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SAFETY BENEFITS OF IMPLEMENTING ADAPTIVE SIGNAL CONTROL TECHNOLOGY: SURVEY RESULTS

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A report of the findings of
ICT-R27-SP20
Safety Benefits of Implementing ASCT

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16. Abstract

The safety benefits and costs associated with implementing adaptive signal control technology (ASCT) were evaluated in this study. A user-friendly online survey was distributed to 62 agencies that had implemented ASCT in the United States. Twenty-two agencies responded to the survey, providing information about the system type, detection type, and cost of ASCT implementation. These agencies were from city governments (47%), state governments (29%), and county governments (24%). They represented both a wide range of ASCT implementation rates (from 1 to 700 intersections) and five of the most popular ASCT systems. There was a range of ASCT costs for different systems and detection types used with the system. The average cost per intersection to the agencies that responded was $38,223 when cost data from all agencies were included, but it was $28,725 when the cost data from agencies with the lowest and highest figures were excluded. Detailed volume and geometry data were provided by the respondents for six specific intersections. Crash data were provided for three of these six intersections. Each of the three intersections exhibited a crash reduction, but the sample size was too small for statistical testing. The observed ASCT cost per intersection per annual crash reduction was computed for the three intersections, and it ranged from $5,444 to $37,500. The scope of this study was very limited; thus, only very limited conclusions could be drawn. The limited data seem to indicate that there are safety benefits for implementing ASCT. It is recommended that a controlled experiment of ASCT implementation in Illinois be conducted to determine benefit–cost ratios and compute a crash modification factor (CMF).

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Members of the Technical Review Panel are the following:

Kyle Armstrong, IDOT, Chair

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EXECUTIVE SUMMARY

Adaptive signal control technologies (ASCTs) have been proven effective in providing operational benefits, but agencies in the United States have been slow to adopt these technologies. One of the major reasons for the lack of ASCT implementation is lack of knowledge about the operational and safety benefits and costs of ASCT. In the literature, the cost of ASCT per intersection was estimated between $46,000 and $65,000.

It is has been shown that ASCT reduces the number of stops along a corridor. It follows that the number of rear-end crashes may decrease with the reduction of stops. However, clear evidence of ASCT's safety benefits has not been found. Only one known safety study has been conducted for ASCT. That study considered the SCATS system in Oakland County, Michigan, and did not find a statistically significant safety benefit.

This small study sought to collect cost and crash data for intersections that had been outfitted with ASCT. The expected outcome of the data collection was a benefit–cost ratio for implementing ASCT. The data collection method was an online survey. A user-friendly survey was designed to collect cost, geometry, volume, and crash data from agencies that had implemented ASCT. A maximum of 62 such agencies could be identified in the United States. They were all asked to complete the survey. Twenty-two of them did respond, but only 17 of them had some information that could be used.

Eight of the 17 agencies that had implemented ASCT were from city governments while the others were from state or county governments. The number of intersections on which each agency had implemented ASCT ranged from 1 to 700. Agencies used a variety of vehicle detection technologies, but inductive loop and video detection were the most frequently used. Seven agencies responded that they did not have any additional maintenance costs resulting from ASCT, but three indicated that there were maintenance costs attributable to ASCT. Volume and geometry information was provided for six intersections, and crash data were provided for only three intersections.

Per intersection, the average cost of ASCT implementation was $38,332 when data from all agencies were included, but it was $28,725 when the cost data from agencies with the lowest and highest figures were excluded. The average cost of ASCT was given by the type of system as well as the type of detection technology. The average cost of ASCT per intersection was highest when used with video detection and lowest when used with magnetometer detection technology. The crash data were combined with cost data to determine the cost of ASCT per annual crash reduction, which ranged from $5,444 to $37,500.

The scope of this study was very limited, thus very limited conclusions could be drawn. The limited data seem to indicate that there are safety benefits for implementing ASCT. It is recommended to conduct a controlled experiment of ASCT implementation in Illinois to determine benefit-cost ratios and compute a crash modification factor (CMF).

CONTENTS

CHAPTER 1 INTRODUCTION

In the 1970s, traffic engineers began to experiment with adaptive signal control technologies (ASCTs) in an effort to improve traffic flow by using ASCT to select optimal signal split, offset, phase length, and phase sequence based on real-time data from a variety of detector systems (Stevanovic 2010). Two of the earliest ASCT systems were the Sydney Coordinated Adaptive Traffic System (SCATS) and the Split Cycle Offset Optimization Technique (SCOOT). Several other systems have been developed. Differences in the systems include the signal parameters (i.e., split, offset, cycle length) that may be optimized, the type and amount of vehicle detection that is necessary, the type of communication necessary, and the algorithm/mathematical optimization technique.

Several studies have reviewed the operational benefits of ASCT systems. In general, there is some operational benefit to installing ASCT, but the degree of benefit is dependent on several factors, including the previous type of traffic control, the quality of previous signal timing, and the predictability/stability of traffic demand.

While the primary motivation for developing and implementing ASCT has been to improve traffic operation, operational benefits such as a reduction in the number of stops may lead to safety benefits for intersections with ASCT installed. Studies documenting these safety benefits are not as numerous nor do they cover as many systems/conditions as those pertaining to the operational benefits. With the publication of the Highway Safety Manual (HSM), quantification of safety benefits has become increasingly important.

A few studies, such as Stevanovic (2010), Selinger and Schmidt (2009), and Selinger and Schmidt (2010) have investigated the cost of implementing ASCT in the United States. As available technology has changed, so has the cost of implementing ASCT.

This purpose of this small research study was to evaluate the costs and safety benefits of implementing ASCT technology in the United States based on the data that might be available from the jurisdictions that have used the technology. The duration of this small study was 5 months. A survey (copy of it is given in appendix) was sent to those jurisdictions asking them to provide ASCT system benefits and cost data.

1.1 LITERATURE REVIEW

A literature review related to the costs and safety benefits of implementing ASCT was conducted.

1.1.1 Costs of Implementing ASCT

Implementation cost data about four ASCT systems (ACS-Lite, OPAC, SCOOT, SCATS) were collected in a 2009 survey by HDR Engineering (Selinger and Schmidt 2009). The HDR survey was updated in 2010 to include information about newly available systems such as InSync and ACSLite (Selinger and Schmidt 2010). In 2010, a National Cooperative Highway Research Program (NCHRP) synthesis report also surveyed agencies that had implemented ASCT in order to estimate the average cost per intersection of implementing ASCT (Stevanovic 2010). The results of these three surveys are summarized in Table 1. The HDR Engineering report included a breakdown of cost by the type of ASCT system; it is included when available. The average cost per intersection ranged from $28,700 to $58,856 among systems. In addition, the overall average for all systems included in the NCHRP report was $19,000 higher than that of the HDR report. Carter and Hicks (2000) also estimated the costs for five of the most popular ASCT systems, but the figures given were not easily compared with the per-intersection costs in the other studies.

Table 1. Cost per Intersection of Implementing ASCT (from Previous Surveys)

System	Range of Values (average value)			Data Source
	Overall System Cost	Number of Intersections	Cost Per Intersection	
ACS-Lite	$236,000 ($236,000)	7 (7)	$33, 700 ($33,700)	HDR (2009)
OPAC	$60,000–$1,800,000 ($953,000)	3–18 (12)	$20,000–$128,600 ($68,042)	HDR (2009)
SCOOT	$197,000–$6,200,000 ($2,141,000)	8–70 (34)	$20,800–$95,400 ($49,291)	HDR (2009)
SCATS	$370,000–$75,000,000 ($10,222,750)	10–650 (100)	$26,400–$115,400 ($58,856)	HDR (2009)
InSync			($28,700)	HDR (2010)
ACS-Lite			($39,000)*	HDR (2010)
All Surveyed			($46,000)	HDR (2010)
All Surveyed			($65,000)	NCHRP Synthesis 403 (2010)

*Interpolated from figure

1.1.2 Safety Benefits

There is a very limited number of publications about the safety benefits of ASCT. Hicks and Carter (2000) wrote that ASCT reduces the number of stops by 28% to 41% and that this reduction in number of stops may result in some safety benefits. Dutta et al. (2010) used an ASCT test bed in Oakland County, Michigan, to determine the safety benefits of the SCATS system. The researchers observed a shift in the severity of crashes from Type A (incapacitating injury, permanent injury) and Type B (non-incapacitating injury, temporary injury) to Type C (possible injury, slight bruises and cuts), as defined by the Southeast Michigan Council of Governments. However, the reductions were not statistically significant at the 95% confidence level.

CHAPTER 2 SURVEY DEVELOPMENT

The literature review provided some information about safety and efficiency benefits of ASCT. However, the one safety study included in the review addressed only the SCATS system, and there are newer systems on the market since that study. Also, because the study took place in another state (Michigan), the results may not be representative of drivers and locations in Illinois.

In consultation with the Technical Review Panel (TRP) chair for this project, it was decided that an online survey would be the primary data collection medium for investigating the safety benefits of ASCT. The list of necessary data elements quickly became very long during the preliminary survey development phase. From this long list, it was clear that there must be a careful balance between survey length and data collection completeness. The danger in having a long survey was a low response rate, and the danger in a shorter survey was insufficient data for meaningful analysis.

The final list of data elements collected through the survey included contact information, ASCT system costs, volume/geometry/traffic signal details for each intersection, and crash frequency and crash type before and after ASCT installation. The online survey was created and hosted using Survey Gizmo, a commercially available survey creation and hosting service.

