Adaptive Traffic Control Systems in the United States

A review of the cost, maintenance and reliability of popular adaptive traffic control technologies

Adaptive traffic control technology holds great promise for reducing congestion on U.S. arterial roadways; however, there are only a handful of adaptive systems in operation in the United States. Why is this? And why does the U.S. lag behind many other countries in the use of adaptive technologies? A survey of agencies that have implemented and operated adaptive control technologies was conducted to gain a greater understanding of why adaptive technology use is limited in the U.S.
**INTRODUCTION**

Adaptive traffic control technology holds great promise for reducing congestion on U.S. arterial roadways; however, there are only a handful of adaptive systems in operation in the U.S. Why is this? Why would a solution with great promise have such limited use? And why does the U.S. lag behind many other countries in the use of adaptive technologies?

In an effort to gain a greater understanding of why use of adaptive technology is limited in the U.S., a survey of agencies that have implemented adaptive traffic control systems was conducted. The survey focused on three primary areas: installation costs, maintenance and reliability. The survey did not include an obvious component of interest: operational benefits. While an important topic, it was not the authors’ intent to explore operational benefits in detail. This topic has been covered in numerous validation studies and other research. It is widely accepted that adaptive systems can provide significant operational benefits.

The information presented in this paper could be a valuable resource to agencies interested in pursuing adaptive technology. The information is based upon owner/operator experience communicated through responses to a series of survey questions. The findings and trends summarized are both quantitative and objective based upon the respondent comments.

It is the authors’ hope that the information presented in this document can be used by the transportation engineering community in advancing the use of adaptive traffic control. The technology, in the authors’ opinion, holds significant promise for improving mobility and reducing congestion, fuel consumption and emissions in the U.S. and abroad.

**BRIEF HISTORY OF ADAPTIVE TECHNOLOGY**

The first adaptive system was implemented in Glasgow, United Kingdom (UK) in the 1960s. The system, named PLIDENT, did not operate effectively and was termed a failure. In the 1970s the SCATS (Sydney Coordinated Adaptive Traffic System) system was deployed by the Road and Traffic Authority of New South Whales, Australia. A few years later, SCOOT (Split Cycle and Offset Optimization Technique) was put into practice in the UK.

In the more recent past, several systems have been developed in the U.S. Some of the more notable U.S. systems include:

- **ACS-Lite** – Adaptive Control Software; Federal Highway Administration (FHWA)
- **ATSAC** – Automatic Traffic Surveillance and Control; Los Angeles Department of Transportation (LADOT)
- **RT-TRACS** – Real Time Traffic Adaptive signal Control System; PB Farradyne, FHWA
- **OPAC** – Optimization Policies for Adaptive Control; University of Lowell, U.S. Department of Transportation (U.S. DOT)
- **RHODES** – Real-time Hierarchical Optimization Distributed Effective System; University of Arizona, Siemens Traffic Solutions

ACS-Lite is one of FHWA’s newest adaptive systems with a series of implementations beginning in 2005. It was developed as a lower-cost and easier to implement adaptive solution. ATSAC, developed by LADOT, is a traffic control system that came online in 1984. In the late 1990s and early 2000s, LADOT completed upgrades to convert the system from responsive to adaptive. Both RHODES and OPAC were developed in the U.S. and were implemented in the 1990s. These systems were both offspring from FHWA’s RT-TRACS development efforts.

There are other systems in the U.S. and abroad that are not covered in this brief overview. It was not the authors’ intent to provide a comprehensive list of the various systems in use, but to instead identify the systems most commonly used in the U.S. It is worth noting that in recent years some newer technologies have emerged in the industry. It was decided that newer technologies would not be considered in the survey because of limited operational experience. Including these systems would likely limit the opportunity to identify general trends and cross check data. It was decided that adaptive systems that have been in the marketplace for three or more years and implemented by at least three separate agencies would be included. This criteria resulted in the elimination of LADOT’s ATSAC system from the list of systems surveyed.

**Adaptive Traffic Control Redefined**

The term “adaptive traffic control” has been used for decades, but given advances in technology over the years it is beneficial to revisit the definition. The common industry definition considers a system to be adaptive if it can adjust splits, cycle length and/or offsets within some period of time after volume or occupancy data is collected along the corridor. While the signals adapt to serve demand, they do so through a responsive process rather than a real-time adjustment method.

Over the years, responsive signal control has been popular in some areas of the U.S. A responsive signal system collects volume data and compares the volumes periodically to a menu of volume levels. The volume levels are matched to predefined signal timing plans which are implemented as the volumes increase or decrease throughout the day. This response to volume changes can be an improvement over static timing plans; however, this approach always lags behind current traffic demand.

