

Using Archived ITS Data Sources to Measure the Effectiveness 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 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.

INTRODUCTION

The Oregon Department of Transportation (ODOT), the City of Portland, Metro (the Portland region's Metropolitan Planning Organization and directly elected regional government) and other jurisdictions are partners in the intelligent transportation systems (ITS) implementation program called *TransPort*. Through regional and statewide cooperation this system provides traffic management, incident response (IR) and traveler information, reducing traffic congestion, stabilizing travel times, and preventing crashes. *TransPort* is comprised of three components:

- Transportation management: monitoring and surveillance equipment identifies incidents and crashes, assisting system operators in managing traffic flows.
- Incident response: COMET (Corridor Management Team) is dispatched to incidents and other appropriate emergency services are notified.
- Traveler information: drivers are notified by variable message signs or via car radio of an incident ahead, enabling them to choose alternate routes to avoid congestion.

ITS programs such as *TransPort* rely on an unseen communications network, mostly invisible sensors, software that is housed within the transportation management center and unique human resources facilitating communication and coordination. Only a small number of individuals are required to operate the transportation management system, and in many cases users do not even know they are benefiting from the system. As with any investment decision, it is important to include some form of evaluation as part of a continuous improvement process. This greater understanding may also lead to improvements in making decisions about where and when to deploy and/or expand these programs, and how to prioritize resources in times of budgetary strain.

Typical measures of effectiveness for incident management programs include improvements in safety, traffic congestion/delay, fuel consumption, air quality, customer satisfaction and prevented collisions. These benefits can be estimated based upon a quantification of the incremental reduction in incident duration and response time due to the presence of the IR program. In this context, the objective of this project is to use existing data, collected via the region's surveillance and communications infrastructure to measure the effectiveness of the COMET incident response program in the Portland metropolitan area.

This project is somewhat unique in that it attempts to extract archived data from five sources to measure the effectiveness of an ongoing program. The existing ITS data sources include: a computer-aided dispatch incident database, automatic vehicle location (AVL) data for the COMET vehicles, 20-second inductive loop detector data from the freeway mainlines, automatic traffic recorders stationed throughout the freeway network and archived weather data. These datasets can provide planners and operators with quantifiable measurements that can be used as ongoing evaluation tools.

BACKGROUND

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. These programs are also very popular with the public, and provide a heightened sense of safety and

security for motorists on the highway system. Thus, incident management programs can provide enhanced customer satisfaction, and improved user perceptions.

There have been several previous studies that estimated the benefits and costs of incident management programs (1,2,3,4,5,6,7,8), 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. One-second loop detector data were archived from 393 loop detectors on the freeway mainline and on-ramps, forming an invaluable archive of freeway performance.

The Bay Area FSP evaluation found that the mean incident duration dropped by 4%, that the mean response times for breakdown incidents decreased 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 Los Angeles FSP evaluation (1998), performed after implementation of an FSP program, 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' 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 FSP and other evaluations, a relationship between delay and incident duration was modeled, resulting in the ability to estimate the benefits of the FSP program according to a range of potential 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 ODOT's 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 rural 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 cost.

The Puget Sound Region of Washington State implemented a freeway service patrol in August of 2000. (4) A study was conducted in which archived incident data from six months following implementation were compared to pre-implementation data from the same six month period during the previous year. This study revealed a decrease in emergency response time from 9 minutes to 5.8 minutes. Faster response time was estimated to reduce annual vehicle hour delay by 13,048 hours and result in a cost savings of nearly \$200,000.

Finally, a study in Phoenix, Arizona studied the effects 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 between 1991 and 1998. The freeway sections were divided into two groups, sections with a FMS system and sections without. The sections with an FMS showed reductions 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 for each individual vehicle varies. 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 more accurate and become more valuable tools to planners and operators of IR programs.

INCIDENT RESPONSE IN PORTLAND

The COMET program began service in March 1997, and now covers the Portland metropolitan area nearly 24 hours a day with 11 specially equipped IR vehicles. 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 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 COMET program covers all the major state and interstate highways in the Portland area. The region is divided into 4 patrol areas; Figure 1 shows the COMET coverage and beat map. They will respond to incidents in other patrol areas as the need arises. As the highways are patrolled almost 24 hours a day, a standard full shift includes 4 vehicles covering their respective beats. At off peak times the beats are consolidated to patrol the region with fewer vehicles. The IR program sometimes provides responders and vehicles for special events and construction projects where additional traffic control is needed. The variable message sign (VMS) on the vehicles makes them very useful for traffic control. A single VMS is often much more efficient, and safer, than a number of police officers directing traffic.

The estimated cost of the incident response program for the 2003-2005 budget cycle is \$2.9 million, of which approximately \$1.5 million is allocated for the responders and vehicles on the road. The remaining \$1.4 million is spent on the TMOC, operators, and remote sensing equipment such as closed circuit television (CCTV) cameras and ice detectors.

DESCRIPTION OF DATA SOURCES

In the Portland metro area ODOT currently operates an extensive advanced traffic management system (ATMS), including 75 CCTV cameras, 18 variable message signs, an extensive fiber optics communications system and 118 ramp meters, including approximately 436 inductive loop detectors. This paper will use data from the loop detectors, AVL system, incident database, automatic traffic recorders and National Oceanic and Atmospheric Administration (NOAA) to measure the effectiveness of the IR program, detail the life of an incident and make suggestions for improvements to the IR program.

Incident Database

The computer aided dispatch (CAD) data included 70,976 records in 2001. Each incident is given a unique number and each time new information about a particular incident is entered into the database, a new record is created using the same incident number. For most of our analysis it was necessary to remove the duplicate entries.

The software used by the TMOC can be used to record the X-Y coordinates of an incident, but is not required unless an incident is severe enough to cause significant delay. This location can then be displayed on ODOT's statewide *Tripcheck* traveler information website (www.tripcheck.com) and shown on the highway map in the TMOC. Approximately 10% of the incidents in 2001 were geocoded.

Automated Vehicle Location

Each IR vehicle is equipped with an AVL system that 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 for dispatching and 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.

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 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 the highway map will prompt TMOC operators to use the CCTV cameras to search for an incident in that area.

Automatic Traffic Recorders

There are 14 automatic traffic recorders (ATR) located throughout the area patrolled by COMET. Using inductive loop detectors these devices record the number of vehicles passing a certain point by hour. The archived data are broken down by direction.

Weather Data

Archived weather data are available from 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.

ANALYSIS

Metro Area Incident Statistics

Of the nearly 71,000 incident records logged in 2001, a total of 21,728 unique incidents were identified. The breakdown of the incident types are shown in Figure 2A. As shown, for the year 2001 half of the recorded incidents were stalls. Stalls are vehicles stopped on the side of the road or in lane for any reason other than a crash or debris removal. Most often it is due to vehicle mechanical failure, overheating or running out of fuel. Crashes and debris are the next two largest categories. The tag and tow category refers to the removal of abandoned vehicles from the roadway, and comprises 11% of recorded incidents.

