ABSTRACT: TTI estimated the annual cost of incidents in Honolulu at $190 million and ranked it as the 12th most congested city in the nation, same as N.Y. City. These motivated a simulation study using INTEGRATION on the potential of incident management (IM) for Honolulu. A 2-freeway corridor was selected as the most promising area for fast-track IM implementation. The simulated incident on Moanalua Freeway increased total network travel times by 16% over the base case. The 60 minute incident increased travel times on the affected freeway by 82% during the incident queue peak. A 42 minute incident duration increased travel times by 40% which reveals the importance of quick response and clearance. Real time information to motorists caused diversion onto the H-1 Freeway saving 40% over the scenario with incident without IM. Diversion is feasible as long as sufficient capacity exists along alternate routes; ramp rather than main line capacity is often the limiting factor.

INTRODUCTION

It has been estimated that 60% of all congestion-induced delay is caused by incidents. While large mishaps on roadways and their effect on traffic usually are covered by the media, minor mishaps and stalls constitute a large majority of incident-induced delay. Minor incidents account for 65% of incident delay; major incidents account for the balance (1). The costs of incidents on the traveling public is staggering. Caltrans estimates that 200,000 vehicle-hours of delay are caused by incidents each day. This translates to a cost of over $1,000,000 daily. Nationally, one study estimated annual incident related delays at 1.29 billion vehicle-hours (2).

The TTI Mobility Study (3) estimates incidents cost Honolulu motorists $190 million annually. This takes into account delay as well as excess fuel costs. The same study ranked Honolulu roadways as the 12th most congested in the nation. A TSM study (4) recommended the implementation of an IM program, and the Oahu Congestion Management System (CMS) incorporates an IM program into the plan. Although there are several studies extolling the benefits of IM, there is a limited understanding of how IM will work in the greater Honolulu area. The ability of traffic software to fit and simulate a complex network and the airing of IM issues were primary objectives of this research. The following issues are discussed in this paper:

- Corridor selection and simplifications for simulation.
- Incident duration and motorist response to real-time information.
- Development of analysis scenarios.
• Sensitivity analysis with respect to incident duration.

CORRIDOR SELECTION, ASSUMPTIONS & SIMPLIFICATIONS

The Moanalua/H-1 Freeway corridor in Honolulu was selected from a set of three candidate corridors. This corridor is unique as it is the only location in which parallel freeway routes exist. As shown later, motorists exhibit a “freeway bias” according to which they are less likely to divert to non-freeway facilities when advised of downstream congestion. The selected corridor permits diversion to an alternate freeway. Furthermore, this corridor experiences heavy congestion with approximately 250,000 vehicles traversing it daily. Its supply and demand characteristics make it a prime candidate for IM implementation. The corridor shown in Figure 1 encompasses two major freeway routes and one major arterial Kamehameha Hwy. which changes into Nimitz Hwy. and runs underneath the H-1 Fwy. They form the northern border of the Honolulu International Airport. The Honolulu CBD is located approximately 3 km east of the merging point (Middle St. interchange, node 38) of the H-1 and Moanalua freeways.

Major assumptions in the modeling process included the following:
• A mobile phone number to report incidents is assumed to exist. (Mobile phone penetration in Honolulu is among the highest in the nation and several radio stations have free numbers for motorist reports). Because of the relatively severe impact of the simulated incident, phone reports are expected within one minute of occurrence.
• Trip postponement by commuters during this period is assumed to be negligible. This is a conservative assumption because real-time information allows motorists to delay trips. It also is a necessary assumption as actual numbers of delayed trips are hard to quantify.
• Specific assumptions on incident duration and driver diversion routes were made (see below).

Some simplifications also were necessary:
• Only the eastbound freeway network was modeled.
• All secondary roadways were ignored, but intersections with the arterials were maintained.
• Due to computer and software limitations, the 10:00-11:30 A.M. period was modeled.
• Due to the complexities of formulating an origin-destination matrix, only vehicles traversing the area reacted to real-time information. Vehicles with intermediate destinations were set to take the same off-ramp they would take if there were no incident.

