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Evaluation and Installation Guidelines for Advance Warning Signal Systems in Utah

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EVALUATION AND INSTALLATION GUIDELINES FOR ADVANCE WARNING SIGNAL SYSTEMS IN UTAH

by

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GRADUATE COMMITTEE APPROVAL

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As chair of the candidate's graduate committee, I have read the thesis of Aaron Paul Jensen in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

EVALUATION AND INSTALLATION GUIDELINES FOR

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Master of Science

Advance warning signals (AWS) provide information warning drivers in advance of the end-of-green phase for an approaching signalized intersection. The purpose of this research was to develop guidelines for the placement of AWS in Utah, both conditions to evaluate the need for AWS installation and guidelines for the AWS system design. The conditions were based on literature of other transportation agencies that had similar AWS systems and were developed using the Policy Delphi method. The Policy Delphi method is the development of a specific policy area through the means of discussion by a committee of experts correlating views and information involving opportunity to react and assess different viewpoints until the committee is in agreement over the policies being recommended. Six conditions are recommended and discussed in detail, including: limited sight distance, posted speed, isolated intersection, high crash rate, approach grade, and heavy vehicle traffic volume. The guidelines for the AWS system design included details about three components: AWS component, advance detection component, and

signal timing component. An evaluation matrix was developed by the Policy Delphi method for the purpose of evaluating and prioritizing a group of intersections for AWS installation. A total of 24 intersections were identified by the Utah Department of Transportation for this project that helped to develop and verify the conditions and evaluation matrix. The recommended guidelines and evaluation matrix results are described.

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1 Introduction

The purpose for this thesis is to provide guidelines for advance warning signal (AWS) systems for the state of Utah. The guidelines include an assessment of the need an intersection has for an AWS system, a method for prioritizing intersections based on their need for an AWS system, and AWS system installation guidelines. An AWS system provides information warning drivers in advance of the end-of-green phase for an approaching signalized intersection. The research is funded by the Utah Department of Transportation (UDOT) and performed by researchers at Brigham Young University (BYU) with the support of a UDOT technical advisory committee (TAC). AWS signs may have a static or dynamic advance warning configuration to reduce the decision to stop at or continue through the approaching intersection, and subsequently improving the driver response and safety.

This chapter outlines: 1) the background for the research, 2) the overall problem statement, 3) project objectives, and 4) organization of the thesis.

1.1 Project Background

Several methods have been identified across North America to provide advance warning for end-of-green phase at a high-speed signalized intersection (HSSI). One of the more common of these is the installation of an AWS system. UDOT has recently installed AWS systems at three locations on Bangerter Highway and one location on S.R. 201. The intent of these installations was to improve safety by providing advance warning to drivers on the change in signal indication. As traffic signals are installed on high-speed rural and urban intersections like those on Bangerter Highway, the need to provide for safety is ever increasing.

The current installations on Bangerter Highway are being evaluated through a research study to determine their effectiveness. The preliminary results of this analysis have indicated that the installation of AWS systems on Bangerter Highway has had a positive impact on reducing speed variability and red light running at the intersection locations (*1*). With this positive impact of AWS installation, it becomes necessary to further develop the process in the state of Utah to take advantage of this technology. This includes the development of guidelines for AWS installation as well as identification of target locations across the state where AWS installations may prove beneficial.

1.2 Problem Statement

This research is necessary to develop the tools needed to identify locations for future AWS installations based on the guidelines and effectiveness identified in the previous AWS evaluation research (*1*). The research provides an opportunity to establish a site selection matrix and to then identify candidate locations for future installations to aid in improving the safety and efficiency of the highway network. There was a need to provide set guidelines for such installations and to identify target locations for installation to aid in the most effective utilization of safety funds statewide.

1.3 Project Objectives

There were four primary objectives of this research. The first objective was to develop guidelines for installation of AWS systems through a literature review and the collaboration of the TAC. The second objective was to develop the process of the identification of candidate AWS installation locations. It was first proposed to utilize the GIS enabled web delivered data almanac to identify high crash locations. Later Region Traffic Engineers who had a better knowledge of intersections than could be derived using online programs were consulted. The third objective was the application of AWS guidelines to the evaluation of several intersections to verify the guidelines are effective in assessing the need for AWS installation. The fourth objective was to develop an evaluation matrix that included a process with the comparison of candidate locations having current AWS evaluation results and guideline criteria to develop a prioritized list of candidate locations.

1.4 Thesis Organization

This thesis consists of five chapters: 1) Introduction, 2) Literature Review, 3) Recommended Guidelines, 4) Intersection Evaluation Matrix, and 5) Conclusions and Final Recommendations. References and an Appendix follow these chapters.

Chapter 2 summarizes the AWS guidelines of 11 transportation agencies. The chapter has a section containing details of the various alternatives of guideline conditions that are used to evaluate the need for AWS installation. Another section describes the various design guidelines for the AWS installation, including sign layout, sign placement, and signal timing.

Chapter 3 outlines recommended guidelines for AWS installations within the state of Utah. The conditions that a signalized intersection should meet and how to evaluate those conditions are described in the first section. The second section explains the intersection evaluation matrix used to compare potential intersections and rank them by need for AWS installation. The third section details the guidelines recommended for AWS system design, including AWS placement and design, advance detection, and AWS signal timing.

Chapter 4 explains the results of applying the guidelines in Chapter 3 to 24 evaluation intersections. The first section explains how the 24 intersections were selected. The second section explains the results of evaluating each intersection. The third section discusses the results of the evaluation matrix that was developed and proposed for use by UDOT in evaluating several intersections to prioritize the need for AWS installation. The fourth section details a sensitivity analysis that was performed to verify the best scoring system of the conditions used in the evaluation process of an intersection.

Chapter 5 contains the conclusions summarizing the process of the research. The chapter ends with recommendations for future development and research for AWS systems installed in Utah.

2 Literature Review

The comprehensive literature review was targeted expressly on identifying current guidelines for the installation and design of an AWS. Transportation agencies with official guidelines in their standard documents were identified throughout the United States and Canada. In Canada AWS systems are often referred to as advance warning flashers. Installation and design guidelines for AWS systems were identified through the literature review for the following transportation agencies:

- Transportation Association of Canada (*2*),
- Minnesota Department of Transportation (*3*),
- Nevada Department of Transportation (*4*),
- Nebraska Department of Roads (*5*),
- The City of Calgary (*6*),
- British Columbia Ministry of Transportation (*7*),
- Manitoba Transportation and Government Services (*8*),
- Kentucky Transportation Cabinet (*9*),
- Washington State Department of Transportation (*10*),
- New Jersey Department of Transportation (*11*), and
- Manual on Uniform Traffic Control Devices (MUTCD) (*12*).

AWS systems began as static signs with a variation of phrases to help warn the driver of the signal ahead. "Prepare To Stop" and "Signal Ahead" were the common messages conveyed to the driver (*12*). A "passive symbolic signal ahead" (PSSA) sign, as called in a report by Bowman, is another common variation to this advance warning of the signalized intersection (*13*). The PSSA sign is a symbol of a intersection signal in a warning sign. In addition to the sign, flashers have been added to draw the attention and respect of the driver to its message. To give the driver more information AWS systems have developed to be dynamic by synchronizing flashers with the change interval of the yellow to red phases. In this manner the driver becomes aware that when the lights are flashing the signal ahead is about to, is changing to red, or is red and they must prepare to stop. The specific details of when, where, and how to use AWS systems is generally agency specific.

To explain how different agencies address these details this chapter is divided into the following sections: 1) installation guidelines, 2) design guidelines, and 3) literature review chapter summary.

2.1 Installation Guidelines

Many factors may contribute to the decision to install an AWS system. An AWS system is used to provide information to the driver of the upcoming signal indication. The use of AWS systems is generally used for correction of a particular problem, and not used in anticipation of future problems (*3*). There are dangerous conditions that transportation agencies analyze in making the decision to install an AWS system. The guidelines reviewed in this chapter and recommended in Chapter 3 include several of these dangerous conditions that can be evaluated for an intersection. The Transportation Association of Canada report: *Advance Warning Flashers: Guidelines for Application and Installation* has the most comprehensive list of conditions including all of conditions mentioned in this report except a dilemma zone condition from the Minnesota Department of Transportation and the Kentucky Transportation Cabinet, and a secondary approach condition for the Manitoba Transportation and Government Services (*2*, *3*, *8*, *9*). The Transportation Association of Canada report directs that two or more of the conditions need to be met in order for an AWS to be seriously considered (*2*). All the other agencies have similar guidelines. Conditions may be classified as primary conditions because of greater safety concerns or as secondary conditions for lesser safety concerns. For AWS system consideration one primary condition may be enough of a concern to qualify an intersection for AWS installation. While multiple conditions met may indicate need for AWS system installation; generally at least one primary condition must be met. In all cases engineering judgment may ultimately decide whether an AWS system is needed.

The conditions found for AWS installation guidelines in the literature include the following: 1) limited sight distance, 2) minimum speed, 3) isolated or first intersection, 4) approach grade, 5) heavy vehicle volume, 6) high crash rate, 7) dilemma zone, 8) engineering judgment, 9) minor road traffic volume, and 10) secondary approach. Each of these conditions will be discussed in the sections that follow. The conditions reviewed had both metric and English units. For consistency, values of acceleration, speed, and distance in equations have been rounded and converted to English units, even though the metric value may have been utilized in the original document.

2.1.1 Limited Sight Distance

Limited sight distance conditions exist where the stopping distance of a vehicle traveling at the speed limit is greater than the actual sight distance of the driver to the signal of an intersection. Stopping sight distance is defined in the American Association of State Highway and Transportation Officials (AASHTO), *A Policy of Geometric Design of Highways and Streets* (AASHTO Green Book), as "the sum of the distance traversed during the brake reaction time and the distance to brake the vehicle to a stop" (*14*). This situation causes the intersection to be unexpected to drivers, especially on high-speed roadways. The AWS system remedies this potentially hazardous situation by warning the driver in advance of the changing signal indication and by providing notice to the driver of the otherwise visually obscured signal. If the AWS is dynamic it will inform the driver if the light is going to be green or not.

Limited sight distance was an important consideration for AWS systems for every transportation agency reviewed. Sight distance problems generally occur in instances where horizontal or vertical curves are present, but may include other obstructions such as a pedestrian overpass. It is generally recommended that the sight distance problem be resolved by other means if at all possible before installing an AWS system (*2*).

2.1.2 Minimum Speed

The Institute of Transportation Engineers (ITE) defines a high speed approach as one with a speed limit of 35 mph or higher (*15*). The minimum speed condition is included in the explanation of other conditions with the intent that AWS systems are used at intersections with a high-speed approach. The conditions that were generally combined with a minimum speed were limited sight distance, isolated or first signalized intersections, approach grade, intersections with high crash rates, and heavy vehicle (*2*, *4*, *6*, *8*, *9*, *10*). The minimum speeds ranged from 45 mph to 65 mph. The Transportation Association of Canada report, the British Columbia Ministry of Transportation, and the City of Calgary conditions treated the minimum speed as a primary condition when the posted speed is 60 mph or greater (*2*, *6*, *7*). The Kentucky Transportation Cabinet considered this condition if the 85^{th} percentile speed was 45 mph or greater (*9*). For the Minnesota Department of Transportation minimum speed is a secondary condition (*3*). The City of Calgary recommended an AWS system be installed for all signalized intersections having a speed limit of 65 mph and for signalized intersections having a speed limit of 45 mph that are the first signal to an urban area or have a collision hazard that is correctable by an AWS system (*6*).

2.1.3 Isolated or First Intersection

The first signalized intersection that transitions from a rural area to an urban area and/or where there is no signal for several miles may be of concern because drivers may underestimate the distance necessary to stop (*4*, *6*, *7*, *8*). The Transportation Association of Canada refers to this condition as a “Gateway” (*2*). For isolated intersections the distance between intersections that would define an isolated intersection is not consistently defined in the literature. The Minnesota Department of Transportation and the Washington State Department of Transportation recommend a distance of 10 miles, while the Manitoba Transportation and Government Services defines an isolated intersection as one that is 1.2 miles from the nearest signalized intersection (*3*, *8, 10*). For the Manitoba Transportation and Government Services and the Nevada Department of Transportation an isolated intersection is considered only in a rural setting (*4*, *8*). The British Columbia Ministry of Transportation is less specific defining the isolated intersection as one that has "many [miles] of high speed driving" (*7*). Another situation that may be considered as an isolated intersection is the end of a freeway (*3, 10*). The isolated or first intersection condition was listed for all the sets of conditions reviewed with the exception of the Kentucky Transportation Cabinet and may be considered a primary condition if the road has high speeds (*9*).

2.1.4 Approach Grade

The condition of approach grades to an intersection is an important safety concern because drivers, especially on downgrades, generally underestimate the distance necessary to stop. The Transportation Association of Canada bases this condition on the speed limit of the roadway suggesting that an AWS system should be considered for roadways with a 30 mph speed limit and a 12 percent approach downgrade, a 35 mph speed limit and a 7 percent approach downgrade, and a 45 mph speed limit and any approach downgrade (*2*). Similarly, the Manitoba Transportation and Government Services approach grade condition is for intersection within 0.6 miles of a 3 percent or greater downgrade with an approach speed of 35 mph or greater (*8*). The Washington State Department of Transportation also specifies a 3 percent or greater downgrade when the truck volume is 15 percent or greater (*10*). The Kentucky Transportation Cabinet recommends a 4 percent grade as a possible consideration for AWS systems (*9*). Several agencies had a consideration for approach grade in the equation used to consider limited sight distance (*3*, *4*, *7*).

2.1.5 Heavy Vehicle Volume

Three agencies mention volumes of heavy vehicle as a condition for AWS system installation. The Transportation Association of Canada calls this a secondary condition and gives ranges of daily heavy vehicle volume upon which a decision may be made—no AWS systems are needed for less than 10 percent trucks, AWS systems might be considered if other conditions are met when there are 10 to 15 percent trucks, and AWS systems are strongly recommended when there are more than 15 percent trucks (*2*). The Minnesota Department of Transportation and the Washington State Department of Transportation combine this condition with approach grade. In this scenario, if the percent of trucks exceeds 15 percent and the approach grade is 3 percent or greater, the intersection may require an AWS system (*3*, *10*).

2.1.6 High Crash Rate

The high crash rate condition is one that may require the most engineering judgment. A high crash rate is most likely an indication that one of a number of other conditions may exist for a specific intersection such as limited sight distance, isolated or first intersection, approach grade, etc. The Transportation Association of Canada recommends a comparison of the difference in correctible collisions for a particular intersection to the average of correctible collisions for similar surrounding intersections. A correctable collision is a collision that occurs during the yellow and all-red phase, as well as collisions occurring during the red phase as a result of an inconspicuous signal. The Transportation Association of Canada also recommends that depending on the ratio of the correctable collisions on a particular intersection and the average correctable collisions of similar surrounding intersections a decision may be made on AWS system installation. For example, if the ratio is two or less then no AWS system is needed; if the ratio is three to five then an AWS system may be necessary if other conditions are met; and, if the ratio is six or more then an AWS system is strongly recommended (*2*).

The Manitoba Transportation and Government Services recommends that AWS systems be considered for intersection approaches with a speed limit of 60 mph or greater with three consecutive years of four or more "fail to stop" right angle collisions (*8*). Right angle collisions are generally a more severe collision that may occur as a result of red light running.

The Minnesota Department of Transportation recommends that AWS systems be considered when there is a high record of crashes and a sight distance and/or dilemma zone problem is present. If a high crash rate is a result of some other situation then an AWS system may not be the appropriate solution (*3*).

2.1.7 Dilemma Zone

A dilemma zone occurs when an approaching vehicle, upon the change of a traffic signal to yellow then red, can neither safely stop before crossing the stop bar nor proceed through the intersection without running the red signal (*16*). A decision zone is defined as the distance between the location where 90 percent of drivers would proceed through an intersection and the location where 10 percent of drivers would stop at the onset of the yellow phase (*16*). Both the dilemma and decision zones have potential safety risks of an uncontrolled skid, a rear-end collision, or a right angle collision. A dilemma zone may be a result of limited sight distance, approach grade, or as a result of improperly timed traffic signals. The distance where the dilemma zone is located before the stopbar varies depending on the vehicle speed and grade.

The Minnesota Department of Transportation addresses the dilemma zone specifically, although, a high crash rate may be evidence of a dilemma zone situation which is a condition listed by four agencies (*3*). The dilemma zone may be remedied first by adjusting the signal timing. If the yellow and all-red intervals are currently at the maximum allowable time then an AWS systems may be desirable. The Nevada Department of Transportation gives as part of the purpose of AWS systems to prevent a dilemma zone situation (*4*). The Kentucky Transportation Cabinet does not mention the dilemma zone directly, but it does recommend that intersections with substantially high frequency of signal cycles in which the green time is maxed out on a regular basis and there is a high number of red-light running events should be considered for AWS systems

(*9*). Frequent maxed out green time cycles lead to decision and dilemma zone situations that may result in more red-light running events. Also, the Kentucky Transportation Cabinet recommends that AWS systems be considered in locations where a bridge deck is adjacent the intersection and loop advance detection is not possible (*9*). In this case the signal is not fully-actuated and drivers may be caught in a dilemma zone because of a fixed cycle length.

