

Incorporating Incident Data into a Freeway Data Archive for Improved Performance Measurement

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ABSTRACT

The Portland Oregon Transportation Archive Listing (PORTAL) archives high resolution traffic data including speed, volume, and occupancy collected from 500 freeway loop detectors in the Portland metropolitan area. PORTAL currently provides measures related to total congestion that occurs on the freeway network, but cannot presently distinguish between recurrent and non-recurrent congestion effects. In response to the need to make such a distinction, the objective of this paper is to describe the incorporation of freeway incident data received from the Oregon Department of Transportation (ODOT) into PORTAL. ODOT's freeway incident database includes information about vehicle crashes and stalls, debris on the road, construction and other random events. The paper describes the incident archive architecture and demonstrates how users can view incident data associated with a particular time frame and location. For example, a user analyzing data from a particular day will be able to immediately access associated incident data so the user can determine if the traffic pattern is related to an incident. In addition, freeway incident performance metrics will be described, including tracking of incident trends over time and location and numbers of incidents by incident type. Finally, the paper will describe how comparing incidents with weather data archived in the PORTAL database can be used to determine how weather has influenced incidents. The above-described incident performance metrics are useful to traffic researchers and practitioners and may contribute to incident-reduction measures in the Portland area.

INTRODUCTION

Non-recurrent congestion is congestion caused by incidents such as crashes, stalls, or special events. Researchers believe that approximately half of the delay experienced by travelers in the United States is due to non-recurrent congestion (1,2,3,4). Further, the California Department of Transportation (Caltrans) estimates that for each minute an incident blocks a lane, approximately five minutes are added to the total time the freeway will be congested (5). Understanding congestion is critical for traffic management operations in a metropolitan area such as Portland, Oregon. Improved information about non-recurrent congestion may improve incident response, improve travel time reliability, reduce secondary crashes, improve customer satisfaction, and reduce overall congestion. Further, intelligent transportation systems (ITS) researchers and practitioners need to be able to distinguish between recurrent and non-recurrent congestion for analysis purposes—for planning, real time operations, calculation of performance measures and for traffic pattern analysis. As part of a larger ITS data archiving program, this paper describes an ongoing effort to develop methods for retrieving, cleaning, storing, and accessing ODOT incident data in an evolving ITS data archive system. Also described is an analysis of about six years' of incident data now available via an web-based retrieval system developed as part of this project.

PORTAL SYSTEM

The Portland Transportation Archive Listing (PORTAL—see <http://portal.its.pdx.edu>) (6,7) is the Portland metropolitan area's transportation data archive and is based on the Archived Data User Service (ADUS) framework (8) developed by the U.S. Department of Transportation (USDOT) as part of the National ITS Architecture. PORTAL has been archiving speed, volume, and occupancy data from the loop detectors on the Portland metropolitan freeway system since July 2004 and has been designated by the Portland ITS and operations agencies as the official ITS data archiving entity for the Portland region. PORTAL receives a live stream of freeway loop detector data from the Oregon Department of Transportation (ODOT). This stream consists of 20-second volume, occupancy, and speed measurements for nearly 500 freeway detectors and 128 metered on-ramps in the metropolitan area. In addition to loop detector data, PORTAL archives weather data and now freeway incident data, as described in this paper. As suggested in the ITS Guidelines from the FHWA (9), user access to the PORTAL data archive is through a web-based interface providing easy access to both raw data sets and a wide range of common summary data and performance measures. Users have the option of graphically viewing data or outputting the data in tabular form. PORTAL's 160 registered users include transportation planners, metropolitan planning organization (MPO) staff, students, traffic management operators, transit operators, transportation researchers, transportation managers, consultants, and one elected official.

DATA DESCRIPTION

The incident data incorporated into PORTAL and the results in this paper are based on incident data from the ODOT Advanced Transportation Management System (ATMS) database. Figure 1 illustrates the incident data architecture as part of PORTAL. Incident data is entered into the ATMS database by operators at the ODOT Traffic Management Operations Center (TMOC). The TMOC operators work closely with emergency responders and the ODOT Corridor Management (COMET) teams who are the incident responders patrolling the freeways. Typically, the progress of an incident follows a logical sequence of events:

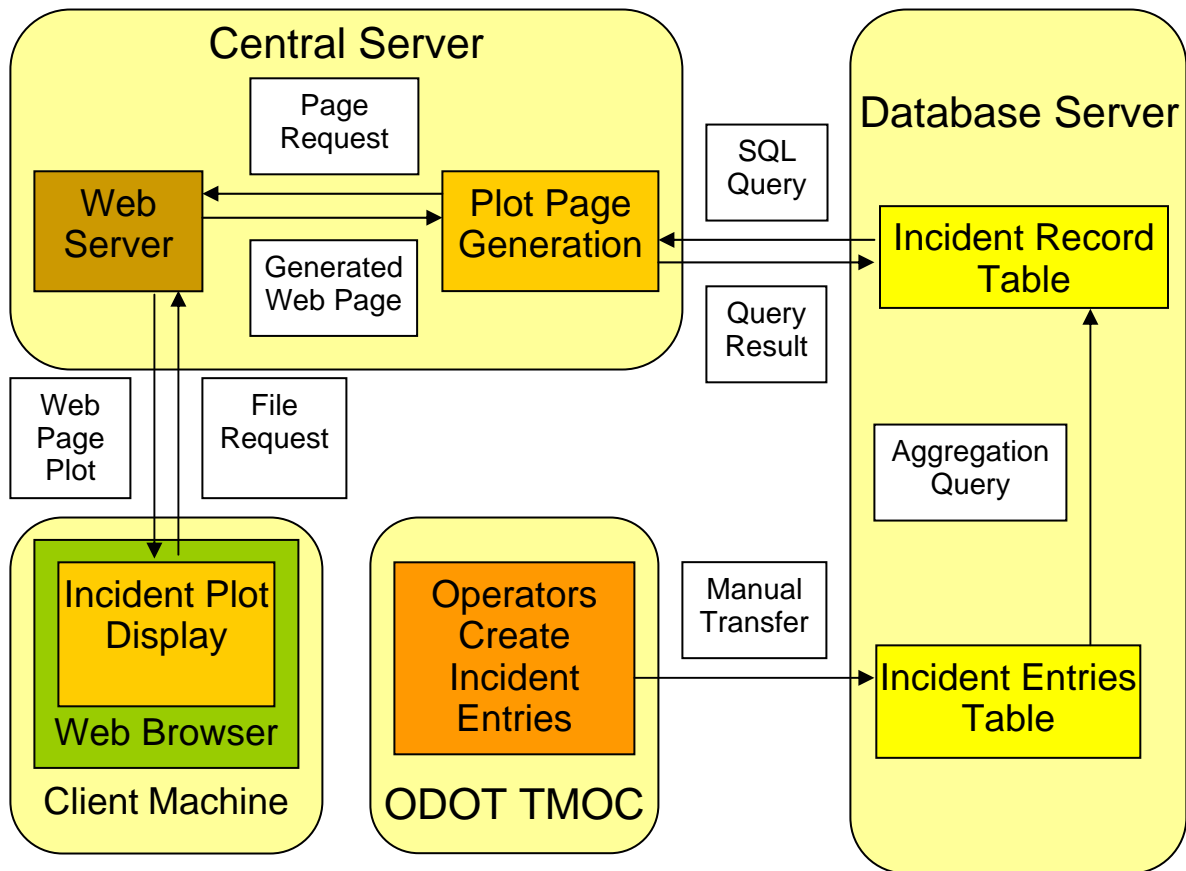


FIGURE 1 Incident data architecture in PORTAL.

- Incident Occurs: actual time may be unknown
- Incident Reported: may be reported by cellular 911, incident responders or TMOC dispatchers
- Incident Confirmed: can be confirmed via CCTV or by incident responders
- Dispatch: TMOC staff dispatch appropriate emergency and/or incident responders
- Response: responders make their way to the incident site
- Incident Cleared: responders and field personnel clear the incident
- Reported as Cleared: scene is clear
- Congestion Ends: traffic returns to normal some time later

For each incident, operators create several entries in the database; entries are created when the incident is reported, when the status of the incident changes throughout the life of the incident, and finally when the incident is cleared. As shown in Table 1, each entry has at least 70 fields including an incident identification that uniquely identifies each incident. Other fields include incident type, mode of detection, last update time, confirm time, primary route, secondary route, and number of lanes affected. Each of the fields is included in each entry for each incident in the database; some of the fields change from entry to entry—for example, the number of lanes affected by an incident may change as an incident is cleared from the mainline highway lanes to the shoulder; while other fields remain relatively static such as confirm time and location information.

For the incident data to be more suitable for analysis, the multiple database entries for each incident must be combined into one incident record providing location, duration and other important parameters for that incident. For the remainder of this paper, the word *entry* is used to refer to an incident entry in the ATMS database and the word *record* to refer to the single incident record that is derived from the incident entries. Finally, since the incident information is entered by human operators in a real time, management center environment, it must be cleaned—for example, inconsistent route names must be standardized. What follows is a description of how these issues are addressed.

TABLE 1 Incident Data Fields

Incident ID	Fire Department Presence	Pickup/Van Count	Scheduled Start
Incident Type ID	Hazardous Materials Presence	DOT Vehicle Count	Scheduled End
Detection Type ID	Injury Count	Construction Vehicle Count	Actual Start
County Code ID	Fatality Count	Motorhome/Bus Count	Actual End
City Code ID	Need Police Flag	Light Truck Count	Confirm Flag
Primary Route	Need COMET Flag	Tractor Trailer Count	Confirm Time
Secondary Route	Need Auto Wrecker Flag	Other Vehicle Count	Confirm Operator
Location Type ID	Need Truck Wrecker Flag	Hazard Flag	Last Update Time
Location Text	Guardrail Damage	Officer Name	Last Update Operator
Direction	Pavement Damage	Officer Badge Number	Action Pending
Affected Lane Type ID	Signal Damage	Estimated End	Plan Flag
Number Lanes Affected	Light Pole Damage	Impact Type	Diversion Flag
Station ID	Structure Damage	Number Calls	X Position, Y Position
Segment ID	Other Damage	Reported Via ID	Alarm Interval
Navlink Start ID	Pedestrian Count	Reported by Name	Incident Level
Navlink End ID	Railroad Count	Contact Name	Comments
Jurisdiction	Automobile Count	Contact Phone	
Located Flag	Motorcycle Count	Radio Unit Number	

DATA AGGREGATION AND CLEANING

The ODOT ATMS incident database contains multiple entries for each incident; one of the biggest challenges in managing and extracting useful information from this database lies in determining how to merge the multiple entries to create one record per incident. This project has developed a method to derive several fields in the incident record from the incident entries. Recall that an entry is made the incident status changes. The fields in incident records are similar to those in incident entries; some major differences are that incident records contain duration information, a flag for those incidents not located, and a standard way to represent the freeways. The first important field to be created in the incident record is the duration field.

To determine the duration of an incident, the first step is to derive estimates for the incident start and end time from the ATMS database. The ATMS database contains two types of time information. First, each entry in the database contains a “last update time” that specifies the time associated with that entry; recall that an incident entry is created by the operator each time the status of an incident changes. Second, incidents have a “confirm time” that indicates the time that an ODOT operator was able to confirm that a reported incident actually occurred. This can happen via CCTV or by a COMET responder. For most incidents, the final entry is an entry indicating that the incident has been cleared; therefore, the time of the final entry for an incident is accepted as the incident’s end time. Though rare, there are times an incident is opened later or even kept open until the next day, thus having a “last update time” that is much later than the actual end time. By searching the table for incidents with large durations, it is possible to examine entries that might be affected by this problem. By subtracting the end time from the start time, it is possible to obtain a reasonable estimate of the duration of the incident.