The INTEGRATION software was chosen for this project because of its: 1) Integrated simulation of a freeway and surface street network; 2) Simulation of the effects of driver information on routing; 3) Flexibility in assigning origin-destination volumes and signal timings; and, 4) Detailed detector statistic outputs. INTEGRATION simulates driver response to real time information, e.g. HAR and VMS, and the subsequent effect on routing. This is desirable as such elements of ITS technology currently exist or are being incorporated into traffic systems in Honolulu. INTEGRATION allows flexibility in assigning origin-destination volumes as well as signal timings, and its user-defined detectors produce volumes, speeds, and occupancy data.
Durations used in Lindley’s report (2) were based on three previous studies of incidents conducted in the 1970s and early 1980s. Incident types were broken into seven categories and were further broken down into detection, response, and clearance times. An accident blocking one lane averaged 50 minutes with the vehicle remaining for 30 minutes on the travelway, and 20 for minutes on a shoulder. Giuliano compiled incident data for a 19 km section of the I-10 Freeway in Los Angeles (5). Average durations and standard deviations for twelve categories of incidents were calculated. Daytime accidents without injuries blocking one lane averaged 38 minutes while those with injuries averaged 54 minutes. Juge et al. (6) reported an average duration of 42 minutes for freeways in California in 1973-1974. Incidents in Chicago and Los Angeles had durations averaging 75 minutes for one lane blocking incidents, while those on the shoulder averaged 30 minutes (1). Also, in Los Angeles, it was found that durations of incidents blocking one lane decreased by 20% with incident response teams. In Chicago, estimated incident duration decreased by 33% with incident response teams and by 47% with response teams and service patrols. In 1993, Skabardonis et al. (7), collected data on the I-880 Freeway in Hayward, CA as part of a freeway service patrol evaluation. Clearance times for shoulder breakdowns and lane-blocking incidents averaged 7 and 20 minutes, respectively. Total duration for assisted breakdowns averaged 38 minutes while crashes averaged 41 minutes. Durations of breakdowns were reduced by 35% with service patrols, while mean incident durations decreased by 30%. Henk, et al. (8) analyzed incidents on San Antonio freeways in 1995. Response times, defined as time between detection and an officer arriving at the scene, averaged 26 minutes for minor and 24 for major incidents. The same TRANSGUIDE before/after analysis of response times to major and minor incidents found that time savings averaged 19 and 21% for minor and major accidents respectively. (They reported response time savings only, as opposed to total incident clearance times.)

Surveys conducted in Los Angeles (9) indicate 51.5% of commuters listen to traffic updates en-route and 43.1% of these change routes in response to en-route information. The same study found that drivers are much less likely to follow advice which takes them off the freeway, i.e., "freeway bias" (9). San Antonio TRANSGUIDE’s “before” surveys indicate 37% of commuters were notified of incidents through radio and/or television reports (8). Of these, 47% took an alternate route to avoid the incident. These numbers indicate that approximately 17% of motorists divert around major incidents without an IM program. Surveys taken one week after implementation of the IM program show a compliance rate of 33%. Several months after implementation the compliance rate was 80%. Surveys conducted in Boston and Seattle indicate that 30% to 40% of travelers frequently adjust travel patterns in response to real-time information (10). Of those responding to information, 45% change travel routes, 45% change travel times, and 10% change mode of travel.

Based on this information, the simulated incident blocked one lane of the Moanalua Freeway for 40 minutes. It was then assumed to remain on the shoulder for another 20 minutes. This study also assumed that 15% of the motorists reroute to avoid major incidents without an IM program, whereas 40% reroute if an IM program is in place.
ANALYSIS SCENARIOS & RESULTS

Existing or Base Case. The base case for this area consisted of normal east-bound conditions from 10:00 AM to 11:30 AM. The relatively long simulation time is necessary to ensure recovery times are adequate to alleviate congestion after the incident is cleared. The base case included multiple calibrations based on comparisons between simulated link volumes and historical volume counts to ensure the accuracy of replication of existing conditions; see (11).

