Using Archived ATMS Data for the Performance Evaluation of a Freeway Incident Response Program

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***Abstract*-The proliferation of new data gathering and archiving technologies has provided a wealth of new transportation data. Engineers, planners and freeway management system operators in many urban areas are finding themselves working in an increasingly data rich environment. The availability of these data allows analysis of multiple aspects of a freeway network from a regional scale down to a single incident. This study uses archived ITS data to evaluate the effectiveness of a freeway incident response program in Portland, Oregon. Data used in this study were extracted from an archived computer aided dispatch database, automatic vehicle location systems, inductive loop detectors, automatic traffic recorders and weather archives. The data are used to show various ways of presenting transportation information being used as indicators of the effectiveness of an incident response program. This type of evaluation is necessary on an on-going basis in order to clearly articulate the benefits and costs of this critical component of the region's traffic management system.**

***Index Terms*—incident response, transportation, archived data, delay.**

I. Introduction

Incident management is a critical public safety and traffic management technique designed to: decrease emergency vehicle response times; reduce incident duration, severity, and associated delay, fuel consumption and emissions; prevent secondary crashes; improve safety for emergency and highway maintenance personnel; and ensure that roadway facilities are kept in safe operating condition for the driving public.

Incident management programs provide opportunities for highway managers to be proactive rather than reactive, and are usually the first and only occasions for direct contact between the state department of transportation (DOT) personnel and highway users. These programs are also very popular with the public, and provide a heightened sense of safety and security for motorists on the highway system. In addition to their measurable delay-reduction benefits, incident management programs can also provide enhanced customer satisfaction, and improved user perceptions.

II. Background

There have been several important previous studies that estimated the benefits and costs of incident management programs [*1,2,3,4,5,6*], each with slightly varying methodologies. The premier incident management program evaluation was a true before and after study conducted on Interstate 880 in Hayward, California in 1995. The Bay Area Freeway Service Patrol (FSP) evaluation focused on a 9.2-mile freeway test site and collected 276 hours of incident and freeway data. [*1*] This experiment was conducted during morning and afternoon peak periods on 24 weekdays prior to the implementation of the FSP and 22 weekdays after implementation. Probe vehicles were dispatched at 7-minute headways on more than 1,700 one-way runs and observers recorded details of 1453 incidents in the before case and 1210 incidents in the after scenario. Loop detector data (count and speed) were archived from 393 loop detectors on the freeway mainline and on-ramps.

The Bay Area FSP evaluation found that the mean incident duration dropped by 4%, that the mean response times for breakdown incidents decreased by 45% from 33 to 18 minutes and that the overall program resulted in savings of 42 vehicle hours per incident, resulting in annual savings of more than 90,000 vehicle hours. Similarly, improvements in fuel consumption and emissions were also documented. The opportunity to conduct a true before and after experiment is rare, particularly since many urban areas have operated incident response programs for many years.

As an example of an evaluation performed after implementation of an FSP program, the Los Angeles FSP evaluation (1998) focused on a 7.8-mile section of Interstate 10 in El Monte and Alhambra, California. [*2*] This project also used the probe vehicle observation method (6-min headways), coupled with archived loop detector data. The evaluation included a total of 192 hours of observation over 32 weekdays, with details on 1,560 incidents, 3,600 probe vehicle runs and data from 240 loop detectors. Using data from the Bay Area and other evaluations, a relationship

Revised manuscript received July 19, 2004. This work was supported by TransNow, Oregon Department of Transportation and Portland State University Department of Civil & Environmental Engineering.

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between delay and incident duration was modeled, resulting in the ability to estimate the benefits of the FSP program according to a range of incident duration reduction. The study found that the program was operating with a benefit-cost ratio between 3.8 and 5.6.

In Oregon, an evaluation of the Oregon Department of Transportation (ODOT) Region 2 Incident Response program also used archived dispatch and traffic flow data collected after the program was initiated. [3] Using a statistical analysis of the incident data, reductions in fuel consumption and delay were estimated for more than 2,500 incidents logged in two 50-mile highway corridors. It was shown that the mean incident duration and thus delay per incident have decreased with expansion of the Region 2 IR program and that the benefits of the program far outweigh its modest cost.