In some cases, an incident is reported to ODOT, but ODOT TMOC operators are unable to locate the incident. In this case, the operator will often enter Unable To Locate (“UTL”) in the comment field in the incident entry. By searching comment fields in incident entries for “UTL” most of the incidents that were never located can be identified. Incident records are created for un-located (UTL) incidents, but are flagged in the database and are not included in the analysis at this time.

Several fields in the incident entries (in the ATMS database) are used to indicate whether a particular action occurred or not; for example, to indicate if police responded or if there was light pole damage. These fields are referred to as flag fields; a flag is set if the action occurred. If any entry for a given incident has such a flag set, then the derived incident record for that incident shows the flag set. For instance, if the first entry for an incident shows no police response, but the second entry does, the final record will show that there was a police response for a particular incident.

Incident entries also contain a field to indicate the impact of an incident on traffic. The impact level may vary over the life of an incident; as a result, different entries for a single incident may have different impact levels. The incident impact options are: no impact, low impact, medium impact, high impact, and unknown impact. The incident record contains the highest impact level from the multiple incident entries. Similarly, incident entries contain lane location information (i.e., all lanes, left lanes, shoulder, gore area). Different entries for an incident may

have different values for the lanes location. The incident record contains the most severe lane impact of all the incident entries.

The derived incident records contain a field for the highway on which the incident occurred. Deriving this field was challenging because ODOT operators hand-enter the name of the primary route on which the incident occurred, causing inconsistencies in how highways are referred to. For example, "I-84" can be written a number of ways such as "I-84," "i84," "84," etc. In addition, one freeway in Portland has several names, adding more complexity. Further, the primary route is sometimes not labeled by the highway at all, but instead by the bridge name for that section of the highway. To address this issue, a list of alternative names for each highway was compiled and the "primary route" field in the incident entries is compared to the list of alternative names. When a match is found, it is possible to associate a highway with an incident. Incident entries also contain a field indicating the direction of the highway. Both of these pieces of information are used to create a "highwayid" field in the derived incident record. The "highwayid" links the incident record to highway and direction information in the PORTAL database; having this link makes it straightforward to associate the incident data with other PORTAL data.

INCIDENT DATA DISPLAY IN PORTAL

The PORTAL system provides a web-based interface for practitioners and researchers to access data. The PORTAL interface has been enhanced to display incident data. Figure 2 shows a plot of speeds on highway I-205 North on November 15, 2005. Traffic travels "upward" on the graph, from milepost 4 at the bottom of the graph to milepost 18 near the top. Green colors indicate freely flowing traffic; yellow and red indicate congestion. The figure shows normal rush hour congestion around mileposts 4-8 and 15-19 in the morning and evening peaks. In this plot, incident data is overlaid on the color map so that a user may understand that the reduced speeds shown starting shortly after noon are the result of an incident. The horizontal bar in the graph represents an incident that occurred near milepost 13 which began shortly after noon and ended shortly after 16:00; the text on the plot is the description of the incident location entered by the ODOT TMOC operators. It is clear that the slower traffic was due to this incident. Displaying incident data on speed plots can be used to better understand traffic patterns and distinguish non-recurrent congestion from recurrent congestion.

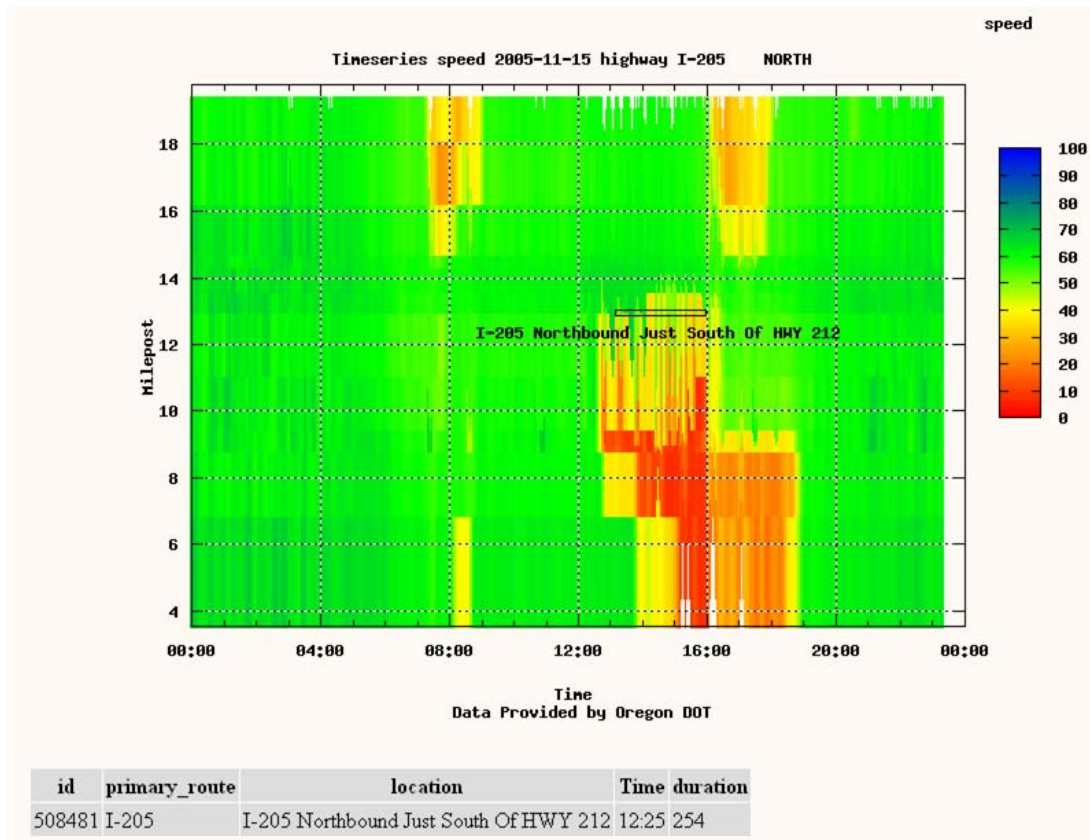


FIGURE 2 Display of incident location and duration in PORTAL.