Figure 2B shows lane blockage statistics for the 18,920 incidents that included lane data. As shown, of the 33% that were lane blocking, most were only blocking one lane.

Shown in Figure 2C is an inventory of the location of the 13,464 incidents that included this information in its log. As shown, 59% of these incidents occurred on the right shoulder and 14% were located in the right lane. More serious safety concerns arise for motorists and responders when incidents occur in left lanes, center lanes, left shoulder and gore areas. A total of 23% of incidents fell into those categories. Three percent of incidents were recorded as blocking all lanes—the most serious category.

Incident distribution also has a notable temporal component. The number of incidents per month categorized by crashes, stalls and other is shown in Figure 3. For 2001 note that the total number of incidents was noticeably higher in October and November. This is typically when seasonal rains begin in Portland after several months of dry weather and oil has accumulated on the pavement.

Incidents and Weather Conditions

As discussed above, weather conditions can have a significant impact on incident frequency and should not be overlooked when extracting data from archived incident records. Unfortunately, the incident dataset in Portland does not include weather information. Using archived weather data from NOAA, each day in the 2001 incident dataset was associated with the reported amount of precipitation. For this study, any day that had a total measured amount of rainfall of 0.05" or greater was counted as a wet day. Figure 4 shows the number of crashes on wet days, the number of crashes on dry days, and the number of wet days per month for 2001. As shown, there was a statistically significant relationship between the amount of rain and the frequency of crashes. Using a chi-square test it was determined that the value of the chi-square was 48.06 with a significance level of 0.001. Looking further into the data it was observed that 44% of the days with a high frequency of crashes, 11 or more, were days with heavy rain. On the other hand 58% of the days with a low frequency of incidents, 3 or fewer, were dry days. This information can be used by IR teams to make changes to their operations for a wet day. This information would also be useful to the public to remind them to be cautious on wet pavement.

Crashes and Stalls

Crashes and stalls account for 65% of all the incidents in the study area. Only 27% of the stalls had durations longer than 30 minutes, while 55% of the crashes lasted longer than 30 minutes. Crashes also block an average of 0.64 lanes per incident, while stalls only block an average of 0.31 lanes per incident. Crashes only account for 15% of the incidents in 2001, but they usually last longer and reduce capacity more than other types of incidents.

It is interesting to note when these crashes occur. With 530 crashes, Friday is the weekday with the most crashes in 2001 and Thursday has the fewest with 445. As one might expect, the AM and PM peak travel times are when crashes occur most often and that the PM peak is the most crash prone time of day. In 2001 there were 272 crashes between 5 and 6 pm as opposed to 137 between 12 and 1 pm.

Resource Allocation

In order to understand the relationship between incident occurrence and responder availability Figure 5A shows all incidents for one particular day (Tuesday, November 18, 2002) by time and duration. Figure 5B shows the number of concurrent incidents by fifteen minute time increments and the number of IR vehicles on the road by time. It is easy to see that the highest number of incidents occurred during the peak commute times. Of the 96 time increments, incidents outnumbered responders during 17 of them.

Figure 6 shows the average number of concurrent incidents and the number of scheduled IR vehicles by day of week for the entire year. The data were sampled at 5 minute increments from 1:00 AM to 11:00 PM. The figure indicates that the operators of the COMET program have scheduled an appropriate number of vehicles to be on the road at any given time. Tuesday at about 9:00 AM is the only time where the average number of ongoing

incidents exceeds the number of scheduled IR vehicles during the week. On the weekends, for a short period of time at about 11:00 AM on Saturday there were more incidents than responders.

An Incident With Response

On Tuesday, November 18, 2002 an incident occurred on northbound I-5. Figure 7 shows the location of the incident, the location of loop detectors available to record data, and the location of the three nearest response vehicles. The summary of the incident follows:

- Incident ID: 13072
- Location: Northbound I-5 near Multnomah Blvd. on-ramp
- Confirmation time 4:15 PM.
- Actual start time: 3:58 PM.
- COMET 15 arrived at 4:05:22 PM from HWY 26 (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, based on data recorded by three different upstream loop detectors. Figure 8 shows a typical incident delay curve similar to what was recorded by the first loop detector upstream of this incident. This figure also clearly depicts the typical stages of an incident. When an incident occurs, the capacity of the freeway is reduced and results in a reduced flow, or incident flow, of vehicles on the highway. When the incident is cleared the freeway reaches maximum capacity flow until the incident queue dissipates, then resumes normal demand flow. With the currently available data, a detailed analysis is possible for incidents and can be used as a tool for evaluation of response procedures.

Delay Estimation

Estimating the delay caused by the 21,728 incidents in the Portland Area in 2001 is not an easy task, and any method employed will introduce some error. However, this study attempts to minimize the error when possible. The CAD data and the average hourly traffic volume from the ATCs were used for delay estimation. This required each incident to be manually located on a map and manually assigned to the nearest traffic recorder. Since there were over 21,000 incidents to locate, a smaller three week sample was selected for analysis. There were 2,300 incident records during a three week period from November 4 to November 24 in 2001. After removing the duplicate entries there were only 660 unique incidents remaining. A closer look at the data shows that only about 25% of those incidents caused delay. A delay causing incident includes those with durations of 1 minute or greater, located on a freeway, either in lane or on a shoulder. Further filtering of the incidents resulted in 164 that were determined to be delay causing. Those filtered out were test records, incidents located on surface roads and incidents with durations of zero.

After each incident was assigned to a traffic recorder, the average hourly traffic volumes for the specific hour of each incident were extracted from the ATC data and associated with the incident as the normal flow for that time of day and location. The capacity reduction percentage caused by each incident was taken from Exhibit 22-6 in the HCM 2000 (page 22-11). The length of each incident was determined by the difference in hours between the time when the incident was first confirmed and the time when it was cleared.

Vehicle hours of delay were then estimated for each incident using the following calculation:

$$D = F * R * T$$

Where: D = Vehicle Hours of Delay
 F = Normal Flow

R = reduction of capacity by percent

T = duration of incident in hours

The result for the three weeks of data was 112,000 total vehicle hours of delay. Extrapolating that result to the full year results in an estimate of 90 vehicle hours of delay per incident and 1,900,000 vehicle hours of delay on the freeways of the Portland metro area in 2001.

Estimating the Cost of Delay

The two primary factors considered in an estimation of delay cost are fuel consumption and time.

Fuel costs were estimated using the following simple General Motors model:

$$E = k_5 * L + k_6 * T$$

Where: E = additional fuel consumed per vehicle

k_5 = 90 ml/km = 0.03826 gallons per mile

L = distance traveled in queue

k_6 = 0.44 ml/sec = 0.4184 gallons per hour

T = travel time in queue

This model estimates the additional fuel consumed by vehicles moving slowly in traffic (average speed under 40 mph) such as those in a queue. The data were not recorded in a format that differentiated vehicles by type so only total numbers of vehicles were used. For the purpose of this report, it was assumed that vehicles average approximately 10 mph throughout the queue and that the cost of fuel is \$1.62 per gallon, the average price for a gallon of mid-grade fuel in 2001. Therefore, the equation can be simplified to:

$$E * 1.62 = \$1.30 \text{ per hour per vehicle}$$

For the Portland Metro Area in 2001 the estimated cost of additional fuel consumption due to delay was \$2,500,000.