In designing the survey, extreme attention was given to including features that made it more user-friendly and quick to complete. Examples of such features include file upload options and information piping, or auto-filling. Each page with significant data input included an option to upload a file instead of filling in the information manually. Most relevant file types were accepted. Also, any information that was entered by the user and be used later in the survey was automatically populated. In addition to the special features, overall layout, font, and color scheme were chosen such that the survey did not appear longer than it actually was.

A draft version of the survey was sent to the TRP chair for his comments, as well as those of other IDOT employees. The suggestions they provided prompted several changes in layout, question numbering, and question wording, but not much of the content changed from the original document. One additional in-house review was provided by post-doctorate and PhD candidate research assistant colleagues. As before, the primary changes from this review process were small modifications to make the survey more user-friendly.

The final survey had six sections: (1) Welcome, (2) Agency Details, (3) System Type/Costs, (4) Intersection Volume/Geometry/Crash, (5) Contact Details, and (6) Thank You (Figure 1). The Welcome section was one page, with instructions on taking the survey and a brief statement of the research topic. The Agency Details section was one page that asked two questions about the respondent's agency. The System Type/Costs section had six questions that asked about the type of ASCT system that was implemented, the cost of implementation, and how many intersections had been implemented. The Intersection Volume/Geometry/Crash section had several questions about up to four specific intersections. The first page of that section asked respondents to choose between one and four intersections for which to provide detailed data. Next, for each chosen intersection, the respondent was asked to complete one page each of questions about volume/geometry and crash. Following the intersection questions, the respondent was asked to enter contact details. This section was included toward the end of the survey to reduce the workload at the front end of the survey. The thought process was that respondents would be more likely to provide meaningful data in the survey if they did not have to answer many simple questions (such as contact details) before the more time-consuming questions (such as crash data). A printed version the final survey is available in the appendix.

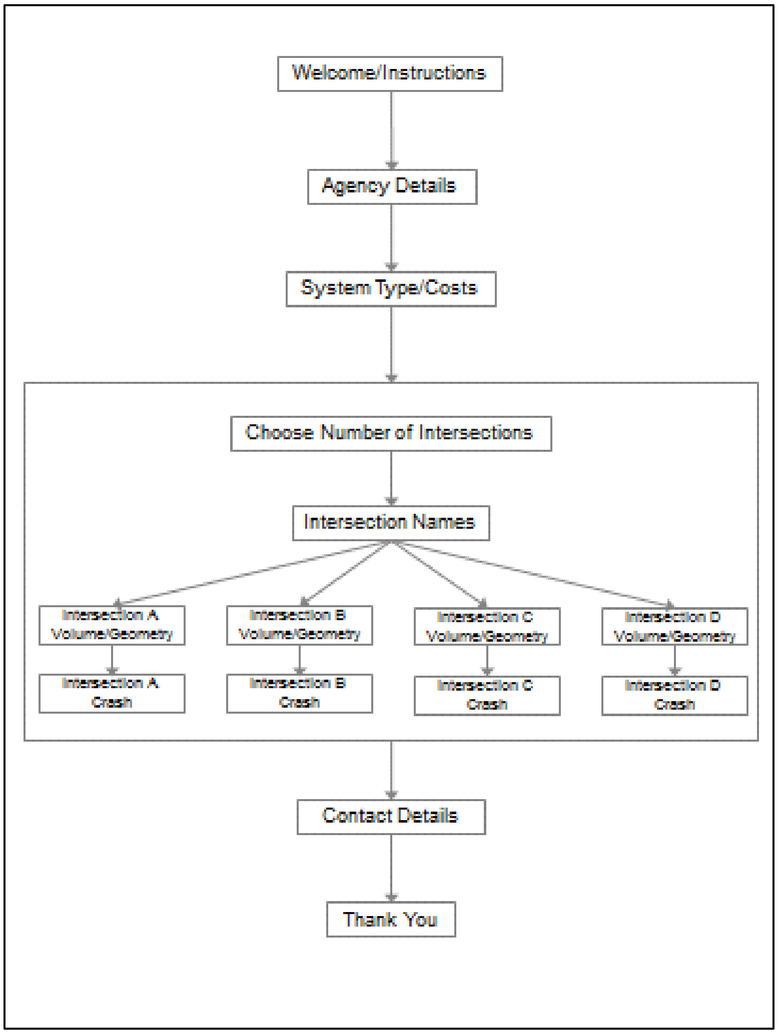


Figure 1.Outline of final ASCT survey.

CHAPTER 3 SURVEY RESPONDENTS

The survey was sent by email to a list of contacts at jurisdictions that were known to have implemented ASCT. The contact list was compiled from several sources including government agencies, industry, and academia. First, the TRP chair of the research sponsor (IDOT) provided the names and email addresses of several people at jurisdictions with ASCT implementations. Second, the websites of the major ASCT product manufacturers were searched for information about recent installations. The Rhythm Engineering website (http://rhythmtraffic.com) provided contact information for jurisdictions that have implemented the InSync ASCT system. Third, Dr. Aleksandar Stevanovic provided a compilation of contact information from a previous study of ASCT. Last, contacts were added from a list of presenters at the 60th Illinois Traffic Engineering and Safety workshop in 2011 on ASCT implementation.

The compiled list of ASCT contacts covered 62 jurisdictions in the United States as well as 15 international. Internationally, there are differences in driver behavior and traffic signal characteristics that could affect the safety effects of ASCT. Therefore, it was decided that the scope of this study would be limited to implementations in the United States. An initial email was sent to the contacts at the 62 jurisdictions on May 29, 2012. Immediately after the initial survey invitation, four email responses were received indicating that either the email address was not valid or the person to whom the email was sent no longer worked at the agency. Of the four "bounce-back" email contacts, two were remedied by finding a new email address and sending another survey invitation on the same day. A reminder email was sent on June 20, 2012, a week and a half before the June 30 survey response deadline. Any response that came by the end of July 2012 is included in this study. Out of the 62 jurisdictions, 22 survey responses were returned.

CHAPTER 4 SURVEY RESULTS

4.1 SUMMARY OF RESPONSES

The responses covered a wide range of geographical areas in the United States. Of the 22 responses, two originated from Canada and one originated from a European country. Since only jurisdictions with deployments in the United States were contacted directly, this means that the link to the ASCT survey was shared among colleagues or the respondents were outside of the United States at that time. This is positive from the point of view of gaining a more complete dataset; however, the international respondents did not provide contact information in the survey. Therefore, details about those ASCT implementations could not be more thoroughly explored.

The 19 survey responses from the United States spanned 17 unique jurisdictions in 14 different states. Eight respondents included information about the number of intersections and type of installed ASCT system, nine about the cost of the system, and ten about the type of detection used with the ASCT system. Most of the respondents did not provide volume, geometric, or crash data for the intersections. Only two respondents provided volume and crash data. One international respondent provided volume information but not crash data. The following sections provide detailed survey results for each question.

4.2 RESULTS FOR EACH QUESTION

This section provides detailed survey results for the first three sections of the survey—those that include general agency and system information rather than intersection-specific information.

4.2.1 Question 1: Has your agency implemented ASCT?

The first question in the survey simply asked respondents whether or not their agency had implemented ASCT. As shown in Figure 2, 17 of the 22 respondents replied that their agency had implemented ASCT, four did not provide a response to the question, and one indicated that his/her agency had not implemented ASCT. The person who answered "No" to the question was directed to a page that explained that the survey was limited to agencies that had already implemented ASCT (obviously, that didn't change the person's response). The respondents who answered "Yes" were directed to the next page in the survey.

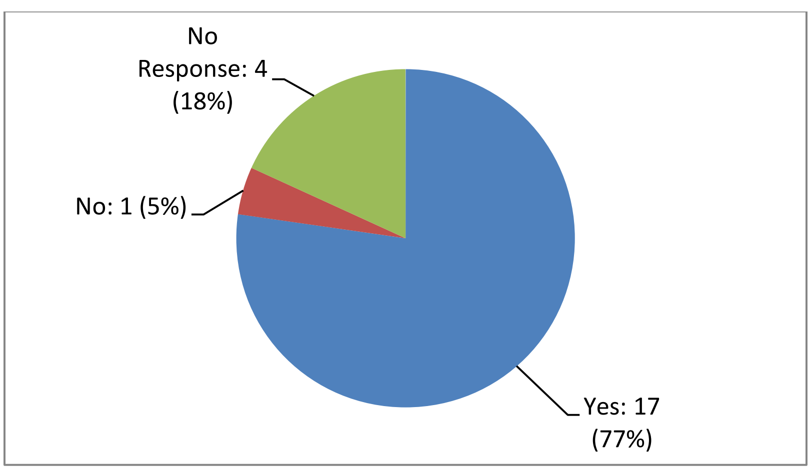


Figure 2. Number and percentage of agencies where ASCT was implemented.

4.2.2 Question 2: What is the type of your agency?

Participants were asked to select one of the following:

- City government
- County government
- State government
- Regional organization (e.g., metropolitan planning organization)
- Federal government
- Consultant
- Other

About half of the respondents were from city government (47%), while 29% and 24% were from state and county government agencies, respectively. None indicated that they were part of any other type of agency.