ANALYSIS OF INCIDENT DATA

In this section, an analysis of the Portland area reported incident data from July 1999 through December 2005 is presented. The data have been analyzed in terms of incident type and lanes affected, in relation to weather, by time of day, and in relation to vehicle miles traveled; finally incident duration has been analyzed as a function of incident type and year. Now that the incident data is incorporated into the PORTAL system, the analysis can benefit from association and comparison with other parameters such as weather and vehicle miles traveled. The purpose of this analysis is to attempt to understand incident incidence in the Portland metropolitan area and to therefore improve incident management.

From July 1999 through December 2005, there were 128,886 located incidents in the Portland area. Figure 3A shows the percentage of incidents of different types. It is noted that over half (57%) of the incidents were stalls. The next most common types of incidents were crashes (15%) and debris (12%). Tows (such as abandoned vehicles), construction, congestion, other closures, and other incidents together accounted for 16% of all incidents. Figure 3B shows incidents broken down by the number of affected lanes for the year 2005 (recall that the number of affected lanes is the maximum number of lanes the incident blocked during its duration). A full 65% of incidents did not block any lanes; this observation is likely related to the high occurrence of stalls as shown in Figure 3A. 62% of the incidents occurring in 0 lanes are caused from stalls. Finally, it is noted that only 4% of incidents blocked two or more lanes.

Figure 4 breaks down incidents from July 1999 to December 2005 by affected lanes. A total of 44% of incidents affected only the right shoulder; this is consistent with a high percentage of incidents being stalls. Over 70% of stalls did no block any lanes. Further, it is revealed that more than half of the incidents had no affect on any lanes and only 36% of incidents were known to affect the travel lanes of the freeways.

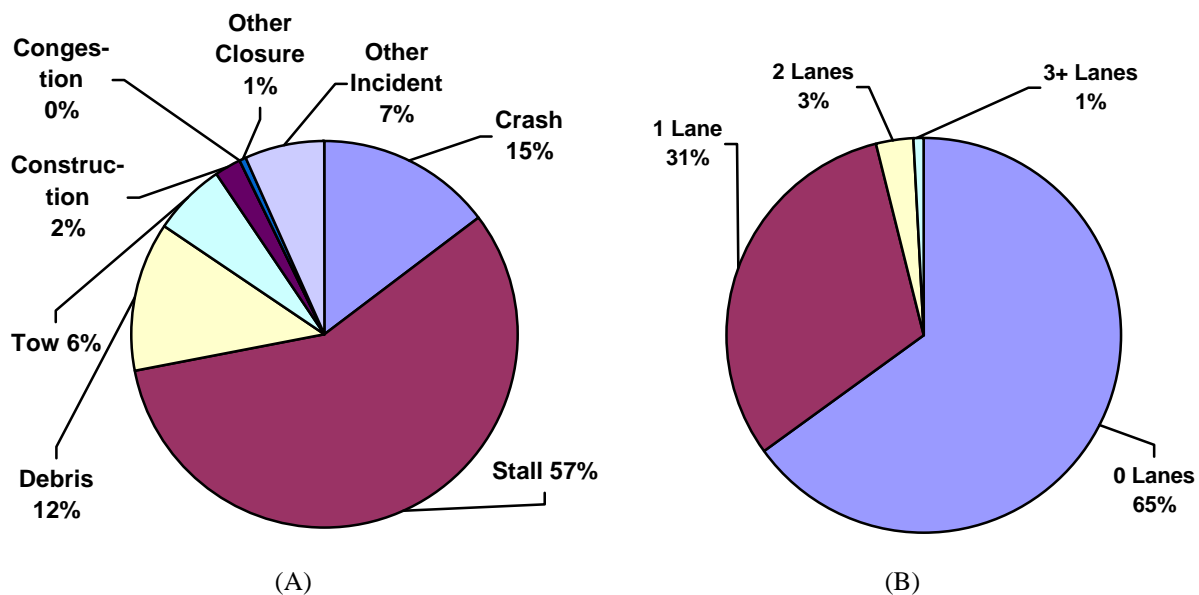


FIGURE 3 Incidents by Type (A) and Number of Lanes Affected (B) for 1999–2005 (N=128,886).