There is considerable similarity between the operations of a responsive signal system and the common adaptive traffic control system. The main difference between the two is that adaptive systems typically do not select from a menu of signal timing plans; they make more complex adjustments. However, most adaptive systems still operate in a responsive mode in which they collect data, calculate what to do and then implement timing changes a short time later.
To help transportation professionals better understand and recognize the technologies that exist and that are emerging, it is the authors’ opinion that a refined definition of adaptive traffic control is needed. The term “adaptive traffic control” should be split into two groups to better define the operation of the system. The term “responsive adaptive” would refer to a system that adjusts signal timings based upon data collected over several minutes or cycles and then implements a timing change. The term “real-time adaptive” would refer to systems that implement changes instantaneously based upon real-time demand.

The systems included in the survey for this paper would all be categorized as “responsive adaptive” systems.

**The Survey**

Information for this paper was gathered through a Web based survey conducted in July 2009. The survey consisted of 30-50 questions, depending on the circumstances of the particular adaptive system. There were 5 to 10 flexible questions that altered the survey specifically for each participant. The list of survey questions can be found in the Appendix.

Initially, 38 individuals were selected to participate in the survey. These individuals were identified by the authors by reviewing past research. Four locations were ultimately removed from the survey due to the local traffic engineer retiring or relocating, leaving no one at the agency with sufficient knowledge to complete the survey. In the end, 34 participants were included in the survey and responses were received from 28, resulting in an 82% completion rate. The completion rates for the surveyed systems are shown in Figure 1.

![Survey Completion](chart.png)

Figure 1: Survey completion rates by system. The authors received responses from 28 of the 34 participants – an 82% completion rate.
The survey covered a wide range of topics relating to the implementation and maintenance of adaptive systems. For the purposes of this paper, the topics are grouped into three categories:

- **Cost:** Includes system procurement costs for equipment and software. An effort was also made to capture hidden costs such as system upgrades and detection that is necessary to implement some of the systems.
- **Maintenance:** Includes level of staff effort and costs to fine tune and maintain the system.
- **Reliability:** Includes the overall functionality and stability of the system.

### SYSTEM COST

<table>
<thead>
<tr>
<th>System</th>
<th>Overall System Cost</th>
<th>Number of Intersections</th>
<th>Cost Per Intersection</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS-Lite</td>
<td>$235,000</td>
<td>7</td>
<td>$33,700</td>
</tr>
<tr>
<td>OPAC</td>
<td>$60,000</td>
<td>3</td>
<td>$20,000</td>
</tr>
<tr>
<td></td>
<td>$1,000,000</td>
<td>18</td>
<td>$55,600</td>
</tr>
<tr>
<td></td>
<td>$1,800,000</td>
<td>14</td>
<td>$128,600</td>
</tr>
<tr>
<td>SCOOT</td>
<td>$50,000</td>
<td>24</td>
<td>$20,800</td>
</tr>
<tr>
<td></td>
<td>$157,000</td>
<td>8</td>
<td>$24,500</td>
</tr>
<tr>
<td></td>
<td>$1,300,000</td>
<td>32</td>
<td>$40,600</td>
</tr>
<tr>
<td></td>
<td>$900,000</td>
<td>22</td>
<td>$45,000</td>
</tr>
<tr>
<td></td>
<td>$1,000,000</td>
<td>20</td>
<td>$50,000</td>
</tr>
<tr>
<td></td>
<td>$4,800,000</td>
<td>70</td>
<td>$68,600</td>
</tr>
<tr>
<td></td>
<td>$6,200,000</td>
<td>65</td>
<td>$95,400</td>
</tr>
<tr>
<td>SCATS</td>
<td>$370,000</td>
<td>14</td>
<td>$26,400</td>
</tr>
<tr>
<td></td>
<td>$500,000</td>
<td>16</td>
<td>$31,300</td>
</tr>
<tr>
<td></td>
<td>$3,000,000</td>
<td>73</td>
<td>$41,100</td>
</tr>
<tr>
<td></td>
<td>$500,000</td>
<td>10</td>
<td>$50,000</td>
</tr>
<tr>
<td></td>
<td>$750,000</td>
<td>11</td>
<td>$68,200</td>
</tr>
<tr>
<td></td>
<td>$762,000</td>
<td>11</td>
<td>$69,300</td>
</tr>
<tr>
<td></td>
<td>$900,000</td>
<td>13</td>
<td>$69,200</td>
</tr>
<tr>
<td></td>
<td>$75,000,000</td>
<td>650</td>
<td>$115,400</td>
</tr>
</tbody>
</table>

Table 1: A summary of the cost to implement adaptive systems as provided by 19 respondents.