Time costs were estimated using the following model:

$$T = C * VO * VHD$$

Where: T = Total cost of time spent in delay

C = One hour of time cost, \$17.87

VO = Vehicle Occupancy, 1.47 for the Portland Metro Area

VHD = Vehicle Hours of Delay

The origin of the time cost and vehicle occupancy rates are taken from official ODOT data used for estimating value of time across the state. For the Portland Metro Area in 2001 the estimated cost of lost time due to delay was \$48,000,000. Time cost is the most expensive portion of delay costs. The estimated cost of incident delay for 2001 including both fuel consumption and time is \$2,350 per incident and a total of \$51,000,000 for all incidents.

Cost/Benefit Analysis of the Incident Response Program

Unfortunately, data prior to the inception of the COMET program are not available for this evaluation, however other studies have shown that incident response systems do reduce the duration of the incidents in which they assist. (2) This reduction is primarily due to faster response times because the vehicles are already patrolling the area and the network of CCTV cameras can identify incidents and call for response more quickly. While it is impossible to determine exactly how much COMET reduces the average duration of incidents we can reasonably assume that there is some reduction. Table 1 shows the vehicle hours of delay, fuel consumption, time cost and total cost for the actual duration of the incidents. In addition it shows the costs if the duration of each incident were increased by 1, 5, or 10 minutes. Making the assumption that without COMET each incident would increase in duration by only 1 minute then the cost of delay increases by \$1,400,000, or roughly twice the cost of operating the Comet program for

one year. If incidents were to increase in duration by more than 1 minute without COMET then the benefits created by the program increase much more dramatically.

Based on the data indicating that an average reduction of about 30 seconds per incident is the break even point for costs and benefits of the program we can plot a curve to show the level of efficiency at which COMET must operate for benefits to exceed costs. Figure 9 shows the percentage of incidents assisted on the vertical axis and the number of minutes duration is reduced on the y axis. For the program to be operating at a cost efficient level they must be operating up and to the right of the curve. For example, if Comet assisted in 50% of the incidents they need to reduce delay by at least one minute per incident to be cost effective.

CONCLUSIONS & RECOMMENDATIONS

As described above, there are numerous other benefits derived from the IR program that have not been quantified due to limitations in the study scope and limitations in data collection feasibility. The IR vehicle is often first on the scene after a crash and is able to provide first aid that may save a person's life or reduce the total health care costs that will be necessary. In addition as the "eyes and ears" of the DOT, the IR staff provide immeasurable good will and public relations value, since many citizens may never have any other contact with ODOT. If their only contact with ODOT staff is a person rescuing them from a roadside stall then their perceptions of ODOT are likely to be positive. The IR program can provide a sense of security and safety for drivers that is difficult to measure.

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.

In addition, IR responders assist with hazardous materials spills, which prevents harm to wildlife, soil and water quality. As the responders patrol the highways they can relay maintenance issues to the TMOC to be quickly handled, possibly preventing future incidents. Finally, with respect to construction areas, the IR staff can monitor the status of cones, barricades and signage to help maintain safety during periods when contractors are not working.

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 COMET program in Region 1 is a benefit to the people of the community.

Given that we have been some of the first to use the CAD data for evaluation purposes, we recommended a few improvements to the database. Some of these include:

- All incidents should be geocoded to allow for easier analysis and incident location at a later time.
- A field indicating COMET assistance should be accurately kept for each incident.
- Unused data fields should be removed from the database.
- Standardize the names used to indicate the primary and secondary routes of incidents.
- Add a field for weather data
- Include a field for the physical characteristics of the incident location including the number of lanes on the highway, and if and where shoulders exist.

Finally, we hope that ongoing analysis of the COMET program will continue. It would be helpful to include a comparison of incidents cleared by COMET and those cleared by police. This could be done with recorded video of each type of incident. It would also be useful to include an evaluation of the variable message sign system to improve the effectiveness and efficiency of this tool. It would also be helpful to consider whether COMET should place stationary response vehicles at key bottleneck locations as a means of further reducing incident delay.

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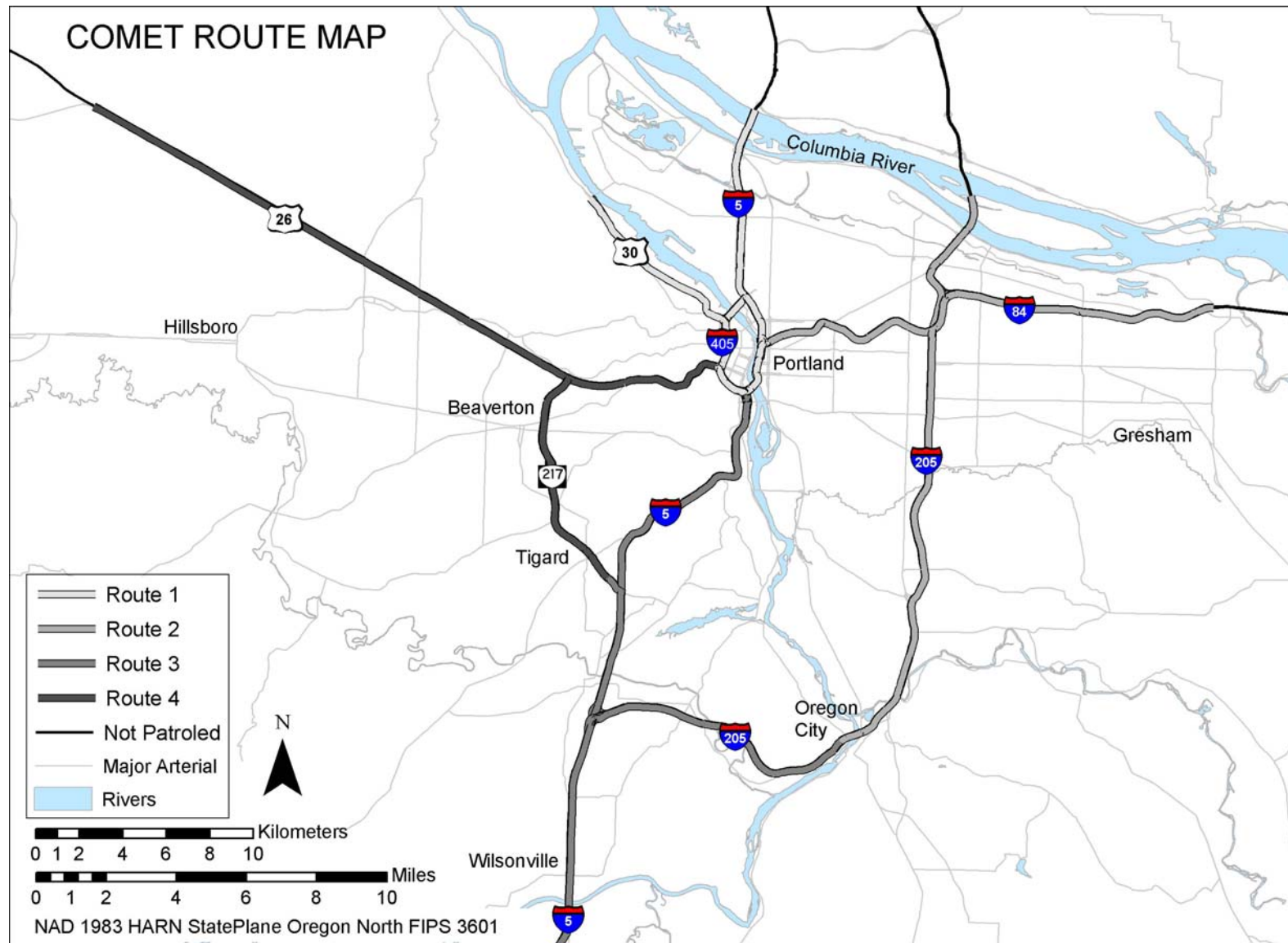


