

# **TOWARD AN AUTOMATED INCIDENT ANALYSIS PROCESS USING ARCHIVED DATA ON THE PORTLAND OREGON FREEWAY SYSTEM**

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## **ABSTRACT**

Using archived traffic data from the Portland Oregon Regional Transportation Archive Listing (PORTAL), this paper summarizes work to characterize the frequency, duration, and pattern of incidents on the instrumented portion of the Portland freeway system for 2005. As in previous studies, this research found that there are trends in the occurrence of incidents that relate to traffic volume and weather. In a more detailed analysis, the cost of incidents (in terms of delay and fuel cost) were calculated for a seven mile study corridor. The methodology used data from loop detectors, incident records, and a deterministic queueing model to estimate an average delay of 417 vehicle-hours per incident on the study section. The analysis also found measurable differences in delay based on incident location (in the roadway cross-section), type and duration. The research estimated the total cost of non-recurring congestion in 2005 was \$187 million United States Dollars (USD). The paper will also describe a prototype methodology for automating the analysis of incidents by corridor within the PORTAL system.

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## **INTRODUCTION**

Traffic data archiving has seen tremendous growth in the nation in recent years. Portland State University's Intelligent Transportation Systems laboratory, in partnership with the Oregon Department of Transportation (ODOT), is working on traffic data archiving and automation to better understand the region's traffic management strategies.

Urban congestion is a growing national problem that affects mobility in the U.S. and many countries. Delay experienced by travelers in the U.S. is due to both recurring congestion caused by high traffic volume as well as non-recurring resulting from incidents, weather, or special events. Some estimate that approximately one-half of the delay experienced by travelers in the U.S. is due to non-recurring congestion. (Bertini *et al.* 2004; Lindley, 1986; Bertini *et al.* 2001). As part of the transportation system, urban freeways provide a significant amount of mobility. In 2005, urban freeways accounted for 50% of the total vehicle miles traveled in the U.S. Clearly, incidents such as crashes, vehicle breakdowns, weather, special events, and construction and maintenance activities can substantially reduce capacity which typically results in congestion. Therefore, many urban areas are actively pursuing congestion management strategies.

One of the available tools for managing congestion is incident management. When compared to other solutions (such as adding capacity) incident management programs are typically viewed as less costly approaches for alleviating freeway congestion and improving safety. Throughout the nation, incident management programs have delivered notable and measurable benefits that justify existing programs and the initiation of new ones (Bertini *et al.* 2004; Nee J. and Hallenbeck, 2001; Skabardonis *et al.* 1995; Skabardonis *et al.* 1998).

### **Scope of Research**

This research examined data from the Advanced Traffic Management Systems (ATMS) including incident response (IR) data for the year 2005. Both of these data sources are archived in the Portland Oregon Regional Transportation Archive Listing (PORTAL), the region's Archived Data User Service (ADUS). With new advances in technology and better data archiving capabilities, the Portland area has seen a major improvement in the ATMS. This paper presents an initial attempt towards automating analysis of incident data archived in PORTAL. Using the methodology presented here, PORTAL may be extended to produce performance metrics for freeway incidents which may include reports that show incident trends and delay metrics over time and space. Incorporating incident data analysis tools in PORTAL will have many benefits. PORTAL users will be able to determine whether traffic patterns are incident-related or not. In addition, basic incident statistics can be efficiently related to other relevant parameters like weather (precipitation and visibility) and exposure (traffic volume) by having all data sources in PORTAL (some of which has been accomplished). As a result, the development of incident performance metrics will be beneficial to traffic researchers and practitioners.

## **METHODOLOGY**

The following paragraph briefly describes PORTAL, the data source used in this research. This is followed by the discussion of the corridor selection process, the diagnostic tools used herein—a deterministic queuing model and a General Motors model—to estimate the delay and fuel consumption. Finally a brief discussion about the operational cost of the IR program is presented.

## PORTAL

This research used the Portland region's ADUS, PORTAL, for all data and analysis. PORTAL has successfully incorporated the data from the regional Traffic Management Operations Center (TMOC) computer aided dispatch records (CAD). PORTAL has developed a process to clean the CAD data for use by analyst and researchers. The CAD data cleaning process creates a unique record for each incident from the many entries in the CAD records. A detailed description of the process is available in Potter *et al.* (2007). Without this process, working with the incident data is extremely laborious and requires much manual effort, data analysis skill, and subjective judgment. With the data process automated, it provides an easier means to access and analyze the data for traffic researchers and practitioners. PORTAL stores 20-second freeway loop detector data received from ODOT's Region 1 TMOC through fiber optic communications. In addition to archiving the data it has a web-based interface accessed via an internet browser (<http://portal.its.pdx.edu>) for visual display and easy accessibility of the ATMS data. It has been operational since July 2004 (Bertini *et al.* 2001; Bertini *et al.* 2005). PORTAL has been used for many purposes – assessment and refinement of real-time travel algorithms (Kothuri *et al.* 2007), ramp-metering evaluations (Ahn *et al.* 2007) etc. In addition to ODOT's ATMS data it also archives incident data and weather data. The study done in Bertini *et al.* (2005) gives a detailed explanation of PORTAL, the Portland region's ADUS. It discusses the steps taken to implement the Portland region's functional ITS data archive, data storage, data processing and user interface. PORTAL gives users the ability to view and extract ATMS data. PORTAL can provide both raw and processed/grouped data. In addition there are various useful tools for examining traffic data. Useful graphical displays of traffic volume and speed data are available in PORTAL enabling researchers and practitioners in the region to make efficient use of the transportation data.