When examining system cost there are many variables to consider. There are obvious costs for system hardware and software, and upgrades to the intersections necessary to make the system work. These upgrades can include new detection, controller upgrades, communication changes, etc. Then there are other costs that are not as easy to identify. These hidden costs can include changes to central software, costs for training, licensing fees or ongoing maintenance. The survey questions were designed to uncover as much cost information as possible.

It is clear from the survey responses that both system costs and other intersection upgrade costs were commonly known by the participants. However, some of the additional, or hidden, costs were only documented in a few cases. A summary of costs, based on information provided by 19 of 28 respondents, is provided in Table 1.
The goal of gathering the cost information was to identify costs per intersection for the systems. Historically, there has not been a good rule of thumb to use for adaptive systems. By reviewing the information in Table 1 it becomes rather obvious why that has been the case.

Figure 2 provides a more visual summary of the costs. Graphically, it is clear that costs for the systems vary greatly.

In general, all of the systems ranged from 10 to 70 intersections. If all of the systems were aggregated, the overall average cost for an adaptive system would be $55,000 per intersection. For comparison, SCOOT averages $49,000 per intersection and SCATS averages $60,000 per intersection. There is not enough information to draw a reasonable conclusion on ACS-Lite and OPAC systems, and no cost data was provided for the RHODES systems.

**Intersection Upgrade Costs**

One of the key components of adaptive systems is detection. This cost can sometimes be overlooked, and as many respondents noted, the systems did not include everything necessary to make them operational. The most common items needed that were not included were detection (loop, video and/or radar), upgraded controllers and interconnect if not previously installed. The survey included a question to identify these costs, if known. Responses are shown in Table 2.
Figure 3: A visual depiction of the wide range of costs associated with intersection upgrades.

The data is also shown graphically in Figure 3. Note the wide range of costs with some general trends. Based on the data, the average intersection upgrade cost for an adaptive system would be $20,000 per intersection. SCATS, SCOOT and OPAC are close to this mark with averages of $19,900, $20,300 and $21,500 respectively.

One ACS-Lite respondent indicated that loop and video detection was used for the system. Overall, two of the three ACS-Lite systems used advanced detection (video), but only one location submitted cost information.

The two OPAC respondents to the question either installed or upgraded loop detection at their system intersections. The three other OPAC respondents did indicate that advanced detection was used in their installations (video or radar); however costs were not provided.

<table>
<thead>
<tr>
<th>System</th>
<th>Overall Cost</th>
<th>Number of Intersections</th>
<th>Cost Per Intersection</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS-Lite</td>
<td>7</td>
<td>$14,000</td>
<td></td>
</tr>
<tr>
<td>OPAC</td>
<td>3</td>
<td>$8,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>$35,000</td>
<td></td>
</tr>
<tr>
<td>SCOOT</td>
<td>32</td>
<td>$4,700</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>$9,200</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>$10,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>$15,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>$20,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$1,600,000</td>
<td>70</td>
<td>$22,900</td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>$60,000</td>
<td></td>
</tr>
<tr>
<td>SCAITS</td>
<td>13</td>
<td>$5,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>$7,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>$9,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$133,684</td>
<td>11</td>
<td>$12,200</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>$20,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>73</td>
<td>$20,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>$25,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>650</td>
<td>$40,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$450,000</td>
<td>11</td>
<td>$40,900</td>
</tr>
</tbody>
</table>

Table 2: A summary of additional costs necessary to update intersections to make adaptive traffic control systems operational.
When looking at the SCOOT survey findings, half of the respondents implemented advanced detection with the downstream loop detection required for SCOOT (two used video; two used radar).

For SCATS it is not a requirement to use advanced detection. Of the systems represented in the survey, about half used only stop bar detection and the other half used stop bar loops with advanced video detection.

**Cost Summary**

From the survey it was determined that the average cost for intersection upgrades to implement an adaptive system was $20,000. Also, from the data collected it was determined that, on average, SCATS was the most expensive system to implement. SCATS averaged an overall cost per intersection of $60,000, while SCOOT averaged $49,000 per intersection. There was not enough cost information provided for OPAC, RHODES and ACS-Lite systems to provide a conclusion on an overall cost-per-intersection. One cause for inadequate cost information was two of the ACS-Lite respondents noted cost information was not available because the system was a demonstration project. Additionally, one OPAC and one SCOOT system received partial or full Federal grants.

**Maintenance**

The second survey category is framed around maintenance of the systems. For the purposes of this discussion, maintenance includes initial implementation, staff training and ongoing maintenance of the system.