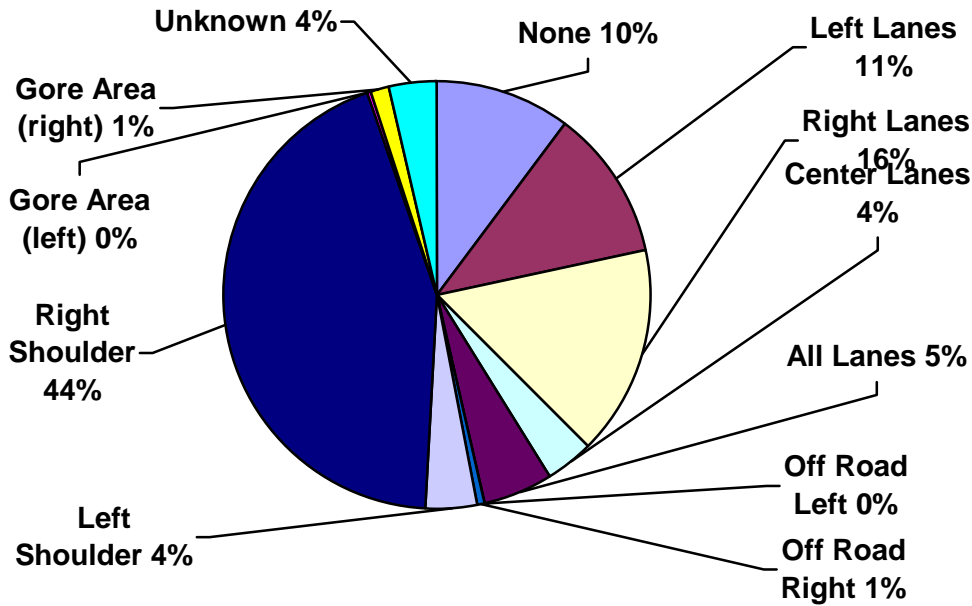
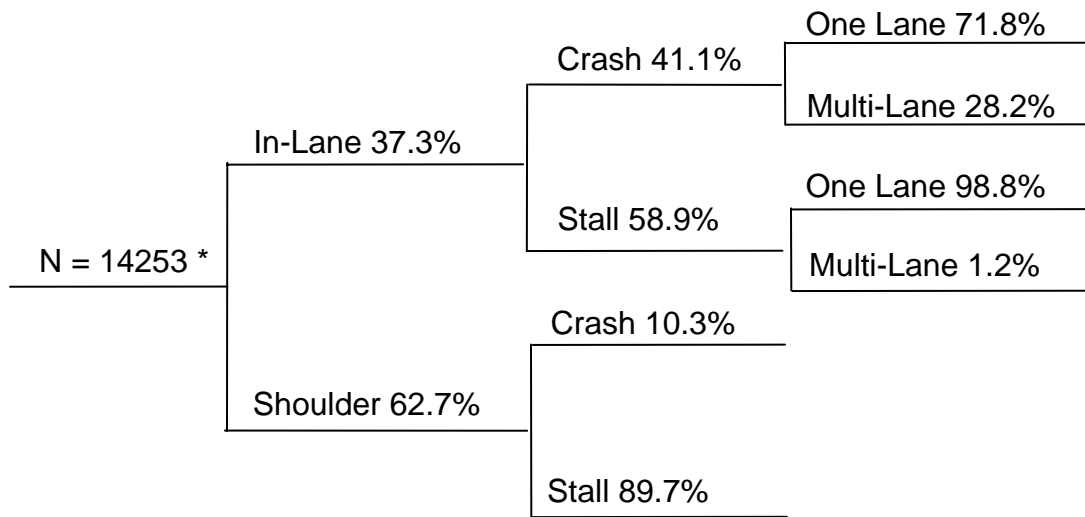


FIGURE 4 Incidents by location for 1999-2005 (N = 17,855).



* Incidents with complete lane location data

FIGURE 5 Incident tree 2005.

Figure 5 displays an incident tree separating crashes and stalls in 2005 by their lane location. This figure confirms that most crashes and stalls (62.7%) occur in shoulder areas and that of the crashes and stalls that occurred on the shoulder; most (89.7%) were stalls, as expected. Of crashes and stalls that occurred in lanes, 58.9% were stalls; this finding demonstrates that a substantial number of stalls do affect freeway travel lanes. Therefore, clearing stalls from of the mainline lanes should remain an important function of the incident management teams. It is important to note that almost all of the stalls that occurred in lanes (98.8%) affected only one lane. Crashes, as expected, had a higher impact on freeway travel; 28.2% of crashes in 2005 affected multiple lanes. Such incidents cause significant congestion and must be dealt with effectively.

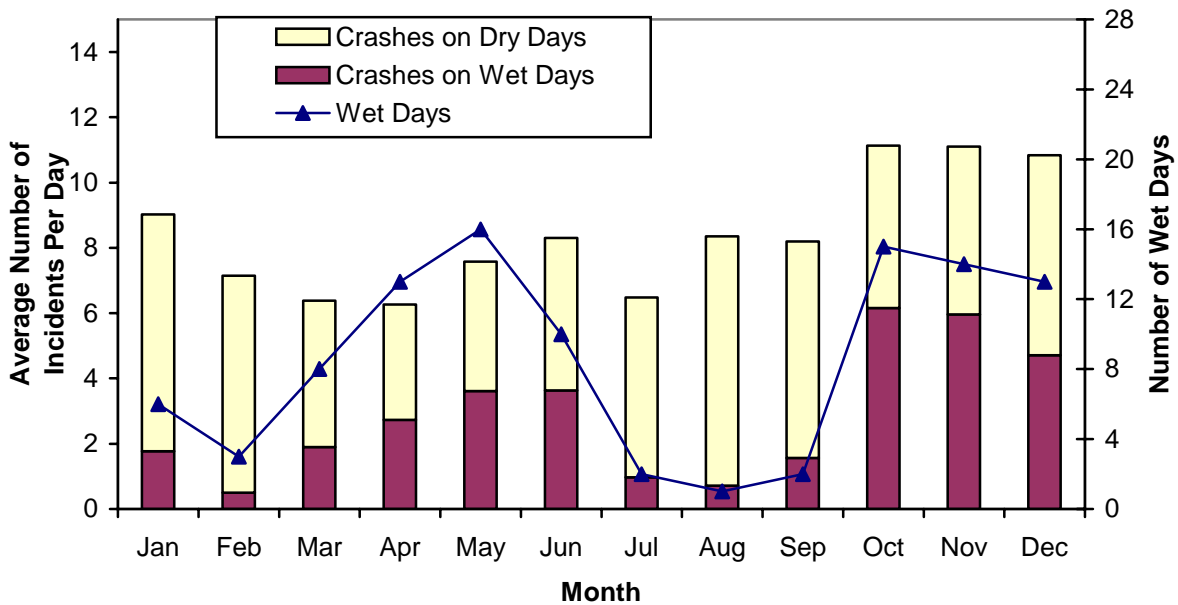


FIGURE 6 Crashes and precipitation (2005).