### Computer Aided Dispatch Data

CAD incident data from PORTAL was used to perform the quantitative analysis described in the summary section in this paper. The PORTAL project obtained incident data from ODOT's TMOC and all incident related data has been cleaned through a backend process as described in Potter *et al.* (2007). The original data from the CAD systems database contains multiple records for each incident that occurs and each record is an entry reflecting the various stages from detection, changes to clearance of an incident. For instance, when an incident is first reported to the TMOC, it is logged into the CAD database by an operator and an incident record is created with the characteristics of the incident. During the course of the detection, verification and clearance process as the stages of the incident change more, records are added to the database pertaining to that particular incident. PORTAL has processes which summarize these records to create one unique record and without a loss of valuable information pertaining to an incident. The current ATMS incident data housed in PORTAL has fields containing information on milepost, the primary route and the secondary route (for example, the entrance and exit ramps). It also has a field containing a text description of where the incident occurred. From the information obtained from these fields, fields were created by the PORTAL developers containing the highway identifier and milepost information. In general, mileposts are not recorded for all incidents. For some incidents, ODOT operators do assign a milepost. On Interstate 5 (I-5), PORTAL has added mileposts to some records based on the primary route and secondary route data. It was observed that a large majority (about 90%) of incidents on I-5 are associated with a small number of secondary routes (overcrossings or interchanges). Mileposts were identified for

each of these thirty or so most common secondary routes associated with I-5 incidents and then assigned those mileposts to the incidents. The statewide crash data, which contains all reported crashes in Oregon, was also used.

### Detector Station Data

Loop detector data from PORTAL were used to obtain the volume of traffic for delay calculations. Raw monthly data were used and this was summarized by stations and by day and then by hour to get the demand (flow) at the time of start of each incident. Detectors collect vehicle count, occupancy, and average speed data at 20-second intervals on the freeways.

### Weather Data

Archived weather data from PORTAL were used to compare incident trends with precipitation. In order to study the effect of ambient light on the incident occurrence, sunrise and sunset timing data from US Naval Observatory data (<http://aa.usno.navy.mil>) was obtained.

### **Selection of Study Corridor**

The corridor selected for detailed delay analysis was I-5 from milepost 295 to 302 (SW Capitol Hwy and SW Broadway) and is shown in Figure 1. I-5 was selected because the incidents were recently matched to a milepost location in the ATMS incident database.



Figure 1 : Study Corridor (I-5 from SW Capitol Highway to SW Broadway)

An analysis of incident by milepost on I-5 showed a higher number of incidents on the selected study corridor. This corridor was selected to estimate delay and fuel cost incurred by incidents in that corridor (to have a fairly large sample for analysis) and obtain the best estimate and limit the possibility of errors. As shown in Figure 2, between milepost 295 and 302 there happens to be a larger number of incidents. There were 5,367 reported incidents on I-5 in 2005, of these 2,422 incidents occurred between milepost 295 and 302 (45%). 1,136

incidents were in the northbound direction and 1,286 were southbound. The incidents had a mean duration of 27 minutes.

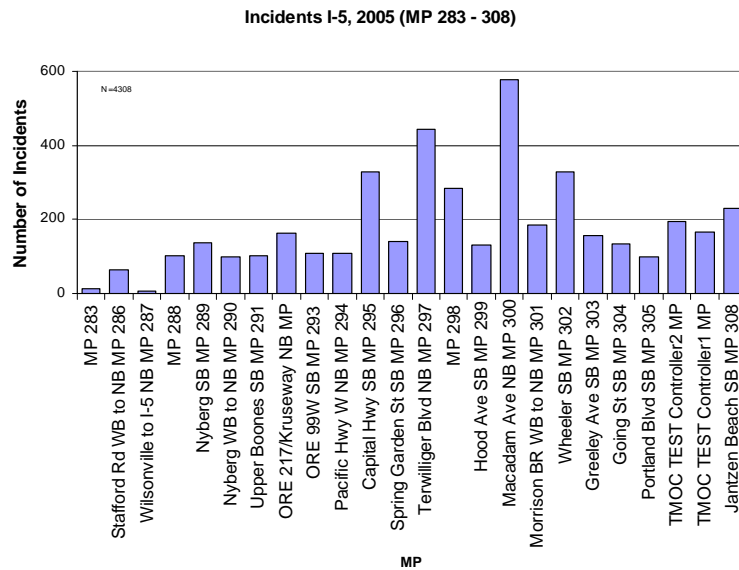


Figure 2: Incident Frequency by Milepost on I-5

## Measures of Effectiveness

Benefits of an IR program have been shown to be savings in delay and fuel cost as a result of reductions in incident duration. Calculations of delay cost and additional fuel cost due to incident-related delay is performed to show how it impacts highway users. The effects of incremental reduction in incident duration show that there can be savings brought about by reduction in response and clearance times.