**Initial Implementation**

Installation time and staff training are key factors that were surveyed. The intent was to determine how much effort it takes for agency staff to implement an adaptive system. Only 15 of 28 respondents answered the question on effort for installation and fine tuning. One likely reason for the limited response is that many of the systems were consultant or vendor installed; therefore, the system owners had limited knowledge of the installation and fine tuning effort. As depicted in Figure 4, there is a wide range of time required to install a system and fine tune it. From the data collected, SCOOT requires the most time, averaging about 630 hours per system. Aggregating all systems together provides an average of 365 hours per system. OPAC and SCATS were lower with averages of 340 hours and 205 hours respectively. ACS-Lite had only one response which indicated 80 hours for a system.
The OPAC installation hours and system size were found to correspond directly. The longest installation time was for the largest application (18 intersections). The second and third longest installation times were for 14 intersections and 3 intersections, respectively. With the OPAC systems, size and installation time correlated, averaging 24 hours of installation and fine tuning time per intersection.

This same logic did not apply for SCOOT and SCATS. The two SCOOT 1,000 hour installation and fine tuning locations were only 20 and 32 intersection systems. The two highest hour SCATS locations were also only 34 and 11 intersection systems. Based upon this information it is clear no direct correlation can be identified between basic system size and the installation and fine tuning effort.

**Training**

Given the complexity of adaptive technologies, staff training has become a common practice. All of the respondents acknowledged a formal training process either through the vendor or a consultant. A summary graph of training hours is shown in Figure 5. The bar graph indicates the number of hours of training that was provided for individuals requiring training.
In reviewing the data in Figure 5 there is a broad range of training hours. Starting from the left there are two 8-hour trainings for ACS-Lite systems. For OPAC, two of the five systems were installed in 2009. These two systems provided the lowest hours of training; only eight and 16 hours. The respondent from the system that had eight hours of training commented that the training was only enough to get a grasp of the system, not sufficient to be able to work with it and make adjustments. The two 40-hour training locations were submitted by both the largest and smallest OPAC systems surveyed. It is apparent that system size is not related to training hours with OPAC.

For the SCOOT systems the average training was fairly consistent except for one case where the training was more intensive. There was no apparent comment or reason for the single SCOOT location to be so dissimilar. When looking at the SCATS systems the three highest training efforts were for a wide range of system sizes (small – 13 intersections; medium – 34 intersections; and large – 65 intersections) leading to no relationship between system size and training hours. Looking at averages, SCATS had the highest average hours of training per application. SCATS averaged 60 hours of training while SCOOT averaged 38 hours of training and OPAC averaged 26 hours. The overall average of training hours was 41 hours.

Based on several respondent comments it should be noted that generally agencies that received less training were dependant on the vendor or consultants for support of their systems.
Ongoing Maintenance

Another area of interest with adaptive systems is ongoing maintenance. How much effort does it really take to keep these systems running smoothly? Two questions were asked about how maintenance expectations compared to the actual maintenance required and staff investment made (see Figures 6 and 7). Overall the survey found that 64% of the respondents felt that the system required more effort than originally expected. Likewise 55% of the respondents noted that staff time was not sufficient to work with the systems.

The responses to the first question are grouped by system in Figure 8 to gain some insight as to how the systems compared. The responses showed that OPAC and SCOOT were the two systems that required more effort and/or training than expected. Based upon the comments, it is safe to say the respondents felt strongly that the effort was significantly underestimated. This may be one of the underlying reasons that only two of the five OPAC systems surveyed were fully operational. And, of the eight SCOOT systems surveyed, only three of these systems were still in operation. Contrast this to the SCATS system where eight of the 10 systems surveyed were still operational.
One of the selling points for adaptive systems is that maintenance should be minimal since the system adjusts to traffic conditions, removing the need for periodic signal timing updates. So just how many hours do the systems take per week for maintenance? Hours of maintenance required per week is shown in Figure 9.

**Figure 9: The average maintenance effort for all systems was 10 hours per week.**

The average maintenance effort based on all systems was 10 hours per week. The OPAC average was slightly above the mean with a weekly maintenance average of 11 hours. The OPAC respondent that averaged 20 hours per week did comment that they would not have installed the system in hindsight due to maintenance and other reasons.

SCOOT had the highest average weekly hours of maintenance with 13 hours per week. The highest maintenance SCOOT location offered comments similar to the OPAC respondent – they would not have installed the system in hindsight.

SCATS averaged the lowest maintenance with an average of 8 hours (besides ACS-Lite with one data point). The one SCATS system that recorded the highest maintenance time did offer an explanation. The respondent noted in the comments that the implementation location was in a coastal city that struggled with frequent power failures that affected the maintenance of the system.

Even with the many hours devoted to maintenance of the adaptive systems, did the respondents feel there was enough time allotted to make the system successful? The results to this question are provided in Figure 10.
Overall SCATS and OPAC had the highest ratio of positive responses regarding the perception of adequate staff time. The SCOOT system respondents were evenly split and ACS-Lite respondents indicated not enough time was allotted.

