of the enhanced warning beacon system.

Although the crash rate remained constant, it would appear that the safety of the intersection was improved based on the lower number of conflicts observed during the post construction period. The largest reduction in conflicts was between through traffic traveling south along VT Route 30 and through traffic along South Street.

The device seems to be most effective during periods of heavier traffic volumes.

The reduction in the number of overall conflicts measured during the evaluation period indicates that the enhanced warning beacon system could be an effective traffic control device to reduce conflicts at an intersection with inadequate intersection sight distance on a low volume road.

Appendix A

Intersection of _____ and _____

Municipality _____ File no. _____ Date _____

Weather sunny cloudy wet snow ice Day S M T W T F S

Observer _____ Conflict # _____ of _____

Indicate North

1. For Signalized intersections only

Left-turn Conflict Occurred during:

Protected Phase For

Permissive Phase Left-turn

Amber or All-red Phase movements

Red Phase (Illegal left) only

2. Primary (type 1)

Secondary (type 2)

Street name

Legend

Car/Light truck/Van/Mini-van

Heavy truck or Bus

Motorcycle

Pedestrian or Cyclist

Time of Incident

Comments: _____

Evasive Action Type

	low	med.	high
Braking	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Swerving	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Accelerating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	2 - 1.6 s.	1.5 - 1.0 s.	0.9 - 0 s.
TTC	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
score	1	2	3
	low	med.	high
ROC	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
score	1	2	3
Combined:	TTC + ROC = <input style="width: 30px;" type="text"/>		

Summary:

Type	TTC	ROC
<input style="width: 30px;" type="text"/>	<input style="width: 30px;" type="text"/>	<input style="width: 30px;" type="text"/>
	+ = <input style="width: 30px;" type="text"/>	

Traffic Conflict Survey Form

Figure A-1: Data collection form.

Appendix B

TableB-1: Before conflict study – June 7th, 2006 from 9:00 am to 7:00 pm (Raining from 12:30 pm to 7:00 pm).

Time	From VT 30 South	From Rice Willis	From South St	From VT 30 North (from VT 4a)	Description	Time to Collision	Risk of Collision
9:49		Left		Straight	Car on South St accelerated	Low	Med
9:51			Straight	Straight	Car on Rice looked south on VT 30, about to start, then stopped	Low	Med
10:18		Left	Left	Straight	Car on Rice braked in the middle of the intersection	Med	Low
11:22			Straight	Right	Car on Rice started, then stopped. Car on VT 30 slowed down to make a right turn	Low	Low
11:22?		Straight		Straight	Car on South St about to start then stopped	Low	Low
12:20	Straight	Straight	Left		Car on Rice was first, but had to wait for VT NB traffic since car on South St went first	Med	Low
12:25		Left		Straight	Car on South St accelerated. Do not know if car on VT 30 slowed down	Low	Low/Med
12:53		Left		Straight	Car on South St had to back up because was too forward. Five cars from VT 30 NB. Impatience, went. Car on VT 30 SB slowed down and honked	Med	Med
13:01		Straight		Straight	Car on South St went then braked.	Low	Low

Time	From VT 30 South	From Rice Willis	From South St	From VT 30 North (from VT 4a)	Description	Time to Collision	Risk of Collision
13:03		Left		Straight	No action. Car from South St was just in other lane when car on VT 30 passed	Low	Low
13:17			Left	Straight	4 NB cars went by, then car on rice moved forward and stopped for car	Low	Low
13:58			Straight	Straight	Car on Rice was about to go then stopped.	Low	Low
14:01		Straight		Straight	Car on South St about to go, then stopped	Low	Low
14:11	Right	Straight			Car on VT 30 NB made a right turn, slowed down when car on South St started (thought maybe that was letting him go), then braked	High	High
14:39			Left	Straight	Car on Rice started to go, then stopped.	Low	Low
15:03			Straight	Straight	Car on Rice about to go, then stopped (for 3 VT 30 SB cars)	Low	Low
15:30		Left		Straight	Car on VT 30 SB slowed down	Med	Low/Med
15:56		Straight		Straight	Car on South St stopped, about to go and stopped again	Low	Low
15:59		Right		Straight	Car on South St accelerated	Low	Low