Incident with no IM Program. This scenario introduced an incident. The incident is located on Moanalua Freeway roughly 1 km before the merge with the H-1 Fwy. (the merge is node 38 in Figure 1.) It is a two-car accident which blocks the right freeway lane for 40 minutes and remains on the shoulder for another 20 minutes. This scenario assumes that 15% of the drivers will divert in response to (currently available) incident radio broadcast information.

Incident with IM Program. The third scenario is similar to the second, but assumes 40% of drivers will divert in response to motorist information provided with VMS. Information provided to motorists is gathered from a freeway surveillance program associated with an IM program. A larger number of drivers have access to this information than in the previous case resulting in increased diversion. Duration, severity, and location of the incident remain the same.

In INTEGRATION, traffic assignment evoked deterministic minimum paths with allowances for error. This error permits the stochastic assignment of vehicles to competitive routes depending on the degree of error. The error term replicates driver uncertainty in knowledge of exact travel times by specifying the coefficient of variation for a normally distributed curve of travel time. Specification of incidents is done by both start and end times as well as link capacity reduction. An incident can affect roadway capacity differently over time which replicates the actual evolution of incidents. For example, a vehicle disablement occurring in the right lane would initially reduce capacity by about 50% on a 3-lane freeway (1). The link-node diagram which formed the simulated network is included in Figure 1.

The results show significant travel time savings with an IM program. Since diversion and reduction of incident duration are the two largest contributors to travel time savings with IM, the analysis focused on the effects of each. Providing real-time driver information in conjunction with an IM program contributes to a significant reduction in delays as shown in Tables 1 and 2.

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>TOTAL NETWORK TRAVEL TIME (vehicle-hours)</th>
<th>EXCESS TRAVEL TIME (vehicle-hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Conditions</td>
<td>2,915.2</td>
<td>-</td>
</tr>
<tr>
<td>No IM and 60 min. Incident (15% reroute)</td>
<td>3,374.4</td>
<td>459.2</td>
</tr>
<tr>
<td>60 min. Incident with IM (40% reroute)</td>
<td>3,189.5</td>
<td>274.3</td>
</tr>
</tbody>
</table>

Total travel times for the second scenario increase by 459.2 vehicle-hours or 15.7% over the base case with no incident. The maximum queue extends approximately 3.2 km back from the incident location. In contrast, incident induced delays decrease to 274.3 vehicle-hours with an IM program in place. This represents a savings of 184.9 vehicle-hours or 40% over the second scenario. The maximum queue extends approximately 2.4 km behind the incident.

Travel to central Honolulu from the divergence of the two freeways is approximately 12 km via Moanalua Freeway and 14.5 km via H-1 Freeway. As a result, in the base case, travel
times via Moanalua Freeway are approximately 1.5 minutes shorter than via the H-1 Freeway. Most vehicles passing through this corridor will take Moanalua rather than H-1 Freeway.

Under the second scenario travel times on H-1 Freeway remain close to those in the base case for most of the incident duration. During the final 30 minutes of the simulation, travel times increase by about a minute. This may seem counterintuitive. However, the release of the incident queue caused congestion at the H-1/Moanalua merge by the Middle St. interchange (node 38). During the incident, volumes on Moanalua Freeway at Middle St. were lower than normal. When the incident queue was released, volumes approached capacity. This, combined with the higher volumes on the H-1 Freeway due to diversion, exceed the capacity of the interchange. This phenomenon is similar to peak hour congestion at this interchange.