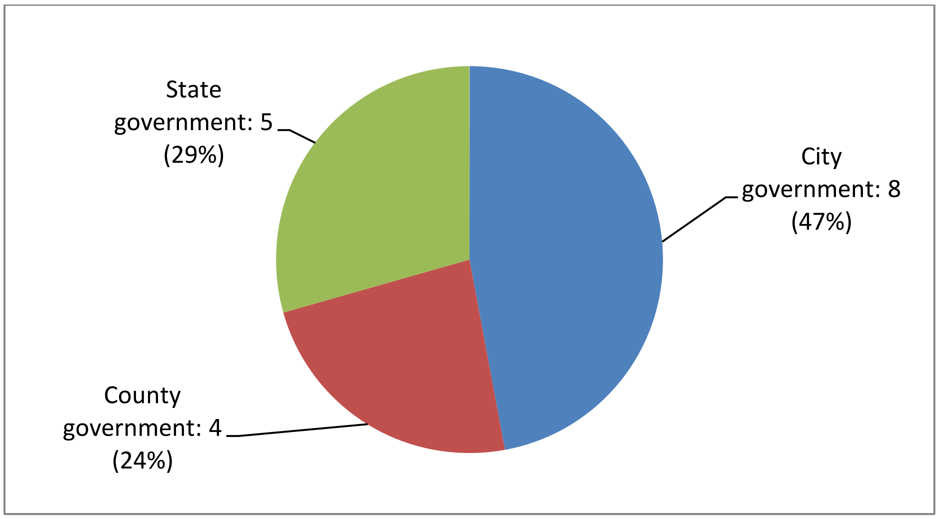


Figure 3. Number and percentage of types of agencies.

4.2.3 Question 3: What is the total number of signalized intersections under your agency's jurisdiction?

The distribution of responses to this question is given in Figure 4. Nearly half of the respondents did not provide the number of intersections in their jurisdiction. Those who responded gave a wide range of numbers, but no distinct trend was noted.

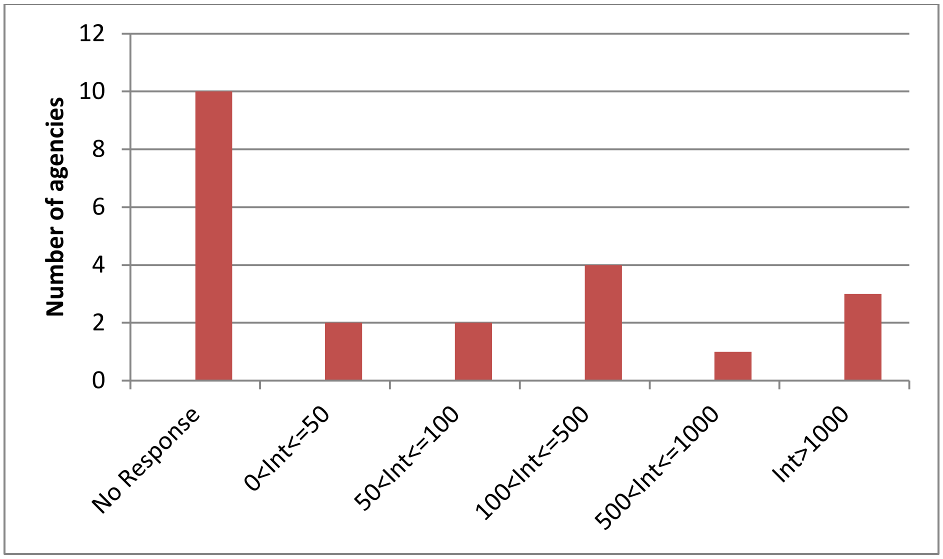


Figure 4. Number of signalized intersections under agencies' jurisdictions.

4.2.4 Question 4: How many intersections have implemented ASCT within your agency's jurisdiction?

As shown in Figure 5, nearly half of the participants did not respond to this question. The others responded with numbers that varied from one to more than 100 intersections with ASCT.

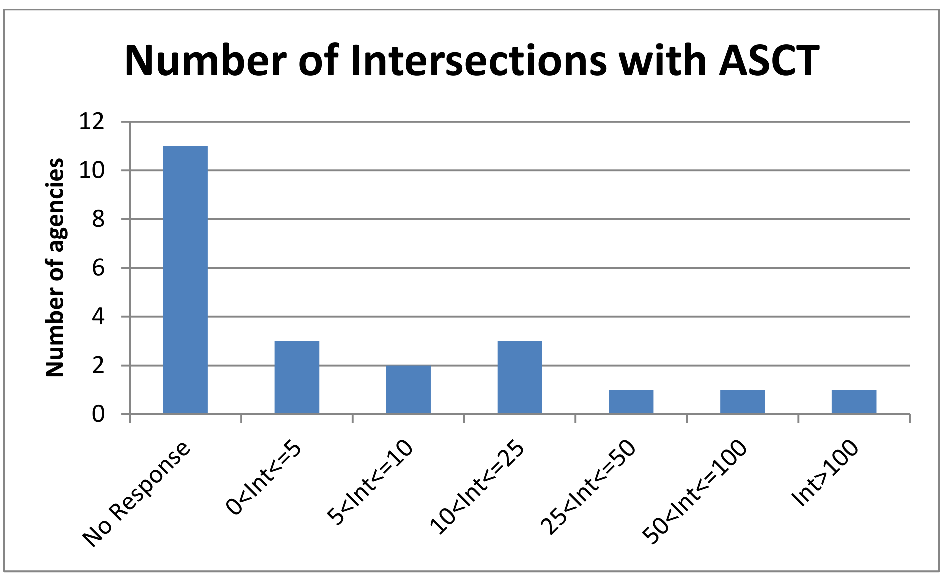


Figure 5. Number of intersections with ASCT per agency.

As shown in Figure 6, the percentage of intersections that implemented ASCT ranged from less than 1% to nearly 54%. The 54% (700 intersections) data point came from an implementation of the SCATS system in a suburb of a large, Midwestern city. Excluding this agency, the average number of intersections with ASCT was 12. There was not a discernible trend between the percentage of intersections that implemented ASCT and the total number of intersections under an agency's jurisdiction.

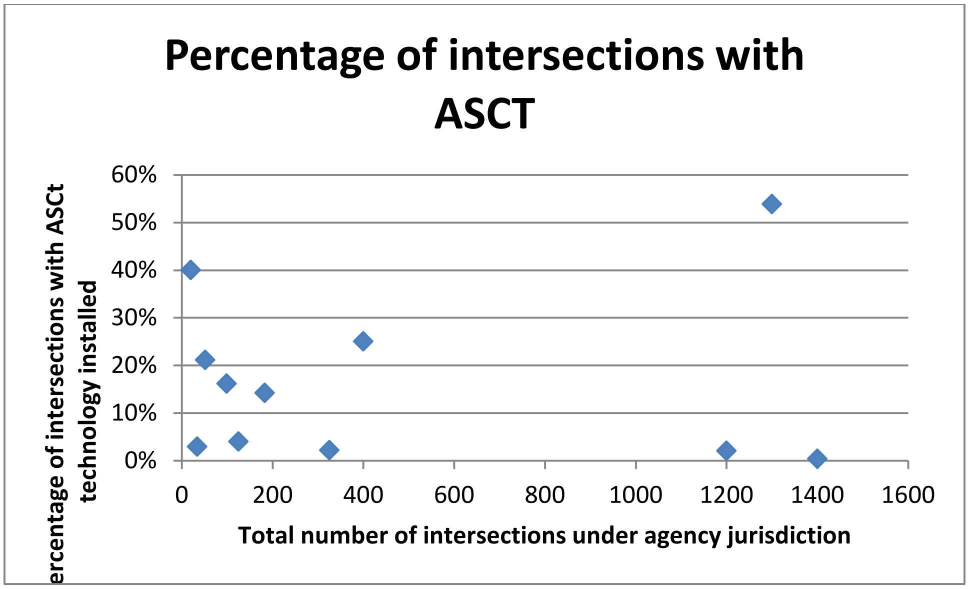


Figure 6. Percentage of intersections with ASCT versus total intersections.

4.2.5 Question 5: What type(s) of ASCT system(s) did your agency implement?

Respondents were asked which ASCT system their agency implemented. The results for this question are shown in Figure 6. Two of the 10 agencies that responded to this question indicated that they implemented more than one type of system. The figure shows that the most implemented system among survey respondents was InSync. It is reasonable to assume that the results could represent the entire population of the ASCT systems in the United States due to the process of identifying the jurisdictions that had implemented ASCT. Multiple sources were used, each with a different distribution of ASCT systems. Therefore, the resulting database was more representative of the entire population of ASCT implementations in the United States than that of any single source.

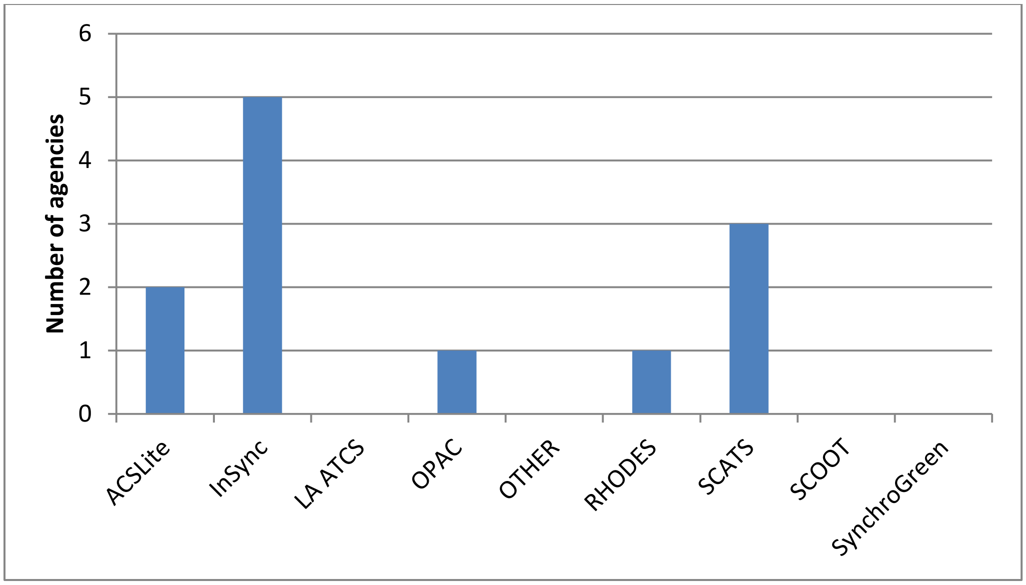


Figure 6. Type of ASCT system implemented by survey respondent agencies.