## Estimation of Delay

The estimation of incident delay was based on a simple deterministic queuing model (Bertini *et al.* 2001; Skabardonis *et al.* 1998). This model has been applied in numerous studies. Figure 3 shows a typical delay curve of cumulative vehicle arrivals and departures versus time. The line represented by  $V$  is the cumulative number of vehicles that have arrived at a particular incident location. The slope of this line  $V$  is the traffic demand (veh/time) of the freeway. When the incident occurs the freeway capacity is reduced to  $C_i$  for the duration of the incident,  $t$ . Once the incident has cleared, after  $t$  minutes, the built-up queue will discharge at the capacity of the freeway,  $C$ , until the queue is dissipated. According to the model, the delay,  $D$ , in vehicle hours is represented by the shaded area in Figure 3.

$$D = \frac{t^2(V - C)(C - C_i)}{2(C - V)} \quad (1)$$

where:

$D$  = Vehicle Hours of Delay

$t$  = duration of incident in hours

$V$  = Normal flow (Traffic Demand) (vehicles per hour)

$C$  = Capacity (1,800 passenger car per hour per lane (pc/hr/ln))

$C_i$  = Reduced Capacity (adjusted based on HCM (Exhibit 22-6))

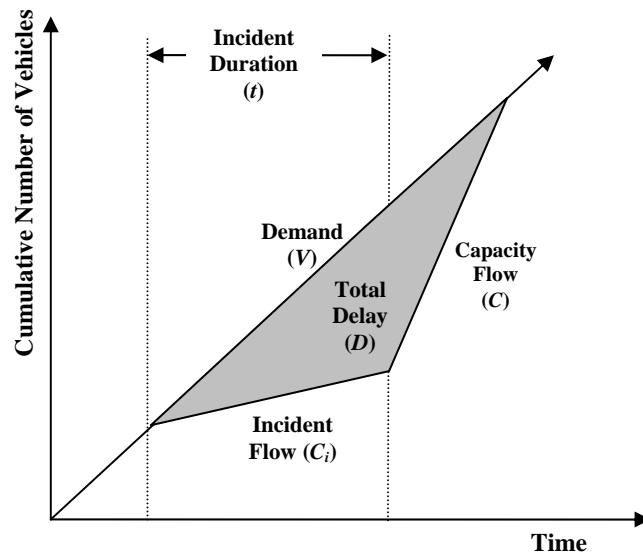


Figure 3: Delay Curve (Queuing Diagram)

### Estimation of Fuel Consumption

Researchers at General Motors developed a simple formula given in equation (2) that has been shown to accurately determine the additional fuel consumption due to very slow moving traffic (traffic moving at average speed under 40 mph) (Bertini *et al.* 2004; Daganzo *et al.*)

$$E = k_5 L + k_6 T \quad (2)$$

where:

- $E$  = additional fuel consumed per vehicle
- $k_5 = 90 \text{ ml/km} = 0.03826 \text{ gallons per mile}$
- $L$  = distance traveled in queue
- $k_6 = 0.44 \text{ ml/sec} = 0.4184 \text{ gallons per hour}$
- $T$  = travel time in queue

For the purpose of this research, it was assumed that vehicles average approximately 10 mph throughout the queue and that the cost of fuel was \$2.42 USD per gallon (ODOT) the average price for a gallon or 3.7 litres of mid-grade fuel in 2005. Using these values the cost of additional fuel consumed per vehicle is:

$$E = \$1.93 \text{ USD per hour per vehicle}$$

### Cost of Incident Response Program

The estimated cost of the incident response program when the first Region 1 ODOT sponsored study was performed in 2004 was stated at \$2.9 million USD for a two year budget cycle. Additionally, ODOT's TMOC/Incident Response Manager for Region 1, Mr. Geoffrey L. Bowyer has stated that the annual crew costs exceeded \$1.1 USD million in 2005.

## ANALYSIS OF INCIDENT DATA

This section presents the results of the analysis of 2005 ATMS incidents, weather and crash datasets described earlier. The analysis includes identification of incident types and their share of impact on the freeways system in ODOT Region 1 using various visualization tools. It presents the results of the analysis in terms of average vehicular delay experienced by motorists due to non-recurrent congestion in the Portland Metro Area in 2005.

### Summary

In 2005, there were 17,796 incidents reported on the Region 1 monitored freeways from the ATMS database. Figure 4(A) shows the distribution of the incidents by type. The most prevalent form of incident was stalls (57%), followed by crashes (16%) and debris (13%). This is similar to the findings of the study done for Region 1 in 2001 (Bertini, *et al.* 2004). Tow and construction categories each contribute to 3 percent of the recorded incidents. The statistics for the number of lane blocked when an incident happens is shown in Figure 4(B). In the majority of incidents there are no lanes blocked (62%). In approximately 33% of the cases one lane was blocked. Blocking of two or more lanes occurred only in 5% of the cases. Figure 4(C) shows the location of the incidents on the freeway cross section for 2005. Nearly half (45%) of the incidents were reported in the right shoulder followed by 16% in the right lane. The incidents occurring in the other areas like the left and center lanes and gore areas accounted for 29% and generally mean more serious safety concerns for the motorists and the responders. Six percent of the incidents were recorded as blocking all lanes.