2.1.8 Engineering Judgment

Engineering judgment should be applied to all situations, especially where safety is a concern at an intersection. One or more conditions may or may not provide substantial reason to install AWS systems; each intersection is different and should be analyzed on an individual basis. The minimum speed and isolated intersection conditions as discussed previously specifically require engineering judgment based on the history for a specific intersection. The Minnesota Department of Transportation recommends that other measures be taken before applying an AWS system (*3*). Redesigning the roadway approach to eliminate sight distance problems or changing the traffic signal timing to accommodate varying driver behavior are examples of other remedial measures that may be taken. The engineer should always use engineering judgment for each intersection individually depending on the specific situation and experience of the driving behavior for the local area.

2.1.9 Minor Road Traffic Volume

The Transportation Association of Canada is the only agency that recommended that the minor road average daily traffic as a secondary condition be considered, stating: “the available research suggests that [AWS] along a major road approach are more effective in reducing collisions when the minor road traffic volume is relatively high” (*2*). AWS is not recommended with minor road average annual daily traffic (AADT) of less than 3,000 vehicles per day, a minor road AADT of between 3,000 vehicles per day and

13,000 vehicles per day an AWS may be effective, and a minor road AADT greater than 13,000 vehicles per day an AWS is more likely to be effective (*2*).

2.1.10 Secondary Approach

The Manitoba Transportation and Government Services was the only agency that specifically addressed the option of AWS systems on the secondary approach (*8*). This agency cited the same conditions as with the major approach of limited sight distance, approach grade, and high crash rate; with the addition of minor road traffic volume. If the AADT value for the minor road is greater than 2,000 vehicles per day then AWS use should be considered. The conditions for determining whether to install an AWS system may be applied to both roads that approach an intersection.

2.1.11 Summary of Conditions

A summary of the agencies with the specific guideline conditions for the installation of AWS systems is provided in Table 2.1. The shaded boxes represent where a condition is used by the corresponding agency. All the agencies listed limited sight distance and minimum speed as conditions, while all but one agency listed isolated or first intersection and approach grade, specifically the Kentucky Transportation Cabinet and City of Calgary respectively. High crash rate as a condition was listed by all the agencies except the Nevada Department of Transportation and the British Columbia Ministry of Transportation. Heavy vehicle, dilemma zone, minor road traffic volume and secondary approach are conditions used by one to three of the agencies. This may indicate a distinction between primary and secondary conditions. Though engineering judgment is only listed by four of the agencies it may be assumed that all agencies would use engineering judgment in each case of AWS application.

Table 2.1 Summary of Installation Conditions

		Agency							
		Trans. Assoc. of Canada	Minnesota Dept. of Trans.	Nevada Dept. of Trans.	City of Calgary	British Columbia Min. of Trans.	Manitoba Trans. & Gov't Services	Kentucky DOT	Washington State DOT
Conditions	Limited Sight Distance	■	■	■	■	■	■	■	■
	Minimum Speed	■	■	■	■	■	■	■	■
	Isolated or 1st Intersection	■	■	■	■	■	■		■
	Approach Grade	■	■	■		■	■	■	■
	Truck Traffic	■	■					■	■
	High Accident Rate	■	■		■		■	■	■
	Dilemma Zone		■					■	
	Engineering Judgment	■	■	■					■
	Minor Road Traffic Volume	■							
	Secondary Approach						■		

Note: Shaded grid indicates the agency considers the condition.

2.2 Design Guidelines

As with installation guidelines various transportation agencies use different variables to determine the physical location and design of an AWS system as well as how to determine the lead flash time. The lead flash time is the interval in seconds that the AWS is activated before the yellow interval begins. This section will be divided into an explanation of the factors used to determine: 1) the placement of AWS systems, 2) factors for lead flash time, 3) a comparison of AWS system design values, and 4) the type of sign specified.

2.2.1 Advance Warning Signal Placement

The primary factors that were used by the agencies reviewed to determine the placement of the AWS system included: 1) vehicle speed, 2) perception reaction time, 3) deceleration rate, 4) approach grade, and 5) friction factor. Not all of these factors are used by each agency, but their equations for the calculation of AWS placement are similar as will be shown by comparison in Section 2.2.3. The values used for the variables may vary according to the experience and judgment of the engineer for each intersection.

2.2.1.1 Vehicle Speed

The majority of agencies used posted speed limit as the vehicle speed. In a study by McCoy and Pesti for the University of Lincoln-Nebraska the 85^{th} percentile speed was used to calculate the placement of the AWS (*5*). Manitoba Transportation and Government Services and Washington State Department of Transportation also use the 85^{th} percentile speed (*8, 10*). The 85^{th} percentile speed was used in designing the AWS systems that are in current operation on Bangerter Highway to better represent the majority of drivers (*1*).

2.2.1.2 Perception Reaction Time

The perception reaction time is the time a typical driver uses to recognize the obstacle ahead for which braking is necessary, such as an intersection with a red signal, and for the driver to transition to apply the brakes (*15*). The amount of perception reaction time varies depending on the driver's expectation of an upcoming signal. The Nevada Department of Roads, the Minnesota Department of Transportation, and the

MUTCD use 2.5 seconds as the perception reaction time as recommended by AASHTO (*3*, *4*, *12*, *14*). A perception reaction of 2.5 seconds seems appropriate for isolated conditions typical for AWS. For the Transportation Association of Canada report this value is 1.5 seconds and in British Columbia it is 1.0 second (*2*, *7*). The Washington State Department of Transportation recommends a perception reaction time of 1.5 seconds and 2.5 seconds when limited sight conditions exist (*10*).

2.2.1.3 Deceleration Rate

Deceleration rates of drivers may vary, but a conservative value is desirable to ensure the safety of the majority of motorists. The agencies reviewed that included a deceleration rate had a wide range values. The Transportation Association of Canada report recommends a rate of 8.5 ft/sec^2 (*2*). The Minnesota Department of Transportation recommends a value of 10.0 ft/sec^2 (*3*). The City of Calgary recommends the most conservative value of 5.2 ft/sec^2 (*6*). The AASHTO Green Book recommends a value of 11.2 ft/sec^2 (*14*).

2.2.1.4 Approach Grade

The Transportation Association of Canada, the Minnesota Department of Transportation, the British Colombia Ministry of Transportation, the Kentucky Transportation Cabinet, and the Washington State Department of Transportation included approach grade in their AWS placement equation (*2*, *3*, *7*, *9*, *10*). The downhill grade has a distance for AWS placement that is farther than that of level ground because of the need for a greater stopping distance. The distance for AWS placement for the uphill grade is then shorter than that of level ground.

2.2.1.5 Friction Factor

A friction factor is a variable that was included in the equations for three agencies. The City of Calgary recommends a friction factor of 0.16 for the rubber tire on asphalt pavement that is wet (*6*). The British Columbia Ministry of Transportation uses

Table 2.2 for friction factors of wet pavement that vary by the vehicle speed which is based on a previous edition of AASHTO Green Book values (*7*). The most recent edition of the AASHTO Green Book suggest a value of 0.34 which is equal to a deceleration rate of 11.2 ft/sec^2 divided by the gravity constant of 32.2 ft/sec^2 (*14*).

2.2.1.6 AWS Placement Equations

Seven agencies had formulas to calculate the distance of the AWS placement from the stop bar. The Transportation Association of Canada and the Washington State Department of Transportation recommended Equation 2.1 using the variables of design speed, perception reaction time, deceleration rate, approach grade, and gravitational acceleration, with the assumption that the friction factor represented in the constant coefficient is 0.27 for wet pavement (*2, 10*). The assumptions are made of a driver's eye height of 3.5 ft and the height of an object seen by the driver of 2.0 ft. The Nevada Department of Transportation uses the AASHTO Green Book stopping sight distance equation, accounting for the approach grade in Equation 2.1 (*4, 14*).

$$D = 1.47Vt_{pr} + \frac{V^2}{30\left(\left(\frac{a}{32.2}\right) \pm G\right)} \tag{2.1}$$

where: D = AWS placement from the stop bar (ft),
V = design speed (mph),
t_{pr} = perception reaction time (sec),
a = deceleration rate (ft/s^2), and
G = grade (ft/100ft).

The City of Calgary recommended Equation 2.2 using variables of design speed, friction factor, and deceleration rate (*6*). The actual recommended values were rounded to the nearest multiple of 10 in metric units.

$$D = \frac{V^2}{30(f)} \tag{2.2}$$

where: f = friction factor (recommended 0.16 value).

The British Columbia Ministry of Transportation recommended Equation 2.3 using variables of design speed, perception reaction time, gravitational acceleration, friction factor as outlined in Table 2.2, and grade (*7*). This is very similar to Equation 2.1 except instead of a deceleration rate a friction factor is used. The value of the friction factor is usually calculated by dividing the vehicle deceleration rate by the gravity constant, and in this case the deceleration rate, and thus the friction factor also, decreases as the vehicle speed increases, shown previously in Table 2.2.

$$D = 1.47Vt_{pr} + \frac{V^2}{30(f \pm G)} \tag{2.3}$$

Note: friction factor (refer to Table 2.2).

Table 2.2 Friction Factors for Wet Pavement (*7*)

Posted Speed		Friction Factor
(mph)	(km/h)	
25	40	0.38
31	50	0.36
37	60	0.34
43	70	0.32
50	80	0.31
56	90	0.30
62	100	0.30

In a report prepared for the Nebraska Department of Roads by McCoy and Pesti, Equation 2.4 was used for the AWS placement, which is the same as Equation 2.1 minus a sign legibility distance. Equation 2.5 was used for the advance detection placement ahead of the AWS with variables of controller passage time setting, 85th percentile speed, and driver sign perception distance. The 85th percentile speed is the design speed plus 10 mph, designed to better represent the normal speed distribution of approaching vehicles. The value of sign legibility distance that is recommended is 125 feet. The value of the controller passage time setting that is recommended is 3 seconds (*5*).

$$D = 1.47Vt_{pr} + \frac{V^2}{0.93a} - d_L \tag{2.4}$$

where: d_L = sign legibility distance (ft).

$$D_{AD} = 1.47Vt_{cpt} + d_L \tag{2.5}$$

where: D_{AD} = distance between advance detector and AWS (ft), and
t_{cpt} = controller passage time setting (recommended 3.0 sec value).

As has been reported, a number of different equations for AWS placement from the stop bar depend on the agency in question. Different agencies have different standards and each agency has adjustments that are unique to their particular area. Equations 2.1 and 2.3 are identical equations with slight differences in the coefficients and constants used. All the equations are based on stopping sight distance.

2.2.2 Lead Flash Time

The Minnesota Department of Transportation, the Manitoba Transportation and Government Services, and the Kentucky Transportation Cabinet give table of distances for AWS placement from the stop bar in their conditions and lead flash times, but there is no equation from which they are calculated (*3*, *8*, *9*). These values are set as a function of the speed limit. The Kentucky Transportation Cabinet recommends AWS placement at a distance of 700 feet for highways with a speed limit of 45 mph and 900 feet for highways with a speed limit of 55 mph, and a lead flash time is to be 9 seconds and 10 seconds respectively. If an approach grade of 5 percent or greater exists then the maximum distance for the AWS is 1000 feet and the lead flash time should be 11 seconds (*9*). The Minnesota Department of Transportation and the Manitoba Transportation and Government Services have set design guidelines for the AWS placement and lead flash time as summarized in Table 2.3 and Table 2.4 respectively (*3*, *8*). Both are a function of posted speed limit. The values for AWS placement and lead flash time will be compared for the various agencies mentioned in Section 2.2.3.

Table 2.3 Minnesota Department of Transportation AWS Placement Distances and Lead Flash Times (*3*)

Speed Limit		AWS Placement		Lead Flash Time
(mph)	(km/h)	(feet)	(meters)	(seconds)
40	64	560	170	8.0
45	72	560	170	7.0
50	80	700	215	8.0
55	89	700	215	7.0
60	97	850	260	8.0
65	105	850	260	7.5

Table 2.4 Manitoba Transportation and Government Services AWS Placement Distances and Lead Flash Times (*8*)

Speed Limit		AWS Placement		Lead Flash Time
(mph)	(km/h)	(feet)	(meters)	(seconds)
37	60	217	66	5.0
43	70	322	98	6.0
50	80	443	135	7.0
56	90	548	167	8.0
62	100	725	221	9.0

The guidelines for seven agencies evaluated included formulas to calculate the lead flash time. The Transportation Association of Canada, the Nebraska Department of Roads, the British Columbia Ministry of Transportation, and the Washington State Department of Transportation recommended Equation 2.6 using the variables of AWS placement distance, driver sign perception distance, and vehicle speed (*2*, *5*, *7*).

$$T = \frac{D + d_L}{1.47V} \tag{2.6}$$

where: T = lead flash time (sec), and

d_L = sign legibility distance (ft).

The Minnesota Department of Transportation recommended Equation 2.7 using variables of AWS placement distance, and vehicle speed (*3*). The value of 1.5 seconds accounts for decision time.

$$T = \frac{D}{1.47V} - 1.5 \tag{2.7}$$

The Nevada Department of Transportation recommended Equation 2.8, which is similar to Equation 2.6 with the subtraction of the distance from the dilemma zone to the stop bar (*4*). The value of 140 feet is the legibility distance before the AWS.

$$T = \frac{D + 140 - D_z}{1.47V} \tag{2.8}$$

where: D_z = distance from the dilemma zone to the stop bar (ft).

In a personal contact within the New Jersey Department of Transportation it was reported that two equations are used for the lead flash time having vehicle speed as the variable and a constant distance between the stop bar and AWS installation of 1,000 feet.

Equation 2.9 is used when the posted speed is 45 mph or above, and Equation 2.10 is used when the posted speed is below 45 mph (*11*).

$$T = \frac{1000}{1.47(V - 10)} \quad (2.9)$$

$$T = \frac{1000}{1.47V} \quad (2.10)$$

The Federal Highway Administration recommended Equation 2.11 using variable of AWS placement distance, and the 85th percentile vehicle speed (*12*).

$$T = \frac{D}{V_{85}} \quad (2.11)$$

where: V_{85} = 85th percentile vehicle speed.

All six equations are similar with slight adjustments as deemed necessary by the particular transportation agency. A summary of the agencies that utilize specific design criteria for AWS systems is found in Table 2.5.

2.2.3 Comparison of AWS System Design Values

An example of the different methodologies for calculating the distance from the AWS to the stop bar and the lead flash time given that the speed limit is 50 mph is found in Table 2.6. The 85th percentile speed that is used when appropriate is 60 mph. The recommended values for deceleration rate and friction factor as recommended by each agency were used for a level roadway. The Kentucky Transportation Cabinet recommended a distance for the placement of AWS and a lead flash time for highways with speed limits of 45 mph and 55 mph, therefore, the average was used.

Table 2.6 shows that the AWS placement and lead flash time can vary greatly depending on the agency's guidelines. It is remarkable how none of the values are repeated. The effectiveness of each system is not reported, and such a comparison would be difficult because of the variety of factors that affect each individual location. This comparison is helpful to show that not every set of guidelines is equal to another.

Table 2.5 Summary of Design Guidelines

		Agency						
		Trans. Assoc. of Canada	Minnesota Dept. of Trans.	Nevada Dept. of Trans.	City of Calgary	British Columbia Min. of Trans.	MUTCD	Washington State DOT
Distance AWS to Stop Line	Vehicle Speed	■	■	■	■	■	■	■
	Perception Reaction Time	■	■	■		■	■	■
	Deceleration Rate	■	■	■	■		■	■
	Grade	■	■			■		
	Gravity	■				■		
	Friction				■	■	■	
Lead Flash	Distance from AWS to Stop Line	■	■	■	■	■		■
	Vehicle Speed	■	■	■	■	■		■
	Sign Sight Distance	■		■	■	■		■

Note: Shaded grid indicates the agency considers the condition.

Table 2.6 Comparison of Design Guidelines

Transportation Agency	AWS Placement (feet)	AWS Placement (meters)	Lead Flash Time (seconds)
Trans. Assoc. of Canada	425	130	6.7
Minnesota DOT	700	215	8.0
Nevada DOT	475	144	5.9
Nebraska Dep. of Roads	375	114	5.0
City of Calgary	525	160	7.0
British Columbia Min. of Trans.	343	104	5.6
Manitoba Trans. and Gov't Services	443	135	7.0
Kentucky Trans. Cabinet	800	244	9.5
Washington State DOT	379	116	6.1
New Jersey DOT	1000	305	13.6

Note: The design speed of 50 mph was used; all other variables used by the agency remained the same as in their individual guidelines.

2.2.4 Sign Type

The type of sign also varies for each individual agency. The most common sign is a dynamic sign with the phrase "Prepare To Stop When Flashing" (PTSWF) which includes warning flashers as shown in Figure 2.1 (*2*, *3*, *4*, *5*, *7*). The MUTCD recommends a similar message stating "when the warning beacon is interconnected with a traffic control signal or queue detection system, the 'Be Prepared to Stop' sign should be supplemented with a 'When Flashing' plaque" (*12*). Figure 2.2 shows a sign the MUTCD calls the "Signal Ahead" sign (*12*).