The Puget Sound Region of Washington State implemented a freeway service patrol in August, 2000. [*4*] A study analyzing archived incident data for six months after the implementation and the same six month period for the previous year, prior to implementation, revealed a decrease in emergency response time. Prior to the service patrol the mean response time for assistance was over 9 minutes, after the implementation the response time was reduced by 61% to approximately 5.8 minutes. Faster response time was estimated to reduce annual vehicle hour delay by 13,000 hours and result in a cost savings of nearly $200,000.

A study in Phoenix, Arizona studied the effect of a Freeway Management System (FMS) on the safety of a freeway network. [*5*] The data included crash records, traffic volumes, and roadway characteristics for approximately 65 miles of urban freeways in the metropolitan Phoenix area from 1991 to 1998. The freeway sections were divided into two groups, sections with a FMS system and sections without. The sections with an FMS showed a reduction of 25% in crashes involving property-damage only. There was also a reduction in the number of crashes involving possible injury and minor injury of 30% and 21% respectively. This study estimated the annual benefit in crash reduction to be between $4.8 and $13.2 million dollars from 1996-1998.

A consistent finding among most IR evaluations is that many of the benefits of these programs are difficult to quantify. For example, incident management programs provide valuable public relations functions, a heightened sense of safety and security for motorists, and also prevent secondary crashes. Furthermore, assigning a value to the lost time of a commuter or shipment of goods due to delay caused by an incident is difficult, debatable and these costs do not accrue to the agency providing the IR service. Each vehicle on the road has a different purpose and the cost of delay to each vehicle can vary greatly. Many studies use wage rates and fuel consumption averages of idling or slow moving vehicles to assign dollar values to incidents. These are really just approximations using the best available data. With the increasing availability of more detailed data these types of evaluations can become institutionalized, more accurate and more valuable as tools for planners and operators of IR programs.

III. Incident Response in Portland

In the Portland metro area ODOT currently operates an extensive advanced traffic management system (ATMS), including 75 closed circuit television (CCTV) cameras, 18 variable message signs (VMS), an extensive fiber optics communications system and 118 ramp meters, including approximately 436 inductive loop detectors.

This study, supported by TransNow, ODOT, and Portland State University, focuses primarily on the incident response program. Incidents are defined as crashes, breakdowns and other random events that occur on our highway system. It is well known that incidents contribute to approximately 50 percent of the congestion delay on the nation’s highways, lead to major road closures and adversely affect the safety of our transportation network. Further, incidents increase drivers’ exposure to hazardous conditions and are known to lead to secondary crashes as well. In Portland, Oregon, maintenance personnel typically managed incidents on an as-needed or reactive basis. Knowing that incidents do not only occur during the hours when maintenance personnel are working, overtime charges were necessary for response to major incidents on weekends and overnight. In recent years, growth in traffic volumes and tightening maintenance budgets have led to the need for more proactive operations management strategies. During this same period, more and more diversion of maintenance resources led to increased overtime costs and increasingly negative effects on maintenance and productivity. Additionally, reducing congestion and minimizing roadway blockages improves freight movement, allowing the flow of commerce to occur unimpeded. Portland is at the convergence of key interstate highways, waterways, rail facilities and an international airport. This multi-modal hub makes timely freight movement along Portland’s highways a high priority for the state’s economy.

The incident response program, known as COMET, began service in March 1997, and now covers the Portland metropolitan area nearly 24 hours a day with 11 specially equipped incident response (IR) vehicles. During a typical weekday there are four response vehicles patrolling the freeways from morning to night and two vehicles on weekends and overnight. Each vehicle travels an average of 120 miles per shift. Standard equipment on the vehicles includes a variable message sign, basic traffic control equipment, gasoline and automotive fluids, basic automotive tools, a communications system, and an AVL system. The cost to operate COMET for one year is about $750,000. The cost of the ATMS is also about $750,000. The COMET program is dependant on the ATMS to record and archive incident data and operate in an efficient manner. Unlike some IR programs, the vehicles in the COMET program do not have towing capabilities. They do have push bumpers and tow cables to push, pull or drag disabled vehicles off the roadway. The responders themselves are a very important part of the program. Each responder is given extensive training in areas such as emergency vehicle operations, traffic control, and bridge inspection.