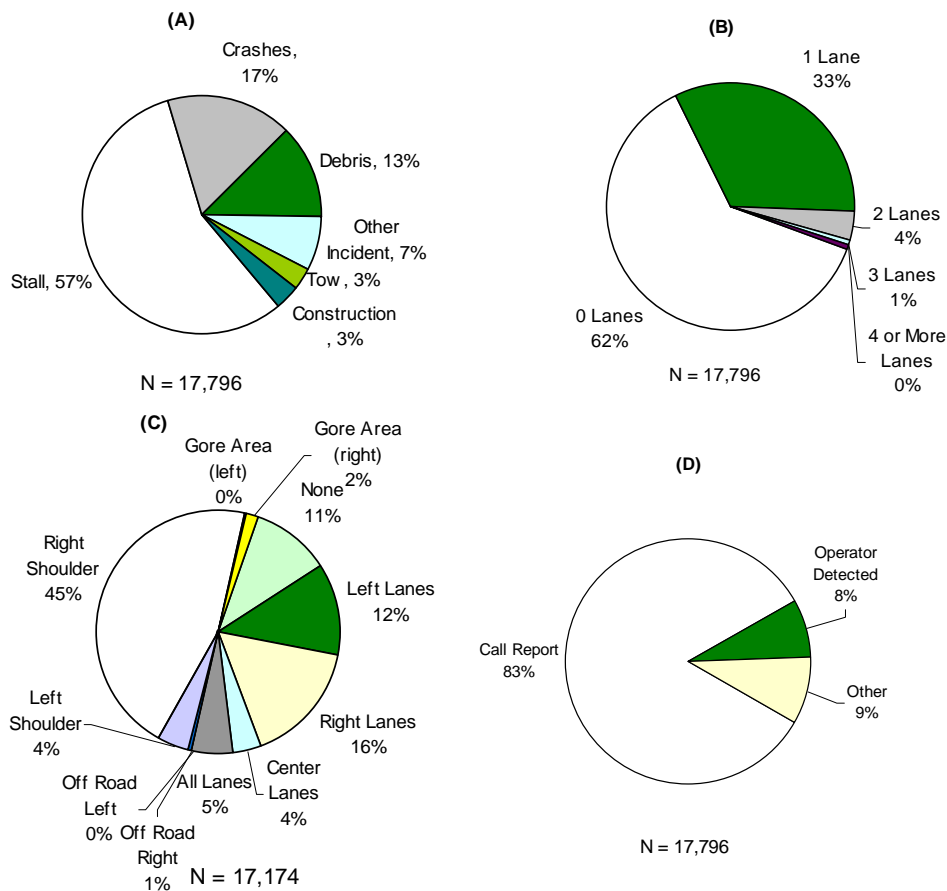


Figure 4: Distribution of (A) Incident Type, (B) Lanes Blocked, (C) Incident Location, and (D) Detection Type in 2005 by Percent

Figure 4(D) shows the statistics for the type of detection for the incidents recorded in 2005. As shown, most of the incidents (83%) were detected when the person involved places a call to report the incident. About 8% were detected by the TMOC operators (likely by the use of freeway surveillance cameras) and the rest were detected by some other methods not identified.

Figure 5 shows the incident frequency and the average daily traffic (ADT) in each month in 2005. An average of 1,483 incidents occurred per month in 2005. The months of October, November and December accounted for almost 30 percent of the total incidents. The ADT's for the whole freeway system, in most months ranged from approximately 88,000 to 99,000, with the exception of May which shows a sharp drop. There were several days in May when the traffic volume data from freeways was not successfully transmitted to PORTAL. In the ADT calculation in PORTAL only days with good data were used. However, it appears that the reported May volume is underestimated. Note that there is a rising trend from the start of summer in the month of May. However, the link between volume and incidents does not appear as strong as one might expect.