Figure 6 compares the number of crashes on wet and dry days to the number of wet days for each month in 2005. Weather data was obtained from PORTAL; days with total measured rainfall greater than .05 inch were considered wet days. In general, the highest number of crashes occurs during the rainy months; however, the month of May exhibits a large number of wet days, but fewer crashes than other rainy months. Also, during 2005, the months January through March were unusually dry in the Portland region.

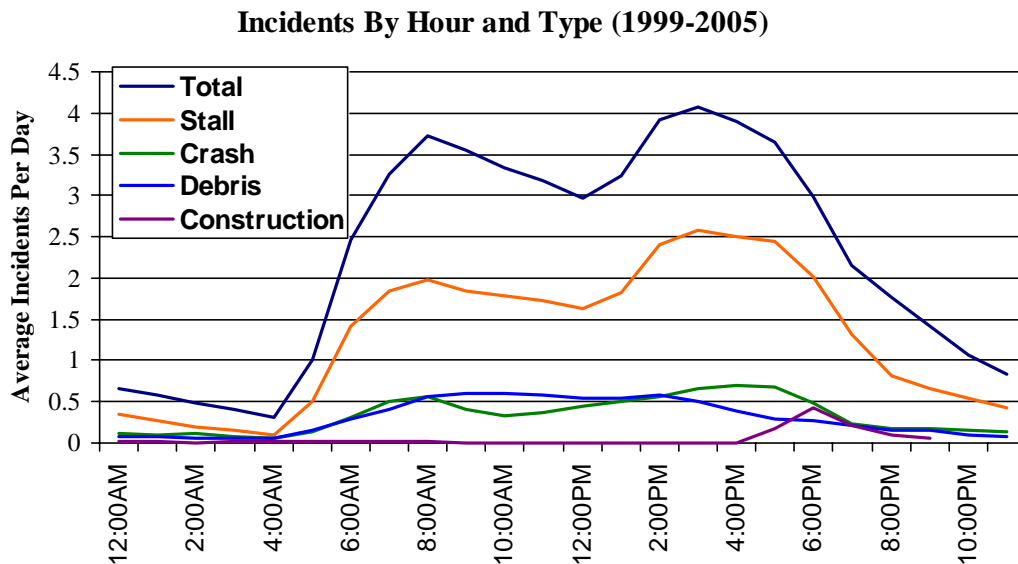


FIGURE 7 Incidents by hour and type (1999-2005).

It is also possible to analyze incidents by incident type and time of occurrence. The time an incident occurred is defined to be the hour in which an incident began. Figure 7 shows the occurrence of incidents by time of day. As, expected, incidents are more likely during peak periods. However, different types of incidents have higher and lower correlations with peak times. Stalls appear to be fairly highly correlated with peak periods. In contrast, incidents involving debris are more common during the day than at night, but do not appear to be highly correlated with peak periods. Finally, it is clear that there is a spike in construction during the evening period from 7PM to 11PM, showing how construction is normally done late at night. Statistics such as those shown in Figure 7 can be used to help understand what types of incident response teams need to be available during what time periods.

TABLE 2 Incident Statistics (1999-2005)

Highway ^a	Length (miles)	Incidents/Mile/Day	Monitored Length (miles)	Incidents/MVMT ^b
I-5 NB	25	0.31	23.02	7.5
I-5 SB	25	0.31	20.72	6.6
1-205 NB	25	0.18	20.07	4.6
1-205 SB	25	0.20	24.12	4.7
I-84 WB	65	0.07	10.53	8.8
I-84 EB	65	0.06	3.7	16.9
US 26 EB	52	0.05	13.33	7.6
US 26 WB	52	0.08	8.41	30.3
OR 217 NB	7	0.13	6.94	2.7
OR 217 SB	7	0.11	10.78	2.4
I-405 NB	4	0.30	0	-
I-405 SB	4	0.34	2.47	20.1

^a Selected highways; table includes located incidents only

^b 2005 incidents only, incidents reported on full length, MVMT calculated on monitored length

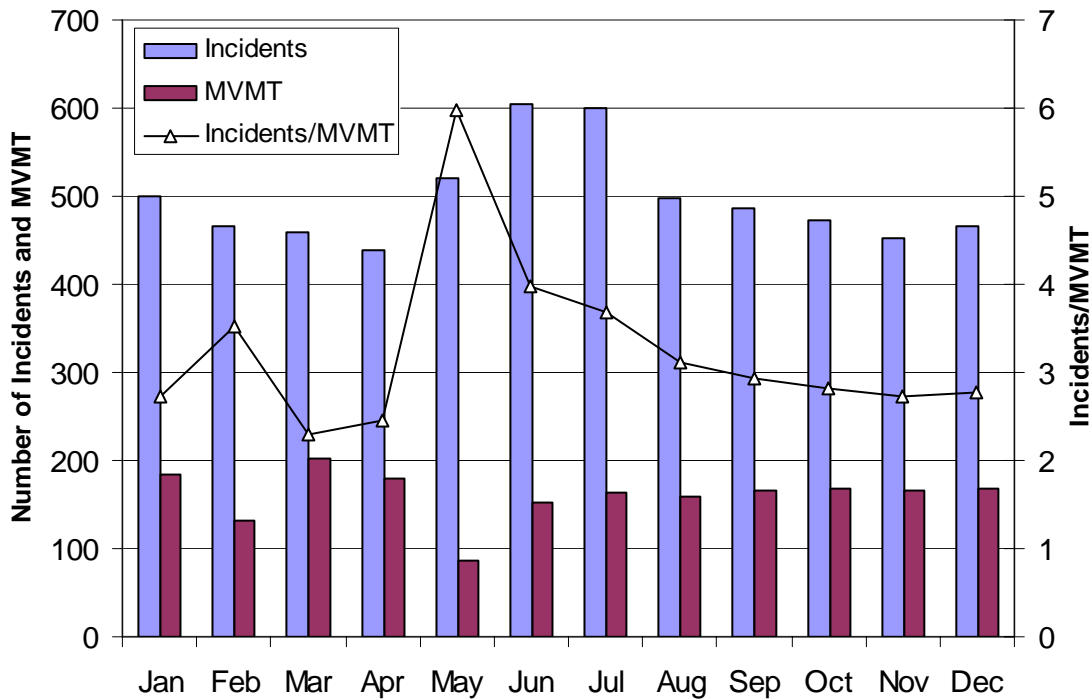


FIGURE 8 Incidents and MVMT by month (1999-2005).