IV. BENEFITS OF INCIDENT RESPONSE

For the purposes of this study, in addition to the costs of implementing the IR program, a number of prospective IR benefits were identified. Some of the benefits accrue to the general public, including:

- Reduced delay
- Reduced fuel consumption
- Improved air quality
- Improved safety and security (avoided crashes and secondary crashes and an improved feeling of security on the transportation system)
- Improved flow of commerce
- Reduced harm to wildlife, soil and water quality

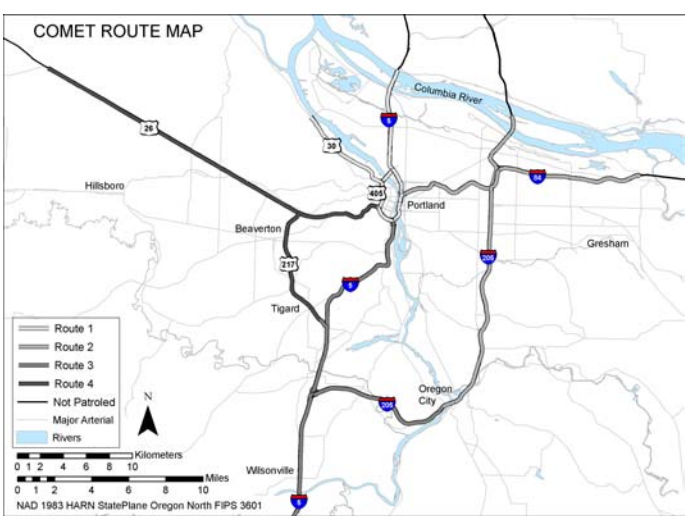
Other IR benefits include those that accrue to ODOT and other agencies, including:

- Reduced maintenance crew cost
- Value of extra maintenance performed
- Increased recovery of Charges Against Others (CAO) from motorists' insurance companies
- Awareness of potentially hazardous items requiring maintenance
- Improved public relations and good will.

V. RESEARCH OBJECTIVES

This study included the extraction and display of incident data on the freeways of the Portland Metro Area in 2001. Further analysis estimates the cost of delay in the region and how COMET is effective in achieving the goal of delay reduction. A final objective was to demonstrate the use of archived data from multiple sources as an evaluation tool.

Figure 1 – Study Area



VI. STUDY AREA

Figure 1 shows the freeways and patrol routes of the program in the Portland Metro Region. The area is divided into 4 patrol regions. The freeways include Interstates 5, 84, 205, 405 and State Routes 217, 26 and 30.

VII. DATA

A. Computer Aided Dispatch

The CAD data in ODOT Region 1 includes 72 different fields. A few of the key data fields used in this study include: incident location by primary and secondary route, incident type, incident begin and end times, lanes blocked, and GPS coordinates identifying incident location. The CAD database included 70,976 incident records in 2001. Due to the configuration of the data entry system, most of the incidents in the CAD data were recorded multiple times throughout the duration of the incident. Each time new or changed information is added to the database a new record is created. Removal of duplicate entries generated a result of 21,728 unique reported incidents.

B. Automatic Vehicle Location

Each IR vehicle is equipped with an AVL device. This device records the time and geographic location of the IR vehicle as reported by a GPS device. These data are periodically transmitted to the TMOC and used to determine where the IR vehicles were at any given time. We have used these data to determine where the vehicles were located at the time of an incident and how long it took them to respond to the incident. These data will be used to further study and make recommendations about the routes used by the operators to respond to incidents.

Each TMOC operator also has direct radio access to the IR vehicles, police, fire and rescue in the jurisdictions patrolled. When an incident is detected by, or reported to, the TMOC, the operators will use the remote sensing equipment to verify the incident and relay the information, via radio, to the appropriate responder in the field. Information about the incidents including location, duration and severity are logged into the database by the operators at the TMOC.