4.2.6 Question 6: What type of detection technology does your agency use for ASCT?

Survey respondents were asked to identify the type of detection technology their agency used on intersections with ASCT. Several choices were given, as indicated in Figure 8, including an Other category. Ten respondents provided an answer to this question. The figure shows the distribution of the responses. Inductive loop and video detection technology were tied for the highest number of agencies (seven out of ten) using that technology. Radar detection and magnetometer technologies were used by fewer than half the number of agencies as inductive loop or video detection—with three and two agencies, respectively. The one respondent who answered Other indicated that the agency used Sensys technology (a wireless magnetometer-based detection system).

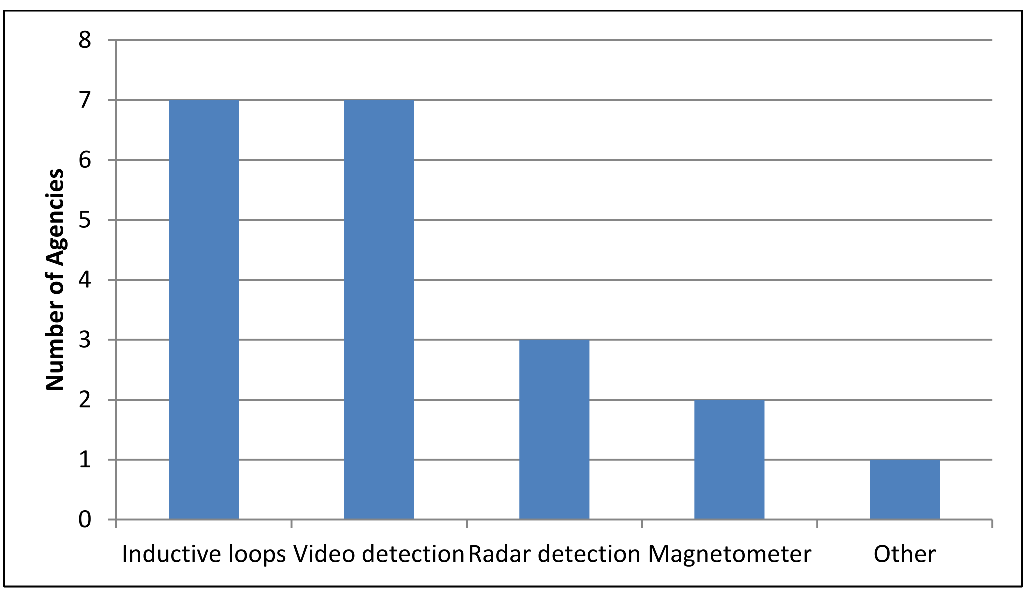


Figure 8. Types of vehicle detection technologies used by agencies that implemented ASCT.

4.2.7 Question 7: What was the *total cost of improvements?*

The researchers were interested in finding out the cost of adding ASCT to an intersection. It was assumed that when upgrading an intersection with ASCT, other intersection improvements may also have been made. Therefore, respondents were asked for both the total cost of improvements and the cost of improvements directly applicable to ASCT (Table 2).

Table 2. Cost of Improvements for Intersections with ASCT

Agency	Number of Improved Intersections	Total Cost of Improvements (Q7)	Total Cost per Intersection	Cost of Improvements Attributable to ASCT (Q8)	ASCT Cost per Intersection	Type of System
1	7	—	—	$500	$71	N/A
2	1	$36,000	$36,000	$34,500	$34,500	InSync
3	5	$150,000	$30,000	$125,000	$25,000	InSync
4	8	$350,000	$43,750	$300,000	$37,500	ACSLite
5	25	$420,000	$16,800	$375,000	$15,000	SCATS/ACSLite
6	11	$700,000	$63,636	$390,000	$35,455	InSync
7	16	$728,000	$45,500	$410,000	$25,625	SCATS
8	26	$1,700,000	$65,385	$728,000	$28,000	InSync
9	700	$100,000,000	$142,857	$100,000,000	$142,857	SCATS

There were eight responses for this question, as shown in Table 2. For the total cost per intersection, the minimum was $36,000, the maximum was $142,857, the median was $40,218, and the average was $55,491.The range of system cost per intersection was $25,000-$35,000 for InSync, $15,000-$38,000 for ACSLite, and $15,000-$143,000 for SCATS. As Table 2 shows, there is no correlation between system cost and type of system.

4.2.8 Question 8: What was the cost of intersection improvements *directly applicable to ASCT?*

There were nine responses for this question, as shown in Table 2. Per intersection, the minimum was $71, the maximum was $142,857, the median was $15,000, and the average was $38,223. The previous figures in Table 2 include the lowest cost ($71) and highest cost ($142,857)—figures that may not be good representative values for “typical” ASCT implementations. When the extreme cost figures were excluded, the minimum cost was $15,000, the maximum was $37,500, the median was $28,000, and the average was $28,725. By contrasting the results of this question and the previous question, it was clear that two agencies attributed the total cost of intersection improvements to ASCT implementation, while seven agencies reported that some of the cost was not related to ASCT implementation.

4.2.9 Question 9: Have there been any maintenance costs directly attributed to the ASCT system?

Respondents were asked whether or not there were any maintenance costs directly associated with the ASCT system (Figure 9). Twelve of them did not respond and seven said that there were no additional maintenance costs. Only three answered that there were additional maintenance costs. The types of maintenance costs that were listed included detection, communication, and ongoing monitoring/adjustments. The annual maintenance due to ASCT was approximately $5,000 for one agency that implemented ASCT in 700 intersections and $25,000 for another agency that implemented ASCT in eight intersections. The third agency did not specify an amount for maintenance costs.

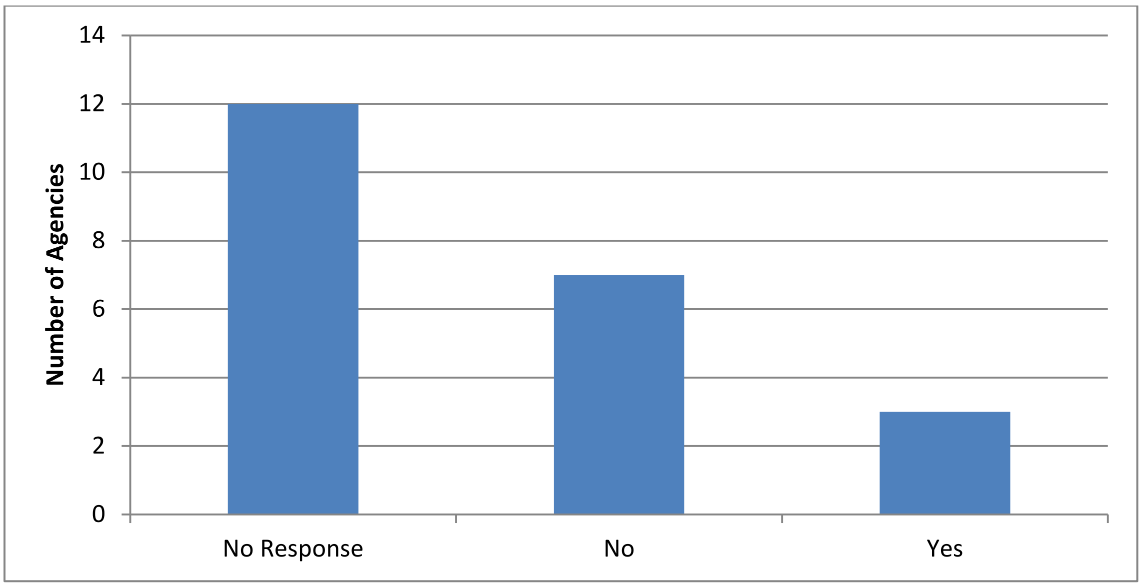


Figure 9. Response to “Have there been any maintenance costs directly attributed to ASCT?”

4.3 RESULTS BY INTERSECTION-RELATED QUESTIONS

The next section in the survey presented several questions related to volume, geometry, and crash frequency of specific intersections. Likely because of the larger time commitment required of the respondent, this section of the survey had a lower response rate than those in the previous section. In addition, many of the responses to the introductory questions in this section did not lead to meaningful responses in the subsequent volume, geometry, and crash frequency questions. The following subsections summarize the responses to the intersection-related questions.

