Using Simulation to Test Traffic Incident Management Strategies

The Benefits of Preplanning

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This study tested a dynamic traffic assignment model as a tool for preplanning strategies for managing major freeway incidents. Incidents of various scales and durations were modeled in the northern Chicago, Illinois, highway network, and the impacts of incidents and response actions were measured in lane mile hours of highway links at Level of Service F and spread of congestion to alternate routes around the incident. It was found that the best response action to a given incident scenario was not necessarily intuitive and that implementing the wrong response could worsen congestion on the directly impacted freeway and its surrounding highway network. The simulation model showed that a full closure of the freeway caused congestion to spread to alternate parallel routes around the simulated incident. An event of this scale constitutes a major disruption that may warrant handing off traffic control authority from first responders to a corridor or regional traffic management center. Major arterials accessible from the impacted freeway sometimes need increased capacity to provide access to less congested parallel alternate routes during incidents. The simulation model showed that congestion increases with delayed response, underscoring the benefits of preplanning to speed the implementation of effective incident response actions. Regression analysis using data generated by the simulation demonstrates that incident scale and duration are statistically significant predictors of lane mile hours of congestion in the zone near the incident and on the expressway.

This study tested dynamic traffic assignment (DTA) simulation as a tool for preplanning the best possible incident response actions and identifying the benefits of preplanning. Congestion due to a simulated incident was monitored on the impacted freeway and on alternate routes around the simulated incident to explore traffic control implications of incidents of different scales and durations.

This study explored two hypotheses. The first is that preplanning may speed the implementation of more effective incident response actions. The second is that major disruptions to the highway network will cause traffic to spread to the point that traffic control responsibilities become too great for first responders to handle locally, and in these cases congestion could be better mitigated by handing off traffic control authority to a traffic management center (TMC) or other transportation agency with broader geographic perspective and control authority.

METHODOLOGY

DTA Simulation

This study used Visual Interactive System for Transport Algorithms (VISTA), a DTA tool developed at Northwestern University under the direction of Athanasis Ziliaskopolous, to test alternate routing and traffic management schemes around simulated incidents of various scales and durations on I-94, the busy Edens Expressway in the Chicago, Illinois, metropolitan area (*1*). DTA is particularly appropriate for modeling highway incidents because the timing of incident occurrence, management, and recovery and the use of alternate routes are critical to roadway performance and driver experience. Static methods based on average daily traffic will fail to identify and test the short-term control actions necessary to manage nonrecurring events such as crashes and infrastructure failures.

VISTA generates spatial–temporal traffic flows instead of static traffic assignment for all origin–destination (O-D) trips loaded into the network. Vehicles are assigned in a user–equilibrium fashion, where no vehicle can change its path and save time. The implicit assumption underlying this modeling approach is that drivers have perfect information and can divert to alternate paths if it reduces travel time. The routes of individual vehicles are calculated iteratively by using time-dependent shortest path (TDSP) algorithms based on deterministic link travel times. The TDSP algorithms do not include a stochastic element to account for immeasurable driver preferences such as comfort and scenery. Vehicles advance along links through the network using Daganzo's cell transmission model (*2*).

Input Data

VISTA requires data inputs including O-D trip matrices, a network of highway links and nodes, and controls for intersections. Most of the data come from the local transportation metropolitan planning organization, the Chicago Area Transportation Study (CATS).

Network Data

The highway network of links and nodes was taken from the CATS 1999 Master Roadway Network, which covers the six-county Chicago metropolitan area. A smaller portion of this network was extracted

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Transportation Research Record: Journal of the Transportation Research Board, No. 1923, Transportation Research Board of the National Academies, Washington, D.C., 2005, pp. 82–90.

to speed computations while still covering a substantial geographic area surrounding the modeled incident. It was assumed that impacts far away from the incident would be negligible.