<table>
<thead>
<tr>
<th>Simulation Time</th>
<th>Free Flow</th>
<th>Base Case (no IM)</th>
<th>60 min. Incident (with IM)</th>
<th>60 min. Incident (with IM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:00 to 10:15</td>
<td>9.2</td>
<td>10.9</td>
<td>10.7</td>
<td>10.7</td>
</tr>
<tr>
<td>10:15 to 10:30</td>
<td>9.2</td>
<td>11.2</td>
<td>11.2</td>
<td>11.4</td>
</tr>
<tr>
<td>10:30 to 10:45</td>
<td>9.2</td>
<td>11.3</td>
<td>11.3</td>
<td>11.5</td>
</tr>
<tr>
<td>10:45 to 11:00</td>
<td>9.2</td>
<td>11.3</td>
<td>11.5</td>
<td>11.7</td>
</tr>
<tr>
<td>11:00 to 11:15</td>
<td>9.2</td>
<td>11.2</td>
<td>12.3</td>
<td>12.2</td>
</tr>
<tr>
<td>11:15 to 11:30</td>
<td>9.2</td>
<td>11.2</td>
<td>12.5</td>
<td>11.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Simulation Time</th>
<th>Free Flow</th>
<th>Base Case (no IM)</th>
<th>60 min. Incident (with IM)</th>
<th>60 min. Incident (with IM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:00 to 10:15</td>
<td>7.9</td>
<td>10.1</td>
<td>11.1</td>
<td>11.2</td>
</tr>
<tr>
<td>10:15 to 10:30</td>
<td>7.9</td>
<td>10.1</td>
<td>15.2</td>
<td>14.8</td>
</tr>
<tr>
<td>10:30 to 10:45</td>
<td>7.9</td>
<td>10.2</td>
<td>18.2</td>
<td>16.5</td>
</tr>
<tr>
<td>10:45 to 11:00</td>
<td>7.9</td>
<td>10.0</td>
<td>17.3</td>
<td>13.4</td>
</tr>
<tr>
<td>11:00 to 11:15</td>
<td>7.9</td>
<td>10.2</td>
<td>13.8</td>
<td>11.2</td>
</tr>
<tr>
<td>11:15 to 11:30</td>
<td>7.9</td>
<td>10.2</td>
<td>13.0</td>
<td>10.9</td>
</tr>
</tbody>
</table>

Travel times along Moanalua Freeway increase dramatically due to the incident. Peak delays of 8 minutes over the existing case occur during the incident. This is a substantial delay considering that the incident has been modeled with off-peak volumes. Travel times decrease once the incident queue clears with delays attributed to excess volumes approaching the interchange.

The third scenario provides real-time information to drivers with variable message signs. Travel times along the H-1 Freeway were about 10 to 20 seconds higher than the previous case. Increased diversion caused this increase. The maximum diversion onto H-1 Freeway was equal to about 500 vehicles/hour during the incident. Since there was ample unused capacity on this route, travel times did not change. Once the incident was cleared, travel times returned to normal faster in this scenario because diversion decreased the incident-generated queue.

Travel times along Moanalua Freeway decreased in response to diversion. Average travel times were approximately 90 seconds less than in the previous case during the peak of the incident. Travel times returned to normal faster than in the previous case because the incident queue was 25% shorter (2.4 vs. 3.2 km). Queues at the merge of the freeways were shorter as.
well. Some congestion occurred at the merge of the two freeways, but the duration was much shorter than in the scenario without IM.

Several links were analyzed in order to determine the amount of vehicles diverting in response to incidents. Link 17, which is the H-1 Freeway just past the divergence with Moanalua Freeway, Link 28 which is on the H-1 Freeway before the Nimitz Hwy. and Dillingham Blvd. off-ramps, Link 13 which is the Moanalua Freeway segment entering the Middle St. merge, and Link 32 which is the H-1 Freeway segment entering the Middle St. merge, are all analyzed in 5-minute intervals. These links can be seen in Figure 1. Loop detector stations were simulated on these links. Due to space limitations, only information on Links 13 and 32 is presented below.