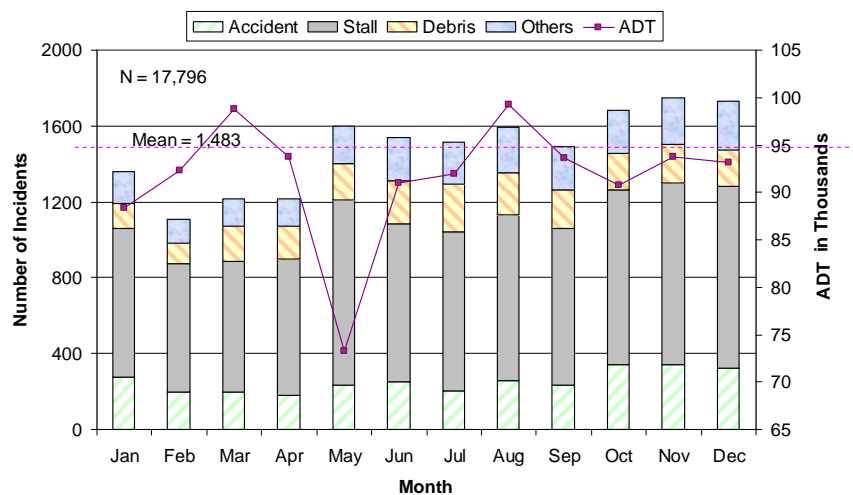


Figure 5: Monthly Incident Frequency and Average Daily Traffic

Figure 6 compares the number of crashes on wet and dry days to the number of wet days for each month in 2005. It is interesting to note that during the month of August, despite the lack of rainy days, the number of crashes is high (almost 8.5% of the total). This is likely attributable to the increase in ADT (the exposure), as shown in Figure 5, on the freeways during that month. The last three months of the year had fairly constant volume but more wet days, and the total crashes were also high. In general, the highest number of crashes occurred during the rainy months; however, the month of May exhibited a large number of wet days, but fewer crashes than other rainy months. Furthermore, it was observed that the months of January through March in 2005 were unusually dry in the Portland region. Weather conditions can have a substantial impact on incident frequency. For this study weather data were obtained from PORTAL (Portland ADUS). A day with total measured rainfall of 0.05” was considered as a wet day.

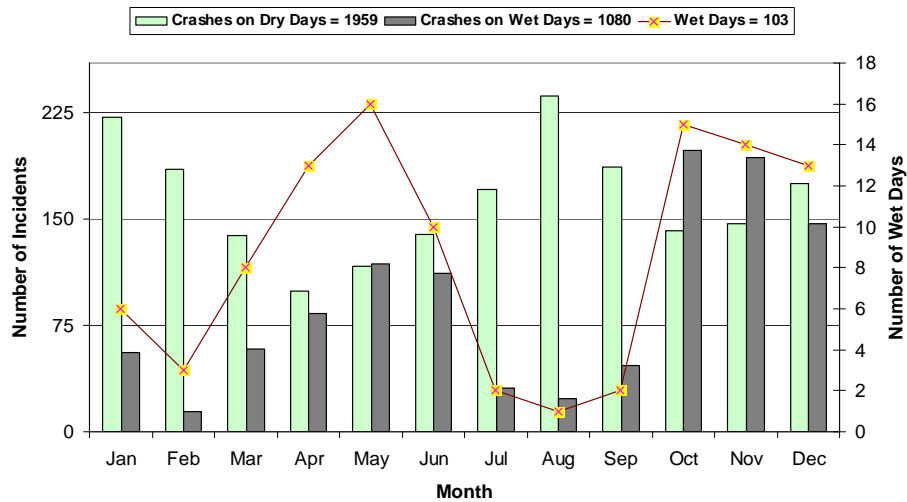


Figure 6: Crashes and Precipitation

Figure 7 shows the daily number of hours of light and darkness in 2005. The daily sunrise and sunset times for Portland have been obtained from the U.S. Naval Observatory to extract the hours of lightness and darkness for each day. Safety-related research suggests there is sufficient ambient light for the driving task 20 minutes before sunrise and 20 minutes after sunset. The times have been adjusted to take this into consideration. After making adjustments, each day's hours of light and darkness was computed. Additionally, each incident was classified as a daylight or darkness event based on the time of occurrence of the incident.