Control Data

The locations of signals and other controls came from the CATS 2001 Signal Inventory. Graduate research assistants at Northwestern University generated most signal phasing and timing plans using algorithms to calculate cycle and green phase times. The cycle time was set to allow the traffic volume on all approaches to pass through the signalized intersection, which does not necessarily minimize vehicle delay. This was changed at 11 selected traffic signals near the simulated incident by manually recalculating the cycle times using Webster's equations for minimizing delay (*3*). The green time was allocated based on critical approach volumes obtained from the simulation.

Demand Data

Demand data were developed in the form of two (O-D) trip matrices: the CATS automobile O-D trip data, 2002 forecasts, and the CATS truck O-D trip data, 2002 forecasts. The O-D matrices indicated that 1,672,283 million automobile trips take place within or pass through the zones of the selected highway network in a typical 24-hour day. To save computational time, only the 3 afternoon hours with the highest demand were modeled. These 3 hours contain 269,440 trips in the CATS data and were assumed to be from 4 p.m. to 7 p.m. on a typical weekday. Running VISTA with this demand showed no congestion on I-94 in the no-incident, base-case scenario and little impact on travel patterns due to modeled incidents. This is inconsistent with recurring congestion on the link of interest, observable through the Gary–Chicago–Milwaukee (GCM) corridor traveler information website (*4*). Therefore, the O-D trip table was scaled up to include 388,976 trips in the 3-hour period. The calibration aims to derive a common, and useful, platform for the comparison of simulation runs of different incident scenarios. Within this context, the escalation of trips is acceptable, but the results may not be adequate for practical use.

For validation purposes, the average travel time data generated by VISTA in the base-case scenario was compared with census journey-to-work data. The average travel time in the modeled network is expected to be somewhat shorter than the average work trip reported by the census because shopping trips, generally closer to home than work trips, are included. The mean travel time to work in the year 2000 census was 31.5 minutes for the Chicago Primary Metropolitan Statistical Area (*5*). The average travel time in the simulated network became 31.19 minutes for all vehicle types and 30.93 minutes for passenger vehicles. This is slightly lower than the 31.5 minutes reported by the census and appears to be reasonable. Local streets not modeled in the network are likely to further alleviate some congestion shown by simulation results.

The percentage of the total demand entering the network in each time interval is called the demand profile and is specified by the VISTA user. The demand profile used in this study is presented in Figure 1. It was not based on actual traffic flows but was designed to simulate steady growth in traffic to a peak period of demand within the highest demand period of the day and then a somewhat steeper decline than the buildup.

Measuring Congestion

One base-case scenario and nine incident scenarios were examined in the simulation. The incident scenarios have a scale of one, two, or all three lanes closed for 1, 2, or 3 hours in the 3-hour simulation. Incident response actions involve closing one, two, or three entrance ramps to the northbound expressway upstream of the incident. The incident location is on the northbound Edens Expressway (I-94) between Willow Road and Tower Road in the Chicago suburb of Northfield, Illinois. The effects of the incident scenarios and response actions were measured both in lane mile hours at Level of Service (LOS) F and by the spread of congestion to alternate routes around the incident.

Lane mile hours were measured by converting the average vehicle density over a 5-minute period to the LOS. A density greater than 45 vehicles per mile (28 vehicles per kilometer) indicates LOS F, or congested traffic flow. The total amount of time a link performs at LOS F during the simulation is summed and then multiplied by the number of lanes on the link and the length of the link (in miles) to get a measure of lane mile hours. This unit was developed independently for this study, but it also has been used by the Florida Department of Transportation as a performance measure for highways (*6*). Here it was used to evaluate the impacts of incident scale and duration on congestion, to identify the best response actions to minimize congestion in various locations, and to determine which alternate routes remain uncongested during an incident. It was also used as the depen-