Base volumes on link 13 average approximately 4,200 vph. Comparing Scenario 2 with the base case shows a decrease in demand of as much as 20% during the incident. Part of this decrease is due to diversion. The rest is attributed to the incident causing a reduction in upstream capacity. Once the incident is cleared and capacity is restored, the resulting queue discharge increases volumes by 20% over normal. Scenario 3 includes an IM program. Comparing the resultant volumes with the base case shows a 23% decrease in demand on this link. The higher reduction in demand is caused by greater diversion onto H-1 Freeway. Similarly, the lower increase in demand as the incident queue is cleared is the result of diversion. Average travel speeds are under the speed limit (90 km/hr) even during non-peak hours. During the incident and past the incident site, speeds increase by 2 or 3 km/hr due to the decreased volume. Analyzing the second scenario shows a considerable drop in speed (from about 68 km/hr to 18-22 km/hr) as the incident queue clears.

Volumes on Link 32 average approximately 1,500 vph in the base case scenario. In Scenario 2, volumes increase by approximately 20% during the incident queue peak. Overall, an average of 1,700 vph pass this detector station. In Scenario 3, this volume increases to 1,850 vph due to diversion attributed to an IM program. During the incident peak, average hourly volumes increase to approximately 2,300 vph. In the case of an incident without an IM program, average speeds decrease by 3 or 5 km/hr during the peak diversion. This is associated with the 20% increase in volumes. Speeds drop further to 6 to 8 km/hr in Scenario 3. The average speed, however, is still 77 km/hr during diversion.

SENSITIVITY ANALYSIS WITH RESPECT TO INCIDENT DURATION

A range of durations were investigated both in response to the uncertainty in determining actual response savings with an IM program, and in an effort to assess the improvement resulting by the potential reduction of incident duration due to IM. Specifically, the original 60 minute incident was reduced in 5% intervals up to 30% or 42 minutes.

To develop a relationship between network travel times and incident durations, the above analysis was conducted using various percentages of random departures. This was done in order to both ensure an adequate number of observations and to account for a broad spectrum of volume distribution due to daily, seasonal, etc. variation. The percentage of random departures were varied from 0% (used in the previous analysis) to 100% in increments of 20%. An exponential curve, with an R² value of 0.469 (linearized), fit the data points best. Consistent with literature sources on actual IM projects, a clearly positive relationship was revealed:
Equation (1) is location-specific. TTT is total travel time in vehicle-hours and ID is incident duration in minutes. Travel times on the affected freeway ranged from a high of 16.5 minutes for a 60 minute incident to a low of 13.4 minutes for a 42 minute incident, a 61.8% and 21.6% increase over normal conditions, respectively. In other words, an 18 minute increase in incident duration (from 42 to 60 minutes) caused a 40% increase in average travel time. This underlines the importance of quick response and clearance.

CONCLUSIONS

Provision of real-time driver information with an IM Program contributes to a significant reduction of incident induced delays. The simulated incident increases total network travel times by 16% over the base case. Real time information provided to motorists encourages diversion onto the H-1 Freeway saving 40% over the scenario without IM.

The simulation confirmed lessons learned from the literature review. As shown in this study, warning drivers of problems downstream, in conjunction with an IM program, prevents vehicles from adding to the incident queue. This decreases delays and travel times. Furthermore, recovery is accelerated as fewer vehicles accumulate in the incident queue.

Diversion is feasible as long as sufficient capacity exists along alternate routes. While physical capacity of mainlines is critical, ramp capacity is often the limiting factor. This study shows that the merge of Moanalua/H-1 freeways is the critical location on the network. While the merging area sustains diversion volumes used in this study, larger volumes may cause excess congestion to form.

REFERENCES


![FIGURE 1. The link-and-node diagram for INTEGRATION simulation.](image-url)