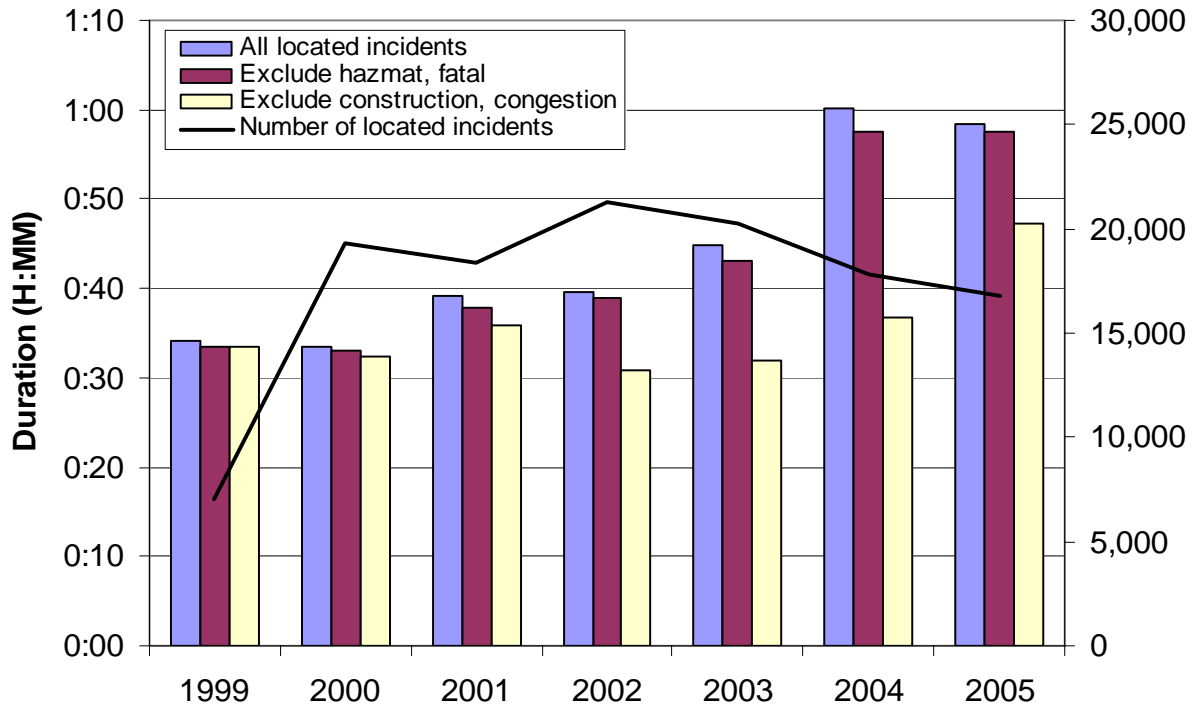


FIGURE 9 Average incident duration by year (July 1999 – Dec 2005).

An important parameter in incident analysis is to understand the rate of incidents on a highway; to do so, incident occurrence is related to vehicle miles traveled (VMT). Consider Table 2; in this table, highway length, incidents per mile per day, and incidents per million vehicle miles traveled (MVMT) are provided for selected highways in the Portland area. Highway I-5 appears to have a higher rate of incidents than Highway I-205. Highways I-5 and I-205 are the main north-south Interstate freeways that run through the Portland region. I-5 runs through downtown Portland, while I-205 skirts the eastern side of the city. Both routes are used by trucks and through vehicles. Northbound and southbound incident rates do not differ significantly for each highway.

The analysis of incident rates is continued in Figure 8 which shows incident rates by month over the period July 1999-December 2005. With the exception of the month of May (when several days' data were missing), there appears to be a fairly steady rate of incidents/MVMT throughout the year. Incidents/MVMT appears to be slightly higher in the summer than in the winter—perhaps due to summer vacation travel. While vehicle miles traveled remained steady between June and December, they were more varied from January to May.

The final portion of this analysis investigates incident duration. Incident duration is a very important parameter in measuring the health of an incident management system. Ideally incident duration stays relatively flat and does not increase significantly. Figure 9 shows incident duration for different types of incidents for the period July 1999 to December 2005 for the Portland region. The figure also shows the number of located incidents as a line plot. This illustrates that the raw number of incidents did not change much between 200 and 2005. The first set of bars shows the average duration for each year for all located incidents. There has been a strong upward trend in duration of located incidents since 1999. In order to attempt to understand this trend, Figure 10 illustrates a breakdown of incident duration by type of incident and year.