In a report by Bowman, 18 variations are given of the physical design of AWS that are dynamically coordinated with the pending signalized intersection (*13*). The different designs include variations in diamond and rectangle background with different background and text coloring, flasher configuration, overhead, and side mounted. The PSSA sign is shown in Figure 2.2. Bowman includes variations in the configuration and wording such as "Stop Ahead When Flashing," "Signal Ahead Prepare To Stop When Flashing," "Red Signal Ahead When Flashing," and "When Flashing Stop Ahead" (*13*).

Figure 2.1 PTSWF sign.

Figure 2.2 PSSA sign or MUTCD W3-3 Signal Ahead sign (*12*).

The New Jersey Department of Transportation uses a dynamic blank-out sign that states “Red Signal Ahead” (*11*). When in active the words “Signal Ahead” are shown and when activated in advance of the signal change the blank-out sign flashes the word “Red” alternated with “Signal Ahead” as shown in Figure 2.3. The figure shows how the sign alternates the words “Red” and “Signal Ahead.”

The comparison of static versus dynamic signs and the side-mounted versus overhead signs was researched. No literature was found making this comparison. Requests for sources on these subjects were made to various traffic signal and transportation professionals and the response was also that no known research was available on these subjects. The general opinion was that an overhead sign is more appropriate for roadways with several lanes. One personal contact expressed the opinion that an overhead sign is more effective than a side mounted sign because it is in the central vision of drivers, although, side-mounted signs on both sides may be as effective as an overhead sign. Another personal contact expressed the opinion that a comparison of overhead versus side-mounded signs would be difficult to test in the field. The same site would have two similar periods with static signs then dynamic signs, or side-mounted signs then overhead signs. This way a comparison can be made with most other conditions remaining constant.

Figure 2.3 New Jersey "Red Signal Ahead" (*11*).

2.3 Literature Review Summary

The literature review found that several transportation agencies have guidelines for the installation and design of AWS systems. The conditions of those guidelines include consideration for an intersection of limited sight distance, minimum speed, isolated intersections and the first intersection to an urban area, approach grade, heavy vehicle volume, high crash rate, dilemma zone, engineering judgment, minor road traffic volume, and secondary approach installations. An explanation of each of these conditions is given in this chapter. The factors used by the various agencies for determining the placement of AWS systems from the stop bar, the advance detection, and the lead flash time are discussed. The various types of sign design are explained. Chapter 3 will discuss the recommended guidelines that are to be used in evaluating the need for AWS installations in the state of Utah. They are based from the agency conditions in this chapter.

3 Recommended Guidelines

This chapter will discuss the guidelines for evaluation and installation of AWS systems recommended for use throughout the state of Utah. They have been developed through the collaboration of BYU researchers and a TAC. The TAC helped in the development process of the conditions for evaluating intersections for AWS system installation. These conditions were developed using the Policy Delphi method. This chapter will discuss each of these conditions and how they are to be evaluated. The evaluation of several intersections is performed using an evaluation matrix. The design of the signal system will also be discussed.

This chapter is organized by the following sections: 1) TAC, 2) methodology, 3) intersection evaluation, 4) guideline conditions, 5) intersection ranking system, 6) AWS system design, and 7) recommended guidelines chapter summary.

3.1 Technical Advisory Committee

As a UDOT funded research project a TAC was formed to guide the development of the evaluation conditions and evaluation matrix for prioritizing intersection AWS system need. The TAC included experienced professionals from the BYU research team, UDOT engineers from each of the four Regions as well as pertinent division engineers. The members of the committee were:

- Shana Lindsey, UDOT Engineer for Research and Development
- Larry Montoya, UDOT Traffic and Safety Design Engineer

- Peter Jager, UDOT Statewide Traffic Studies Engineer
- Rob Clayton, UDOT Safety Programs Engineer
- Deryl Mayhew, UDOT Intelligent Transportation Systems Project Manager
- Bryan Chamberlain, UDOT Intelligent Transportation Systems Engineer
- Mark Taylor, UDOT Traffic Operation Center Engineer
- Keith Wilde, UDOT Traffic Operation Center Engineer
- W. Scott Jones, UDOT Traffic and Safety
- Darin Deursch, UDOT Region One Traffic Engineer
- Evan Sullivan, UDOT Region Two Assistant Traffic Engineer
- Danielle Herrscher, UDOT Region Two Assistant Traffic Engineer
- Oanh Le, Region Two Signal Engineer
- Kris Peterson, UDOT Region Two Operations Engineer
- Doug Bassett, Region Three Traffic Engineer
- Troy Torgersen, Region Four Traffic Engineer
- Grant Schultz, BYU Assistant Professor
- Aaron Jensen, BYU Graduate Student
- Eric Talbot, BYU Undergraduate Student

3.2 Methodology

The process of development for the guideline conditions and evaluation matrix was done following the Policy Delphi method, described by Linstone and Turoff (*17*). According to Linstone and Turoff, the Policy Delphi approach is "an organized method for correlating views and information pertaining to a specific policy area and for allowing the respondents [which are experts in the field of study] representing such views and information the opportunity to react to and assess differing viewpoints" (*17*). The TAC members were decision makers as well as experts in the field of traffic engineering and, therefore, worked as a committee in an iterative process to refine the guidelines suggested by the monitoring group of BYU researchers. There are four phases to the Policy Delphi method: 1) exploration of the subject, 2) finding how the group views the issues, 3) exploring the disagreements, and 4) final evaluation.

3.2.1 Exploration of the Subject

The first step of the Policy Delphi method was done by the monitoring group of BYU researchers as found in the list of TAC members. A literature review was performed as described in Chapter 2. This information was summarized and presented to the TAC including specific conditions for the evaluation of intersections for AWS system and an evaluation matrix as they were developed. The details of each of the conditions and the process of evaluation that make up the guidelines were presented and discussed in monthly meetings with the TAC.

3.2.2 Finding How the Group Views the Issues

The TAC was given rough drafts of the recommended guidelines as each step was developed by the BYU researchers for review before and at the monthly TAC meetings. TAC members were allowed to ask question and voice concerns or opinions about each of the recommended guidelines. Many times the members of the TAC brought up new issues with regards to the recommended conditions. These were addressed with the collaborative help of the TAC members and presented for further evaluation in the Policy Delphi process.

3.2.3 Exploring the Disagreements

The valuable input of all the members was used to consider issues related to the guidelines and other aspects of the research. Every opinion that was shared was considered and the group debated the issues of the guidelines for that meeting. The group would come to a final decision of what should be used as the guidelines. The BYU researchers made the necessary adjustments for review by the members of the TAC in the following meeting. This iterative process was utilized in each of the monthly TAC meetings to finalize the guidelines recommended in this thesis for the use by UDOT.

3.2.4 Final Evaluation

After the guidelines were developed the evaluation of 24 locations was performed to verify that the conditions were effective for the evaluation of intersection for AWS installation and prioritizing the need for AWS systems for a group of intersections. The final results of the six conditions that will be discussed in Section 3.3 and Section 3.4 and the forms presented in Figures 3.1, 3.2, and 3.3 were refined and finalized by the TAC. Cutoff values for the conditions were first based from conditions of the reviewed agencies, and then modified by the committee through the Policy Delphi method as explained.

3.3 Intersection Evaluation

The guidelines for AWS evaluation include the evaluation of six conditions, which are limited sight distance, posted speed, isolated intersection, high crash rate, approach grade, and heavy vehicle volume. Section 3.4 discusses these conditions in detail. An intersection may be evaluated by the conditions using the "Intersection Evaluation for Advance Warning Signals" form displayed in Figure 3.1, which will be referred to as the intersection evaluation form. On the intersection evaluation form the six conditions are used to assist the person making a field evaluation. Several values are recommended to be collected by UDOT personnel, if possible, prior to performing field visits to more efficiently evaluate intersections, including the posted speed, distance to upstream intersection, expected and existing crash rates, approach grade, AADT, and heavy vehicle percentage. Supplemental information is provided with the intersection evaluation form including a table of stopping sight distances and a place to record intersection details, shown in Figure 3.2.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: ________________________________ **Date:__________**

City: ______________________ **Region: ______**

Approach Direction (circle): NB / SB EB / WB **Analyst:_________________**

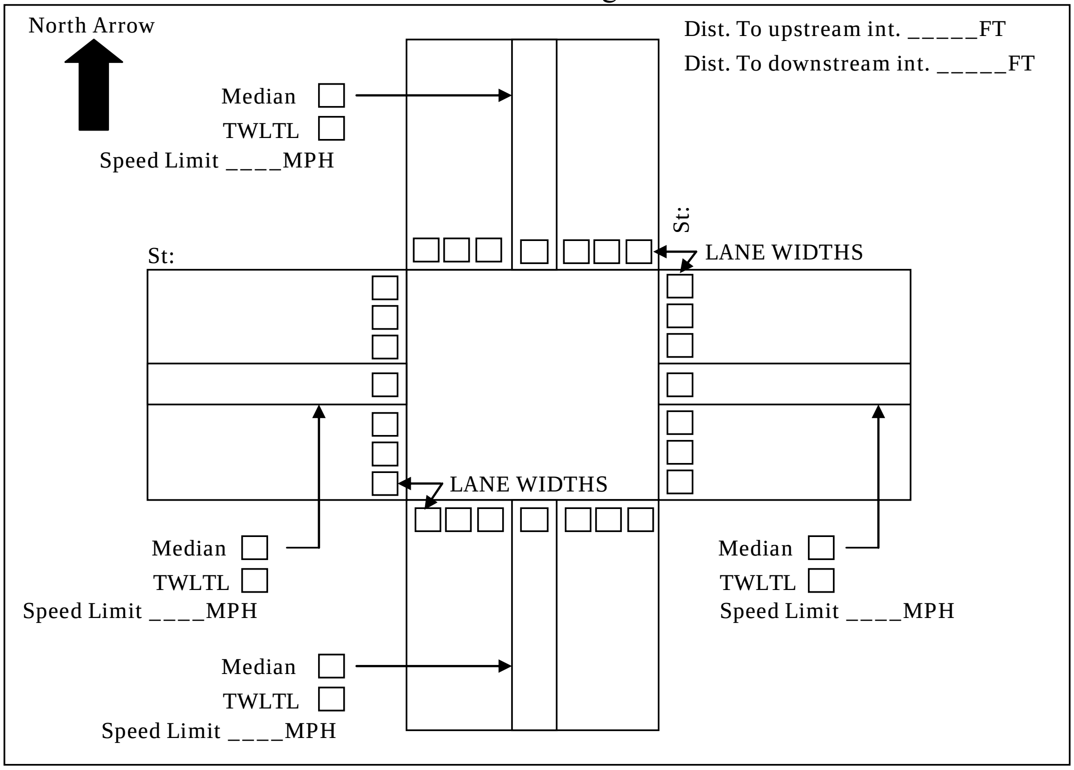
Condition[2]	Details	Evaluation[3] NB/EB	Evaluation[3] SB/WB
1 - Limited Sight Distance[4]			
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: ________ft SSD required plus queue length: ________ft		
2 - Posted Speed			
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:________mph		
3 - Isolated Intersection			
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): ________mi Dist. to upstream int. (SB/WB): ________mi		
4 - High Crash Rate[5]			
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: ________crashes/MEV Existing crash rate: ________crashes/MEV		
5 - Approach Grade			
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): ________% Approx. Grade (SB/WB): ________%		
6 - Heavy Vehicle Traffic Volume[5]			
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: ________vpd Heavy Vehicle: ________%		
Final comments and recommendations[7,8]:			
	Total:		

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure 3.1 Intersection evaluation for advance warning signals form.

Intersection Diagram[1]



Stopping Sight Distance (SSD)[4]

Design Speed (mph)	Stopping sight distance (ft)						
	Level grade	Downgrades			Upgrades		
	0%	3%	6%	9%	3%	6%	9%
15	80	80	85	85	75	75	75
20	115	120	120	130	110	110	105
25	155	160	165	175	150	145	140
30	200	205	215	230	190	185	180
35	250	260	271	290	240	230	225
40	305	315	333	355	290	280	270
45	360	380	400	430	345	335	320
50	425	450	474	510	405	390	375
55	495	520	553	595	470	450	435
60	570	600	638	690	540	515	495
65	645	685	728	790	615	585	565
70	730	775	825	895	690	660	635
75	820	870	927	1005	775	740	705
80	910	970	1035	1125	860	820	785

Figure 3.2 Intersection evaluation for advance warning signals form: supplemental information for evaluation.

3.4 Guideline Conditions

This section explains the six conditions that comprise the guidelines for evaluating the need for an AWS system. The conditions that are included are derived from the literature and Policy Delphi approval by of the TAC. The recommended conditions are: 1) limited sight distance, 2) posted speed, 3) isolated intersection, 4) high crash rate, 5) approach grade, and 6) heavy vehicle traffic volume. These conditions are principally applied to a HSSI where the danger of fatal crashes is more serious. HSSI as explained previously is defined in the literature as a roadway with a design speed of 45 mph or more (*15*). The six conditions are grouped into two categories based on the information contained in the literature as well as through the Policy Delphi Process with the TAC. The two categories are primary and secondary conditions. The conditions of limited sight distance, posted speed, isolated intersection, and high crash rate are primary conditions and the conditions of approach grade and heavy vehicle volume are secondary conditions. It was determined by the TAC that in order to consider the installation of an AWS system two or more conditions should be met and at least one of them should be a primary condition for installation of an AWS system for each condition in the sections that follow.

Through the Policy Delphi evaluation process it was determined that a condition may be met by meeting the minimum requirement or have greater emphasis when the condition may have a significant impact on the overall safety of the intersection. The condition that is not met receives a score of "0," the condition that is met receives a score of "1," and the condition that is considered with greater emphasis receives a score of "2." The points from each of the six conditions are added up for total score for the intersection. The definition of how each condition is scored by evaluation will be described individually in the sections that follow.

3.4.1 Limited Sight Distance

Limited sight distance can make an intersection or signal unexpected for drivers and place them in a dilemma zone as defined in Section 2.1.7. An AWS can aid in providing reliable information to prepare the driver to stop. The AASHTO Green Book stopping sight distance equations should be used to calculate the limited sight distance. The resulting values of stopping sight distance, a function of design speed and grade, are displayed in Table 3.1 (*14*). This table is also provided on the reverse side of the intersection evaluation form for convenience of the reviewer. An appropriate queue length is recommended to be added to the stopping sight distance at the discretion of the reviewer, and based on the TAC Policy Delphi approach a minimum queue length of 125 to 150 feet is noted on the intersection evaluation form; this is to accommodate approximately five to six passenger vehicles.

Table 3.1 Stopping Sight Distance (*14*)

Design Speed (mph)	Stopping Sight Distance (feet)						
	Level grade	Downgrades			Upgrades		
	0%	3%	6%	9%	3%	6%	9%
15	80	80	82	85	75	74	73
20	115	116	120	126	109	107	104
25	155	158	165	173	147	143	140
30	200	205	215	227	200	184	179
35	250	257	271	287	237	229	222
40	305	315	333	354	289	278	269
45	360	378	400	427	344	331	320
50	425	446	474	507	405	388	375
55	495	520	553	593	469	450	433
60	570	598	638	686	538	515	495
65	645	682	728	785	612	584	561
70	730	771	825	891	690	658	631
75	820	866	927	1003	772	736	704
80	910	965	1035	1121	859	817	782

The intersection evaluation form includes a place for the stopping sight distance to be recorded as well as the same distance plus a queuing distance. To evaluate this condition at the intersection the person stands at the stopping sight distance plus queue length. This distance may be measured with a measuring wheel or some other distance measuring device. If the signal is in clear sight at 2 ft from the pavement, the typical driver eye level, then this condition is not met. If the signal is possible to see but is difficult to see with traffic or during harsh weather conditions typical to the area, or if the signal to the intersection is visible, but may not obvious to most drivers then this condition is met. The condition is met with greater emphasis if any permanent obstruction is present, such as the hillside, roadway, trees, bridge, or building.

3.4.2 Posted Speed

As previously stated, AWS systems are primarily a concern for HSSIs due to the risks of serious crashes. The literature indicates that posted speed is a consideration for AWS installation in nearly every instance (*2*, *3*, *4*, *6*, *7*, *8*, *9*, *10*). Based on the literature reviewed and the TAC Policy Delphi approach, the condition of posted speed was considered to be met at intersections with a posted speed on the approach equal to or greater than 45 mph and less than 60 mph. If the posted speed on the approach is 60 mph or greater, the condition is considered with greater emphasis. It is recommended for analysis that the reviewer identify the posted speed limit upstream of the intersection for use in the analysis. This value and the corresponding values can be entered on the intersection evaluation form.

3.4.3 Isolated Intersection

Isolated intersections have the potential to be hazardous because a driver may have become accustomed to a rural or otherwise unsignalized environment. An isolated intersection can be defined as the first signalized intersection to an urban area or an intersection that is unexpected due to a long distance to the nearest upstream signalized intersection. A long distance may vary depending on engineering judgment of the reviewer according to the local area. This may be a distance greater than 1 mile or 5 miles. The literature defines isolated intersections as those ranging from 1.2 miles (*8*), 10 miles (*3*, *10*), or “many” miles (*7*).

The behavior of driving should be considered when identifying an isolated intersection. A period of time at a consistently high speed may result in drivers having a slower perception/reaction time and deceleration rate when they approach an intersection. For example, what is considered an isolated intersection in an urban area may not be considered isolated by the reviewer in a rural area.