Time	From VT 30 South	From Rice Willis	From South St	From VT 30 North (from VT 4a)	Description	Time to Collision	Risk of Collision
16:07			Straight	Straight	Car on Rice was about to go	Low	Low
16:25	Straight		Left		Car on Rice was about to go then stopped	Low	Low
16:30			Left	Straight	Car on Rice stopped in the middle of the intersection (3 to 5 cars from the right)	Med	Low
16:35			Left	Straight	Car on Rice about to go, then stopped	Low	Low
16:37			Right	Straight	Vehicle on Rice was moving a house. Had to brake after completing turn	Low	Low
16:44			Straight	Straight	Car on Rice accelerated (car on VT 30 was about at crest)	Low	Low
17:05			Straight	Straight	Car on Rice about to go, then stopped	High	Med
17:06			Left	Straight		High	Low
17:10		Left		Right	Car on South St about to go, then stopped	Low	Low
18:32			Left	Straight	Car on Rice started to go, stopped before entering at an angle (SB car was just at the crest)	Low	Low

Time	From VT 30 South	From Rice Willis	From South St	From VT 30 North (from VT 4a)	Description	Time to Collision	Risk of Collision
18:35	Straight			Left	Car on VT 30 SB cut the corner	Low	Low

Table B-2: After conflict study – April 8th, 2008 from 8:30 am to 6:30 pm.

Time	From VT 30 South	From Rice Willis	From South St	From VT 30 North (from VT 4a)	Description	Time to Collision	Risk of Collision
8:42	Left			Straight	Car on VT 30 NB was about to turn then made a jerky movement to make the car straight when saw oncoming car	Low	Low
9:16			Left	Straight	Car on Rice was on CB.	Low	Low
9:17		Left		Straight	No action. Car from South St was just in other lane when car on VT 30 passed		
9:54	Straight	Straight			Very low conflict. Car on South St stopped, and stopped again	Very Low	Very Low
10:39		Left		Straight	No action. Car from South St was just in other lane when car on VT 30 passed		
11:15			Left	Straight	Car on Rice was stopped for a while: combed his hair, fix his denture. Light started flashing when he started to go	Low	Low
11:39			Straight	Straight	Car on Rice went. Was passed intersection. Started going when light started flashing	Low	Very Low

Time	From VT 30 South	From Rice Willis	From South St	From VT 30 North (from VT 4a)	Description	Time to Collision	Risk of Collision
12:29		Left		Straight	One car from either side road went, then Car on South St accelerated	Low	Low
12:30					Was about to go, then moved forward, then stopped when saw the car	Low	Low
12:38			Straight	Straight	Car on Rice was starting slowly, braked	Low	Low
12:50	Straight	Left			Car on South St was looking at flashing light, after a SB car passed, did not look the other way before moving, was not really in the intersection, about to go	Med	Low
13:54		Straight		Straight	Car on South St looked both ways, just went	Low	Low
15:05		Straight		Straight	Car on South St was in other lane, went was flashing, no evasive actions	Low	Very Low
15:15	Straight		Left		Car on Rice seemed to just turn, no evasive actions	Low	Low

Time	From VT 30 South	From Rice Willis	From South St	From VT 30 North (from VT 4a)	Description	Time to Collision	Risk of Collision
16:04					She stepped on it, had been waiting for a while, but was first, could not see him until she was passed	Med	Med
16:20	Straight		Left		Both cars were in their lane, no actions	Low	
16:21			Left	Straight	No actions. Car on Rice was just SB when NB truck was by barn	Low	Low
16:50		Right		Straight	By the time car on South St completed the turn, NB car was by the barn	Med	Low
16:53			Left	Straight	NB car honked. Car on Rice waited for many cars, light was still flashing but decided to go	Med	Low