C. Inductive Loop Detectors

These detectors collect vehicle count, occupancy, and average speed data at 20-second intervals on the freeways. The loop detector data are important for determining the length of delay and recovery for incidents along the highways. These data are continuously monitored at the TMOC, where they are displayed on a highway map which uses various colors to represent the current travel speed along each section of freeway. The TMOC is equipped with 14 video monitors which allow the operators to view many areas of the transportation network at once through a closed circuit TV system. The operators can control each of the cameras through their fiber-optic network to pan, tilt and zoom as needed to obtain the best view of incidents on the highway. An indication of sudden slowdown on a section of a highway will prompt TMOC operators to use the CCTV cameras to search for an incident in that area.

D. Automatic Traffic Recorders

There are 14 automatic traffic recorders (ATR) located throughout the area patrolled by COMET. These devices record the number of vehicles passing their location by hour. The archived data are broken down by direction.

E. Weather Data

Archived weather data are available from the National Oceanic and Atmospheric Administration (NOAA) at their website (www.noaa.gov). For this study we have downloaded and used detailed weather data recorded at the Portland International Airport for 2001.

VIII. FINDINGS

From analysis of these multiple data sources for the year 2001 this study was able to determine the following results. Figures 2, 3 and 4 show that stalls account for half of all incidents. Most reported incidents are on the right shoulder and do not block any lanes.

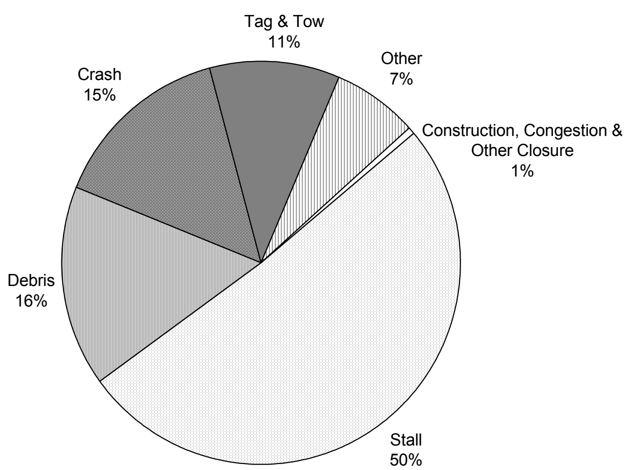


Figure 2 – Incidents by Type

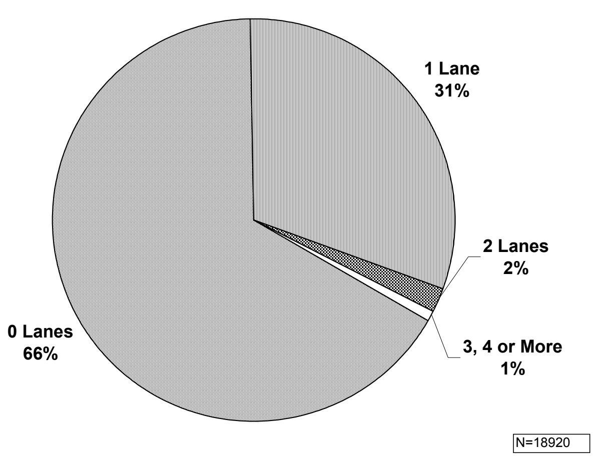


Figure 3 – Number of Lanes Blocked

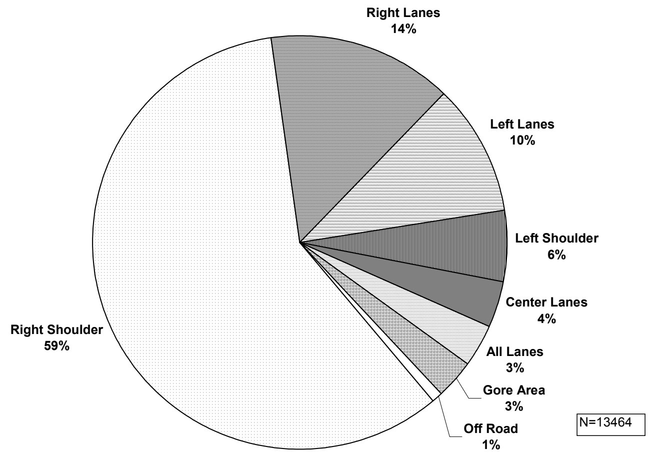


Figure 4 – Incident Location

Figure 5 maps the location, by frequency, of incidents in the region. This map was created using the GPS coordinates extracted from the CAD database. Only about 10% of all incidents included GPS coordinates in 2001. However, even with a small sample, the pattern of more incidents occurring closer to the central city emerges.