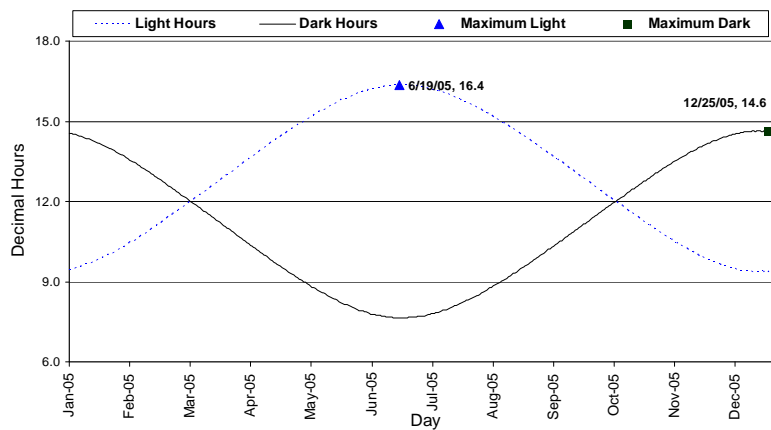


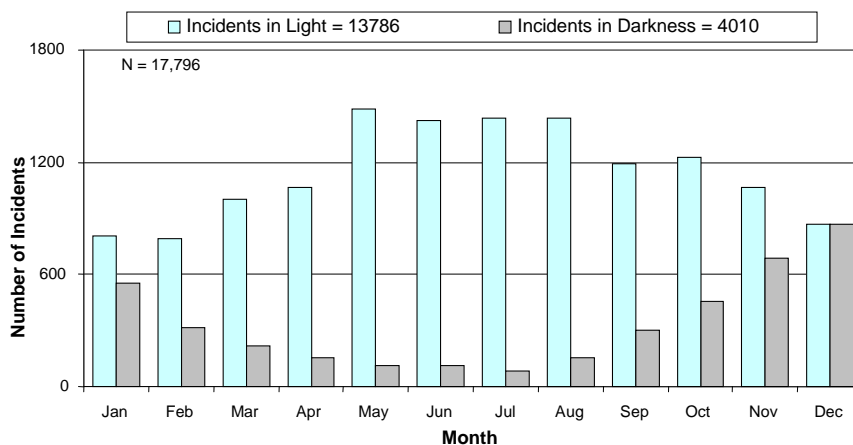
Figure 7: Hour of Light and Darkness in 2005

Figure 8 (A) shows a frequency distribution of the incidents that occurred in each month in 2005 by light condition. As one would normally expect, the frequency of incidents under light conditions is higher than that under dark conditions. Incidents under dark conditions increase in months which have more dark hours (Jan and Oct through Dec). It follows the same pattern as the hours of light or darkness shown in Figure 7.

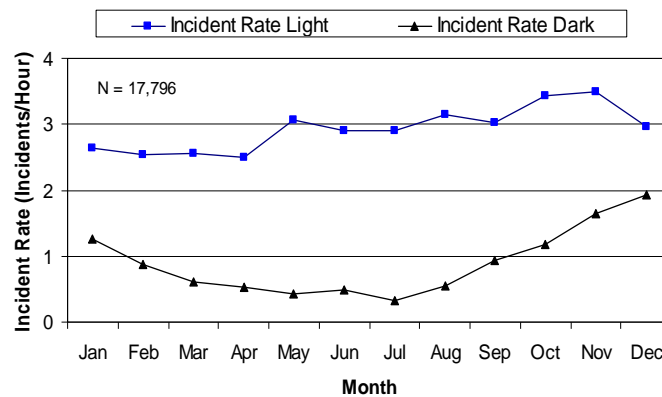
Figure 8 (B) shows the monthly incident rate per hour for each light condition. There are higher number of incidents per light hour in the months of October and November. From

May to September the incident rate is fairly constant at about 3 incidents/light hour. For incidents under dark condition, as the dark hours increase the rate of incidents per dark hour also increases, as can be seen from the rates in the months of October through December and in January.

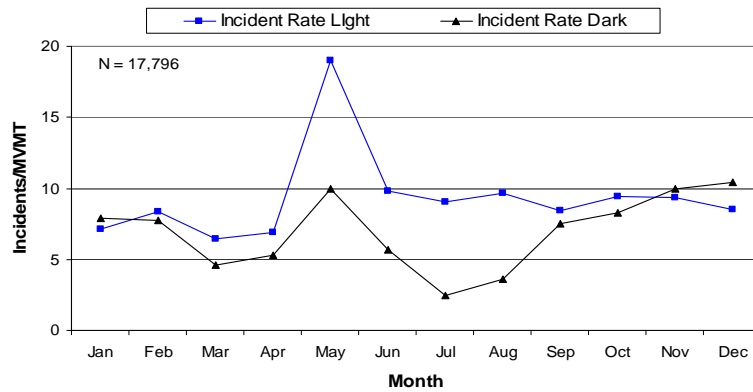
Figure 8(C) shows the incident rate per million vehicle miles of travel (MVMT) for each month in 2005 by light condition. For most months the incident rate under light condition ranged between 6.45 (in March) and 9.78 (in June) with the exception of May when it showed an unusual spike (19 incidents per MVMT). The rates under dark condition, however, show a more substantial change from month to month.



(A – Incident Frequency by Light Condition)



(B – Hourly Rate (Incidents/Hour))



(C – Volume Rate (Incidents/MVMT))

Figure 8: Incident by Light Condition (A), Hourly Rate (Incidents/Hour) (B), Volume Rate (Incidents/MVMT) (C)

## Incident Delay and Fuel Consumption

### Capacity Reduction During an Incident

The capacity reduction of the freeway section during an incident's occurrence was determined based on Capacity Reduction table (Exhibit 22-6), obtained from the Highway Capacity Manual (HCM). The reduction takes into account the number of lanes in the freeway section and type of the incident (i.e., crashes or other) for shoulder incidents. For incidents that have lane blockage the reduction takes into account the number of lanes blocked by the incident and the total number of lanes in the freeway section. As can be interpreted from the table, the actual loss of capacity is greater than the capacity blocked by an incident. The base capacity was assumed as 1,800 passenger car per hour per lane using an assumed headway of 2 seconds between vehicles. Under ideal conditions, it is generally assumed that vehicles will travel at an average headway of 2.0 seconds, resulting in a saturation flow rate of 1,800 passenger car per hour per lane.

### Incident Duration

Incident duration is a very important parameter in measuring the health of an incident management system. For this research the duration is obtained from the PORTAL ATMS incident database which calculates it as the difference between the last update time and the confirm time (start time) of the incident. Delay estimations can vary considerably depending on this parameter. Actual duration of lane closures should be calculated to the best possible accuracy so that delay can be estimated more precisely.