The intersection evaluation form includes a section for the reviewer to record the distance to the upstream intersection for both roadway directions. The upstream intersection recorded on the form is intended as a signalized intersection or major junction where the roadway begins, whether it is signalized or not. The reviewer must judge whether the condition is met with or without greater emphasis. Driver frequency of use, expected signal phase, speed limit, frequency of driveway or side street access, and traffic volume of the roadway and cross street are a few factors that may be considered by the reviewer in determining the need for an AWS by this condition.

3.4.4 High Crash Rate

A high crash rate is most likely an indication that one of the other conditions exists for a specific intersection, such as, sight distance problems, an unexpected intersection, excessive grade, etc. A high crash rate may also be a result of improper signal timing, driver confusion, and a number of other factors. The reviewer must be confident that AWS installation is the proper mitigation to help prevent crashes.

To begin to evaluate the safety impact of the analysis site as a function of crash rate, values for the previous year's expected and existing crash rates, in units of crashes per million entering vehicles (MEV), are obtained from the UDOT Traffic and Safety Division. The values are recommended to be obtained and input on the intersection evaluation form prior to the site visit. The engineer performing the evaluation of an intersection for an AWS should examine the cause of a higher expected crash rate to determine if the installation of an AWS system may help to reduce this rate. This condition may be considered as met when the difference between the existing crash rate minus the expected crash rate is between zero and one, or considered with greater emphasis when the difference is one or greater. These parameters for evaluating high crash rates were recommended to the TAC through the Policy Delphi process and the committee agreed that they were adequate for the evaluation process.

3.4.5 Approach Grade

Drivers on a downhill grade may have a more difficult time estimating their stopping, which may lead to a vehicle running a red light, potentially colliding with cross traffic vehicles, or rear-ending another vehicle already stopped at or behind the stop bar. As outlined previously in Table 3.1, the stopping sight distance increases as the downgrade increases thus compounding the problem of stopping. The grades in this table are listed as multiples of 3 percent for simplicity of fieldwork and evaluation. Actual values should be rounded to the nearest multiple of 3 percent when calculating the stopping sight distance from Table 3.1. Approach grades should be measured as accurately as possible by the field crew. In the absence of field grade measuring devices, approximate values can be utilized.

To evaluate approach grades the approximate approach grade in each direction of the roadway to the intersection can be entered on the intersection evaluation form. For approach grades that vary, a grade that represents the overall effect on vehicle speeds for the length of the stopping sight distance should be used. This condition may be considered as met if the grade is equal to or greater than 3 percent and less than 6 percent, or may be considered with greater emphasis if the grade is 6 percent or greater. The Manitoba Transportation and Government Services and the Washington State Department of Transportation use a cutoff of 3 percent grade for the need for AWS installation (*8*, *10*). This was the basis for the choice of 3 percent for this condition as met. The AASHTO Green Book refers to 3 percent and 6 percent grades to specify the stopping sight distance (*14*). These same parameters have been used here and were discussed and agreed upon through the TAC Policy Delphi approach.

3.4.6 Heavy Vehicle Traffic Volume

Operating conditions for heavy vehicles vary from passenger cars such that red light running for heavy vehicles may be a result of a dilemma zone situation, which is different for heavy vehicles than for passenger vehicles. Sudden stops by heavy vehicles have also been known to result in load spills that may be hazardous for other vehicles, while increasing the cost of maintenance of the roadway. AWS systems provide information to heavy vehicles operators that can aid the driver in making decisions to avoid difficult situations.

The value for the most recent heavy vehicle volume and the roadway AADT may be obtained from the UDOT Traffic and Safety Division and can be recorded on the intersection evaluation form. The AADT may be useful as a comparison for field visits and for heavy vehicle traffic volume evaluation. Heavy vehicle traffic may be seasonal in some cases, such as in an agricultural area and should be noted in making an evaluation. Although values of 10 percent and 15 percent were used by the Transportation Association of Canada as cutoff values for this condition (*2*), the Policy Delphi approach determined that 10 and 20 percent should be used for the evaluation of this condition. Through the evaluation process it was determined that this condition may be met if the percent of trucks is equal to or greater than 10 percent and less than 20 percent. A percent of trucks of 20 percent or greater may qualify as met with greater emphasis.

3.5 Intersection Ranking System

The intersection ranking system is an analysis of intersections for AWS installation decisions. There were no ranking systems found from the literature review. As such the intersection ranking system was developed for this research by BYU researchers and the TAC using the Policy Delphi approach, including possible scoring systems. Variations of the scoring system were analyzed through a sensitivity analysis which was also discussed in a TAC meeting. The comparison of intersections and the sensitivity analysis are discussed in further detail in Chapter 4. Once the intersection evaluation has been performed the prioritization of several intersections by need of AWS installation may be prepared using the "Intersection Comparison for Advance Warning Signals" form. This form is displayed in Figure 3.3 and will be referred to as the intersection comparison form.

Intersection Comparison for Advance Warning Signals

Region:____________________ **Date:**____________________

Analyst:____________________

Intersection	City	Condition							Total	Rank
		1	2	3	4	5	6	±		
Intersection A										
Intersection B										
Intersection C										
Intersection D										
Intersection E										
Intersection F										
Intersection G										
Intersection H										
Intersection I										
Intersection J										
Intersection K										
Intersection L										
Intersection M										
Intersection N										
Intersection O										
Intersection P										
Intersection Q										
Intersection R										
Intersection S										
Intersection T										

Final comments & recommendations:

Notes:

1. Two or more conditions must be met including one of the following conditions: 1,2,3,or 4.
2. Rank with a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
3. Ranking shall be done according to engineering judgment.
4. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure 3.3 Intersection comparison for advance warning signals form.

The intersection evaluation form and the intersection comparison form should be considered together in the evaluation matrix process. For example, an intersection that receives a low point ranking but has two fatalities in the past 3 years would be a high priority intersection to correct with an AWS system or some other mitigation. In all cases, especially in the case of intersections with equal ranking, engineering judgment should be exercised.

The values for each condition are input into the table of the intersection comparison form and the total score for each intersection are presented in the last column. This form allows for a convenient display of all the intersection evaluation results consisting of the evaluation for each condition and the total score. The results are ranked by the total score for each intersection to prioritize the implementation of AWS systems according to the engineering judgment of the reviewers. The researchers at BYU performed a sensitivity analysis to provide a way to rank the intersections evaluated in an effective way. Application of the process is provided and the method and results of the sensitivity analysis in Chapter 4.

3.6 Advance Warning Signal System Design

The AWS system design that is recommended as part of the installation guidelines is based on previous research by Schultz and Peterson (*1*). The details of the installation guidelines are included to provide a complete recommendation of AWS guidelines in this chapter.

The AWS system was installed at three locations along S.R. 154 (Bangerter Highway) at S.R. 68 (Redwood Road), 2700 West, and 13400 South in the summer of 2005. This system was described and analyzed at the intersection of Bangerter Highway and 13400 South in previous research (*1*). Cost estimates were collected for this thesis for comparison of various AWS system designs. A table of installation parameters was prepared for use in the standard drawings for the AWS system.

The AWS system is composed of three components that will be discussed: 1) AWS component, 2) advance detection component, and 3) a signal timing component.

3.6.1 Advance Warning Signal Component

The AWS component consists of the AWS design and the AWS placement upstream of the intersection stop bar. The AWS design is an overhead mounted sign on a cantilever arm consisting of a blank-out message sign containing the words “Prepare To Stop” and two flashing beacons as illustrated in Figure 3.4 (*1*). Equation 3.1 is based on Equation 2.4 recommended by McCoy and Pesti, modified to include the variable of approach grade similar to Equation 2.1 from the AASHTO Green Book. This equation is used to calculate the distance the AWS is placed from the stop bar (*5, 14*).

$$D = 1.47Vt_{pr} + \frac{V^2}{0.93(a \pm G)} - d_L \qquad (3.1)$$

where: D = AWS placement from the stop bar (ft),
V = design speed (mph),
t_{pr} = perception reaction time (sec),
a = deceleration rate (ft/s^2),
G = grade (ft/100ft), and
d_L = sign legibility distance (ft).

For the purpose of demonstrating the difference in cost for various AWS system designs the most recent costs of the system were obtained from UDOT for the three installations on Bangerter Highway installed in 2005. These costs are summarized in Table 3.2, broken down by AWS sign type. The cost of the blank-out message sign which has two rows of 14 inch letters and overall sign dimensions of 48 inches by 96 inches by 12 inches was reported to be $7,000 (2004 dollars). The cost of the overhead mounted blank-out sign installed at three locations on Bangerter Highway was reported to be $17,900 per installation (2004 dollars). The side-mounted blank-out message sign design was reported to be a cost of $11,000 (2004 dollars). The total cost for a static shoulder mounted 60 inch by 60 inch MUTCD warning sign that says “Prepare To Stop When Flashing” was reported to be $5,100 (2004 dollars).

From the professional opinions obtained and the discussion in TAC meetings the overhead mounted sign should be used on a four lane highway or greater, while a two lane highway may have side mounted AWS signs.

Figure 3.4 AWS sign and flashers.

Table 3.2 AWS Sign Cost Estimates

AWS Sign Type	**Cost (2004 dollars)**			**Total**
	Advance Warning Sign	**Sign Support Structure**	**Foundation and Installation**	
Blank-out Overhead Mounted	$7,000	$5,900	$5,000	$17,900
Blank-out Side-mounted	$7,000	$1,500	$2,500	$11,000
Static Shoulder Mounted	$600	$1,000	$3,500	$5,100

3.6.2 Advance Detection Component

The advance detection component is a detection device that senses a vehicle at a distance from the AWS determined by Equation 3.2 (*5*). Advance detection is necessary to sense a gap in traffic for the AWS system to work more efficiently. A gap in traffic is desirable to activate the signal change such that no vehicles are caught in the dilemma zone during the yellow change interval.

$$D_{AD} = 1.47Vt_{cpt} + d_L \tag{3.2}$$

where: D_{AD} = distance between advance detector and AWS (ft), and
t_{cpt} = controller passage time setting (recommended 3.0 sec value).

The most recent estimated cost of the advance detection component based on the costs from the AWS installations on Bangerter Highway was provided by UDOT. The advance detection device sensor was reported to be $4,000 (2004 dollars). The advance detection device sensor may be mounted on an existing pole such as a street light pole or the blank-out side mounted pole at a cost of $2,500 (2004 dollars) may be required. This includes the cost of the pole, reinforced concrete foundation, and installation fees. Additional costs for the wiring, electronic equipment, and miscellaneous parts of $1,635 (2004 dollars), along with installation fees of approximately $6,280 to $7,280 (2004 dollars) are also required. The total estimated cost for the advance detection component, therefore, is approximately $11,415 to $15,415 (2004 dollars).

3.6.3 Signal Timing Component

From the research by McCoy and Pesti, the equation for the lead flash time, shown previously in Equation 2.6, has been modified in previous UDOT research (*1*). The lead flash time is calculated using Equation 3.3, which has variables of distance of the AWS placement from the stop bar, sign legibility distance, design speed, and time of travel from the AWS sign to the beginning of the decision zone. The location of the beginning of the decision zone is where approximately 5 to 10 percent of drivers would stop at the intersection they are approaching at the onset of the yellow phase. The distance of advance detection ahead of the stop bar is connected with the signal time so that a vehicle traveling at the 85th percentile speed that observed the activated AWS cannot safely traverse the intersection during the green or yellow phase and will have to stop.

$$T = \frac{D + d_L}{1.47V} - DCZ_n \qquad (3.3)$$

where: T = lead flash time (sec), and

DCZ_n = time needed for n percent probability of stopping (assume 2.5 sec, for 5 percent probability of stopping),

n = desired probability of stopping (1, 5, or 10 percent).

The calculations for the distance from the stop line of the AWS sign and advance detection zone, and the lead flash time are found in Table 3.3. This table is recommended to be used in the standard drawings for the AWS system. The distances are based on the design speed or the 85th percentile speed. The lead flash time assumes a 2.5 second reduction for the 5 percent probability of stopping. This can be adjusted based on local conditions, while an equation and guidelines for calculating such a value can be found in the literature (*1*).

Table 3.3 Design Installation Guidelines (*5*)

85th Percentile Speed (mph)	Design Speed (mph)	Distance From Stop Line (ft)		Lead Flash Time (sec)
		Advance Detection	AWS	
65	55	755	445	4.1
60	50	655	365	3.7
55	45	560	290	3.3
50	40	470	225	3.0
45	35	385	160	2.5

Note: AWS placement for approach grades other than zero may be calculated using Equation 3.1.

As noted previously the distance from the stop line of the AWS sign and advance detection are calculated from the equations found in the report by McCoy and Pesti, assuming a zero percent grade (*5*). The location the AWS sign from the stop line may be calculated using Equation 3.1. The values of lead flash time are calculated from the equation recommended in the research by Schultz and Peterson (*1*).

3.7 Recommended Guidelines Chapter Summary

This chapter outlined guideline conditions derived from the literature review and the engineering judgment of the researchers from BYU and the TAC following the Policy Delphi method throughout the course of the research. The guidelines recommended include limited sight distance, isolated or first intersection, approach grade, high crash rate, heavy vehicle volume, and high traffic volume. The first four conditions are to be considered primary conditions and the last two conditions are secondary conditions. The reasons why these six conditions are important are provided in the discussion. In addition, the intersection ranking system is explained and the design options for AWS systems are specified. Forms are given for the intersection evaluation and the intersection ranking system in Figure 3.1, Figure 3.2, and Figure 3.3. Chapter 4 utilizes the guideline outlined in this chapter and applies the evaluation process to 24 intersections across the state of Utah.

4 Intersection Evaluation Matrix

This chapter will discuss the process of identifying intersections for the consideration of AWS systems. The process of the evaluation matrix described in this chapter included application and subsequent revision and clarification of the conditions and evaluation matrix described in Chapter 3 to a point that they effectively evaluate an intersection on criteria that are appropriate for consideration of an AWS system. Intersections were identified using various resources provided by UDOT. The form "Intersection Evaluation for Advance Warning Signals" illustrated previously in Figure 3.1 and Figure 3.2 was used to evaluate the intersections according to the installation conditions outlined in Chapter 3. The form "Intersection Comparison for Advance Warning Signals" illustrated previously in Figure 3.3 was used to rank each of the intersections to determine the prioritization for an AWS system. The results of the intersection were compared in a variety of ways as part of a sensitivity analysis to finalize the Policy Delphi analysis results. The application of this process to existing intersections was done as verification that the conditions and forms are effective in analyzing the need and appropriateness of an AWS system.

This process is explained in further detail in the following sections: 1) identifying intersections, 2) evaluation sites, 3) evaluating matrix, 4) sensitivity analysis of results, and 5) conclusion to the evaluation matrix.

4.1 Identifying Intersections

A total of 24 intersections were identified and evaluated for possible AWS system application. The intersections for evaluation were identified in four steps: 1) state routes were identified on maps that had approaches to urbanized areas, 2) crash data was analyzed to identify intersections with high crash rates that were isolated, 3) video of the state routes were observed to verify intersections that were isolated and may have had approaches with limited sight distance, and 4) the TAC provided the researchers recommendations for review and comments.

4.1.1 State Route Identification

To begin identifying intersections for AWS evaluation Region maps from the UDOT website were used to identify each state road that would have possible isolated intersections (*18*). The maps used display the urbanized area of each region with the state routes labeled. The state routes that entered urbanized areas were identified because they may have met several of the guideline conditions including isolated intersection and high posted speeds.

4.1.2 Crash Data Almanac

Next the identified highways that were selected formed the basis for identifying intersections using the UDOT Crash Data Almanac (*19*). The Crash Data Almanac is a database maintained by UDOT where statistics and details of all the crashes on Utah state roads reported by law enforcement officers are stored for past years that data are available. Intersections were identified by setting up search filters identifying the severity of crashes for intersections along the designated state route. A three year period of the most recent crash history was used from 2002 to 2004. The searched produced lists of all the accidents with a crash rate representing the severity of the incidents that occurred by milepost. The output of these searches was a list of incidents where the nearby signalized intersections may have been a factor in the crashes. No incidents were found having high crash rates in areas where AWS systems seemed appropriate by the criteria of proximity to a signalized intersection near an urbanized area. The output had a frequency of incidents that was helpful to identify possible isolated intersections.

4.1.3 State Route Video

The third step was to evaluate and identify road segments with the UDOT Roadview system (*20*). The Roadview system shows video of every state highway by milepost. Intersections identified by the Crash Data Almanac were verified using the Roadview system to ensure that they were indeed isolated. This was effective in verifying that intersections were isolated since the milepost was known and the previous intersection could be observed. Details of rural and urban area were observed as well. Intersections that had stopping sight distance concerns could also be evaluated and identified using the Roadview system.

4.1.4 TAC Review and Comments

Once a list of potential intersections was compiled by BYU researchers from the first three steps, these results were taken to the TAC for review and further recommendations. The Region traffic engineers on the TAC were resourceful for their recommendations and comments on the intersections recommended by BYU researchers. The knowledge locally of each area by the Region Traffic Engineer proved to be more valuable than using the Crash Data Almanac or Roadview programs. The Region Traffic Engineers evaluated the intersections first recommended, removing several and recommending several intersections in their place that were proven to be good candidates. It is recommended that the Region Traffic Engineers or a person with equivalent knowledge of the area be utilized to identify possible intersection for AWS installation in the future and that the Crash Data Almanac and Roadview programs be used only in extreme cases where the qualified personnel are not available.