**Maintenance Summary**

SCATS averaged less installation and fine tuning time and fewer maintenance hours per week compared to the other systems. The survey responses also indicated that SCATS systems on average did have the greatest investment in training which could be a contributor to the systems success in the maintenance section of the report. Not enough data was available for ACS-Lite and RHODES for a reasonable comparison to the other systems in this survey.

**SYSTEM RELIABILITY**

The third survey category focused on the reliability experience of the adaptive systems. Three primary questions were explored:

- What percentage of time would you estimate the system is down for any reason?
- What are some of the reasons that the system would not be in operation?
- Knowing what you know now, would you have installed the same system if you had the opportunity to do it again?
**Down Time**

When considering reliability, the goal was to identify the percentage of time a system would not be operational over any given time. The summary of responses is shown in Figure 11.

![Percent Offline](chart.png)

**Figure 11:** Some of the adaptive systems surveyed were offline as much or more as they were online. The newer system appeared to be more reliable.

From the data it is clear that a handful of systems were offline as much or more than they were online. If we ignore the “mostly offline” systems we can see most systems operate with at least 90% up time. This value may be viewed as acceptable; however, 10% downtime still equates to about 2.5 hours of downtime per day. Even if the down time was at 5% there would still be over one hour of down time on average each day.

From the two responses on ACS-Lite there is a range of extremes; it either works well or it had severe problems. The respondent that noted the ACS-Lite system was never operational also noted that the system was a one-year demonstration project and time ran out prior to addressing all the system issues.

When looking at the OPAC system, three respondents answered 10% as the average downtime. The OPAC location with the highest downtime (70%) noted the system suffered from several issues. It is worth noting that this particular system was the earliest installation surveyed for OPAC (1998). Likely, this data trend shows the newer systems have worked out the issues and are more reliable.
reliable. SCOOT had three locations under 10% and two locations over 50%. These two locations were both installed in the 1990s as well. Again, this suggests that the newer systems may be more reliable. Lastly, the SCATS system showed more positive results compared to the other systems. All but one of the system locations noted less than 5% down time. When averaging all of the more reliable systems (downtime less than or equal to 10%) the average is 5% which equates to 1.2 hours per day, or more than eight hours per week, of the system being offline.

**Down Time Causes**

There are many factors that affect an adaptive system’s reliability. Based upon the survey responses there are some key issues and trends that are worth noting. Common reliability issues are summarized in Figure 12.

![Figure 12: A summary of the many factors that can affect an adaptive system's operational reliability.](image)

For ACS-Lite and RHODES there is not enough information to draw out a common problem. For OPAC, detection problems and software issues were noted more often than other issues. SCOOT respondents noted a wide spectrum of issues with detection and communication mentioned more than the others. For SCATS, the reliability issues were related mostly to communication and detection. When all of the reliability responses were aggregated it was clear that overall detection and communication were the dominant issues that impacted reliability.

**Hindsight**

One of the final questions in the survey was, “Knowing what you know now, would you have installed the same system if you had the opportunity to do it all again?” This question provided the opportunity...
for respondents to reflect on their experience and decide if the system was worth the time, capital and effort. If the respondent answered “No,” they had an opportunity to provide comments on what they may have done instead.

The responses showed that 62% would have installed the same system knowing what they know now (Figure 13). For the 38% that responded “No,” SCATS, ACS-Lite and LADOT’s ATSAC were mentioned as alternatives they would have liked to consider if they could do it again.

Additional hindsight questions were included to determine reasoning for why a respondent would or would not have installed their adaptive system. The responses are summarized in Figure 14. The responses on the left represent the reasons respondents would choose to install their system again and the responses on the right provide the reasons why the respondents would do it differently if they could do it again.

Of all of the respondents that answered yes, 15 of the 16 people said that results (operational benefits) were one of the reasons that they would install the system again. Of the 11 respondents that would not install their particular adaptive system again, the most noted issue was maintenance. Both cost and installation were other reasons commonly noted as well. It is interesting to note that three respondents listed “Results” as a reason they would not install the system. This infers that three of the systems must not have provided traffic flow improvements.

Figure 13: Despite some challenges, a majority of respondents would install the same system again.

Figure 14: Reasons why respondents would or wouldn’t install the same system again.
To provide additional details, the survey answers were categorized by system in Figure 15. When reviewing the ACS-Lite responses, for example, one respondent noted they would install the system again and that same respondent identified results, maintenance and cost as reasons for installing ACS-Lite. In the “No” column two respondents answered they would not install the system again offering results and maintenance as the reasons.