FIGURE 1 Incident Response Coverage and Beat Map

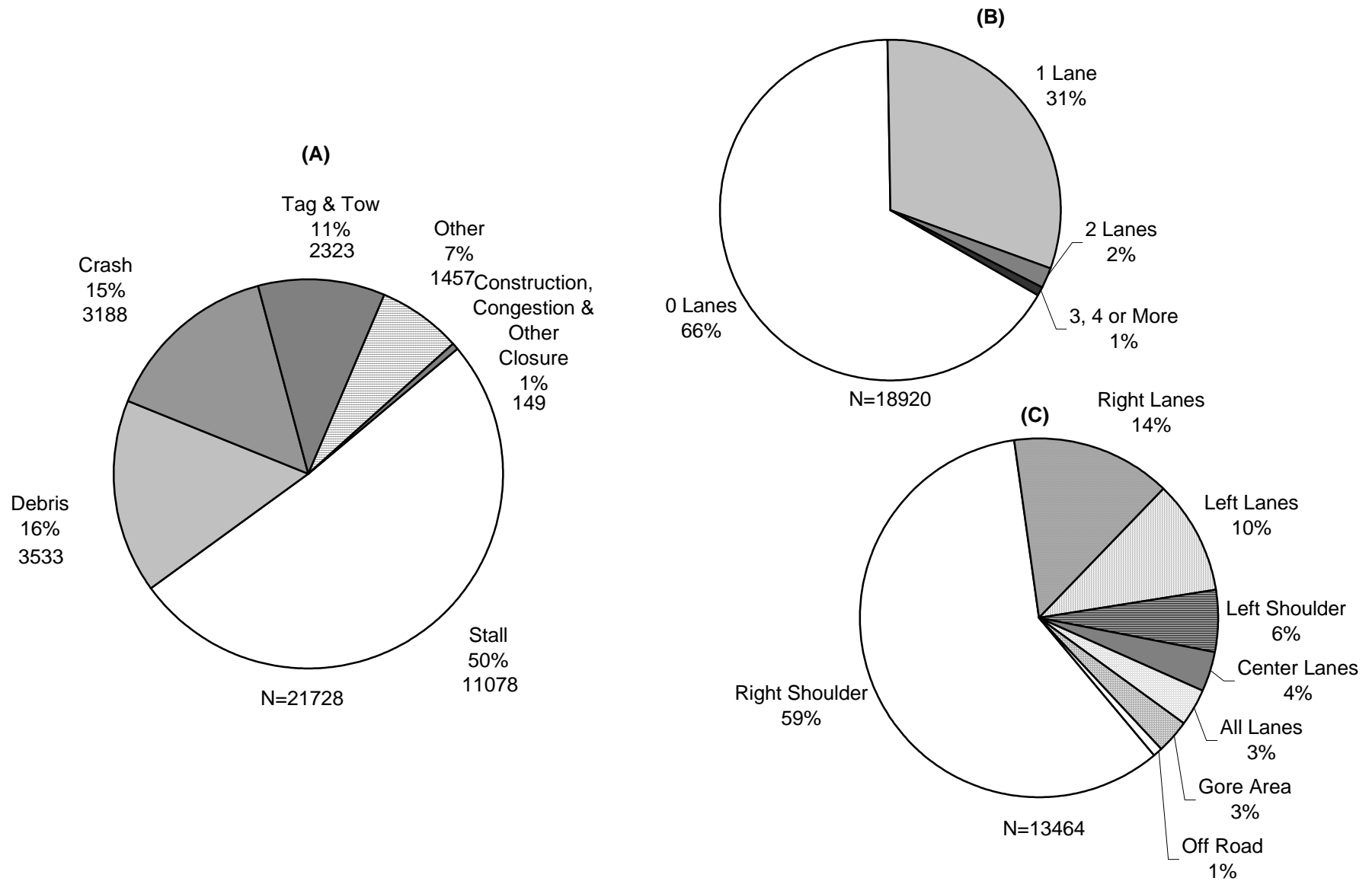


FIGURE 2 Incident Type (A), Lanes Blocked (B), and Incident Location (C) by Percent