4.3.1 Introductory Intersection-Related Questions

Two pages of the survey were dedicated to introductory intersection-specific questions. The first page asked the respondent, “Select the highest number of intersections with ASCT for which you will provide information on this survey (intersections that were previously actuated-coordinated are preferred).” The respondents had the option of selecting one, two, three, or four as the number of intersections for which to provide detailed intersection information. This was a required question, as indicated by an asterisk in the online survey, so respondents had to choose a number to continue with the survey. The reason for making this a required question was to ensure that the survey populated the correct number of pages with appropriate questions for the number of intersections that the respondent chose. Ten of the 22 respondents provided a response to this question. The number of intersections was capped at four so that respondents would not be overwhelmed with the amount of requested data. The maximum number of intersections that a respondent selected was four, and the average was 2.4.

The next page asked respondents to name the cross streets for each intersection (the number of which was chosen on the previous page). The survey was designed to automatically populate the street names in the text of several questions on subsequent pages in an effort to reduce the typing required of the respondent. Eight of the ten respondents who chose a number of intersections (on the previous page) provided the street names for at least one intersection.

4.3.2 Question A.1: Where (city, county) is the intersection located?

After the introductory intersection questions, the survey continued with questions about the volume, geometry, and crash frequency of specific intersections. Of the eight respondents who provided information in the introductory questions, three continued and provided details for at least one intersection. One of these three respondents provided data from a Canadian city, while the others were from U.S. agencies in Midwestern states. The number of intersections at which these two agencies had implemented ASCT was 26 for Agency A and eight for Agency B. The number of intersections for which these agencies provided data was one for Agency A and two for Agency B.

4.3.3 Question A.2: Volume in both directions

For each intersection, respondents were asked to provide before and after ASCT implementation values for average daily traffic (ADT), percentage of heavy vehicles, left-turn ADT, and speed limit. Table 3 shows the results of these questions.

Two respondents from the United States included before and after volume information for a total of three ASCT intersections. One Canadian respondent provided before volume information for three intersections (the after study had not been conducted at the time of the survey). The ADT for the major roads (from U.S. respondents only) were 23,000, 26,000, and 45,000 and for the minor roads were 8,000, 13,600, and 23,000.

The speed limits on the major roads ranged from 30 to 50 mph, while those of the minor roads ranged from 30 to 40 mph. When given, the left-turn ADT was higher for the minor road than for the major road.

Table 3. Volume of Intersection with ASCT Installed

			Before				After			
Observation	Country	Type of Road	ADT	% Trucks	Left-Turn ADT	Speed Limit (mph)	ADT	% Trucks	Left-Turn ADT	Speed Limit (mph)
1	U.S.	Major	23000	—	—	40	23000	—	—	40
		Minor	8000	—	—	30	8000	—	—	30
2	U.S.	Major	26000	3	4200	50	26000	3	4200	50
		Minor	13600	3	5000	40	13600	3	5000	40
3	U.S.	Major	45000	3	6100	50	45000	3	6100	50
		Minor	23000	3	9000	35	23000	3	9000	35
4	Canada	Major	34000	—	—	30–36	—	—	—	—
		Minor	8800	—	—	30	—	—	—	—
5	Canada	Major	34000	—	—	35	—	—	—	—
		Minor	17400	—	—	—	—	—	—	—
6	Canada	Major	34000	—	—	—	—	—	—	—
		Minor	14000	—	—	35	—	—	—	—

'—' indicates that no response was given.

4.3.4 Question A.3: Number of lanes on major road in both directions

The respondents were asked to describe the geometry of the intersections by indicating how many of several types of lanes existed on the major and minor roads. The results are included in Table 4.

Table 4. Geometry of Intersections with ASCT Installed

			Before					After				
Observation	**Country**	**Type of Road**	**# of Thru Only Lanes**	**# Left-Turn Only Lanes**	**# Right-Turn Only Lanes**	**# Left-Turn/Thru Shared Lanes**	**# Right-Turn/Thru Shared Lanes**	**# Thru Only Lanes**	**# Left-Turn Only Lanes**	**# Right-Turn Only Lanes**	**# Left-Turn/Thru Shared Lanes**	**# Right-Turn/Thru Shared Lanes**
1	U.S.	Major	4	1	0	0	0	4	1	0	0	0
		Minor	2	1	—	—	—	2	1	—	—	—
2	U.S.	Major	2	1	0	0	2	2	1	0	0	2
		Minor	2	2	2	0	0	2	2	2	0	0
3	U.S.	Major	4	2	1	0	1	4	2	1	0	1
		Minor	2	3	3	0	0	2	3	3	0	0
4	Canada	Major	4	1	0	0	—	4	1	0	0	—
		Minor	2	1	0	0	—	2	1	0	0	—
5	Canada	Major	4	1	0	0	—	4	1	0	0	—
		Minor	—	—	—	—	—	—	—	—	—	—
6	Canada	Major	4	1	0	0	—	4	1	0	0	—
		Minor	—	—	—	—	—	—	—	—	—	—

4.3.5 Question A.4: What type of traffic control was present before ASCT?

Respondents were asked to specify the type of traffic control that was present at the intersection before ASCT was installed. The following choices were available in a drop-down menu:

- Fixed-time coordinated control
- Actuated coordinated control
- Fixed-time isolated control
- Actuated isolated control

Of those who responded, three indicated that traffic signals were previously had been actuated coordinated and three said they had been fixed-time coordinated. Those who said fixed-time coordinated were responding about Canadian intersections, while the actuated coordinated intersections were in the United States.

4.3.6 Question A.5: Please indicate the type of left-turn phases at Intersection A.

The respondents were asked to indicate the type of left-turn traffic signal phase present at the intersections before and after the ASCT installation. All responses to this question showed that the left-turn signal phase did not change after the ASCT installation. The respondents had the choice between the following options in a drop-down menu.

- Protected
- Permitted
- Permitted-protected
- Prohibited

Figure 10 shows the responses of the survey participants who answered this question. Major roads were more likely than minor roads to have protected left-turn phases, while minor roads were more likely to have permitted-protected phases.

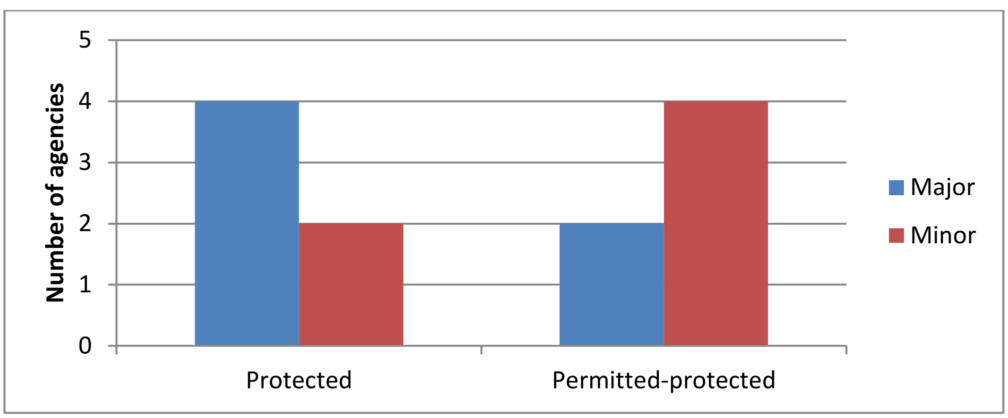


Figure 10. Type of left-turn signal phase at intersections with ASCT installed.

4.3.7 Question A.6: What is the time period (months) for the crash data?

Two respondents from the United States provided crash data for a total of three intersections. For two of the intersections, the time period was 12 months for before and after data. However, the third intersection listed the time period as ‘1’. It is very likely that this respondent intended 1 year of data, instead of 1 month because the number given was much too high for a month.

4.3.8 Question A.7: Crash severity

The respondents did not provide crash severity breakdowns. However, for two of the intersections, the respondent indicated that there were no fatal crashes before or after the ASCT installation.

4.3.9 Question A.8: Crash type

None of the respondents include breakdowns by crash type.