![Hindsight Questions by System](image)

**Figure 15:** Reasons why respondents would or wouldn’t install the same system again, categorized by system type.

Notice that from this summary it cannot be determined how each respondent individually answered; just the overall count of certain responses is noted. This figure is a little confusing; however, there are trends worth noting.

- Most of the respondents marked “Results” as the majority in the “Yes” column. This means a majority of the respondents have observed beneficial results and recognize that the results are significant enough to reinstall the system.
- ACS-Lite was the only system that referred to cost in a positive way. On the negative side, all except one of the respondents for SCOOT and OPAC noted that cost was a reason not to install the system in hindsight.
- When looking at the “No” responses for the OPAC system, every respondent noted maintenance was a reason to not install the OPAC system in hindsight.
- For both ACS-Lite and OPAC, a majority of respondents indicated they would not install the adaptive system in hindsight.
- For SCATS, the respondents clearly indicate the results were the primary reason they would reinstall the system in hindsight.
- SCOOT showed a similar trend where all but one “Yes” respondent noted “Results” as a reason to reinstall the system.
**System Longevity**

Another interesting finding was how many of the systems included in the survey have been abandoned. A summary of the surveyed systems is shown in Figure 16. The two extremes from the figure include SCOOT having five of eight systems abandoned and SCATS only having two of 10 systems shut down. Of the 28 systems surveyed, 13 have been shut down or abandoned.

![Figure 16: Many of the systems included in the survey have since been abandoned.](image)

**CONCLUSIONS**

The purpose of this research effort was to gather and summarize information on the installation costs, maintenance and reliability of the most common or well known adaptive traffic control systems operating in the U.S. The information presented in this paper is based upon survey responses from the owner/operators of the surveyed systems (ACS-Lite, OPAC, RHODES, SCOOT and SCATS). Thirty-four systems were identified for inclusion in the survey; a total of 28 responses were received. The findings summarized in the paper are quantitative and objective based upon the survey responses and respondent comments.

**Cost**

One of the challenges with adaptive systems is simply identifying the cost of implementing a system. In addition to the costs for the actual adaptive system hardware and software, an agency needs to consider other costs such as detection, communication, controller upgrades, central system changes, installation, etc. In an effort to provide a useful estimate for practitioners, the survey was designed to provide information needed to estimate adaptive system costs on a “per intersection” basis. Based
upon the responses received there was not enough information to estimate costs for ACS-Lite and RHODES.

<table>
<thead>
<tr>
<th>System</th>
<th>Overall Cost per Intersection</th>
<th>Intersection Upgrade Cost per Intersection</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS-Lite</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>OPAC</td>
<td>$68,100</td>
<td>$21,500</td>
</tr>
<tr>
<td>RHODES</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>SCOOT</td>
<td>$49,300</td>
<td>$20,300</td>
</tr>
<tr>
<td>SCATS</td>
<td>$60,000</td>
<td>$19,900</td>
</tr>
</tbody>
</table>

Table 3: A summary of overall costs of installation, as well as additional upgrade costs.

For the remaining three systems (OPAC, SCOOT and SCATS) the overall average system cost per intersection ranged between $49,000 and $68,000 per intersection. This cost included about $20,000 per intersection for other upgrades necessary to implement the system (detection, communication, controller upgrades, etc). Note that the overall estimated average cost for these systems was based on a wide range of data provided by the respondents. Costs provided for their systems were as high as $128,000 per intersection and as low as $20,000 per intersection. This high variability in system costs was one of the concerning findings from the survey.

**Maintenance & Reliability**

The survey gathered information on maintenance and reliability in order to provide traffic engineers some background on the effort involved in operating adaptive traffic systems. It would be logical to assume that if an advanced traffic control system can change signal timing to address demand then there would be less involvement by engineering and technical staff to manage that system. This logic unfortunately does not hold true based upon the information provided in the survey responses.

**Initial Implementation**

Implementation and initial system fine tuning was found to vary widely with some systems. The average implementation and fine tuning hours for SCATS was 210 hours. SCOOT averaged 630 hours. It is important to note that the number of intersections per system and the implementation time did not correlate for these two systems. In one example a system of 20 intersections required 1,000 hours of implementation time.

OPAC implementation time and system size were found to correlate. The average implementation time for OPAC was 340 hours per system. Given there was a system size and costs correlation, an average of 24 hours per intersection could be estimated. Again ACS-Lite and RHODES did not have sufficient responses to present implementation effort estimates.
Training

It is common for training to accompany new adaptive systems. Overall the average amount of training time spent with owner/operator staff was 41 hours. The range of training time went from a low of eight hours (ACS-Lite) to as much as 150 hours (SCATS). Based upon survey respondent comments it was clear that minimal training resulted in greater dependence on contractor or consultant support.