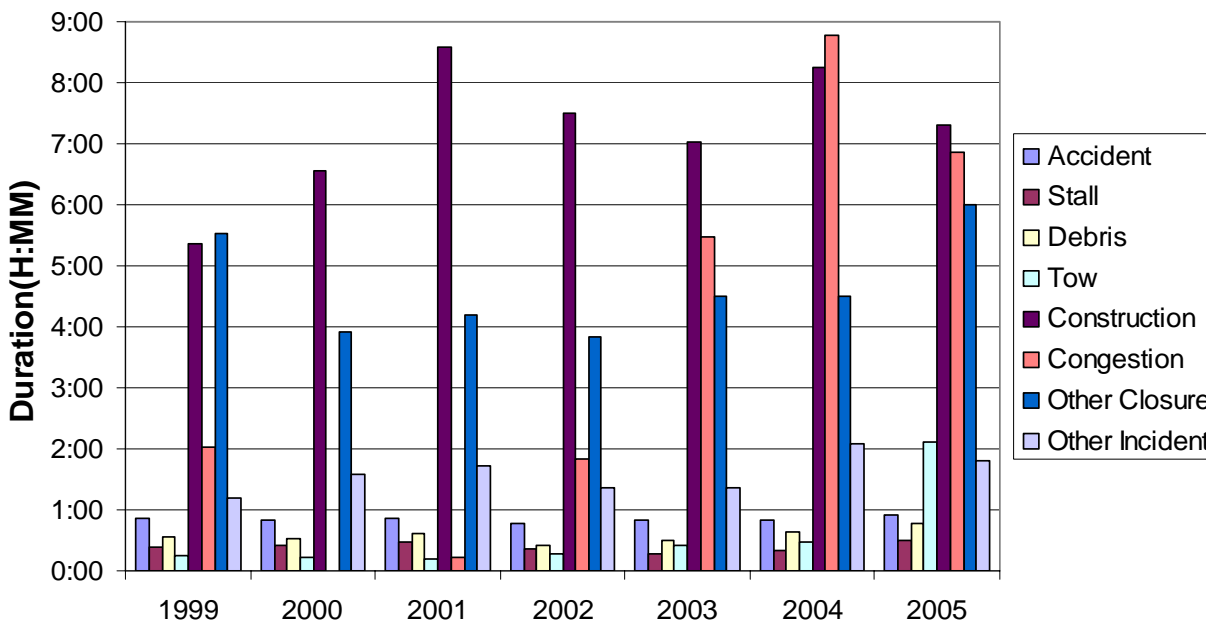


FIGURE 10 Average incident duration by incident type.

Figure 10 clearly shows that incident duration is dominated by Construction and Congestion. Congestion, in particular, shows an upward trend from 1999 to 2005. The on-line traffic information system TripCheck (www.tripcheck.com) displays the congestion information, so this is not indicative of an increase in congestion, just an increase in the desire to report congestion. To further understand the trends in incident duration, Figure 9 shows two additional sets of bars—one excluding fatal and hazardous materials crashes and one excluding congestion and construction. Fatal and hazardous materials crashes are excluded since those types of crashes tend to have unusually long durations and may skew the other statistics. Excluding hazardous materials and fatal crashes had a limited impact on the duration statistics; however, excluding congestion and construction, on the other hand, did have an impact on duration statistics. Without congestion and construction, durations are much shorter; however, one can still observe the upward trend in incident duration from 1999 to 2005. Figures 9 and 10 show that in understanding incident trends, it is important to differentiate between types of incidents.

Analysis of incident trends in time and space would be made easier if all incidents were geolocated. Figure 11A shows the percent of all reported incidents that were geolocated by incident impact level. There is a clear association in this graph which indicates that most medium and high impact incidents are geolocated, which enables their display on TripCheck and simplifies their analysis. Figure 11B shows an increasing trend in the number of lanes affected and geolocated incidents. In the future it would be useful if all incidents were geolocated but this is an effort that needs to be implemented within the TMOC. Further research on reasons that certain incident types are geolocated is ongoing.

CONCLUSIONS

This paper has described an automated data cleaning and aggregation process for incident data from the ODOT ATMS database. By automating the data cleaning, it is now possible to quickly produce incident records from ATMS database incident entries, which are stored in the PORTAL data archive. Having such incident records in PORTAL allows incident statistics to be generated with minimal effort. In addition, any PORTAL user can easily access the incidents for a particular freeway during a time interval so that traffic patterns can be compared with associated incident data. In particular, this research has demonstrated how incidents can be displayed on speed contour plots to allow users to distinguish between recurrent and non-recurrent congestion. Finally, since PORTAL archives weather data, weather conditions can be easily compared to incident records. This flexible, automatic incident cleaning and archive technology provides a new and useful tool to traffic practitioners and researchers.

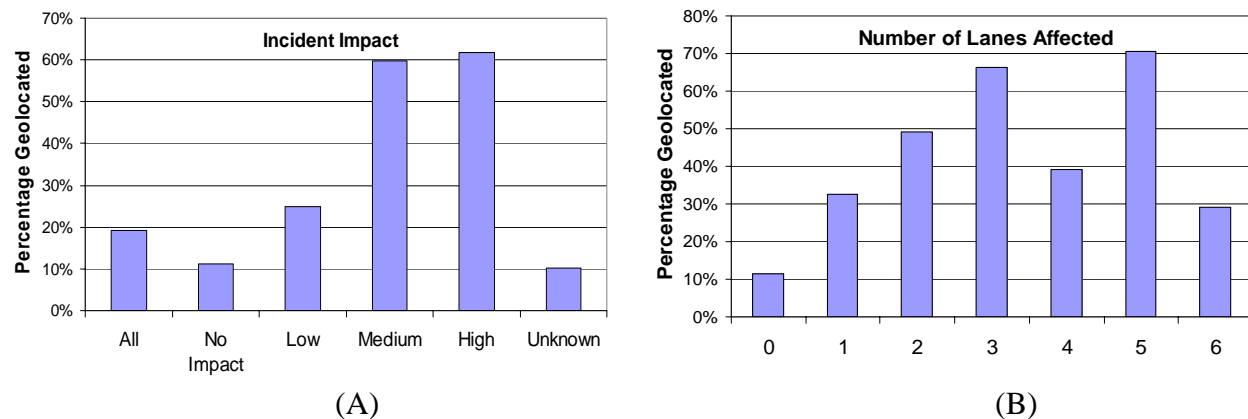


FIGURE 11 Percentage of geolocated incidents by incident impact and number of lanes affected.

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