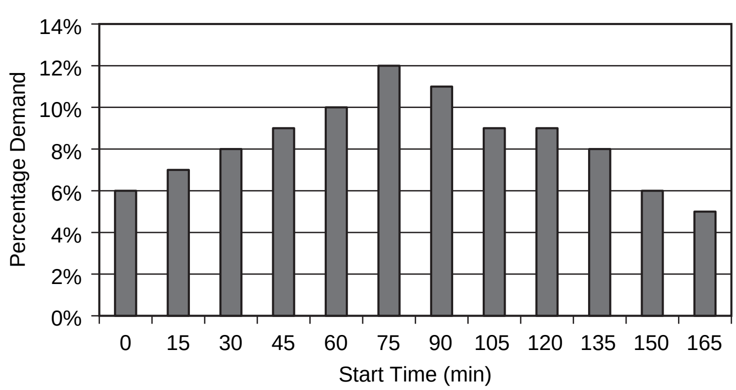

FIGURE 1 Demand profile.

dent variable in a linear regression to integrate the results of the experiments and test the statistical significance of the effect of scale, duration, and response type on congestion. The relationships between scale, duration, and the spread of congestion were used to define a major disruption warranting a higher level of network control.

Geographic Definitions

Congestion was quantified and measured for each incident and response scenario on 46 links near the incident, referred to as the indirectly impacted zone. These links comprise the subnetwork impacted by the incident and the resulting traffic diversions. They are highlighted in Figure 2 as part of an alternate route or as a major arterial perpendicular to the expressway. Alternate routes were identified as the major parallel routes closest to the expressway and were added to the indirectly impacted zone until an uncongested route was found in the worst-case incident scenario, three lanes closed for 3 hours. Characteristics of the links, such as length, number of lanes, and the routes to which they are assigned, are presented in Table 1. Some links are a part of more than one route but were not double counted when congestion was measured. Within the indirectly impacted zone is the directly impacted zone, defined as the expressway itself, the northbound Edens Expressway from Oakton Street on the south to Dundee

FIGURE 2 Alternate route map.

TABLE 1 Links Monitored for Congestion

Route	Name	Direction	From	To	Length (ft)	Lanes
I-94—Edens Expressway	I-94	NB	Oakton	Dempster	4792	3
	I-94	NB	Dempster	Old Orchard	8572	3
	I-94	NB	Old Orchard	Lake	6395	3
	I-94	NB	Lake	Skokie	3401	3
	I-94	NB	Skokie	Willow	5860	3
	I-94	NB	Willow	Tower	5903	3
	I-94	NB	Tower	Dundee	7467	3
Frontage Road alternate	Ramp	WB	I-94 NB	Willow WB	707	1
	Willow	WB	NB Ramp	SB Ramp	900	2
	Willow	WB	SB Ramp	Central	300	2
	Frontage	NB	Willow	Tower	5738	1
	Tower	EB	Frontage	NB Ramp	900	1
	Ramp	NB	Tower	I-94 NB	707	1
Forestway Drive alternate	Ramp	EB	I-94 NB	Willow EB	640	1
	Willow	EB	Ramp	Lagoon	1400	2
	Willow	EB	Lagoon	Forestway	1200	2
	Forestway	NB	Willow	Tower	6082	1
	Tower	WB	Forestway	Ramp	2302	1
	Ramp	NB	Tower	I-94 NB	707	1
Green Bay Road alternate	Green Bay	NB	Winnetka	Church	2282	2
	Green Bay	NB	Church	Willow	781	2
	Green Bay	NB	Willow	Elm	3106	2
	Green Bay	NB	Elm	Tower	3138	2
	Tower	WB	Green Bay	Hibbard	2400	1
	Tower	WB	Hibbard	Greenwood	2601	1
	Tower	WB	Greenwood	Forestway	1503	1
	Tower	WB	Forestway	Ramp	2302	1
	Ramp	NB	Tower	I-94 NB	707	1
Hibbard Road alternate	Hibbard	NB	Lake	Illinois	1900	1
	Hibbard	NB	Illinois	Winnetka	3300	1
	Hibbard	NB	Winnetka	Willow	2700	1
	Hibbard	NB	Willow	Elm	2600	1
	Hibbard	NB	Elm	Tower	2601	1
Sunset Ridge alternate	Sunset Ridge	NB	Willow	Driftwood	5700	1
	Sunset Ridge	NB	Driftwood	Happ	900	1
	Sunset Ridge	NB	Happ	Skokie	4300	1
	Skokie	NB	Sunset Ridge	Dundee	1118	2
Willow Road WB	Ramp	WB	I-94 NB	Willow WB	707	1
	Willow	WB	NB Ramp	SB Ramp	900	2
	Willow	WB	SB Ramp	Central	300	2
	Willow	WB	Central	Old Willow	500	2
	Willow	WB	Old Willow	Wagner Rd	2000	1
	Willow	WB	Wagner	Old Willow	2302	1
	Willow	WB	Old Willow	Sunset Ridge	800	1
Lake Ave EB	Ramp	EB	I-94 NB	Lake EB	583	1
	Lake	EB	Ramp	Skokie	600	2
	Lake	EB	Skokie	Hibbard	700	2
	Lake	EB	Hibbard	Locust	2601	2
Lake Ave WB	Lake	WB	NB Ramp	SB Ramp	1300	2
	Lake	WB	SB Ramp	Harms	2700	2
	Lake	WB	Harms	Wagner	2500	2
	Lake	WB	Wagner	Sunset Ridge	2600	2