<table>
<thead>
<tr>
<th>System</th>
<th>Maintenance</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Installation and Fine Tuning Hrs</td>
<td>*Hours per Week</td>
</tr>
<tr>
<td>ACS-Lite</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>OPAC</td>
<td>340 Hrs</td>
<td>11 Hrs</td>
</tr>
<tr>
<td>RHODES</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>SCOOT</td>
<td>630 Hrs</td>
<td>13 Hrs</td>
</tr>
<tr>
<td>SCATS</td>
<td>210 Hrs</td>
<td>8 Hrs</td>
</tr>
</tbody>
</table>

*Only average implementations with less than 100 intersections  
**Only averaged systems with less than 10% downtime

Table 4: The average amount of training time spent with owner/operator staff was 41 hours.

Ongoing Maintenance - Staff Time

Based on all survey responses the average maintenance effort expended to operate an adaptive system was 10 hours per week. Again, each system varied and the overall average is based upon systems that required less than five hours per week to as much as 40 hours per week. Note that about two-thirds of the respondents felt their adaptive system required more training or maintenance effort than they expected.

Reliability - Downtime

Maintaining an adaptive system and minimizing downtime is an obvious goal. In the survey results there were four systems that were noted as offline 50% or more of the time. Assuming that these are problem systems an average of the remaining systems indicates that 5% downtime is the norm. Over a week this would be just over eight hours of downtime. The causes for downtime consistently centered on communication and detection.

Hindsight - Longevity

About two-thirds of the respondents noted if they had to do it all over again, they would. This leaves one-third of the respondents saying they would do it differently. The results or operational benefit was the most noted reason for respondents saying they would install their system again. Those that would have done it differently in hindsight noted cost, installation and maintenance most often as the reasons. Of the 28 systems surveyed through this effort, 13 of the systems had been abandoned.
Where Adaptive Technology Needs to Go...

The information provided through this survey effort shines a light on the adaptive technology arena. It is clear from the survey respondent comments that greater arterial management can be achieved with this technology; however, there are many obstacles that exist that to date has limited widespread adoption. System costs, equipment replacement costs, staff time and downtime are a handful of the challenges that must be overcome. Also, the architecture of the adaptive systems may need to be revisited. With current technology, real-time adaptive systems need to be developed that instantaneously respond to traffic demand changes. These systems need to be easy to deploy, manage and maintain and should be able to operate with 99% or more up time. Cost-effective, real-time adaptive systems with wide implementation would significantly enhance transportation in the U.S.

SPECIAL THANKS

We would like to extend a special thank you to all of the survey respondents. Your time and effort in responding to the survey is greatly appreciated. Thank you to the following:

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Agency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Michael Andrako</td>
<td>Assistant City Engineer</td>
<td>City of Gahanna, OH</td>
</tr>
<tr>
<td>Rene Baile</td>
<td>Transportation Engineer</td>
<td>City of Menlo Park, CA</td>
</tr>
<tr>
<td>Ron Chandler</td>
<td>Engineering Associate</td>
<td>Santa Barbara, CA</td>
</tr>
<tr>
<td>Cecil Chau</td>
<td>Signal Systems Engineer</td>
<td>City of Chula Vista, CA</td>
</tr>
<tr>
<td>Jim Clacher</td>
<td>Manager, Transportation Management Center</td>
<td>Delaware DOT</td>
</tr>
<tr>
<td>Laura Cove</td>
<td>Traffic and Transportation Manager</td>
<td>Town of Cary, NC</td>
</tr>
<tr>
<td>Hazem El-Assar</td>
<td>Chief Engineer</td>
<td>Orange County, FL</td>
</tr>
<tr>
<td>Kevin Eppley</td>
<td>TMC Project Engineer</td>
<td>City of Chesapeake, VA</td>
</tr>
<tr>
<td>Jim Gelhar</td>
<td>Civil Engineer</td>
<td>City of Gresham, OR</td>
</tr>
<tr>
<td>Trev Holman</td>
<td>City Traffic Engineer</td>
<td>City of El Cajon, CA</td>
</tr>
<tr>
<td>Duncan Hughes</td>
<td>Senior Traffic Engineer</td>
<td>City of San Diego, CA</td>
</tr>
<tr>
<td>Jerry Kotzemacher</td>
<td>Senior Engineering Specialist</td>
<td>Minnesota DOT</td>
</tr>
<tr>
<td>Brook Martin</td>
<td>Traffic Signal Engineer</td>
<td>Cobb County DOT, GA</td>
</tr>
<tr>
<td>Adam Moser</td>
<td>Senior ITS Engineer</td>
<td>Pinellas County Public Works, FL</td>
</tr>
<tr>
<td>Gary Piotrowicz</td>
<td>Director of Traffic-Safety</td>
<td>Road Commission for Oakland County, MI</td>
</tr>
<tr>
<td>Robert W. Reck</td>
<td>Traffic Operations Manager</td>
<td>Pasco County Traffic Operations Division, FL</td>
</tr>
<tr>
<td>Les Sipowski</td>
<td>Senior Project Manager</td>
<td>City of Ann Arbor, MI</td>
</tr>
<tr>
<td>Carmen Talavera</td>
<td>Senior Transportation Engineer</td>
<td>City of Sunnyvale-Public Works, CA</td>
</tr>
<tr>
<td>John Thai</td>
<td>Principal Traffic Engineer</td>
<td>City of Anaheim, CA</td>
</tr>
<tr>
<td>Bob Tipton</td>
<td>Director</td>
<td>Collier County Traffic Operations, FL</td>
</tr>
<tr>
<td>Brenda VanCleave</td>
<td>Staff Engineer</td>
<td>Pickerington, OH</td>
</tr>
<tr>
<td>Nickolas VanGunst</td>
<td>Professional Engineer</td>
<td>City of Minneapolis, MN</td>
</tr>
</tbody>
</table>
REFERENCES