The final list of intersections for evaluation included:

- S.R. 91 & S.R. 142 in Richmond,
- S.R. 91 & S.R. 101 in Wellsville,
- S.R. 91 & Main Street in Brigham City,

- S.R. 91 & 775 West in Brigham City,
- S.R. 39 & S.R. 126 in Marriot-Slatterville,
- S.R. 126 & S.R. 79 in Ogden,
- S.R. 126 & S.R. 134 in Farr West,
- S.R. 201 & 8400 West in Magna,
- S.R.248 & S.R. 40 near Park City,
- S.R. 190 & 7000 South in Sandy,
- S.R.210 & Wasatch Boulevard in Sandy,
- S.R.68 & S.R.140 in Bluffdale,
- S.R. 92 & Triumph Boulevard in Lehi,
- S.R. 92 & Center Street in Lehi,
- S.R. 92 & 1200 East in Lehi,
- S.R. 40 & S.R. 32 in Heber,
- S.R. 189 & S.R. 52 in Provo,
- S.R. 89 & 1860 South in Provo,
- S.R. 89 & S.R. 75 in Springville,
- S.R. 130 & Cross Hollow in Cedar City,
- S.R. 56 & Lund Highway in Cedar City,
- S.R. 56 Airport Way in Cedar City,
- S.R. 9 & Telegraph Road in Washington, and
- S.R. 18 & Snow Canyon Parkway in St. George.

4.2 Evaluation Sites

Preliminary data for each of the 24 intersections was prepared by UDOT where possible, including posted speed, distance to upstream intersection for both approaches, expected and existing crash rate, AADT values, and percent of heavy vehicles. Site visits were made to each intersection where the intersections were evaluated using the "Intersection Evaluation for Advance Warning Signals" form, displayed previously in

Figure 3.1 and Figure 3.2. The intersection evaluation form was revised over the course of the intersection evaluation process to ensure an easy-to-use format with clear directions. All of the necessary information became apparent as the variations of the form were being tested. The intersections were evaluated concurrently with TAC members.

The unique characteristics of each intersection will be discussed in the following subsections. Posted speed and AADT values will be provided with completed evaluation forms provided in the Appendix organized by Region. The forms have been typed from the handwritten forms used as field visits were made. The reverse side of the intersection evaluation form shown in Figure 3.2 for each intersection is for supplemental notes and as such is not included in this thesis.

Of the 24 intersections evaluated, seven intersections were in Region 1, five intersections were in Region 2, seven intersections were in Region 3, and five intersections were in Region 4. Three of the intersections currently have PSSA signs present, S.R. 201 with 8400 West, S.R. 189 with S.R. 52, and S.R. 9 with Telegraph Rd. At the intersections of S.R. 18 with Snow Canyon Pkwy and S.R. 91 with Main Street there are AWS systems of an overhead PTSWF sign and flashers. Each of the intersections will be discussed by Region in the following sections.

4.2.1 Region 1

Seven intersections were evaluated in Region 1: 1) S.R. 91 & S.R. 142 in Richmond, 2) S.R. 91 & S.R. 101 in Wellsville, 3) S.R. 91 & Main Street in Brigham City, 4) S.R. 91 & 775 West in Brigham City, 5) S.R. 39 & S.R. 126 in Marriot-Slatterville, 6) S.R. 126 & S.R. 79 in Ogden, and 7) S.R. 126 & S.R. 134 in Farr West. Detailed intersection evaluation forms are provided in Appendix A.

4.2.1.1 S.R. 91 & S.R. 142 in Richmond

The intersection of S.R. 91 & S.R. 142 in Richmond is shown in Figure 4.1. S.R. 91 for this area is a four lane highway intersection that has uphill approaches from the north and the south. The AADT value is 11,550 vehicles per day. This intersection services traffic from three nearby schools, and as such two points were added to the evaluation score to account for the increased pedestrian use. There is, however, clear sight distance and a posted speed of 45 mph, which one of the lowest posted speeds of all the intersections compared.

Figure 4.1 Intersection of S.R. 91 & S.R. 142 in Richmond.

4.2.1.2 S.R. 91 & S.R. 101 in Wellsville

The intersection of S.R. 91 & S.R. 101 in Wellsville is shown in Figure 4.2. S.R. 91 for this area is a four lane highway in a rural setting. There is clear sight distance from both approaches. The posted speed is 60 mph which is one of the highest posted speeds of all the intersections compared. The AADT value is 17,540 vehicles per day. There is a railroad crossing north of the intersection, as shown in Figure 4.2 that would make placement of an AWS sign at the recommended distances from the stop bar difficult, as the AWS sign should not detract from the railway signage.

Figure 4.2 Intersection of S.R. 91 & S.R. 101 in Wellsville.

4.2.1.3 S.R. 91 and Main Street in Brigham City

The intersection of S.R. 91 and Main Street in Brigham City is shown in Figure 4.3. S.R. 91 for this area is a four lane highway, and is the first intersection to an urban area with a posted speed of 55 mph. This site was added as the intersection of S.R. 91 and 775 West was being evaluated because of its proximity and potential for an upgrade to the recommended AWS system from this research. On the eastbound approach there are currently overhead static PTSWF AWS signs with flashers. The approach grade for this direction is negative 6 percent or greater. The AADT value is 20,883 vehicles per day. The westbound approach is at a slight uphill and comes from the urban side.

Figure 4.3 Intersection of S.R. 91 & Main Street in Brigham City.

4.2.1.4 S.R. 91 and 775 West in Brigham City

The intersection of S.R. 91 and 775 West in Brigham City is shown in Figure 4.4. S.R. 91 for this area is a four lane highway in an urban area with a posted speed of 55 mph. This intersection is nearly a quarter mile of the intersection of S.R. 91 and Main Street, and 1.2 miles from the nearest signalized intersection on the eastbound approach. The AADT value is 20,883 vehicles per day.

Figure 4.4 Intersection of S.R. 91 & 775 West in Brigham City.

4.2.1.5 S.R. 39 and S.R. 126 in Marriot-Slatterville

The intersection of S.R. 39 and S.R. 126 in Marriot-Slatterville is shown in Figure 4.5. S.R. 39 for this area is a four lane highway in a rural setting. The posted speed is 55 mph and the AADT is 9,910 vehicles per day. The two main highways crest at the intersection, thus making it difficult to see vehicles approaching from the opposite direction. Currently, the intersection signal is unobscured and as it was evaluated it was thought by the reviewers that an overhead AWS sign might obstruct the intersection signal. This would need to be considered in more detail if an AWS system were to be installed at this location.

Figure 4.5 Intersection of S.R. 39 & S.R. 126 in Marriot-Slatterville.

4.2.1.6 S.R. 126 & S.R. 79 in Ogden

S.R. 126 ends at the intersection with S.R 79 in Ogden as shown in Figure 4.6. The posted speed is 55, the AADT value is 12,890 vehicles per day, and the intersection has clear sight distance. The northbound approach of S.R. 79 has two through lanes and a free-flow right turn lane, and the southbound approach has a left-turn lane and a free-flow through lane separated from the intersection by a concrete barrier. On the westbound approach to this intersection there is no through movement. As such, drivers must stop or slow down to make a left in one lane or right turn in another lane. Because of the free-flow right turn, it was determined by the reviewers that a message preparing drivers to stop when not all lanes must stop would not command attention and respect. This is a situation where AWS may not be appropriate because of the geometry of a T-intersection. The purpose of an AWS system is to warn drivers to stop in advance of the onset and activation of the yellow and red phase.

Figure 4.6 Intersection of S.R. 126 & S.R. 79 in Ogden.

4.2.1.7 S.R. 126 and S.R. 134 in Farr West

The intersection of S.R. 126 and S.R. 134 in Farr West is shown in Figure 4.7. S.R. 126 for this area is a four lane highway that is in an urban area, and has a posted speed of 55 mph. This intersection is very near a freeway interchange east on S.R. 134. To the west of the intersection on S.R. 134 is a school. There is high probability of future development occurring in the area. The intersection is given greater emphasis as an isolated intersection from the southbound approach; however, it is coming from a growing urban area as well. The AADT value is currently low at 8,735 vehicles per day.

Figure 4.7 Intersection of S.R. 126 & S.R. 134 in Farr West.

4.2.2 Region 2

Five intersections were evaluated in Region 2: 1) S.R. 201 & 8400 West in Magna, 2) S.R.248 & S.R. 40 near Park City, 3) S.R. 190 & 7000 South in Sandy, 4) S.R.210 & Wasatch Boulevard in Sandy, and 5) S.R.68 & S.R.140 in Bluffdale. Detailed intersection evaluation forms are provided in Appendix B.

4.2.2.1 S.R. 201 and 8400 West in Magna

The intersection of S.R. 201 and 8400 West in Magna is shown in Figure 4.8. S.R. 201 for this area is a four lane highway in a rural setting with a posted speed of 60 mph which is one of the highest posted speeds of all the intersections compared. There is clear sight distance at the intersection. There are currently side-mounted AWS signs in place, called by the MUTCD as PSSA signs (*12*). The intersection design is a channelized T- intersection with the westbound left-turn lane divided by islands. The entering westbound traffic from 8400 West is divided by an acceleration lane from the westbound through traffic as well. As a result, the westbound traffic does not necessarily need an AWS system. The eastbound traffic has horizontal curves on the approach to the intersection that has a traffic calming effect. The AADT value is 22,605 vehicles per day.

Figure 4.8 Intersection of S.R. 201 & 8400 West in Magna.

4.2.2.2 S.R. 248 and S.R. 40 near Park City

The intersection of S.R. 248 and S.R. 40 is part of an interchange near Park City, as shown in Figure 4.9. S.R. 248 for this area is a four lane highway in a rural setting, several miles from another intersection, and has horizontal curvature combined with downward vertical curve approaches to the interchange with the over passing S.R. 40.

The posted speed drops to 45 mph, likely because of the interchange and geometric design. The AADT is 13,830 vehicles per day with a heavy vehicle traffic volume of 13 percent. This is a good candidate for AWS installation because of the conditions of limited sight distance, posted speed, isolated, approach grade, and heavy vehicle traffic volume.

Figure 4.9 Intersection of S.R. 248 & S.R. 40 near Park City.

4.2.2.3 S.R. 190 and 7000 South in Sandy

The intersection of S.R. 190 and 7000 South in Sandy is shown in Figure 4.10. S.R. 190 for this area is a four lane highway in an urban setting. The posted speed is 50 mph, the AADT is low at 4,145 vehicles per day, and the heavy vehicle traffic is 15 percent. The northbound approach is the likely direction to need AWS installation. This approach has a downgrade of over 6 percent and is more than 1 mile from the previous signalized intersection. The southbound direction includes a horizontal upgrade and vertical curve approach, limiting the sight distance. There is a large overhead directional sign at the location where AWS placement should go, which however, may make the AWS system design more difficult, if UDOT were to determine to install an AWS system at this location.

Figure 4.10 Intersection of S.R. 190 & 7000 South in Sandy.

4.2.2.4 S.R. 210 and Wasatch Boulevard in Sandy

The intersection of S.R. 210 and Wasatch Boulevard in Sandy is shown in Figure 4.11. S.R. 210 for this area is a two lane highway in an urban area with a posted speed of 50 mph. The intersection is a T-intersection with Wasatch Boulevard ending at a skewed angle. The northbound approach has a downhill approach grade greater than 6 percent with a free-flow right turn lane, it was determined by the reviewers that a message preparing drivers to stop when not all lanes must stop would not command attention and respect. This intersection services winter ski resorts resulting in seasonal traffic and the AADT value is 19,775 vehicles per day.

Figure 4.11 Intersection of S.R. 210 & Wasatch Boulevard in Sandy.

4.2.2.5 S.R.68 and S.R.140 in Bluffdale

The intersection of S.R.68 and S.R.140 in Bluffdale is shown in Figure 4.12. S.R. 68 for this area is a four lane highway that is in an urban area with one of the lowest speed limits of all intersection analyzed at 45 mph. The intersection is at the base of a vertical curve with downhill approach grades between 3 and 6 percent. From the southbound approach the intersection may be unexpected due to a vertical curve. The AADT value is 8,865 vehicles per day with a high heavy vehicle traffic volume at 12 percent. Although the intersection can be seen without obstruction, it may be difficult to distinguish from the background of the roadway from both approaches.

Figure 4.12 Intersection of S.R. 68 & S.R. 140 in Bluffdale.

4.2.3 Region 3

Seven intersections were evaluated in Region 3: 1) S.R. 92 & Triumph Boulevard in Lehi, 2) S.R. 92 & Center Street in Lehi, 3) S.R. 92 & 1200 East in Lehi, 4) S.R. 40 & S.R. 32 in Heber, 5) S.R. 189 & S.R. 52 in Provo, 6) S.R. 89 & 1860 South in Provo, and 7) S.R. 89 & S.R. 75 in Springville. Detailed intersection evaluation forms are provided in Appendix C.

4.2.3.1 S.R. 92 and Triumph Boulevard in Lehi

The intersection of S.R. 92 and Triumph Boulevard in Lehi is shown in Figure 4.13. S.R. 92 for this area is a four lane highway in an urban area with a posted speed of 45 mph. There is potential for considerable growth in the area in coming years that should be considered if an AWS system is recommended by UDOT at this location. This growth may impact the speed limit and overall character of the site. The AADT value is 17,150 vehicles per day. There is a railroad crossing just east of the intersection that causes a crest restricting sight distance. This is evident by many rear-end crashes reported by the police. The railroad crossing also would make placement of an AWS sign at the recommended distances from the stop bar more challenging, as the AWS sign should not detract from the railway signage.

Figure 4.13 Intersection of S.R. 92 & Triumph Boulevard in Lehi.

4.2.3.2 S.R. 92 and Center Street in Lehi

The intersection of S.R. 92 and Center Street in Lehi is shown in Figure 4.14. S.R. 92 for this area is a two lane highway in an urban area with a posted speed of 55 mph. There is potential for considerable growth in the area in coming years that should be considered if an AWS system is recommended by UDOT at this location. The AADT value is 17,150 vehicles per day.

Figure 4.14 Intersection of S.R. 92 & Center Street in Lehi.

4.2.3.3 S.R. 92 and 1200 East in Lehi

The intersection of S.R. 92 and 1200 East in Lehi is shown in Figure 4.15. S.R. 92 for this area is a two lane highway in an urban area with a posted speed of 55 mph. There is potential for considerable growth in the area in coming years that should be considered if an AWS system is recommended by UDOT at this location. The AADT value is 17,175 vehicles per day.

Figure 4.15 Intersection of S.R. 92 & 1200 East in Lehi.

4.2.3.4 S.R. 40 and S.R. 32 in Heber

The intersection of S.R. 40 and S.R. 32 in Heber is shown in Figure 4.16. S.R. 40 for this area is a four lane highway in a rural setting with a posted speed of 55 mph. The AADT value is 16,280 vehicles per day. There is clear sight distance. This is an isolated intersection from the eastbound direction, with the nearest intersection being more than 3 miles away. The westbound direction had more than 1 mile between intersections. As seen in Figure 4.16 there is currently a PSSA sign installed at this location with continuous flashers.

Figure 4.16 Intersection of S.R. 40 & S.R. 32 in Heber.

4.2.3.5 S.R. 189 and S.R. 52 in Provo

The intersection of S.R. 189 and S.R. 52 in Provo is shown in Figure 4.17, and is a T-interchange with S.R. 52 ending at S.R. 189 having overpass and ramp connections for the eastbound approach. The posted speed is 50 mph and the AADT is 15,385 vehicles per day. In the southbound direction the intersection has a signalized through lane and one right-turn lane. The northbound direction has a continuous flow through lane and a signalized left-turn lane. As seen in Figure 4.17 there is currently a PSSA sign installed with continuous flashers. The southbound approach is the direction being considered for an upgrade to the AWS system, but this may pose two difficulties that were identified while making a field visit. First, there is a large overhead directional sign at the location where AWS placement should go, which makes the AWS system design more difficult. Second, the southbound right-turn movement has permanent right-of-way. The message of "Prepare To Stop" when the sign is activated may convey the wrong message to southbound drivers turning right at this intersection. These adjustments would have to be considered by UDOT if an AWS system were to be installed at this location.

Figure 4.17 Intersection of S.R. 189 & S.R. 40 in Provo.

4.2.3.6 S.R. 89 and 1860 South in Provo

The intersection of S.R. 89 and 1860 South in Provo is shown in Figure 4.18. S.R. 89 for this area is a four lane highway in an urban area with a posted speed of 55 mph and AADT value of 18,000 vehicles per day. The northbound approach is the direction of concern because it met with greater emphasis the conditions of limited sight distance, isolated intersection, and approach grade.

Figure 4.18 Intersection of S.R. 89 & 1860 South in Provo.

4.2.3.7 S.R. 89 and S.R. 75 in Springville

The intersection of S.R. 89 and S.R. 75 in Springville is shown in Figure 4.19. S.R. 89 for this area is a four lane highway in an urban area with a posted speed of 50 mph and AADT value of 18,890 vehicles per day. The southbound approach is met with greater emphasis for the isolated intersection condition at this location.

Figure 4.19 Intersection of S.R. 89 & S.R. 75 in Springville.