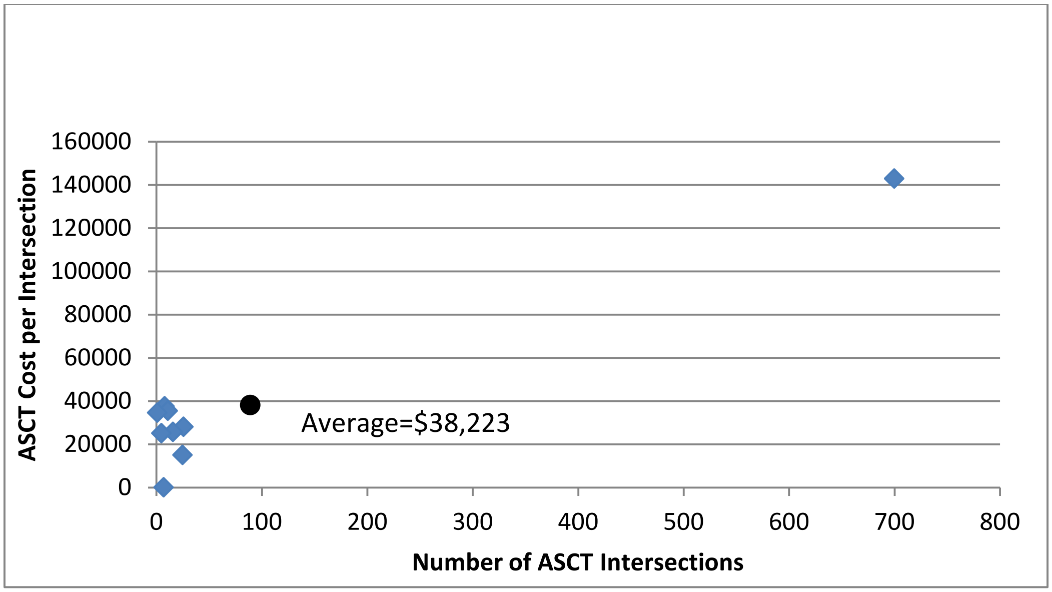
CHAPTER 5 ANALYSIS

5.1 ANALYSIS OF ASCT COST

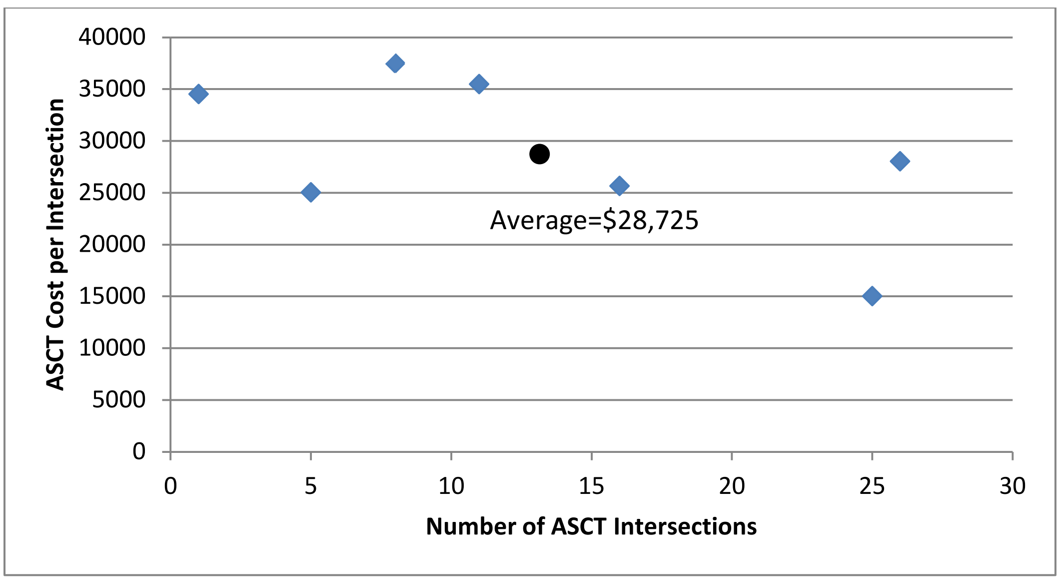
Survey respondents were asked to provide the total cost of implementing ASCT on a number of intersections. However, it was desirable to acquire an average cost of implementing ASCT per intersection. Therefore, the average cost for implementing ASCT for each agency was computed by dividing the total cost attributable to ASCT (Question 8) by the number of intersections provided for each type of ASCT system (Question 6). The average costs of ASCT implementation for the agencies collected are plotted in Figure 11.

In Figure 11(a), the responses of all of the agencies are included. The figure shows a large difference between the highest average value of $142,857 and the lowest average value of $71. Between the lowest and highest average values was a cluster of data points, but there were large gaps separating this cluster from the minimum and maximum. When the minimum and maximum were included, the average cost per intersection was $38,332. This value was computed by finding the mean of the average values of all agencies, regardless of the number of ASCT intersections they have.

In Figure 11(b), the minimum and maximum average cost values that seemed to be outside the norm were omitted. The resulting figure has a minimum of $15,000, maximum of $37,500, and average value of $28,725. Both average values in Figure 11(a) and (b) are lower than those cited in the literature.



(a)



(b)

Figure 11. ASCT costs per intersection (a) including extreme values (minimum $71 and maximum $142,857); and (b) not including extreme values.

Figure 12 shows the average cost breakdown by the type of ASCT system. The ACSLite and InSync systems were $26,250 and $30,739, respectively, while the SCATS system was $61,161, including the minimum and maximum values. The $61,161 for the SCATS system was more similar to average costs provided in other studies than the ACSLite or InSync systems.

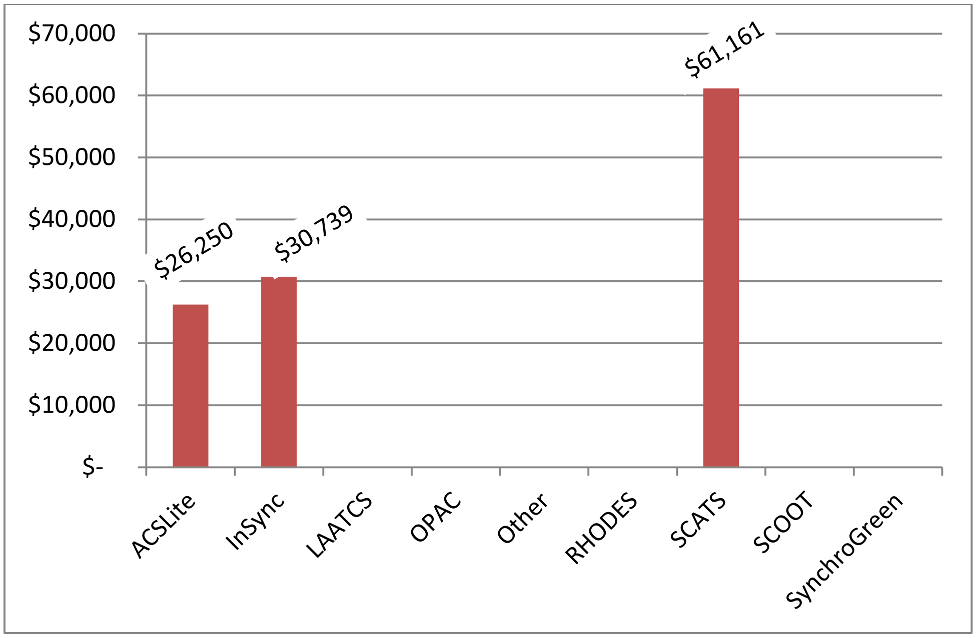


Figure 12. Average cost per intersection of ASCT systems.

Figure 13 shows the breakdown of ASCT cost per intersection by the type of detection used. While this plot is helpful in showing the general trend of ASCT costs, it is important to consider that some ASCT systems require specific detection technology. Therefore, the cost breakdown by detection type considered not only the detection technology but also the ASCT system type, indirectly. With this caveat, ASCT was most expensive, when video technology was used and least expensive when magnetometers were used. Inductive loop was the second most expensive after video; video and inductive loops were the most popular detection technologies (previously shown in Figure 8).

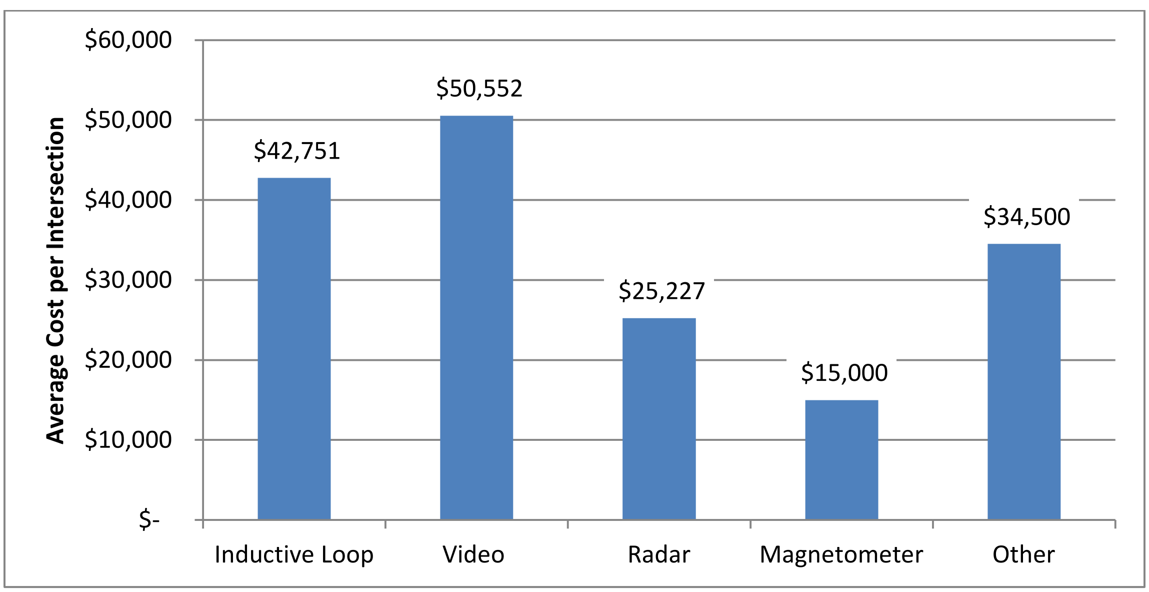


Figure 13. Average cost of ASCT per intersection for detection types.

5.2 ANALYSIS OF CRASH DATA

There were three intersections for which crash data were provided by the respondents. For each intersection, crash data were given for one year. Table 5 shows the annual crash reductions for the three intersections were five, one, and two. Next, the ASCT cost per intersection per annual crash reduction was computed. The range of values for the cost per crash reduction ranged from $5,444 to $37,500. Clearly, this value is very sensitive to the annual crash reduction. To account for the difference in traffic volumes between the intersections, the cost in column A was normalized by the number of million vehicle miles at the intersection. Column B was computed as

$$B = \frac{A}{365 * \frac{ADT_{major} + ADT_{minor}}{100000}}$$

The ratio between the highest and lowest values in Column A was 6.9, while the same ratio for Column B was only 3.1. Column B is more representative of the cost of the ASCT per road user. Therefore, considering the ratios stated, the per-user cost of crash reduction (Column B) is more similar between intersections than when just the cost and crash reduction values were considered (Column A).