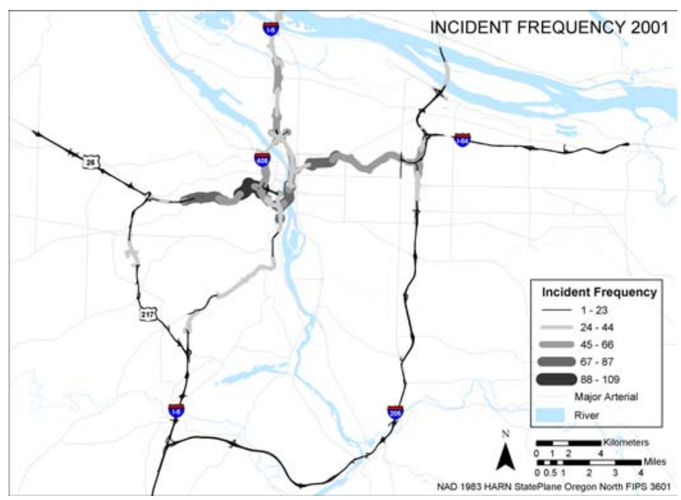


Figure 5 – Incident Frequency

Incident type by month is displayed in Figure 6. An average of 1,576 incidents occurred per month in 2001. While there is no distinct pattern it is notable that the number of incidents increased by 24% from September to October. Seasonal rains usually begin around October, and drivers used to dry summer conditions can be caught unprepared for wet driving conditions exacerbated by accumulated oil on the pavement. This is further illustrated in Figure 7 showing that the number of wet days increased from 2 in September to 12 in October and the number of crashes increased from 195 to 304 with well over half of those crashes in October occurring on wet days. The average duration of a crash was 65 minutes and the average duration of a stall was only 47 minutes.