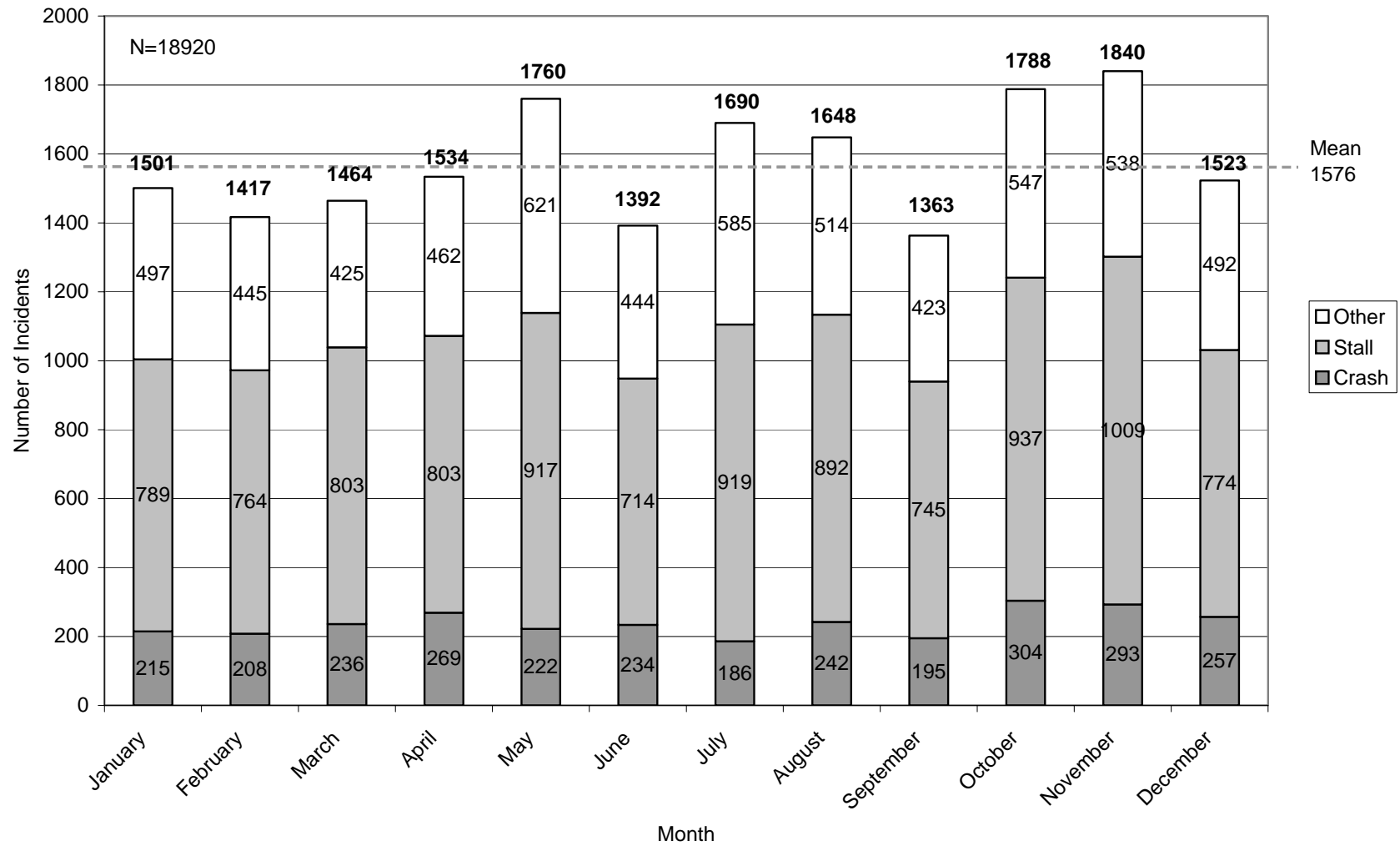


FIGURE 3 Incidents Per Month by Type

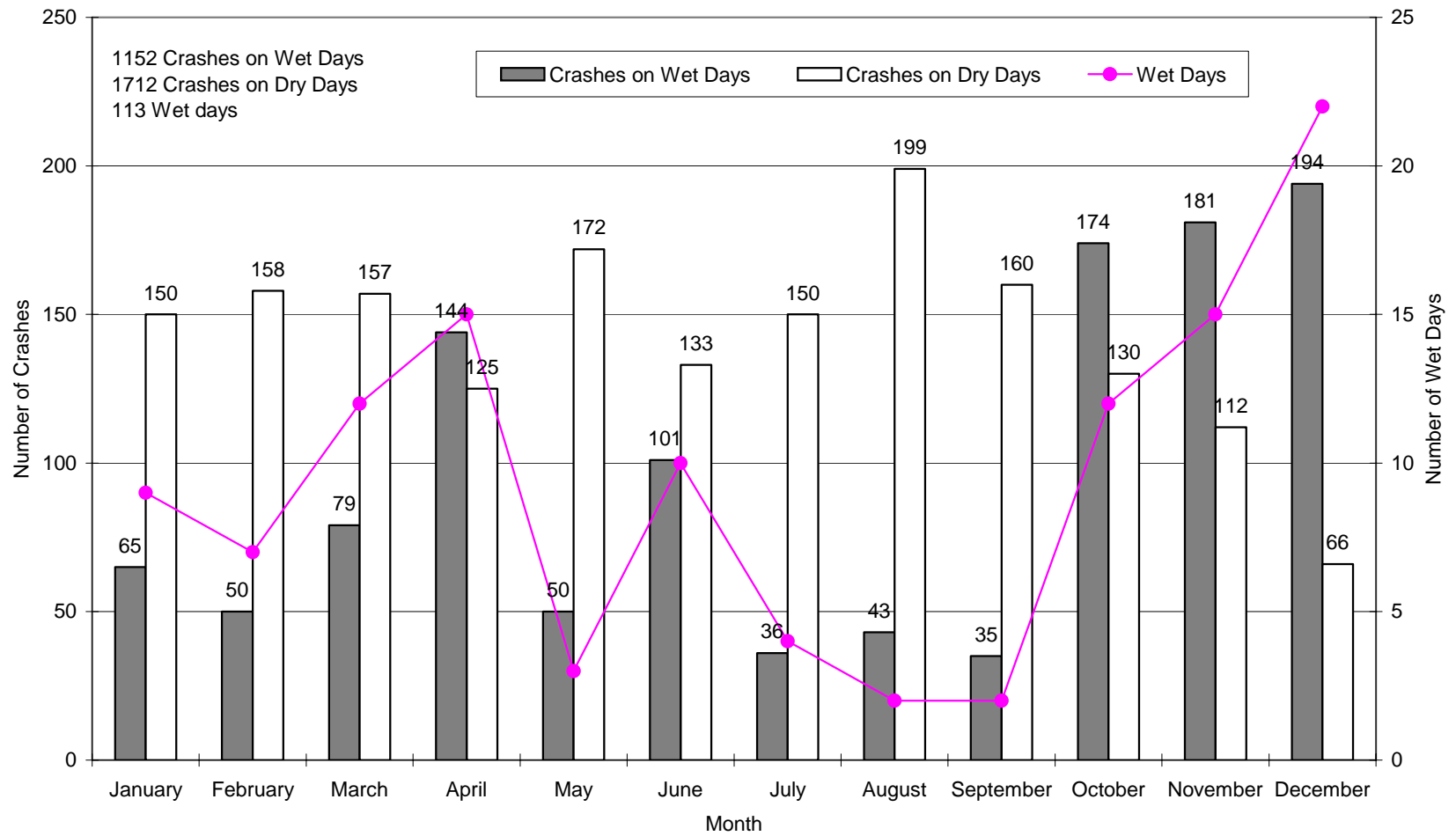


FIGURE 4 Crashes and Precipitation

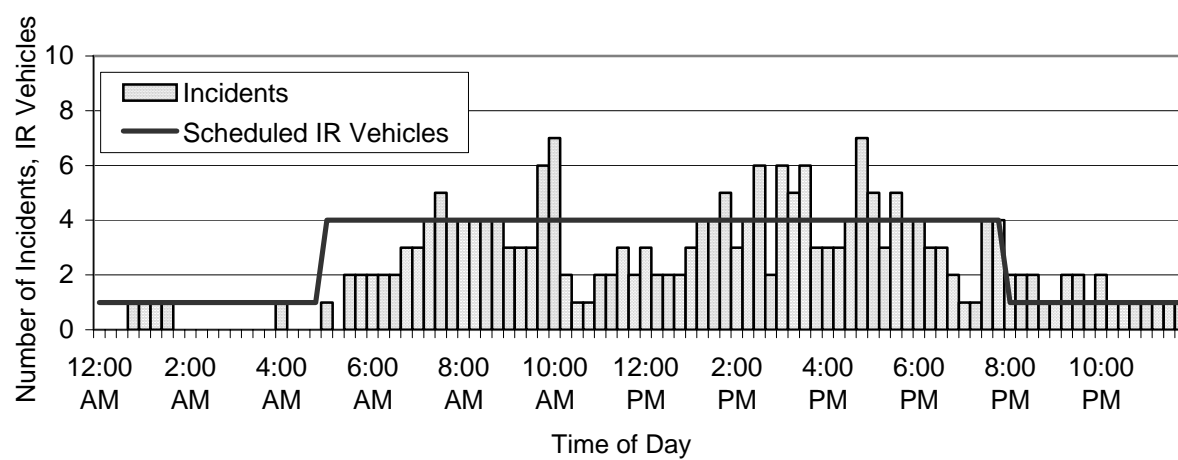