NB = northbound; SB = southbound; EB = eastbound; and WB = westbound.

Road on the north. These two zones are the locations where first responders and transportation officials would be expected to attempt to minimize congestion.

Response Actions

After retiming selected traffic signals, three response actions involving ramp closures were tested for each of the nine incident scenarios, resulting in 27 more scenarios. Closure 1 eliminated the first entrance ramp upstream of the incident, from Skokie Boulevard and Lake Avenue to the northbound Edens Expressway. Closure 2 removed access from the Skokie Boulevard ramp in addition to the second entrance ramp upstream of the incident, from Old Orchard Road to I-94 north. In Closure 3, the third northbound on ramp upstream of the incident at Dempster Street was also closed. Reducing upstream demand entering the freeway during an incident is expected to result in less queuing on the expressway and therefore less congestion. Closing the ramps is intended to be analogous to ramp metering, but during extremely congested traffic conditions (i.e., an incident) the ramp would be entirely shut down instead of metered. Studies of ramp metering in California and Minnesota found that benefits of ramp metering outweigh the costs (*7, 8*).

RESULTS

Best Responses by Incident Type

It is interesting to compare best incident management responses for the freeway (directly impacted zone) with the best actions for the larger surrounding network (indirectly impacted zone), which includes logical alternate routes. The simplest, easiest, and perhaps most common incident management strategy focuses only on the impacted roadway and ignores spillover effects onto the adjacent highway network. Ignoring the spillover effect would likely lead to more modest, localized responses that do not require interjurisdictional collaboration.

Table 2 presents the total lane mile hours of congestion measured in the indirectly impacted zone by type of incident and response action. Table 3 presents similar results for the directly impacted zone. The duration of the incident is indicated in the rows and ranges from 0 hours (in the base-case scenario) to 3 hours. The scale of the incident and the response actions tested are indicated in the columns of the tables, on a scale ranging from zero lanes closed (in the base-case scenario) to a full three-lane closure. Response actions close zero, one, two, or three entrance ramps immediately upstream of the incident. The lowest estimated congestion level for an incident type is highlighted in bold in Tables 2 and 3. Table 4 presents a list of best response actions by incident type but does not give numeric values of congestion.

Indirectly Impacted Zone

The simulation, using congestion levels in the indirectly impacted zone as a criterion, shows that the best response if one or two lanes are closed is not to close upstream ramps. For example, if an incident closing one lane of the expressway is expected to last for 1 hour, then closing no entrance ramps is predicted to result in 14.87 lane mi h (23.93 lane km h) of congestion in the indirectly impacted zone. Closing one upstream entrance ramp results in 15.93 lane mi h (25.64 lane km h) of congestion, closing two ramps results in 15.96 lane mi h (25.68 lane km h), and closing three results in 16.21 lane mi h (26.09 lane km h).