Table 5. Cost of ASCT per Crash Reduction

					A	B
Intersection	**Time Period in Years (Before and After)**	**Crash Frequency Before ASCT**	**Crash Frequency After ASCT**	**Annual Crash Reduction**	**ASCT Cost per Intersection per Annual Crash Reduction**	**ASCT Cost per Intersection per Annual Crash Reduction per Million Vehicles**
1	1	20	15	5	$5,444	$481
2	1	34	33	1	$37,500	$1,511
3	1	25	23	2	$18,750	$1,297

The survey respondents did not provide a breakdown of crash severity or crash type. However, it was noted that intersections 2 and 3 did not have any fatal crashes. Since the cost of a crash depends to a large extent on its severity, it is difficult to determine a meaningful benefit–cost ratio. Table 5 (based on the very small sample we could gather, which should not generalized) shows that for every $5,444–$37,500 spent on intersection improvement with ASCT, the number of crashes is reduced by one. The cost figures can be easily justified if any of the crashes are non-property-damage-only (non-PDO).

To determine a range for a benefit–cost ratio, a few crash cost values were used for an illustrative purpose. It is assumed that the cost figures for rear-end type crashes are reasonable values to use since this is the crash type most likely to be reduced by ASCT. With this assumption, the following illustration can be made: The mean cost of rear-end, non-fatal crashes is in the range of $13,573 (no injury) to $116,043 (for severe injury), depending of the severity crashes (Zaloshnja et al. 2005). Therefore, from the values in Table 5, the range for a benefit–cost ratio if one rear-end crash is reduced could be 2.5 to 21.3 (again, for purpose of illustration only). For comparison, the mean cost for a non-fatal crash involving multiple vehicles that cross paths at a signalized intersection ranges from $8,544 (no injury) to $182,177 (for severe injury). This results in an illustrative benefit–cost range of 1.6 to 33.5 for each reduction of this crash type. A benefit–cost ratio greater than one is desirable for an investment. It is important to note that, owing to the small sample size, these observations are not statistically significant and cannot be generalized or applied to other situations.

CHAPTER 6 CONCLUSIONS

An online survey was distributed to agencies in the United States that had implemented ASCT in order to provide updated cost and crash data. The survey response did not provide an adequate sample on which to perform statistical testing. However, the following observations can be made about the survey responses:

- The average cost of ASCT per intersection is $28,725 based on data for most implementations and $38,223 based on data for all implementations. These figures are much lower than the values found in the literature, which were $46,000–$65,000. The lower average cost is partially due to the lower cost of implementing ASCT technologies now compared with the past.
- The observed range of ASCT intersection cost per annual crash reduction was $5,444–$37,500.
- The response rate for the survey was about one third, but most of the participants did not provide sufficient data to allow statistical comparison, determine benefit–cost ratios, or develop a crash modification factor.

The scope of this study was very limited; thus, only very limited conclusions can be drawn. The limited data seem to indicate that there are safety benefits for implementing ASCT. However, the findings in this report suggest that a controlled experiment of ASCT implementation in Illinois is required to determine significant benefit–cost ratios and to compute a crash modification factor (CMF).

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APPENDIX ASCT SURVEY

Questions marked with an asterisk (*) were required.

Welcome!

Safety Impacts of Adaptive Signal Control Technology (ASCT)

The University of Illinois is conducting a study for the Illinois Department of Transportation to determine the safety impacts of Adaptive Signal Control Technology (ASCT). The survey asks questions about the costs associated with implementing ASCT, the details of the intersections and systems, and the crash data before and after. The purpose of this survey is to collect safety/crash data from agencies that have implemented ASCT. Your assistance in acquiring the necessary data will help to advance the state of knowledge with regard to ASCT.

This survey should take about 20 minutes to provide data about one intersection and several more minutes for each additional intersection.

Special instructions for taking the survey:

There are several opportunities to submit data files (.xlsx, .docx, .jpeg, .pdf) instead of filling in the information on this survey form. When you are submitting data files, please read through the questions to ensure that you have responded to all the questions.

Use the "Back" button on the bottom of the page instead of your browser's "Back" button at the top of the page.

You may save your progress and continue. Click on the link at the top of the page (beginning with p. 2). A link will be sent to your email. Click on the link to continue taking the survey.

Contact:

1. Has your agency implemented ASCT?*
( ) Yes
( ) No

2. What is the type of your agency?
( ) City government
( ) County government
( ) State government
( ) Regional organization (e.g., metropolitan planning organization)
( ) Federal government
( ) Consultant
( ) Other

Please specify the type of your agency: ____

ASCT System Costs

The next several questions refer to the number and cost of ASCT intersections under your agency's jurisdiction. You are encouraged to answer the questions, but you may, additionally, upload a file (s) with the relevant information.

3. What is the total number of signalized intersections under your agency's jurisdiction?

____

4. How many intersections have implemented ASCT within your agency's jurisdiction?

____

5. What type(s) of ASCT system(s) did your agency implement?
If you need more space, you may increase the size of the "Feedback" field by clicking and dragging the bottom right corner.

	# of intersections with this system	**Feedback about this system**
ACS Lite	___	___
InSync	___	___
LA ATCS	___	___
OPAC	___	___
RHODES	___	___
SCATS	___	___
SCOOT	___	___
SynchroGreen	___	___
Other (Please Specify)	___	___

6. What type of detection technology does your agency use for ASCT? Mark all that apply.

[ ] Inductive loops

[ ] Video detection

[ ] Radar detection

[ ] Magnetometer

[ ] Other

Please specify the type of detection.

____

7. What was the *total cost of improvements* for all intersections where ASCT was installed (including improvements other than ASCT)?

____

8. What was the cost of intersection improvements *directly applicable to ASCT* (total for all intersections with ASCT)?

____

9. Have there been any maintenance costs directly attributed to the ASCT system?

( ) Yes

( ) No

Please describe the type of maintenance and provide the total cost of maintenance.

If any of the information provided in Question 3 - Question 9 is available online, please provide the url(s).

Number of Intersections

Now, you have the opportunity to provide site specific data for up to four ASCT intersections. Those intersections that previously had actuated-coordinated signal control are preferred. Otherwise, choose intersections that represent the most common characteristics (volume, geometry, phasing, speed limit, etc.) in your system.

For each intersection, there are two pages of survey input: (1) intersection volume and geometry and (2) crash data. You may upload files on each page in place of filling in the survey blanks. Please be sure that your data files contain the information that is requested (if available). If data is missing, just fill in those blanks to complete the requested survey data.

If you would like to provide information on more than four intersections, please contact Mike Lodes at lodes@illinois.edu.

Select the highest number of intersections with ASCT for which you will provide information on this survey (intersections that were previously actuated-coordinated are preferred).*

( ) 4

( ) 3

( ) 2

( ) 1

Intersection Details

Intersection A

Intersection A: Name of major road

____

Intersection A: Name of minor road

____

Intersection B

Intersection B: Name of major road

____

Intersection B: Name of minor road

____

Intersection C

Intersection C: Name of major road

____

Intersection C: Name of minor road

____

Intersection D

Intersection D: Name of major road

____

Intersection D: Name of minor road

____

Volume/Geometry (Intersection A)

The questions in this section ask about intersection volume, geometry, and control. Please feel free to either answer the questions or submit the information by uploading files.

Intersection Information*

Name of major road	___
Name of minor road	___

A.1 Where (City, County) is the intersection located?

____

A.2 (a) Volume on major road in both directions

	ADT	% Trucks	Left-turn ADT	Speed limit (mph)
Before	___	___	___	___
After	___	___	___	___

A.2 (b) Volume on minor road in both directions

	ADT	% Trucks	Left-turn ADT	Speed limit (mph)
Before	___	___	___	___
After	___	___	___	___

A.3 (a) Number of lanes on major road in both directions ([name of major road was displayed here])

Example: Two northbound thru lanes and two thru southbound lanes should be answered as four thru lanes.

	# of thru only lanes	# left-turn only lanes	# right-turn only lanes	# left-turn/thru shared lanes	# right-turn/thru shared lanes
Before	___	___	___	___	___
After	___	___	___	___	___

A.3 (b) Number of lanes on minor road in both directions

Example: One southbound left-turn lane and one northbound left-turn lane should be answered as two left-turn lanes.

	# of thru only lanes	# left-turn only lanes	# right-turn only lanes	# left-turn/thru shared lanes	# right-turn/thru shared lanes
Before	___	___	___	___	___
After	___	___	___	___	___

A.4 What type of traffic control was present before ASCT?

( ) Fixed-time coordinated control

( ) Actuated coordinated control

( ) Fixed-time isolated control

( ) Actuated isolated control

( ) Other

Please specify the type of control.

____

A.5 Please indicate the type of left-turn phases at Intersection A.

	Type of left-turn phase on the major road				Type of left-turn phase on the minor road			
	Protected	Permitted	Permitted-protected	Prohibited	Protected	Permitted	Permitted-protected	Prohibited
Before	___	___	___	___	___	___	___	___
After	___	___	___	___	___	___	___	___

If any of the information provided in Question A.1 –Question A.5 is available online, please provide the url(s).