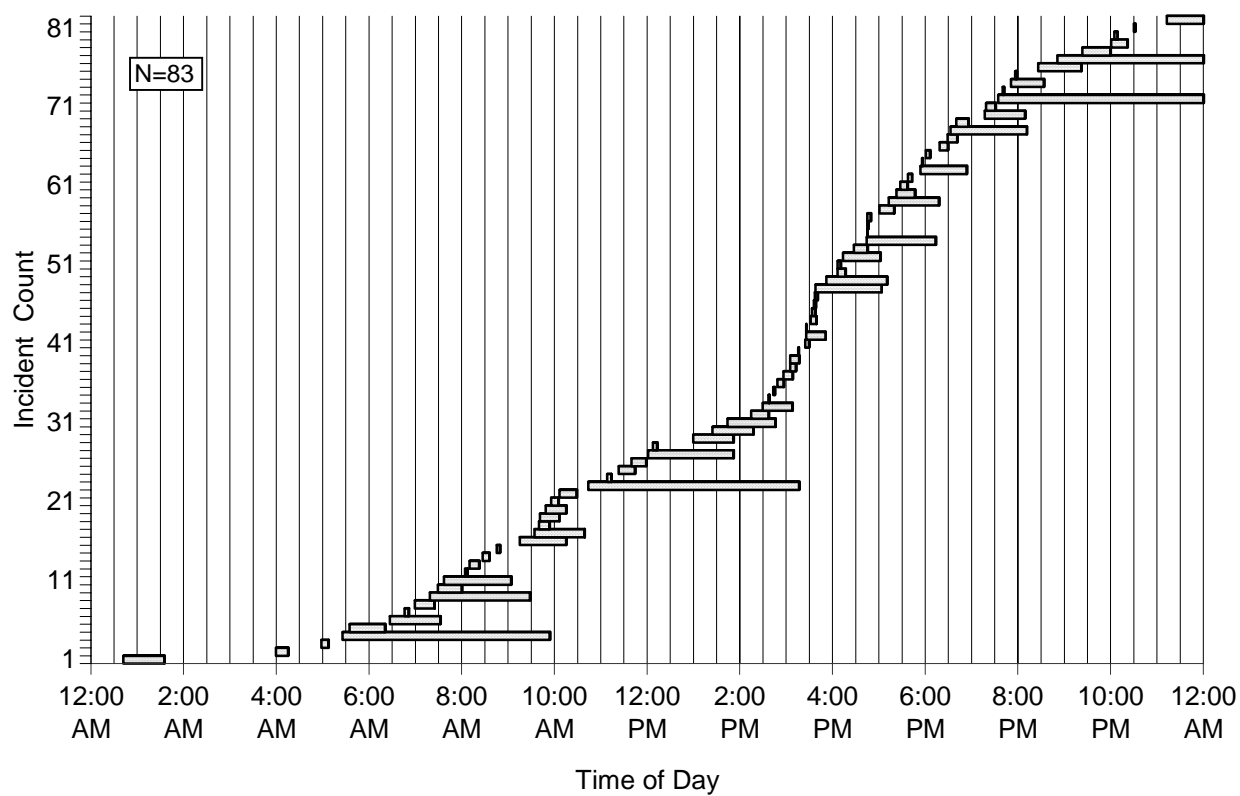


FIGURE 5 Incidents by Time and Duration (A), and by Concurrent Incidents vs. Available IR Vehicles (B) for One Tuesday