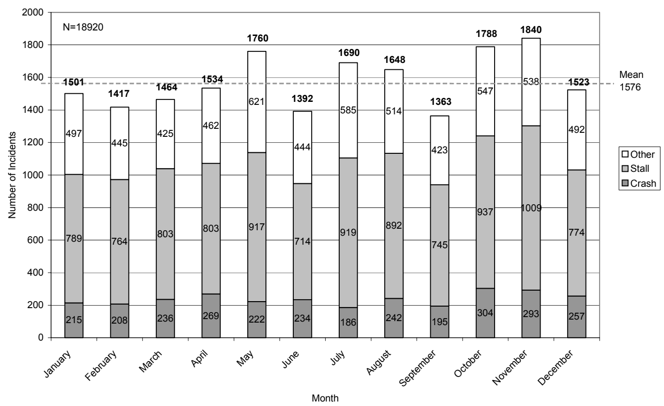


Figure 6 – Incidents by Type by Month

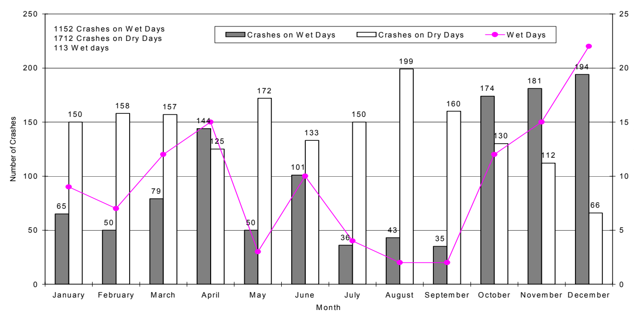


Figure 7 - Wet Days and Crashes by Month

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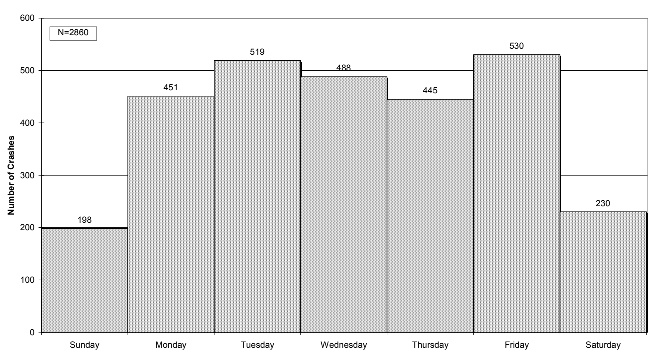

Figure 8 – Crashes by Day of Week

Crashes are more likely than stalls to cause significant delay because they are often in lane, involve multiple vehicles, hazardous material spills, and may include injured passengers. Figures 8 and 9 show a slightly higher frequency of crashes on Tuesdays and Fridays, with the largest number occurring during the evening commute time.

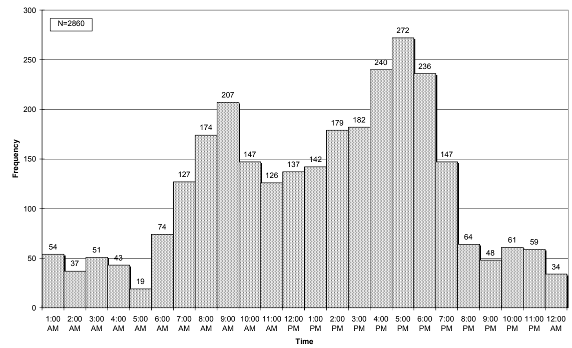

Figure 9 – Crashes by Time of Day

Comparing scheduled IR vehicles and ongoing incidents revealed that the current staffing levels are adequate to meet the demands of incidents on the freeways. Figure 10 shows the IR vehicles scheduled to be on patrol compared to the average number of ongoing incidents at five minute intervals for the year. There are only 2 points in time where the average number of incidents is greater than the vehicles available to assist them. Having one responder on weekdays start an hour later and end an hour later would improve the overall efficiency of the program.

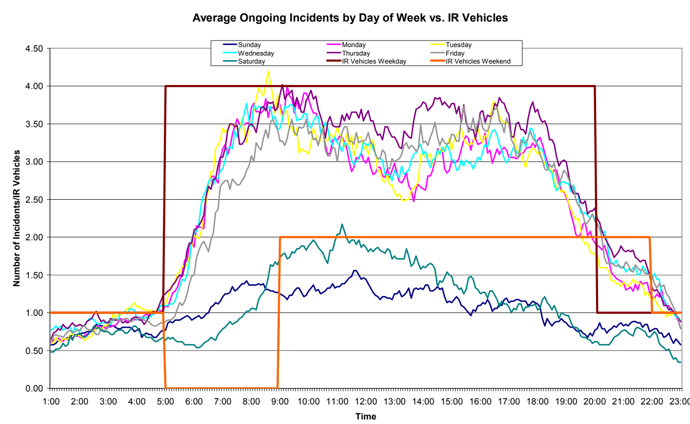

Figure 10 – Ongoing Incidents vs. IR Vehicles

On Tuesday, November 18, 2002 an incident occurred on northbound I-5 near the Multnomah Blvd. on-ramp. Figure 11 shows the location of the incident, the location of loop detectors available to record data, and the location of the three nearest response vehicles.