Crash (Intersection A)

The questions in this section ask about intersection volume, geometry, and control. Please feel free to either answer the questions or submit the information by uploading files.

Do you have crash data available for intersection A?*

( ) Yes

( ) No

A.6 What is the time period (months) for the crash data? (up to 3 years)

	Time period (months)
Before	___
After	___

A.7 Crash severity

	Total number of crashes	**# Fatal**	**# Injury A**	**# Injury B**	**# Injury C**	**# Property damage only**
Before	___	___	___	___	___	___
After	___	___	___	___	___	___

A.8 Crash type

Please indicate the number of crashes in each of the following crash type categories.

	# Rear end	**# Angle**	**# Other crashes attributed to ASCT system (please explain)**
Before	___	___	___
After	___	___	___

If any of the information provided in Question A.6–Question A.8 is available online, please provide the url(s).

Volume/Geometry (Intersection B)

The questions in this section ask about intersection volume, geometry, and control. Please feel free to either answer the questions or submit the information by uploading files.

Intersection Information*

Name of major road	___
Name of minor road	___

B.1 Where (City, County) is the intersection located?

____

B.2 (a) Volume on major road in both directions.

	ADT	% Trucks	Left-turn ADT	Speed limit (mph)
Before	___	___	___	___
After	___	___	___	___

B.2 (b) Volume on minor road in both directions

	ADT	% Trucks	Left-turn ADT	Speed limit (mph)
Before	___	___	___	___
After	___	___	___	___

B.3 (a) Number of lanes on major road in both directions

	# of thru only lanes	# left-turn only lanes	# right-turn only lanes	# left-turn/thru shared lanes	# right-turn/thru shared lanes
Before	___	___	___	___	___
After	___	___	___	___	___

B.3 (b) Number of lanes on minor road in both directions

	# of thru only lanes	# left-turn only lanes	# right-turn only lanes	# left-turn/thru shared lanes	# right-turn/thru shared lanes
Before	___	___	___	___	___
After	___	___	___	___	___

B.4 What type of traffic control was present before ASCT?

( ) Fixed-time coordinated control

( ) Actuated coordinated control

( ) Fixed-time isolated control

( ) Actuated isolated control

( ) Other

Please specify the type of control.

____

B.5 Please indicate the type of left-turn phases at Intersection B

	Type of left-turn phase on the major road				**Type of left-turn phase on the minor road**			
	Protected	**Permitted**	**Permitted-protected**	**Prohibited**	**Protected**	**Permitted**	**Permitted-protected**	**Prohibited**
Before	___	___	___	___	___	___	___	___
After	___	___	___	___	___	___	___	___

If any of the information provided in Question B.1–Question B.5 is available online, please provide the url(s).

Crash (Intersection B)

The questions in this section ask about intersection volume, geometry, and control. Please feel free to either answer the questions or submit the information by uploading files.

Do you have crash data available for intersection B?*

( ) Yes

( ) No

B.6 What is the time period (months) for the crash data? (up to 3 years)

	Time period (months)
Before	___
After	___

B.7 Crash severity

	Total number of crashes	# Fatal	# Injury A	# Injury B	# Injury C	# Property damage only
Before	___	___	___	___	___	___
After	___	___	___	___	___	___

B.8 Crash type
Please indicate the number of crashes in each of the following crash type categories

	# Rear end	# Angle	# Other crashes attributed to ASCT system (please explain)
Before	___	___	___
After	___	___	___

If any of the information provided in Question B.6–Question B.8 is available online, please provide the url(s).

Volume/Geometry (Intersection C)

The questions in this section ask about intersection volume, geometry, and control. Please feel free to either answer the questions or submit the information by uploading files.

Intersection Information*

Name of major road	___
Name of minor road	___

C.1 Where (City, County) is the intersection located?

____

C.2 (a) Volume on major road in both directions

	ADT	% Trucks	Left-turn ADT	Speed limit (mph)
Before	___	___	___	___
After	___	___	___	___

C.2 (b) Volume on minor road in both directions

	ADT	% Trucks	Left-turn ADT	Speed limit (mph)
Before	___	___	___	___
After	___	___	___	___

C.3 (a) Number of lanes on major road in both directions

	# of thru only lanes	# left-turn only lanes	# right-turn only lanes	# left-turn/thru shared lanes	# right-turn/thru shared lanes
Before	___	___	___	___	___
After	___	___	___	___	___

C.3 (b) Number of lanes on minor road in both directions

	# of thru only lanes	# left-turn only lanes	# right-turn only lanes	# left-turn/thru shared lanes	# right-turn/thru shared lanes
Before	___	___	___	___	___
After	___	___	___	___	___

C.4 What type of traffic control was present before ASCT?

( ) Fixed-time coordinated control

( ) Actuated coordinated control

( ) Fixed-time isolated control

( ) Actuated isolated control

( ) Other

Please specify the type of control.

____

C.5 Please indicate the type of left-turn phases at Intersection C

	Type of left-turn phase on the major road				Type of left-turn phase on the minor road			
	Protected	**Permitted**	**Permitted-protected**	**Prohibited**	**Protected**	**Permitted**	**Permitted-protected**	**Prohibited**
Before	___	___	___	___	___	___	___	___
After	___	___	___	___	___	___	___	___

If any of the information provided in Question C.1–Question C.5 is available online, please provide the url(s).

Crash (Intersection C)

The questions in this section ask about intersection volume, geometry, and control. Please feel free to either answer the questions or submit the information by uploading files.

Do you have crash data available for intersection C?*

( ) Yes

( ) No

C.6 What is the time period (months) for the crash data? (up to 3 years)

	Time period (months)
Before	___
After	___

C.7 Crash severity

	Total number of crashes	**# Fatal**	**# Injury A**	**# Injury B**	**# Injury C**	**# Property damage only**
Before	___	___	___	___	___	___
After	___	___	___	___	___	___

C.8 Crash type
Please indicate the number of crashes in each of the following crash type categories

	# Rear end	**# Angle**	**# Other crashes attributed to ASCT system (please explain)**
Before	___	___	___
After	___	___	___

If any of the information provided in Question C.6–Question C.8 is available online, please provide the url(s).

Volume/Geometry (Intersection D)

The questions in this section ask about intersection volume, geometry, and control. Please feel free to either answer the questions or submit the information by uploading files.

Intersection Information*

Name of major road	___
Name of minor road	___

D.1 Where (City, County) is the intersection located?

____

D.2 (a) Volume on major road in both directions

	ADT	% Trucks	Left-turn ADT	Speed limit (mph)
Before	___	___	___	___
After	___	___	___	___

D.2 (b) Volume on minor road in both directions

	ADT	% Trucks	Left-turn ADT	Speed limit (mph)
Before	___	___	___	___
After	___	___	___	___

D.3 (a) Number of lanes on major road in both directions

	# of thru only lanes	# left-turn only lanes	# right-turn only lanes	# left-turn/thru shared lanes	# right-turn/thru shared lanes
Before	___	___	___	___	___
After	___	___	___	___	___

D.3 (b) Number of lanes on minor road in both directions

	# of thru only lanes	# left-turn only lanes	# right-turn only lanes	# left-turn/thru shared lanes	# right-turn/thru shared lanes
Before	___	___	___	___	___
After	___	___	___	___	___

Please specify the type of control.

____

D.5 Please indicate the type of left-turn phases at Intersection D

	Type of left-turn phase on the major road				Type of left-turn phase on the minor road			
	Protected	**Permitted**	**Permitted-protected**	**Prohibited**	**Protected**	**Permitted**	**Permitted-protected**	**Prohibited**
Before	___	___	___	___	___	___	___	___
After	___	___	___	___	___	___	___	___

If any of the information provided in Question D.1–Question D.5 is available online, please provide the url(s).

Crash (Intersection D)

The questions in this section ask about intersection volume, geometry, and control. Please feel free to either answer the questions or submit the information by uploading files.

Do you have crash data available for intersection D?*
( ) Yes
( ) No

D.6 What is the time period (months) for the crash data? (up to 3 years)

	Time period (months)
Before	___
After	___

D.7 Crash severity

	Total number of crashes	# Fatal	# Injury A	# Injury B	# Injury C	# Property damage only
Before	___	___	___	___	___	___
After	___	___	___	___	___	___

D.8 Crash type
Please indicate the number of crashes in each of the following crash type categories

	# Rear end	# Angle	# Other crashes attributed to ASCT system (please explain)
Before	___	___	___
After	___	___	___

If any of the information provided in Question D.6–Question D.8 is available online, please provide the url(s).

Submit

You are almost finished!

Please provide your contact information
First Name: ____
Last Name: ____
Title: ____
Agency: ____
Street Address: ____
Apt/Suite/Office: ____
City: ____
State: ____
Zip: ____
Email Address: ____
Phone Number: ____

Are there any publications related to your agency's ASCT implementation?*
( ) Yes
( ) No

Please provide information about the publications (author, title, journal name, url, etc.).

Check the box if you would like a copy of the final report of this study (after sponsor approval).
( ) Yes
( ) No

We appreciate your time and the information you provided. Please click "Submit" to finish the survey.

Thank You!

Thank you for submitting the survey. You may close your browser to exit. The information you provided will help advance the state of knowledge regarding safety of Adaptive Signal Control Technology (ASCT).

Please send your comments/questions to:

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Rahim F. Benekohal, Ph.D., Professor of Civil and Environmental Engineering, rbenekoh@illinois.edu

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