### Hourly Volume

Flow at the start of occurrence of each incident was calculated by relating the data from the milepost, time (hour) and the highway id fields in the incidents table to the highway id and milepost and time (hour) field in the monthly loop data downloaded from PORTAL.

### Estimation of Delay

Delay pertaining to each incident was calculated using the deterministic queuing model described before. There were 5,367 incidents on I-5 in 2005. Of these 2,422 incidents occurred between mileposts 295 and 302 (Capitol Hwy and Broadway). The incidents had a mean duration of 27 minutes. A total of 1,136 incidents were in the northbound direction and 1,286 were southbound.

Of the 2,422 incidents, flow data could be obtained from PORTAL for 2,101 from the detector station data from PORTAL. For the remainder of the incidents, flow data were not available due to missing data. Delay caused by each of the 2,101 incidents was calculated using equation (1). After the delay calculations it was observed that only 705 incidents resulted in actual measurable vehicular delay. There was one incident (incident id “496541”) with a reported duration of about 17 hours and affecting 2 lanes that caused an exceptionally high delay. On further verification of the incident’s duration against detailed CAD records it was observed that the actual lane closure of 2 lanes was in effect for only 12 minutes of the total duration and the rest of the time it was a shoulder disablement. Adjustment was made to this particular incident to reflect the actual duration of lane closure and the delay was recalculated for this incident. This highlights the need for additional data screening, perhaps in an automated process.

Total delay for the 2,101 incidents was estimated to be 876,600 vehicle-hours, with 542,700 in the northbound direction and 333,300 in the southbound direction, resulting in an average delay of 417 vehicle-hours per incident with a mean ( $\mu$ ) duration of 27 minutes for the seven mile study corridor. Neglecting those incidents that did not cause measurable delay, the average delay for the remaining 705 incidents was estimated at 1,240 vehicle-hours per incident with a mean ( $\mu$ ) duration of 33 minutes.

The breakdown of delay statistics by type of incident, the location in the freeway (lane location) and number of lanes affected by incident is shown in Table 1.

Table 1: Delay Statistics by Incident Type

Measure	Incident Type						
	Accident	Construction	Debris	Other Closure	Other Incident	Stall	Tow
Frequency	359	14	173	5	43	1,446	61
Average Delay (veh-hrs)	824	2,671	463	0	678	299	14
Total Delay (veh-hrs)	295,980	37,395	80,110	0	29,155	432,874	839
Maximum Delay (veh-hrs)	35,953	37,387	18,752	0	9,108	190,250	665
StDev Delay (veh-hrs)	2,893	9,992	2,421	0	2,092	5,390	87
Average Duration	0:38:28	4:29:50	0:21:49	4:52:15	1:03:01	0:19:16	0:48:52
StDev Duration	0:40:03	2:59:44	0:30:40	3:43:58	1:55:28	0:30:11	3:18:47
Maximum Duration	5:05:54	9:59:46	3:31:32	9:34:44	9:46:43	9:32:32	18:59:26
Minimum Duration	0:00:02	0:25:03	0:00:01	0:53:26	0:00:03	0:00:00	0:00:03

Construction incidents (although a few only) in the sample, caused a higher average delay (2,671 vehicle-hours) per incident. Crashes resulted in 824 vehicle-hours of delay per incident. Stalls with an average delay of approximately 300 vehicle-hours per incident, caused the maximum delay as a whole.

Table 2 shows the delay statistics by the type of lane blocked by an incident. Incidents blocking all lanes had an average delay of around 2,400 vehicle-hours per incident with an average duration one hour and fifteen minutes per incident. Incidents blocking the center and

left lanes and left shoulders also caused noticeable delay per incident as shown in the table below.

Table 2: Delay Statistics by Location of Incident

Measure	Lane Location Type					
	All Lanes	Center Lanes	Left Lanes	Left Shoulder	Right Lanes	Right Shoulder
Frequency	47	82	290	41	352	1,084
Average Delay (veh-hrs)	2,423	634	521	575	420	353
Total Delay (veh-hrs)	113,864	51,963	151,050	23,592	147,903	382,536
Maximum Delay (veh-hrs)	35,953	9,650	37,387	18,040	19,207	190,250
StDev Delay (veh-hrs)	6,358	1,698	2,730	2,887	1,572	6,223
Average Duration	1:18:12	0:29:53	0:33:28	0:25:33	0:37:43	0:20:17
StDev Duration	1:36:33	0:27:02	1:01:21	0:30:43	1:05:03	0:56:51
Maximum Duration	7:58:11	1:41:48	9:59:46	2:21:27	9:46:43	18:59:26
Minimum Duration	0:00:03	0:00:02	0:00:01	0:00:02	0:00:02	0:00:02

Lane blocking incidents cause the major portion of the delay as can be interpreted from Table 3. In 60% of the sample there was no lane blockage and the average delay was only 3 vehicle-hours per incident. In approximately 40% there was a blockage of one lane and the average delay caused was 800 vehicle-hours per incident. The total delay caused by this type of incidents was the most notable.