4.2.4 Region 4

Five intersections were evaluated in Region 4: 1) S.R. 130 & Cross Hollow in Cedar City, 2) S.R. 56 & Lund Highway in Cedar City, 3) S.R. 56 Airport Way in Cedar City, 4) S.R. 9 & Telegraph Road in Washington, and 5) S.R. 18 & Snow Canyon Parkway in St. George. Detailed intersection evaluation forms are provided in Appendix D.

4.2.4.1 S.R. 130 and Cross Hollow in Cedar City

The intersection of S.R. 130 and Cross Hollow in Cedar City is shown in Figure 4.20. The south leg of this intersection is an on and off ramp for the east side of Interstate 15. The posted speed is 45 mph and the AADT value is 11,150 vehicles per day. Although the intersection was evaluated using the same criteria as other locations, the reason why this may not be an appropriate location is that an AWS system may not be appropriate for intersections that are part of a freeway interchange, and drivers that use this intersection are most likely aware of the freeway on and off ramps or are at least expecting to enter a more urban setting.

Figure 4.20 Intersection of S.R. 130 & Cross Hollow in Cedar City.

4.2.4.2 S.R. 56 & Lund Highway in Cedar City

The future signalized intersection of S.R. 56 & Lund Highway in Cedar City is shown in Figure 4.21. S.R. 56 is a four lane highway in a rural area. The posted speed is 50 mph and the AADT value is 5,025 vehicles per day. Lund Highway is currently stop sign controlled while S.R. 56 has no control. The intersection is planned to be signalized in the near future. The primary condition of concern at this location is that this intersection when signalized will be unexpected, though there is clear sight distance.

Figure 4.21 Intersection of S.R. 56 & Lund Highway in Cedar City.

4.2.4.3 S.R. 56 and Airport Way in Cedar City

The intersection of S.R. 56 and Airport Way in Cedar City is shown in Figure 4.22. S.R. 56 for this area is a four lane highway in an urban area with a posted speed of 45 mph and AADT value of 5,025 vehicles per day. With the installation of a signalized intersection on S.R. 56 and Lund Highway there may not be as much need for an AWS system at this location as the intersection of S.R. 56 and Lund Highway will become the entry point for the urban environment.

Figure 4.22 Intersection of S.R. 56 & Airport Way in Cedar City.

4.2.4.4 S.R. 9 & Telegraph Road in Washington

The intersection of S.R. 9 & Telegraph Road in Washington is shown in Figure 4.23. S.R. 9 for this area is a four lane highway in a growing urban area. As seen in Figure 4.23 there is currently a PSSA sign installed with continuous flashers at 750 and 1500 feet for both the eastbound and westbound approaches. Skid marks were also evident on the roadway indicating the possibility of abrupt stops at this location. This intersection is an isolated intersection with a distance 2 miles west and over 10 miles east before another signalized intersection. As the intersection serves an industrial area, including the Hurricane Wal-Mart Distribution Center, the truck traffic is also quite high.

Figure 4.23 Intersection of S.R. 9 & Telegraph Road in Washington.

4.2.4.5 S.R. 18 & Snow Canyon Parkway in St. George

The intersection of S.R. 18 & Snow Canyon Parkway in St. George currently has an overhead static AWS sign with flashers that have the message “Prepare To Stop When Flashing” on the southbound approach, as shown in Figure 4.24. This intersection received the highest score of all 24 intersections. All six conditions were met and the conditions of isolated intersection, high crash rate, and approach grade. The posted speed is 45 mph. Actual vehicles speeds for the southbound approach are likely higher because the intersection is isolated with more than 10 miles distance from a previous intersection and the approach grade is 6 percent or greater. The AADT value is 3,715 vehicles per day.

Figure 4.24 Intersection of S.R. 18 & Snow Canyon Parkway in St. George.

4.3 Evaluation Matrix

The evaluation matrix was developed through preparation by BYU researchers and discussion by the TAC following the Policy Delphi method. The evaluation matrix involves two steps: 1) the evaluation of intersections described in Section 4.2, and 2) the comparison of intersections. After the intersection evaluations were complete for the 24 sites, the scores were input in the intersection comparison form. Using a computer spreadsheet the intersections were ranked and sorted by total score and the results are shown in Figure 4.25 by Region and Figure 4.26 for all intersections evaluated. The intersections are reported in priority order from the intersection with the highest score to the intersection or group of intersections with the lowest score. If two or more intersections had the same evaluation score then the same ranking value was give for each intersection. The results of the analysis completed to verify and evaluate the guidelines had six degrees of prioritization for AWS system installation, shown in the last column of Figure 4.26.

Intersection	City	Condition							Total	Rank
		1	2	3	4	5	6	±		
Region 1										
S.R. 126 & S.R. 134	Farr West	0	1	2	2	0	2	0	7	1
S.R. 91 & Main Street	Brigham City	0	1	2	0	2	1	0	6	2
S.R. 91 & S.R. 142	Richmond	0	1	2	0	0	1	2	6	2
S.R. 39 & S.R. 126	Marriot/Slatterville	0	1	1	2	0	1	0	5	3
S.R. 91 & S.R. 101	Wellsville	0	2	2	0	1	0	0	5	3
S.R. 126 & S.R. 79	Ogden	0	1	2	0	0	1	0	4	4
S.R. 91 & 775 West	Brigham City	0	1	1	0	0	1	0	3	5
Region 2										
S.R. 248 & S.R. 40	Park City	2	1	2	0	1	1	0	7	1
S.R. 210 & Wasatch Blvd.	Sandy	1	1	2	0	2	0	0	6	2
S.R. 68 & S.R. 140	Bluffdale	0	1	2	0	1	1	0	5	3
S.R. 201 & 8400 West	Magna	0	2	2	0	0	1	0	5	3
S.R. 190 & 7000 South	Sandy	2	1	0	0	1	1	0	5	3
Region 3										
S.R. 189 & S.R. 52	Provo	2	1	2	0	0	1	0	6	1
S.R. 89 & S.R. 75	Springville	1	1	2	0	0	1	0	5	2
S.R. 92 & Triumph Blvd.	Lehi	0	1	1	0	2	1	0	5	2
S.R. 89 & 1860 South	Provo	1	1	0	0	1	1	0	4	3
S.R. 40 & S.R. 32	Heber	0	1	2	0	0	1	0	4	3
S.R. 92 & 1200 East	Lehi	0	1	1	0	0	1	0	3	4
S.R. 92 & Center Street	Lehi	0	1	1	0	0	1	0	3	4
Region 4										
S.R. 18 & Snow Canyon Pkwy.	St. George	1	1	2	2	2	1	0	9	1
S.R. 9 & Telegraph Rd.	Washington	0	1	2	2	0	1	0	6	2
S.R. 130 & Cross Hollow	Cedar City	0	1	2	0	0	1	0	4	3
S.R. 56 & Lund Hwy	Cedar City	0	1	2	0	0	1	0	4	3
S.R. 56 & Airport Way	Cedar City	1	1	0	0	1	1	0	4	3

Figure 4.25 Intersection comparison results by Region.

Intersection Comparison for Advance Warning Signals

Region: 1-4 **Date:** ____________________

Analyst: ____________________

Intersection	City	Condition 1	2	3	4	5	6	±	Total	Rank
S.R. 18 & Snow Canyon Pkwy.	St. George	1	1	2	2	2	1	0	9	1
S.R. 126 & S.R. 134	Farr West	0	1	2	2	0	2	0	7	2
S.R. 248 & S.R. 40	Park City	2	1	2	0	1	1	0	7	2
S.R. 91 & S.R. 142	Richmond	0	1	2	0	0	1	2	6	3
S.R. 91 & Main Street	Brigham City	0	1	2	0	2	1	0	6	3
S.R. 9 & Telegraph Rd.	Washington	0	1	2	2	0	1	0	6	3
S.R. 210 & Wasatch Blvd.	Sandy	1	1	2	0	2	0	0	6	3
S.R. 189 & S.R. 52	Provo	2	1	2	0	0	1	0	6	3
S.R. 39 & S.R. 126	Marriot/Slatterville	0	1	1	2	0	1	0	5	4
S.R. 91 & S.R. 101	Wellsville	0	2	2	0	1	0	0	5	4
S.R. 68 & S.R. 140	Bluffdale	0	1	2	0	1	1	0	5	4
S.R. 201 & 8400 West	Magna	0	2	2	0	0	1	0	5	4
S.R. 92 & Triumph Blvd.	Lehi	0	1	1	0	2	1	0	5	4
S.R. 89 & S.R. 75	Springville	1	1	2	0	0	1	0	5	4
S.R. 190 & 7000 South	Sandy	2	1	0	0	1	1	0	5	4
S.R. 126 & S.R. 79	Ogden	0	1	2	0	0	1	0	4	5
S.R. 40 & S.R. 32	Heber	0	1	2	0	0	1	0	4	5
S.R. 130 & Cross Hollow	Cedar City	0	1	2	0	0	1	0	4	5
S.R. 56 & Lund Hwy	Cedar City	0	1	2	0	0	1	0	4	5
S.R. 89 & 1860 South	Provo	1	1	0	0	1	1	0	4	5
S.R. 56 & Airport Way	Cedar City	1	1	0	0	1	1	0	4	5
S.R. 91 & 775 West	Brigham City	0	1	1	0	0	1	0	3	6
S.R. 92 & 1200 East	Lehi	0	1	1	0	0	1	0	3	6
S.R. 92 & Center Street	Lehi	0	1	1	0	0	1	0	3	6

Final comments & recommendations:

Notes:

1. Two or more conditions must be met including one of the following conditions: 1,2,3,or 4.
2. Rank with a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
3. Ranking shall be done according to engineering judgment.
4. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure 4.26 Intersection comparison results for all intersections.

The results of the ranking may vary as the evaluation matrix is performed by different people because of engineering judgment of one reviewer compared to another. Engineering judgment is needed to allow the expertise of an area to determine if AWS installation is appropriate for a particular intersection. The evaluation and comparison process presented here was developed to act as guidelines to prioritize the intersections that have the greatest need for AWS systems. The final decision to install an AWS system should be done considering other factors that are not included in this process, such as available funding or public opinion.

The results from the comparison by Region, in Figure 4.25, has one first priority intersection for each Region, except for Region 1 has two intersections with equally high scores. The comparison of all the intersections, in Figure 4.26, shows one intersection ranked first, three intersections ranked second and three intersections ranked third. The first ranked intersection is S.R. 18 with Snow Canyon Parkway, while currently has an AWS system installed, verifying that the AWS system is indeed needed. This priority ranking does not have a large spread for priorities. For this purpose a sensitivity analysis was conducted as described in Section 4.4. The sensitivity analysis also verified the Policy Delphi analysis results of the ranking system used in the intersection comparison analysis.

Several intersections seem to be good candidates for AWS installation, while other intersections do not even though they may have a higher score or ranking. For instance an approach that ends at a T-intersection or freeway off ramp may not be good locations for AWS installations and some other means may be more appropriate to reduce the safety risk that is present.

From field observations six intersections may not be good candidates for an AWS system based on the guideline conditions. The intersection of S.R. 126 and S.R. 134 in Farr West is adjacent to a freeway interchange on S.R. 134, has clear sight distance, and does not appear by the reviewers to be an unexpected intersection. The intersections of S.R. 91 with 775 West in Brigham City and S.R. 39 with S.R. 126 in Marriot/Slatterville have uphill or level approaches from both sides and clear sight distance. Even though these intersections are isolated the review process did not make the intersections stand out as necessary to have AWS systems. The intersection of S.R. 126 with S.R. 79 in

Ogden is T-intersections where the roadway that is being considered ends at the intersection. S.R. 126 ends as it intersects the cross street S.R. 79 and does not meet any of the requirement besides being isolated and high-speed intersection. The intersection of S.R. 210 and Wasatch Boulevard is a skewed T-intersection that only the northbound approach is where an AWS system might be helpful, but with the existing conditions the right turn lanes are free-flow, which may be a situation where the sign would not command attention and respect. The intersection of S.R. 130 and Cross Hollow is where S.R. 130 begins opposite of the intersection to off-ramp of the freeway. An AWS system may not be the best mitigation to the potential dangers of these HSSIs. The evaluation process was very helpful in identifying these intersections as not having the greatest potential for AWS system installation. The final decision for AWS installation, however, will be made by UDOT

More importantly, the evaluation matrix gives prioritization of intersections that may benefit from AWS installation. Seven such intersections that ranked high on the evaluation matrix. The intersection of S.R. 91 with S.R. 142 in Richmond is located near three schools and because of limited sight distance of possible pedestrians crossing an AWS system would be appropriate. The westbound approach of intersection of S.R. 91 and Main Street in Brigham City is a steep, high-speed downgrade with high heavy vehicle traffic volume that is the first intersection for several miles. The intersection of S.R. 248 and S.R. 40 near Park City has on both approaches high speed, limited sight distance, downgrades, high heavy vehicle traffic volume, and isolated intersections. The southbound approach of the intersection of S.R. 189 and S.R. 52 in Provo has limited sight distance, high heavy vehicle traffic volume, and is an isolated intersection. The intersection of S.R. 89 and 1860 South in Provo has on the northbound approach limited sight distance, downgrade approach, and is an isolated intersection. The intersections of S.R. 18 with Snow Canyon Parkway in St. George and S.R. 9 with Telegraph Road in Washington in Region 4 currently have AWS installations described in Section 4.2, and the system could be upgraded to the type recommended in this report. The southbound approach of the intersection of S.R. 18 and Snow Canyon Parkway is an isolated intersection that has a high crash rate, steep downgrade, and high heavy vehicle traffic volume. The intersection of S.R. 9 and Telegraph Road is an isolated intersection with high heavy vehicle traffic volume.

4.4 Sensitivity Analysis

The sensitivity analysis involved changing the point system given in the evaluation of each condition for the intersections evaluated. The purpose of the sensitivity analysis was to derive the best ranking system for the intersection comparison. Six variations of the point system were compared to the original results. The variation method of the scoring of the conditions is displayed in Table 4.1. In each variation the evaluation score given to the conditions that were met and met with greater emphasis were changed. In all the variations the condition of not met remained a value of "0." The results of these six variations are provided in Figure 4.27. With this comparison changes in ranking could be seen and understood.

Table 4.1 Sensitivity Analysis Variations

Ranking System	Scoring			Description
	Not met	Met	Greater Emphasis	
Original	0	1	2	Original scoring
Variation 1	0	1	3	Higher weight on conditions evaluated as greater emphasis
Variation 2	0	1	5	Higher weight on conditions evaluated as greater emphasis
Variation 3	0	3	4	Intersections that met several conditions
Variation 4	0	1	3 (primary) 2 (secondary)	Higher weight on primary conditions with greater emphasis
Variation 5	0	1	4 (primary) 2 (secondary)	Higher weight on primary conditions with greater emphasis
Variation 6	0	1	5 (one cond.) 4 (primary) 2 (secondary)	Emphasis on safety and conditions with greater emphasis

Intersection	City	Orig-inal	Var 1	Var 2	Var 3	Var 4	Var 5	Var 6
S.R. 18 & Snow Canyon Pkwy.	St. George	1	1	1	1	1	1	1
S.R. 126 & S.R. 134	Farr West	2	2	2	3	2	2	2
S.R. 248 & S.R. 40	Park City	2	3	3	2	2	2	3
S.R. 9 & Telegraph Rd.	Washington	3	4	4	4	3	3	3
S.R. 91 & S.R. 142	Richmond	3	4	4	4	3	3	4
S.R. 189 & S.R. 52	Provo	3	4	4	4	3	3	4
S.R. 91 & Main Street	Brigham City	3	4	4	4	4	5	6
S.R. 210 & Wasatch Blvd.	Sandy	3	4	4	4	4	5	6
S.R. 91 & S.R. 101	Wellsville	4	5	5	7	4	4	5
S.R. 201 & 8400 West	Magna	4	5	5	7	4	4	5
S.R. 39 & S.R. 126	Marriot/Slatterville	4	6	5	5	5	6	6
S.R. 68 & S.R. 140	Bluffdale	4	6	6	5	5	6	7
S.R. 190 & 7000 South	Sandy	4	6	6	5	5	6	7
S.R. 89 & S.R. 75	Springville	4	6	5	5	5	6	7
S.R. 92 & Triumph Blvd.	Lehi	4	6	6	5	6	8	9
S.R. 126 & S.R. 79	Ogden	5	7	7	8	6	7	8
S.R. 40 & S.R. 32	Heber	5	7	7	8	6	7	8
S.R. 130 & Cross Hollow	Cedar City	5	7	7	8	6	7	8
S.R. 56 & Lund Hwy	Cedar City	5	7	7	8	6	7	8
S.R. 89 & 1860 South	Provo	5	8	8	6	7	9	10
S.R. 56 & Airport Way	Cedar City	5	8	8	6	7	9	10
S.R. 91 & 775 West	Brigham City	6	9	9	9	8	10	11
S.R. 92 & 1200 East	Lehi	6	9	9	9	8	10	11
S.R. 92 & Center Street	Lehi	6	9	9	9	8	10	11

Figure 4.27 Sensitivity analysis results.