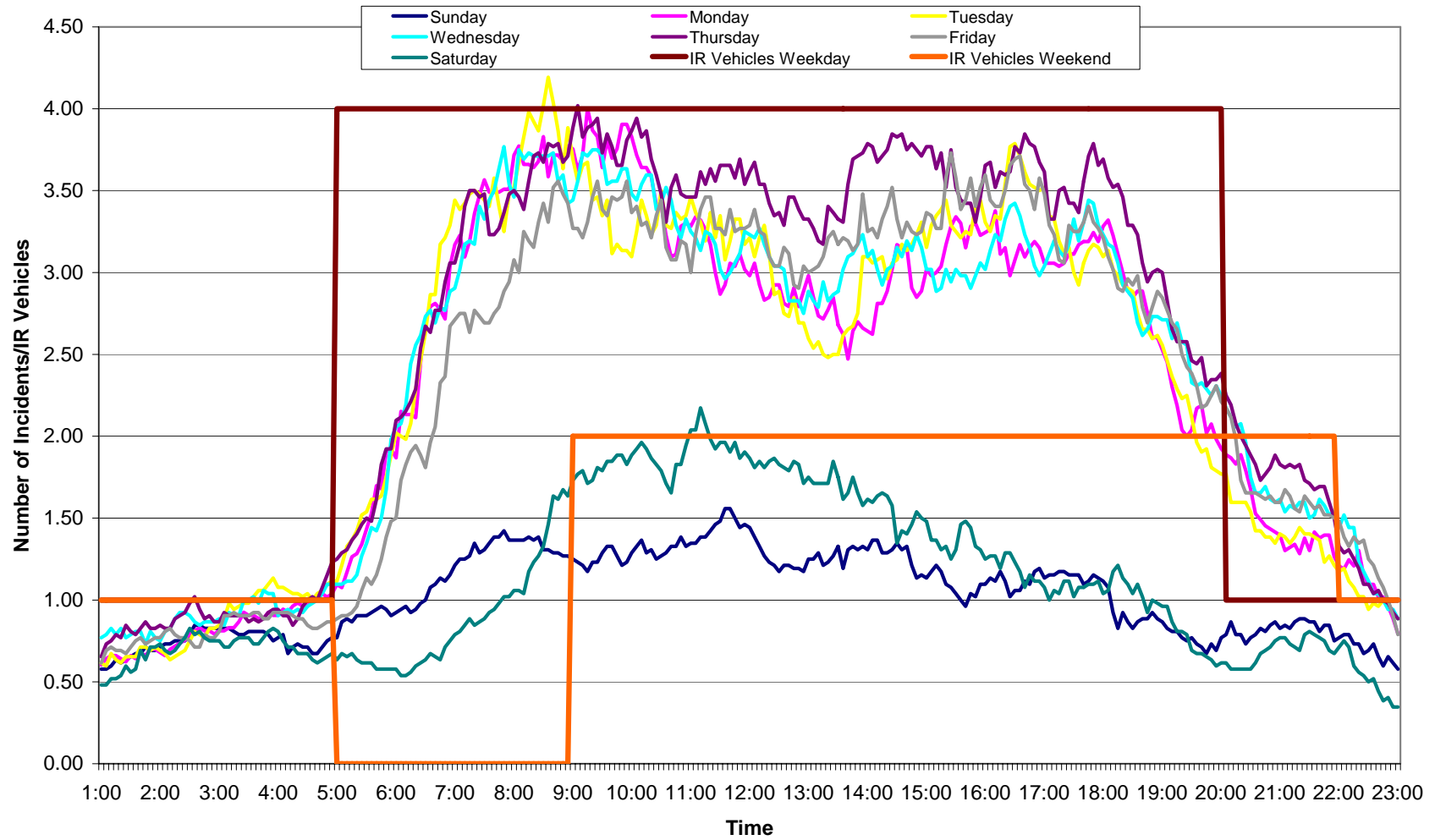


FIGURE 6 Average Ongoing Incidents by Day of Week vs. IR Vehicle

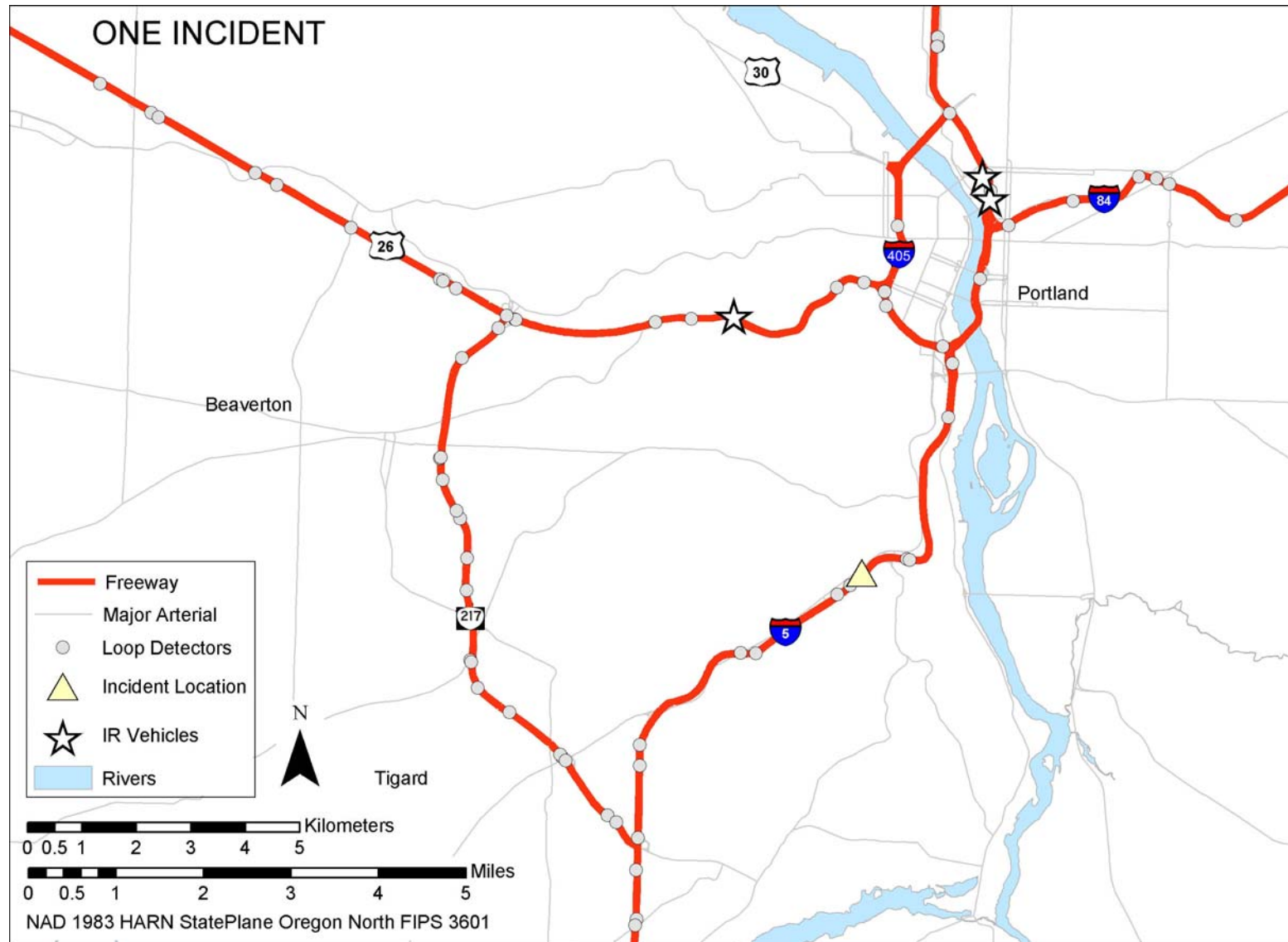


FIGURE 7 Location of One Incident, IR Vehicles, and Loop Detectors

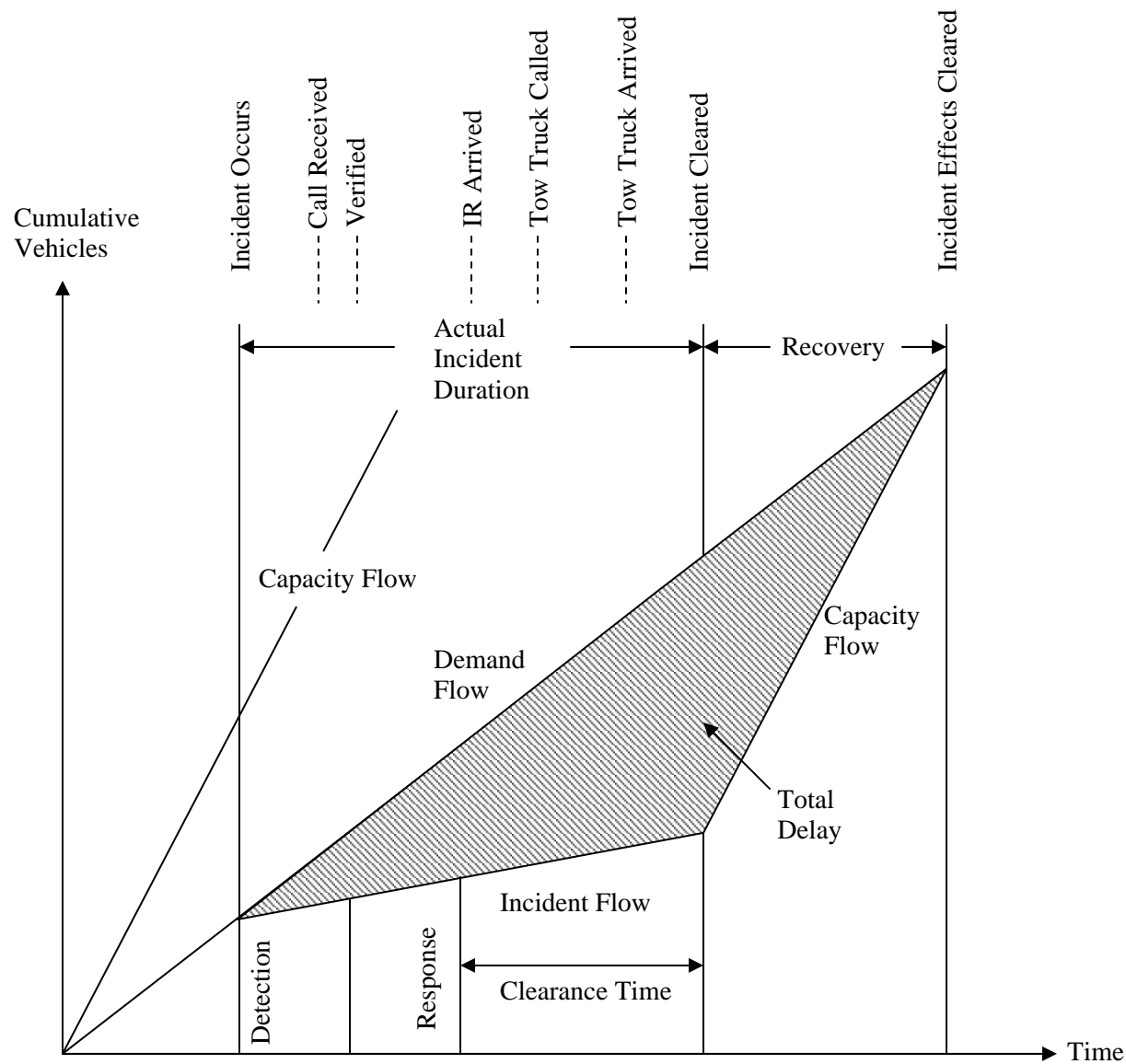
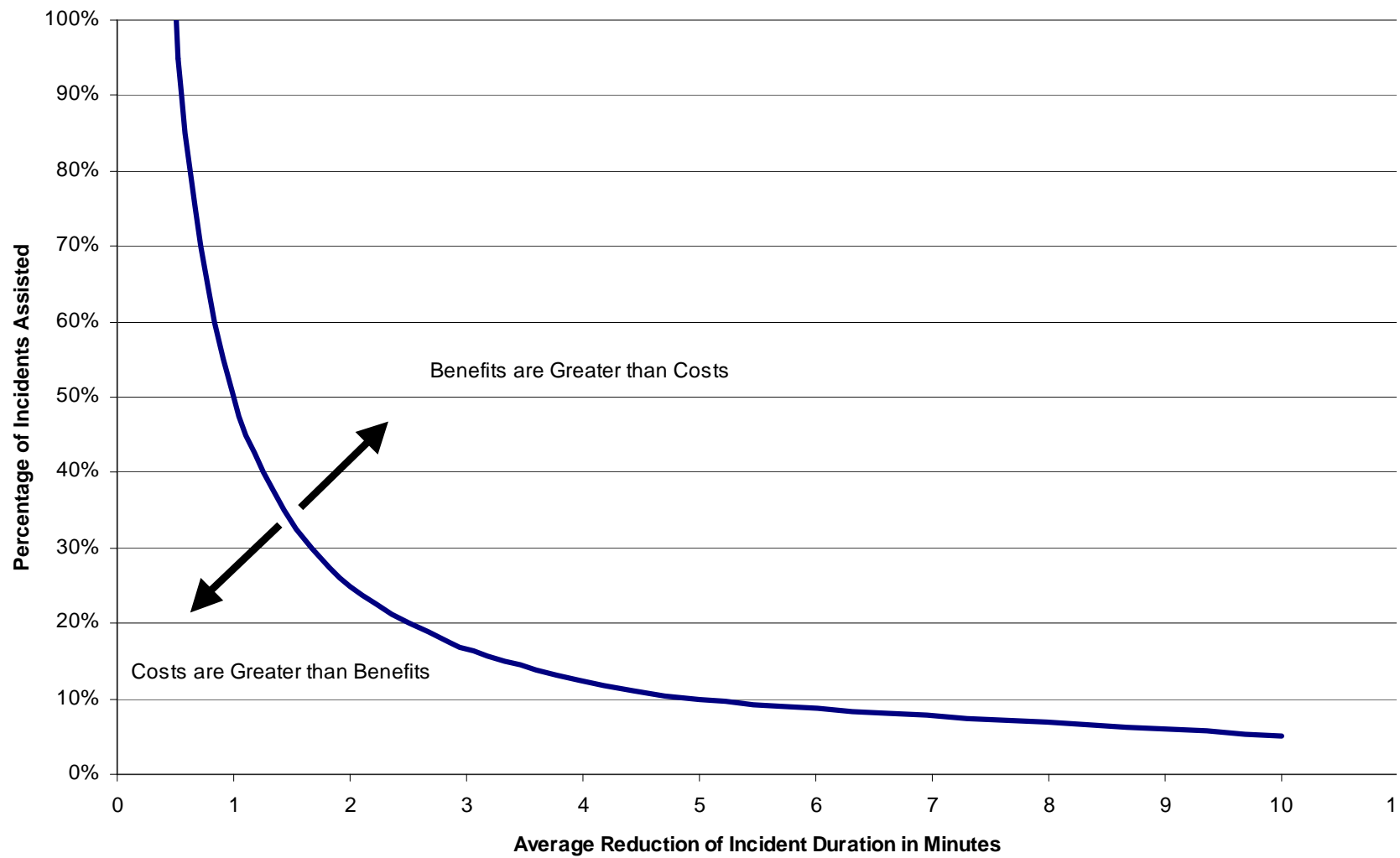


FIGURE 8 Typical Delay Curve

**FIGURE 9 Efficiency Curve**

	Actual Incident Delay	+ 1 minute per incident	+ 5 minutes per incident	+ 10 minutes per incident
Hours of Delay	1,900,000	2,000,000	2,200,000	2,500,000
Fuel Consumption	\$2,500,000	\$2,600,000	\$2,900,000	\$3,200,000
Time	\$48,000,000	\$50,000,000	\$55,000,000	\$62,000,000
Total Cost	\$51,000,000	\$52,000,000	\$58,000,000	\$65,000,000

TABLE 1 Actual Cost of Delay and Cost with an Estimated Increased Incident Duration