Table 3: Delay Statistics by Number of Lanes Affected

Measure	Lanes Affected				
	0	1	2	3	4
Frequency	1,246	788	59	6	2
Average Delay (veh-hrs)	3	800	3,441	6,249	608
Total Delay (veh-hrs)	4,222	630,385	203,036	37,495	1,216
Minimum Delay (veh-hrs)	0	0	0	11	63
Maximum Delay (veh-hrs)	2,100	190,250	35,953	18,551	1,153
StDev Delay (veh-hrs)	70	7,496	6,019	6,718	771
Average Duration	0:19:48	0:33:39	1:11:50	2:27:31	0:28:03
StDev Duration	0:53:11	1:00:57	1:00:30	1:30:22	0:28:38
Maximum Duration	18:59:26	9:59:46	6:02:12	4:14:03	0:48:17
Minimum Duration	0:00:00	0:00:02	0:00:04	0:06:09	0:07:48

### Cost/Benefit Analysis of Incident Response Program

A direct cost benefit analysis of the incident response program in the Portland region is not possible since data prior to the inception of the program is not available and hence a true before after picture cannot be drawn. The collection and archiving of incident data started only after the initiation of the program in 1997. Also there is some degree of inaccuracy involved in the estimation of delay caused by the incidents because a precise measurement of duration of the incidents or flow cannot be obtained. The incident flow  $C_i$  as shown in Figure 3 in the queuing diagram, in reality is not constant but changes as the incident progresses. But the model assumes it as a constant throughout the duration of the incident. The way duration has been calculated may overstate delay because it uses the whole duration from the confirmation of the incident to the time when the last change was made to the incident. In other words, the duration might be actually lower since the major clearing may have been done prior to the last update added to the incident. Moreover, the technique used in the data cleaning process filters the data in such a way that the most crucial lane closures is only stored, whereas, that might be true for only a small portion of the actual duration. As such,

there are certain limitations in the methodology used here to estimate the delay. An incremental analysis on the incident duration for the same set of data is performed to show the impact of duration on delay and fuel consumption cost.

Using an average delay of 417 vehicle-hours per incident, the total vehicular delay for 2005 incidents on the entire Portland freeway system can be estimated to be 7.42 million vehicle-hours for the entire Portland system. Using an average occupancy factor of 1.30 (ODOT), the total person delay was estimated to be 9.65 million person-hours. Using an average value of time of \$17.88 USD per person-hour (ODOT), the total delay cost was estimated to be \$172.5 million USD or approximately \$9,700 USD per incident.

Fuel costs were estimated using equation (2) as described earlier. For the Portland metropolitan area in 2005 the cost of additional fuel consumption due to delay was estimated to be \$14.3 million USD.

The estimated cost of incident delay for 2005 for both fuel and time is approximately \$186.8 million USD or \$10,500 USD per incident. Assuming that in the absence of the IR program the incidents increase in duration by a minute an increase in total cost of delay and fuel consumption of \$5.6 million USD or approximately \$315 USD per incident results, which is close to five times the annual cost of operating the COMET program on the Portland freeways. This net benefit indicates that the program produces substantial benefits. Based on the delay calculations of incidents on the study corridor an average reduction of about 13 seconds per incident is the break even point for cost and benefit of the program.

## **CONCLUSIONS**

The purpose of this research was to explore performance measures for the COMET program. The effectiveness of the COMET program is evaluated based on benefit/cost analysis using incident data from the year 2005. To accomplish this, an analysis of incidents in terms of delay and fuel consumption using the region's archived data user service PORTAL was conducted.

For the entire freeway system in 2005, the analysis shows that breakdowns or stalls are the primary type of incident followed by crashes and debris. The delay calculations on the study corridor indicate that lane blocking incidents cause most of the delay. Incidents with one lane blocked represent 72% of the delay, and they constitute 92% of lane blocking incidents. Incidents blocking two lanes account for 23% of the delay, and are 7% of all lane blocking incidents. The delay calculations from the raw CAD data found outliers when severity is high or when traffic volumes are very low relative to the roadway capacity. A few incidents with higher calculated delay were checked to verify this and it was found that in most cases it was either the how the duration was coded in the CAD data or the number of lanes affected that caused these variations. This highlights that an automated process would need to have filtering mechanism to avoid calculating these large artificial delays. Duration, demand and lane blockage are very important parameter in measuring the long-term effectiveness of an incident management system and any discrepancy in there values can lead to inaccurate results. A method should be developed in the PORTAL data cleaning process to capture or flag unusual incidents to the best possible degree.

This research is one of many studies that have demonstrated the usefulness of a region wide transportation data archive. A central data repository can aid in analysis of an ATMS system

and make it meaningful for generation of performance measures. The delay savings brought about 37 by efficient management of any freeway incident management can be well identified from the finding of this research. PORTAL has made transportation related studies extremely meaningful and now all the regions users have to get familiar with the interface and make the best use of the system. The results of this study confirm previous research that COMET is a successful, cost-effective operational program.

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