Variation one consisted of a value of “1” for met conditions and a value of “3” for conditions with greater emphasis. Variation two consisted of a value of “1” for met conditions and a value of “5” for conditions with greater emphasis. Variation three consisted of a value of “3” for met conditions and a value of “4” for conditions with greater emphasis. Variation four consisted of a value of “1” for met conditions, a value of “2” for secondary conditions with greater emphasis, and a value of “3” for primary conditions with greater emphasis. Variation five consisted of a value of “1” for met conditions, a value of “2” for secondary conditions with greater emphasis, and a value of “4” for primary conditions with greater emphasis. Variation six consisted of a value of “1” for met conditions, a value of “2” for secondary conditions with greater emphasis, a value of “4” for primary conditions with greater emphasis, and a value of “5” for a condition of the reviewer’s choice of greatest concern with greater emphasis.

The comparison shows that with different ranking systems the degree of prioritization varies from six levels for the original ranking system up to eleven levels for variation six. This is due to the various combinations of descriptions met and greater emphasis. For instance, a value with two conditions met and one condition with greater emphasis receives a score of 4 according to the original ranking system and a score of 5 with variation one. The same score resulted if two conditions had greater emphasis for the original ranking system, but for variation one the score is 6. For all of the variations the intersections with conditions of greater emphasis have a greater prioritization. The increase of the greater emphasis score beyond “3” with the condition of met having a score of “1” does not change the intersection comparison results, as shown by the results of variation one and two.

As previously stated the purpose of the sensitivity analysis was to verify the scoring system of the evaluation matrix. From all the variations the results yielded similar order of prioritization for the top several intersections. The largest change in intersection prioritization occurs with the intersections in the middle. Since decisions to install and AWS system depend on factors of funding and opinion, and this report provides guideline conditions to evaluate the need for an AWS system as well as an evaluation matrix, the comparison ranking system could vary by the preference of the reviewer. The original ranking system is a good comparison for the individual Regions. Variation one and two are good ranking systems if the conditions with greater emphasis should have more weight. Variation three might be useful if intersections that meet several conditions are being sought out. Variation four and five may be desirable if the reviewer wants to distinguish more between primary and secondary conditions. Variation six is a useful ranking system if the reviewer desires to favor one condition that may be of greater concern. The ranking system should be decided by the reviewer to assist in the decision making process.

The ranking systems, including the variations, were reviewed by the TAC in a Policy Delphi approach as outlined previously. As a result, the original ranking system was recommended to be used. The results of the intersection comparison of all the intersections and by Region still have a few intersections that were first priority. This is helpful as the likelihood that all the intersections evaluated that showed a need for AWS installation would not be funded at once. The evaluation matrix is helpful to give a prioritization to start from. As future development occurs and additional intersections are identified by UDOT the process should be repeated to ensure that the current conditions are being considered.

4.5 Intersection Evaluation Matrix Summary

The evaluation matrix is comprised of the intersection evaluations and comparison using the intersection evaluation form, found previously in Figure 3.1 and Figure 3.2, and the intersection comparison form, found previously in Figure 3.3. The evaluation matrix and overall process was developed using the Policy Delphi method. The exercise of identifying possible intersections for AWS consideration and their evaluation and comparison helped to refine the conditions and forms used for this evaluation matrix. The result of the evaluation matrix is a prioritization of intersections selected for AWS system consideration. The original scoring system is recommended, but a variation scoring system may be used to reflect the reviewer's desired emphasis for determining prioritization of AWS system need. The ranking provided can be used by UDOT as guidance in decision making, but ultimately any final decisions should be agreed upon by UDOT personnel using engineering judgment.

5 Conclusions and Recommendations

This thesis provides details and guidelines for the evaluation and installation of AWS systems in the state of Utah. An evaluation matrix was developed to verify the guidelines. The guidelines and evaluation matrix are tools that UDOT may use to evaluate the need an intersection or a group of intersections by priority have for an AWS system. A literature review provided a basis for which the guidelines for AWS installation were developed. A Policy Delphi method was used to involve BYU researchers as monitors of a TAC to develop guidelines for AWS installation. The guidelines are described in Chapter 3 including the evaluation conditions and the signal system design and functionality. The conditions for evaluation and comparison of intersections for AWS installation were developed and verified through an evaluation matrix process. Guidelines were developed so that AWS systems are not to be warranted, but rather, evaluated using the guidelines and decided by the engineering judgment of UDOT personnel to install an AWS system to improve the overall safety of that intersection.

This chapter will discuss conclusions of all the steps that fulfill the purpose of this research. The chapter is organized as follows: 1) recommended guidelines, 2) evaluation matrix, 3) recommendations for further research and development.

5.1 Recommended Guidelines

The guideline conditions for the evaluation of intersections for AWS installations include the conditions for the evaluation of need for AWS installation, and the signal system design and functionality. The six conditions for AWS installation are limited sight distance, posted speed, isolated intersection, high crash rate, approach grade, and heavy vehicle traffic volume. A form, displayed previously in Figure 3.1 and Figure 3.2, called the "Intersection Comparison for Advance Warning Signals" is used to evaluated in field visits a intersection by the conditions with input values of stopping sight distance, posted speed, distance to upstream intersection, expected and existing crash rates, approach grade, average annual daily traffic, and heavy vehicle percentage which may be collected prior to a field visit. A condition may be evaluated as not met, met, and met with greater emphasis, and a score of "0", "1", or "2" are given respectively.

The signal design is a blank-out AWS sign with flashers activated by a lead flash time prior to the onset of the yellow phase that is placed a distance upstream of the stop bar as calculated by Equation 3.1. The AWS sign is activated when an advance detector, placed upstream of the AWS sign as calculated by Equation 3.2, senses a 3 second gap in traffic. The lead flash time is calculated by Equation 3.3. The system is designed such that a driver that is past the point of AWS sign legibility will be able to safely proceed through the intersection. The driver immediately following the onset of the AWS sign that sees it activated will not be able to proceed safely through the intersection and will have sufficient time and distance to stop safely.

5.2 Evaluation Matrix

The evaluation matrix is the process by which several intersections are evaluated using the "Intersection Evaluation for Advance Warning Signals" form and the "Intersection Comparison for Advance Warning Signals" form, displayed previously in Figure 3.3. Intersections are best identified by the recommendations of the Region Traffic Engineers. The scores from the evaluation of the intersection are input in the intersection comparison form for ranking and prioritization for AWS installation. The result of the evaluation matrix may guide UDOT to decide which intersections need AWS installation and an appropriate order to install AWS systems.

5.3 Recommendations for Future Research and Development

Through the literature review and development of the AWS guidelines several areas relating to AWS guidelines and systems were encountered that could not be explained because there was no previous research on the issue and the issue was not within the scope of this project. These included two suggestions for future research and one recommendation that UDOT perform further development of the process of intersection evaluation using the AWS guidelines. The two recommendations for future research are comparisons of the effects of AWS signs that are static versus dynamic or side-mounted versus overhead.

No literature was found related to the issue of static versus dynamic AWS signs. The difficulty in performing such research is having the same site for both types where all other variables will be relatively constant. For example, the AWS system currently installed on the southbound approach of S.R. 18 and Snow Canyon Parkway was discussed in a TAC meeting. The AWS system at this location is an overhead mounted static AWS sign saying "Prepare To Stop When Flashing." This location would be a good location to perform this study, having a period of time where measures of effectiveness could be measured for a period and then the dynamic blank-out sign installed and monitored for an equivalent period.

No literature was found related to the issue of side-mounted versus overhead AWS signs. The difficulty in performing such research again is having the same site for both types where all other variables will be relatively constant. Several installations of side-mounted AWS systems are located throughout Utah and a similar study as described for a comparison of static versus dynamic AWS signs could be conducted.

As previously mentioned the purpose of this research was to develop a tool that UDOT could use in assessing the need an intersection has for AWS based on a set of guidelines. The recommendation for further development of the process of intersection evaluation using the AWS guidelines is a tool for UDOT to use. It is the responsibility within UDOT to determine when and how this tool will be used such that it is appropriately applied in intersection evaluation for AWS installation so that there are no legal implications that may follow.

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Appendix A Region 1 Intersection Site Evaluation Forms

Intersection Evaluation for Advance Warning Signals

Intersection[1]: S.R. 91 & S.R. 142 **Date: 12/04/06**

City: Richmond **Region: 1**

Approach Direction (circle): (NB / SB) EB / WB **Analyst: BYU**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: 360 ft SSD required plus queue length: 510 ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed: 45 mph		
3 - Isolated Intersection		**2**	**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): 6 mi Dist. to upstream int. (SB/WB): +5 mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: 0.78 crashes/MEV Existing crash rate: 0.58 crashes/MEV		
5 - Approach Grade		**0**	**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): +3 % Approx. Grade (SB/WB): +3 %		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: 11550 vpd Heavy Vehicle: +10 %		
Final comments and recommendations[7,8]:		**2**	**2**
Very isolated and the truck traffic volume seems high compared with the observed truck traffic. Service traffic from three schools: Darin Deursch recommend adding 2 points to overall score.			
	Total:	**6**	**6**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure A.1 Intersection of S.R. 91 & S.R. 142.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 91 & S.R. 101______________ **Date: _12/04/06_**

City: __Wellsville_____ _____ **Region: __1___**

Approach Direction (circle): (NB / SB) EB / WB **Analyst:__BYU ________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __600___ft SSD required plus queue length: __750___ft		
2 - Posted Speed		**2**	**2**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__60____mph		
3 - Isolated Intersection		**2**	**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __5_____mi Dist. to upstream int. (SB/WB): __17____mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __0.89__crashes/MEV Existing crash rate: __0.80__crashes/MEV		
5 - Approach Grade		**0**	**1**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __+3____% Approx. Grade (SB/WB): __-3____%		
6 - Heavy Vehicle Traffic Volume[5]		**0**	**0**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __17540_vpd Heavy Vehicle: __7____%		
Final comments and recommendations[7,8]:		**0**	**0**
Skid marks ar e evident; Northside Railroad Crossing (~500 ft) The truck volume may be too low from the actual truck traffic volume.			
	Total:	**4**	**5**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure A.2 Intersection of S.R. 91 & S.R. 101.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 91 & S.R. Main Street _________ **Date: _12/04/06 _**

City: __Brigham City __ ______ **Region: __1___**

Approach Direction (circle): NB / SB (EB / WB) **Analyst:__BYU _________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __553___ft SSD required plus queue length: __705___ ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__55____mph		
3 - Isolated Intersection		**1**	**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __0.6___mi Dist. to upstream int. (SB/WB): __+5____mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.21__crashes/MEV Existing crash rate: __0.71__crashes/MEV		
5 - Approach Grade		**1**	**2**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __+(3-6)_% Approx. Grade (SB/WB): __-6____%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __20883_vpd Heavy Vehicle: __11____%		
Final comments and recommendations[7,8]:		**0**	**0**
WB - Existing overhead PTSF sign at 500 ft			
	Total:	**4**	**6**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure A.3 Intersection of S.R. 91 & Main Street.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 91 & 775 West__________ **Date: _12/04/06_**

City: __Brigham City______ **Region: __1___**

Approach Direction (circle): NB / SB (EB / WB) **Analyst:__BYU________**

<table>
<tr><th rowspan="2">Condition[2]</th><th rowspan="2">Details</th><th colspan="2">Evaluation[3]</th></tr>
<tr><th>NB/EB</th><th>SB/WB</th></tr>
<tr><td colspan="2">1 - Limited Sight Distance[4]</td><td>0</td><td>0</td></tr>
<tr><td>- Vertical & Horizontal Curves
- Obstacles (trees, overpasses, buildings)</td><td colspan="3">Comments/Description:
SSD required: __493___ft
SSD required plus queue length: __650___ft</td></tr>
<tr><td colspan="2">2 - Posted Speed</td><td>1</td><td>1</td></tr>
<tr><td>- ≥ 45 mph met
- ≥ 60 mph greater emphasis</td><td colspan="3">Comments/Description:
Posted Speed:__55____mph</td></tr>
<tr><td colspan="2">3 - Isolated Intersection</td><td>1</td><td>1</td></tr>
<tr><td>- 1st intersection in an unsignalized area
- 1st intersection to an urban area
- Higher speed indicate greater need</td><td colspan="3">Comments/Description:
Dist. to upstream int. (NB/EB): __1_____mi
Dist. to upstream int. (SB/WB): __0.6___mi</td></tr>
<tr><td colspan="2">4 - High Crash Rate[5]</td><td>0</td><td>0</td></tr>
<tr><td>- Existing minus expected crash rate
- > 0 met
- ≥ 1 greater emphasis</td><td colspan="3">Comments/Description:
Expected crash rate: __1.21__crashes/MEV
Existing crash rate: __0.11__crashes/MEV</td></tr>
<tr><td colspan="2">5 - Approach Grade</td><td>0</td><td>1</td></tr>
<tr><td>- ≥ 3% met
- ≥ 6% greater emphasis</td><td colspan="3">Comments/Description:
Approx. Grade (NB/EB): __+(0-3)_%
Approx. Grade (SB/WB): __-(0-3)_%</td></tr>
<tr><td colspan="2">6 - Heavy Vehicle Traffic Volume[5]</td><td>0</td><td>0</td></tr>
<tr><td>- ≥ 10% met
- ≥ 20% greater emphasis</td><td colspan="3">Comments/Description:
AADT: __20883_vpd
Heavy Vehicle: __11___%</td></tr>
<tr><td colspan="2">Final comments and recommendations[7,8]:</td><td>0</td><td>0</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td colspan="2" align="right">Total:</td><td>2</td><td>3</td></tr>
</table>

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure A.4 Intersection of S.R. 91 & 775 West.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 39 & S.R. 126__________ **Date: _12/06/06_**

City: __Marriot-Slatterville____ **Region: __1___**

Approach Direction (circle): NB / SB / (EB) / WB **Analyst:__BYU_________**

Condition[2]	Details	Evaluation[3] NB/EB	Evaluation[3] SB/WB
1 - Limited Sight Distance[4]		**0**	
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __450___ft SSD required plus queue length: __600___ft		
2 - Posted Speed		**1**	
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__55____mph		
3 - Isolated Intersection		**1**	
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __+3____mi Dist. to upstream int. (SB/WB): __0.25___mi		
4 - High Crash Rate[5]		**2**	
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.22__crashes/MEV Existing crash rate: __3.13__crashes/MEV		
5 - Approach Grade		**0**	
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __+6____% Approx. Grade (SB/WB): __-____%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __9910_vpd Heavy Vehicle: __28___%		
Final comments and recommendations[7,8]:		**0**	
Does not appear necessary; clear SSD for the signal and uphill approaches. An overhead AWS may obscure the signal. All approaches crest at the intersection; hard to see opossing traffic.			
	Total:	**5**	

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure A.5 Intersection of S.R. 39 & S.R. 126.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 126 & S.R. 79__________________ **Date: _12/06/06_**

City: __Ogden__________________ **Region: __1___**

Approach Direction (circle): NB / SB EB / (WB) **Analyst:__BYU__________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]			**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __493___ft SSD required plus queue length: __650___ft		
2 - Posted Speed			**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__55____mph		
3 - Isolated Intersection			**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __-_____mi Dist. to upstream int. (SB/WB): __2____mi		
4 - High Crash Rate[5]			**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.21__crashes/MEV Existing crash rate: __0.35__crashes/MEV		
5 - Approach Grade			**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __0____% Approx. Grade (SB/WB): __0____%		
6 - Heavy Vehicle Traffic Volume[5]			**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __12890_vpd Heavy Vehicle: __16___%		
Final comments and recommendations[7,8]:			**0**
T-intersection, southbound speed limit is 50 mph and the northbound speed limit is 55 mph. Use an alternative solution.			
	Total:	**0**	**4**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure A.6 Intersection of S.R. 126 & S.R. 79.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 126 & S.R. 134__________ **Date: _12/06/06_**

City: __Farr West________ **Region: __1___**

Approach Direction (circle): (NB / SB) EB / WB **Analyst:__BYU_________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __493__ft SSD required plus queue length: __650__ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__55__mph		
3 - Isolated Intersection		**1**	**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __1__mi Dist. to upstream int. (SB/WB): __3__mi		
4 - High Crash Rate[5]		**2**	**2**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.30__crashes/MEV Existing crash rate: __2.85__crashes/MEV		
5 - Approach Grade		**0**	**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __0__% Approx. Grade (SB/WB): __0__%		
6 - Heavy Vehicle Traffic Volume[5]		**2**	**2**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __8735_vpd Heavy Vehicle: __21__%		
Final comments and recommendations[7,8]:		**0**	**0**
Potential for future development nearby. More logically appropriate for SB direction.			
	Total:	**6**	**7**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure A.7 Intersection of S.R. 126 & S.R. 134.