- www.peek.co.uk: SCOOT Overview (accessed July 2009)
- Betsy Williams, “The Technology Side of the Sydney Coordinated Adaptive Traffic Systems (SCATS)”, Georgia’s Intelligent Transportation Society
- Kevin Fehon, “Adaptive Traffic Signals: Are we missing the boat?”, ITE District 6 Annual Meeting, 2004
APPENDIX

Survey Questions

Initial questions
- How many types of adaptive systems do or did you work with? (number answer)
- Please identify the first Adaptive System you have worked with?
  - ACS-Lite
  - OPAC
  - RHODES
  - SCOOT
  - SCATS
  - Other

Before and After Conditions
- What year was the system installed?
- What year was the system last in operation?
- To implement the ATCS did you need to upgrade or implement new detection?
  - Loop, Video, Other
- What kind of traffic control system do you use currently instead of ATCS?

Geographical Questions
- Does the ATCS extend through multiple jurisdictions?
- If coordination issues existed, what did the issue relate to?
  - Different policies
  - Different Detection
  - Connecting the Systems
- How many intersections use/used the ATCS?
- How many arterials use/used the ATCS?
  - Grid or Arterial application.

Capital Questions
- What was the cost for the ATCS all together?
- What did the system include?
- What was not included with the system but required for the system to operate?
- How was the cost for the ATCS broken down?
  - Cost per intersection
  - Cost for the system
  - Cost per intersection and cost for the system
- What was the cost for upgrading intersection detection or other intersection necessities for the system?
  - Is this a cost per intersection or an overall cost?
- Were there initial startup costs just to have the system itself?
  - Training
  - Licensing and Legal
  - System Expenses
  - Other
- Please list the number and percent utilization of the employees working on the system.
Ex: Employee 1: 15%, Employee 2: 10% etc.

**Performance Questions**
- What percentage of the time would you estimate the system is down for any reason?
- What are some of the reasons that the system would not be in operation?
  - Installation and setup
  - Interface between detection and ATCS
  - Detection problems (loop, video or other)
  - ATCS software itself
  - Other
- What is the biggest problem that hinders the system from 100% up time?
- Was a validation report created for this ATCS?

**Training Questions**
- Was there a formal training process from a vendor or consultant?
- How many people were trained?
- How many hours of training were needed per person?
- What did the training entail?

**Maintenance Questions**
- Did this system take more effort or require more training than expected?
- Do you feel there is/was enough staff time allotted to make the system successful?
- How many staff hours did it take to install and fine-tune the system?
- How many hours per week does/did it take to maintain the system on average?
- Was ample time allowed to fine tune the system parameters?

**SCOOT Questions**
- Where were the loops located for the SCOOT system?

**SCATS Questions**
- Was Fallback Mode always successfully engaged when a problem or error occurred?
- What was the percent of success that the system converted to Fallback Mode?
- What was the main reason for automatic activation of Fallback Mode?
- How many times did Fallback Mode activate per year?
- How fast was the transition to Fallback Mode?
- How long did it take to fix the problem causing Fallback Mode on average?

**Hindsight Questions**
- Are you optimistic about the use of adaptive traffic control systems to address congestion?
- Knowing what you know now, would you have installed the same system if you had the opportunity to do it all again?
  - What is the reasoning why?
    - Results
    - Cost
    - Maintenance
    - Installation
    - Other
- Is there another system you would have rather installed in hindsight?