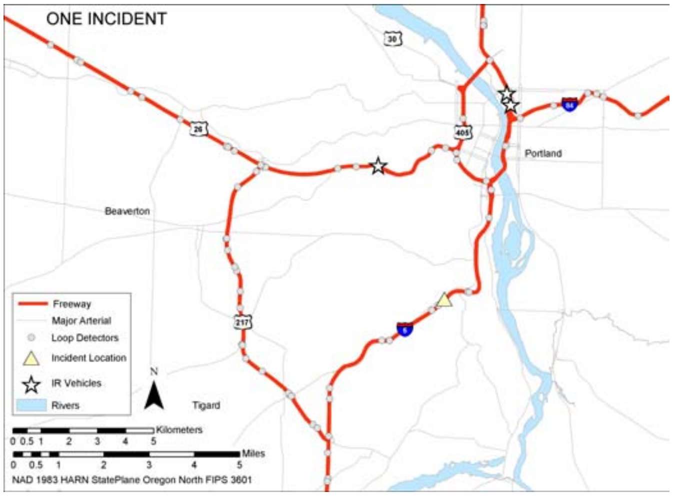

Figure 11 – One Incident

The summary of the incident follows:

- Incident ID: 13072
- Location: Northbound I-5 near Multnomah Blvd on-ramp
- Date: Tuesday, November 18th 2002
- Confirmation time 4:15 PM.
- Actual start time: 3:58 PM.
- COMET 15 arrived at 4:05:22 PM from I-405 (7 min)
- COMET 14 arrived at 4:04:29 PM from I-5/I-205 (6 min)
- Number of vehicles involved: 11
- Number of lanes blocked: one (left lane)
- Number of injuries: zero
- Involved vehicles were towed and the incident was cleared by 5:15 PM.
- Incident log had eleven entries for this incident.
- Incident level 3, based on a 0-4 scale.
- COMET 14 left the scene at 4:45:14
- COMET 15 left the scene at 5:25:34
- Highway completely recovered by 5:35 PM (based on loop detector data)

The duration of the incident was 1 hour and 27 minutes. The highway was completely recovered 10 minutes after the last IR vehicle left the scene. With the data currently available, a detailed analysis is possible for almost all incidents and can be used as a tool for evaluation of response procedures when necessary.

Finally, a key component in any IR evaluation is an estimate of cost savings provided by the program. As with other IR programs, there is no "before" data since the incident reporting system was initiated at the same time as the COMET program. Therefore, a true before and after study was not possible. However, by estimating the cost of delay for 2001 we can determine the cost savings of delay reduction and develop a tool to assist program operators evaluating the effectiveness of their program. The estimated cost of delay on the Region 1 freeways for 2001 was $51 million. If each delay-causing incident increased in duration by an average of 30 seconds the increased cost of delay would be $711,300, or roughly the cost of operating COMET for 1 year. Figure 12 shows an efficiency curve plotted using these time and cost values. If the program is operating up and to the right of the curve the benefits are greater than the costs. Previous research has shown that incident duration reductions possible with the presence of a proactive IR program would be on the order of 10 to 15 minutes. Therefore, as currently deployed, the COMET program more than pays for itself.

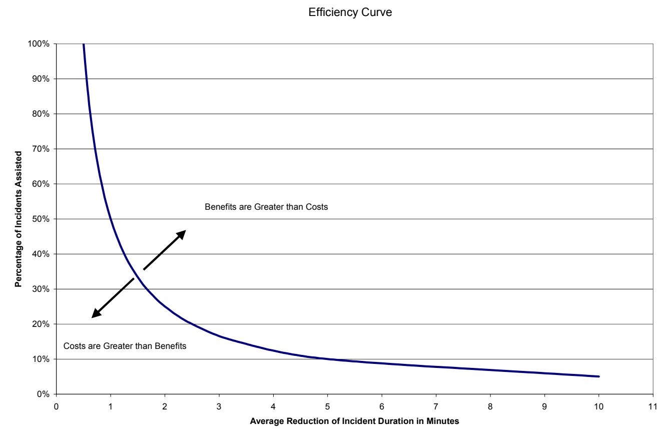

Figure 12 – Efficiency Curve

IX. Conclusions

While the data were not available to definitively conclude that the benefits of COMET outweigh the costs it is reasonable to conclude that it does. The responders only need to reduce the duration of each incident by just a few minutes to have a measurable impact on the flow of traffic. It is impossible to measure and assign a dollar value to the numerous other environmental and public relations benefits of the program discussed above. Our study concludes that the benefits of the COMET program in Region 1 are greater than the costs.

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