Appendix B Region 2 Intersection Site Evaluation Forms

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 201 & 8400 West____________ **Date: _11/07/06 _**

City: __Magna________ _ _ ______ **Region: __2___**

Approach Direction (circle): NB / SB (EB / WB) **Analyst:__BYU__ _________**

Condition[2]	Details	Evaluation[3] NB/EB	Evaluation[3] SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __567___ft SSD required plus queue length: __720___ft		
2 - Posted Speed		**2**	**2**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__60____mph		
3 - Isolated Intersection		**2**	**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __5_____mi Dist. to upstream int. (SB/WB): __17____mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.21__crashes/MEV Existing crash rate: __0.68__crashes/MEV		
5 - Approach Grade		**0**	**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __0____% Approx. Grade (SB/WB): __0___%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __22605_vpd Heavy Vehicle: __14___%		
Final comments and recommendations[7,8]:		**0**	**0**
	Total:	**5**	**5**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure B.1 Intersection of S.R. 201 & 8400 West.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: S.R. 248 & S.R. 40 **Date: 11/29/06**

City: Park City **Region: 2**

Approach Direction (circle): NB / SB (EB / WB) **Analyst: BYU**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**2**	**2**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: 380 ft SSD required plus queue length: 530 ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed: 45 mph		
3 - Isolated Intersection		**2**	**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): 2 mi Dist. to upstream int. (SB/WB): 11 mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: 0.94 crashes/MEV Existing crash rate: 0.29 crashes/MEV		
5 - Approach Grade		**1**	**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): -(0-3) % Approx. Grade (SB/WB): -(0-3) %		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: 13830 vpd Heavy Vehicle: 13 %		
Final comments and recommendations[7,8]:		**0**	**0**
Grade separated interchange with horizontal and verticle curves. Intersection is visable from SSD but not the signal light status.			
	Total:	**7**	**6**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure B.2 Intersection of S.R. 248 & S.R. 40.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: S.R. 190 & 7000 South **Date: 11/07/06**

City: Sandy **Region: 2**

Approach Direction (circle): NB / (SB) EB / WB **Analyst: BYU**

Condition[2]	Details	Evaluation[3] NB/EB	Evaluation[3] SB/WB
1 - Limited Sight Distance[4]			**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: 405 ft SSD required plus queue length: 555 ft		
2 - Posted Speed			**2**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed: 50 mph		
3 - Isolated Intersection			**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): - mi Dist. to upstream int. (SB/WB): 1 mi		
4 - High Crash Rate[5]			**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: 1.23 crashes/MEV Existing crash rate: 1.08 crashes/MEV		
5 - Approach Grade			**1**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): -6 % Approx. Grade (SB/WB): +3 %		
6 - Heavy Vehicle Traffic Volume[5]			**0**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: 4145 vpd Heavy Vehicle: 15 %		
Final comments and recommendations[7,8]:			**0**
A large directional sign is currently at the SSD for the southbound direction.			
	Total:	**0**	**5**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure B.3 Intersection of S.R. 190 & 7000 South.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 210 & Wasatch Blvd.___________ **Date: _11/07/06 _**

City: __Sandy________ _ _______ **Region: __2___**

Approach Direction (circle): (NB / SB) EB / WB **Analyst:__BYU __________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __460___ft SSD required plus queue length: __610___ft		
2 - Posted Speed		**2**	**2**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__50____mph		
3 - Isolated Intersection		**2**	**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __0.5____mi Dist. to upstream int. (SB/WB): __+1____mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.22__crashes/MEV Existing crash rate: __0.50__crashes/MEV		
5 - Approach Grade		**0**	**1**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __-6____% Approx. Grade (SB/WB): __+3____%		
6 - Heavy Vehicle Traffic Volume[5]		**0**	**0**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __19775_vpd Heavy Vehicle: __5____%		
Final comments and recommendations[7,8]:		**0**	**0**
Skewed intersection for the northbound direction.			
	Total:	**4**	**5**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure B.4 Intersection of S.R. 210 & Wasatch Boulevard.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: S.R. 68 & S.R. 140 **Date: 11/07/06**

City: Bluffdale **Region: 2**

Approach Direction (circle): (NB / SB) EB / WB **Analyst: BYU**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: 350 ft SSD required plus queue length: 500 ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed: 50 mph		
3 - Isolated Intersection		**2**	**0**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): +5 mi Dist. to upstream int. (SB/WB): +2 mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: 1.67 crashes/MEV Existing crash rate: 1.30 crashes/MEV		
5 - Approach Grade		**1**	**1**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): -3 % Approx. Grade (SB/WB): -3 %		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: 8865 vpd Heavy Vehicle: 12 %		
Final comments and recommendations[7,8]:		**0**	**0**
	Total:	**5**	**3**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure B.5 Intersection of S.R. 68 & S.R. 140.

Appendix C Region 3 Intersection Site Evaluation Forms

Intersection Evaluation for Advance Warning Signals

Intersection[1]: S.R. 92 & Triumph Blvd. **Date: 12/11/06**

City: Lehi **Region: 3**

Approach Direction (circle): NB / SB (EB / WB) circled **Analyst: BYU**

Condition[2]	Details	Evaluation[3] NB/EB	Evaluation[3] SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: 400 ft SSD required plus queue length: 550 ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed: 45 mph		
3 - Isolated Intersection		**0**	**1**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): 0.3 mi Dist. to upstream int. (SB/WB): 1.7 mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: 1.67 crashes/MEV Existing crash rate: 0.08 crashes/MEV		
5 - Approach Grade		**0**	**2**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): +(3-6 % Approx. Grade (SB/WB): -(3-6) %		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: 17150 vpd Heavy Vehicle: 12 %		
Final comments and recommendations[7,8]:		**0**	**0**
Future development. Railroad tracks crest at the SSD westbound causing sight distance issues. Police report issues with railroad tracks and the intersection, reporting many rear-end crashes.			
	Total:	**2**	**5**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure C.1 Intersection of S.R. 92 & Triumph Boulevard.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 92 & Center St.__ **Date: _12/11/06_**

City: __Lehi__ **Region: __3__**

Approach Direction (circle): NB / SB (EB / WB) **Analyst: __BYU__**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __493__ft SSD required plus queue length: __650__ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__55__mph		
3 - Isolated Intersection		**1**	**1**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __1.7__mi Dist. to upstream int. (SB/WB): __1__mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.67__crashes/MEV Existing crash rate: __0.93__crashes/MEV		
5 - Approach Grade		**0**	**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __+(0-3)_% Approx. Grade (SB/WB): __-(0-3)_%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __17150_vpd Heavy Vehicle: __12__%		
Final comments and recommendations[7,8]:		**0**	**0**
T-intersection; Potential growth and development during the next 20 years. Skid marks, weather (Blizzards and wind)			
	Total:	**3**	**3**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure C.2 Intersection of S.R. 92 & Center Street.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 92 & 1200 East____________ **Date: _12/11/06_**

City: __Lehi__________ **Region: __3___**

Approach Direction (circle): NB / SB (EB / WB) **Analyst:__BYU_________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __493___ft SSD required plus queue length: __650___ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__55____mph		
3 - Isolated Intersection		**1**	**1**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __1_____mi Dist. to upstream int. (SB/WB): __1.5___mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.67__crashes/MEV Existing crash rate: __0.47__crashes/MEV		
5 - Approach Grade		**0**	**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __+(0-3)_% Approx. Grade (SB/WB): __-(0-3)_%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __17175_vpd Heavy Vehicle: __12___%		
Final comments and recommendations[7,8]:		**0**	**0**
Potential development in this area within 20 years.			
	Total:	**3**	**3**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure C.3 Intersection of S.R. 92 & 1200 East.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 40 & S.R. 32__________________ **Date: _11/29/06_**

City: __Heber_____________ **Region: __3___**

Approach Direction (circle): NB / SB (EB / WB) **Analyst:__BYU__________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __493___ft SSD required plus queue length: __650___ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__55____mph		
3 - Isolated Intersection		**2**	**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __3.2____mi Dist. to upstream int. (SB/WB): __+3____mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __0.75__crashes/MEV Existing crash rate: __0.45__crashes/MEV		
5 - Approach Grade		**1**	**1**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __0____% Approx. Grade (SB/WB): __0____%		
6 - Heavy Vehicle Traffic Volume[5]		**0**	**0**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __16280_vpd Heavy Vehicle: __12____%		
Final comments and recommendations[7,8]:		**0**	**0**
	Total:	**4**	**4**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure C.4 Intersection of S.R. 40 & S.R. 32.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: S.R. 189 & S.R. 52 **Date: 12/11/06**

City: Provo **Region: 3**

Approach Direction (circle): NB / (SB) EB / WB **Analyst: BYU**

Condition[2]	Details	Evaluation[3] NB/EB	Evaluation[3] SB/WB
1 - Limited Sight Distance[4]			**2**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: 425 ft SSD required plus queue length: 575 ft		
2 - Posted Speed			**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed: 50 mph		
3 - Isolated Intersection			**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): 0.8 mi Dist. to upstream int. (SB/WB): +5 mi		
4 - High Crash Rate[5]			**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: 1.21 crashes/MEV Existing crash rate: 0.27 crashes/MEV		
5 - Approach Grade			**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): +(0-3) % Approx. Grade (SB/WB): -(0-3) %		
6 - Heavy Vehicle Traffic Volume[5]			**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: 15385 vpd Heavy Vehicle: 16 %		
Final comments and recommendations[7,8]:			**0**
Obvious need Existing directional signage located at ~470 feet.			
	Total:	**0**	**6**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure C.5 Intersection of S.R. 189 & S.R. 52.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 89 & 1860 South__________ **Date: _12/11/06_**

City: __Provo__________ **Region: __3___**

Approach Direction (circle): (NB / SB) EB / WB **Analyst:__BYU__________**

Condition[2]	Details	Evaluation[3] NB/EB	Evaluation[3] SB/WB
1 - Limited Sight Distance[4]		**2**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __450___ft SSD required plus queue length: __600___ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__55____mph		
3 - Isolated Intersection		**2**	**1**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __1.9____mi Dist. to upstream int. (SB/WB): __1.4____mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.21__crashes/MEV Existing crash rate: __0.87__crashes/MEV		
5 - Approach Grade		**1**	**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __-(3-6)_% Approx. Grade (SB/WB): __+(0-3)_%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __18000_vpd Heavy Vehicle: __16___%		
Final comments and recommendations[7,8]:		**0**	**0**
Skid marks ar e evident; Northside Railroad Crossing (~500 ft) The truck volume may be too low from the actual truck traffic volume.			
	Total:	**7**	**3**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure C.6 Intersection of S.R. 89 & 1860 South.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 89 & S.R. 75______________ **Date: _12/11/06_**

City: __Springville______ **Region: __3___**

Approach Direction (circle): (NB / SB) EB / WB **Analyst:__BYU_________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**1**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __425___ft SSD required plus queue length: __575___ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__50____mph		
3 - Isolated Intersection		**1**	**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __1_____mi Dist. to upstream int. (SB/WB): __1.9___mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.21__crashes/MEV Existing crash rate: __0.96__crashes/MEV		
5 - Approach Grade		**0**	**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __0____% Approx. Grade (SB/WB): __-(0-3)_%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __18890_vpd Heavy Vehicle: __17____%		
Final comments and recommendations[7,8]:		**0**	**0**
	Total:	**3**	**5**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure C.7 Intersection of S.R. 89 & S.R. 75.

Appendix D Region 4 Intersection Site Evaluation Forms

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 130 & Cross Hollow ___________ **Date: _01/17/07 _**

City: __Cedar City _ ______ **Region: __4___**

Approach Direction (circle): (NB / SB) EB / WB **Analyst:__BYU _________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __378___ft SSD required plus queue length: __530___ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__45____mph		
3 - Isolated Intersection		**2**	**1**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __+10___mi Dist. to upstream int. (SB/WB): __1____mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.46__crashes/MEV Existing crash rate: __0.84__crashes/MEV		
5 - Approach Grade		**0**	**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __-(0-3)_% Approx. Grade (SB/WB): __+(0-3)_%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __11150_vpd Heavy Vehicle: __12___%		
Final comments and recommendations[7,8]:		**0**	**0**
Freeway exit going northbound.			
	Total:	**4**	**3**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure D.1 Intersection of S.R. 130 & Cross Hollow.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 56 & Lund Hwy.__ ___________ **Date: _01/17/07_**

City: __Cedar City__ _ ______ **Region: __4___**

Approach Direction (circle): NB / SB (EB / WB) **Analyst:__BYU__ _________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __446__ft SSD required plus queue length: __600__ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__50____mph		
3 - Isolated Intersection		**2**	**1**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __+5____mi Dist. to upstream int. (SB/WB): __1.5__ mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __0.91__crashes/MEV Existing crash rate: __0.38__crashes/MEV		
5 - Approach Grade		**0**	**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __+(0-3)_% Approx. Grade (SB/WB): __-(0-3)_%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __5025_vpd Heavy Vehicle: __12___%		
Final comments and recommendations[7,8]:		**0**	**0**
Currently unsignalized. Signal will be installed soon.			
	Total:	**4**	**3**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure D.2 Intersection of S.R. 56 & Lund Highway.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 56 & Airport Way____________ **Date: _01/17/07_**

City: __Cedar City______ **Region: __4__**

Approach Direction (circle): NB / SB (EB / WB) **Analyst:__BYU__________**

Condition[2]	Details	Evaluation[3] NB/EB	Evaluation[3] SB/WB
1 - Limited Sight Distance[4]		**0**	**1**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __378__ft SSD required plus queue length: __530__ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__45____mph		
3 - Isolated Intersection		**1**	**0**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __1.5____mi Dist. to upstream int. (SB/WB): __0.25__mi		
4 - High Crash Rate[5]		**0**	**0**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __NA__crashes/MEV Existing crash rate: __NA__crashes/MEV		
5 - Approach Grade		**0**	**1**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __+(0-3)_% Approx. Grade (SB/WB): __-(0-3)_%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __5025_vpd Heavy Vehicle: __21___%		
Final comments and recommendations[7,8]:		**0**	**0**
Skid marks ar e evident; Northside Railroad Crossing (~500 ft) The truck volume may be too low from the actual truck traffic volume.			
	Total:	**3**	**4**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure D.3 Intersection of S.R. 56 & Airport Way.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 9 & Telegraph Rd.__ ___________ **Date: _01/17/07_**

City: __Washington__ _ ______ **Region: __4___**

Approach Direction (circle): NB / SB (EB / WB) **Analyst:__BYU__ _________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**0**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __493___ft SSD required plus queue length: __650___ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__55____mph		
3 - Isolated Intersection		**2**	**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __+2____mi Dist. to upstream int. (SB/WB): __+10___mi		
4 - High Crash Rate[5]		**2**	**2**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __0.94__crashes/MEV Existing crash rate: __1.96__crashes/MEV		
5 - Approach Grade		**0**	**0**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __-(0-3)_% Approx. Grade (SB/WB): __+(0-3)_%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __20200_vpd Heavy Vehicle: __10___%		
Final comments and recommendations[7,8]:		**0**	**0**
Skid marks ar e evident; Northside Railroad Crossing (~500 ft) The truck volume may be too low from the actual truck traffic volume.			
	Total:	**6**	**6**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure D.4 Intersection of S.R. 9 & Telegraph Road.

Intersection Evaluation for Advance Warning Signals

Intersection[1]: __S.R. 18 & Snow Canyon Pkwy._______ **Date: _01/17/07_**

City: __St. George____ _ ______ **Region: __4___**

Approach Direction (circle): (NB / SB) EB / WB **Analyst:__BYU__ _________**

Condition[2]	Details	Evaluation[3] NB/EB	SB/WB
1 - Limited Sight Distance[4]		**0**	**1**
- Vertical & Horizontal Curves - Obstacles (trees, overpasses, buildings)	Comments/Description: SSD required: __400___ft SSD required plus queue length: __550___ft		
2 - Posted Speed		**1**	**1**
- ≥ 45 mph met - ≥ 60 mph greater emphasis	Comments/Description: Posted Speed:__45____mph		
3 - Isolated Intersection		**0**	**2**
- 1st intersection in an unsignalized area - 1st intersection to an urban area - Higher speed indicate greater need	Comments/Description: Dist. to upstream int. (NB/EB): __1_____mi Dist. to upstream int. (SB/WB): __+10___mi		
4 - High Crash Rate[5]		**2**	**2**
- Existing minus expected crash rate - > 0 met - ≥ 1 greater emphasis	Comments/Description: Expected crash rate: __1.04__crashes/MEV Existing crash rate: __2.62__crashes/MEV		
5 - Approach Grade		**1**	**2**
- ≥ 3% met - ≥ 6% greater emphasis	Comments/Description: Approx. Grade (NB/EB): __+3____% Approx. Grade (SB/WB): __-6____%		
6 - Heavy Vehicle Traffic Volume[5]		**1**	**1**
- ≥ 10% met - ≥ 20% greater emphasis	Comments/Description: AADT: __3715_vpd Heavy Vehicle: __11____%		
Final comments and recommendations[7,8]:		**0**	**0**
Skid marks ar e evident; Northside Railroad Crossing (~500 ft) The truck volume may be too low from the actual truck traffic volume.			
	Total:	**5**	**9**

Notes:

1. Record intersection details on the figure found on the reverse side including any abnormalities or obstructions.
2. Two or more conditions should be met including one of the following conditions: 1,2,3,or 4.
3. Place a "2" if the description has greater emphasis, a "1" if the description is met, a "0" if not.
4. A table with limited sight distance values can be found on the reverse side. Consider a minimum 125 to 150 foot queue length in addition to the stopping sight distance.
5. Expected, existing crash rates, AADT values, and truck volumes must be obtained prior to evaluation from the traffic and Safety Division at UDOT for use in evaluation.
6. Engineering judgment is to be used to evaluate the importance of each condition. The reviewer may add or subtract points as deemed necessary next to Final comments and recommendations.
7. For more details, consult the "Advance Warning Signal Installation and Design Guidelines."

Figure D.5 Intersection of S.R. 18 & Snow Canyon Parkway.