When all three lanes on the expressway are closed to through traffic, congestion becomes significant enough to warrant limiting access to the highway. The best response for an incident blocking three lanes for 1 hour is to close three upstream entrance ramps. If three lanes are closed for 2 or 3 hours, closing two upstream ramps reduces congestion the most. It makes sense that more benefits are realized from ramp closings during a severe incident than during minor incidents, just as ramp metering benefits a congested freeway but not a free-flowing one. However, the incident scenario closing three lanes for only 1 hour does not fit this logic. Short-duration incidents should not benefit more from closing upstream entrance ramps than longer duration incidents of the same scale. Poor model convergence is likely to blame for the anomaly. When a response is warranted, closing the upstream ramps on average saves 2.58 lane mi h (4.15 lane km h) of congestion—an 11% reduction compared with doing nothing.

Directly Impacted Zone

The simulations showed that the best responses in the directly impacted zone differ somewhat from the best responses in the indirectly impacted zone. The expected incident duration plays a larger role in determining the best response action for the directly impacted zone. If any number of lanes are expected to be closed for 1 hour, or if one lane is expected to be closed for 2 hours, the best response to minimize congestion in the directly impacted zone is to not implement any upstream entrance ramp closures. If two lanes are closed for 3 hours, all three ramps from Skokie Road, Old Orchard Road, and Dempster Street should be closed. For all other scenarios with the expressway

TABLE 2 Congestion in Indirectly Impacted Zone by Incident Type and Response Action

Total Congestion (lane mi h)	**Scale (Lanes Closed)**													
Response Action	Base Case	Close No Ramps			Close 1 Ramp			Close 2 Ramps			Close 3 Ramps			
Duration (h)	**0**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	
0	4.80													
1		**14.87**	**15.76**	17.30	15.93	16.46	18.72	15.96	15.86	17.60	16.21	15.77	**16.71**	
2		**15.30**	**15.66**	25.38	17.47	17.67	22.81	17.69	17.42	**20.65**	17.84	17.44	23.02	
3		**15.70**	**15.91**	25.69	18.32	18.50	25.25	17.80	18.51	**23.27**	17.85	18.02	24.20	

TABLE 3 Congestion in Directly Impacted Zone by Incident Type and Response Action

Edens Congestion (lane mi h)	**Scale (Lanes Closed)**												
Response Action	Base Case	Close No Ramps			Close 1 Ramp			Close 2 Ramps			Close 3 Ramps		
Duration (h)	**0**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
0	0.61												
1		**8.50**	**9.31**	**7.28**	9.54	9.99	9.31	9.54	9.31	8.90	9.76	9.31	8.19
2		**8.90**	9.31	9.46	9.31	9.72	9.31	9.31	**8.90**	**7.38**	9.31	8.90	9.54
3		9.31	9.54	9.46	9.76	9.94	9.31	**8.90**	9.31	**8.09**	8.90	**8.90**	9.31

TABLE 4 Best Responses to Minimize Congestion

Scale (Lanes Closed)	Duration (h)	Area of Interest	Best Response
1	1	Directly impacted zone	Close nothing
		Indirectly impacted zone	Close nothing
1	2	Directly impacted zone	Close nothing
		Indirectly impacted zone	Close nothing
1	3	Directly impacted zone	Close 2 upstream ramps
		Indirectly impacted zone	Close nothing
2	1	Directly impacted zone	Close nothing
		Indirectly impacted zone	Close nothing
2	2	Directly impacted zone	Close 2 upstream ramps
		Indirectly impacted zone	Close nothing
2	3	Directly impacted zone	Close 3 upstream ramps
		Indirectly impacted zone	Close nothing
3	1	Directly impacted zone	Close nothing
		Indirectly impacted zone	Close 3 upstream ramps
3	2	Directly impacted zone	Close 2 upstream ramps
		Indirectly impacted zone	Close 2 upstream ramps
3	3	Directly impacted zone	Close 2 upstream ramps
		Indirectly impacted zone	Close 2 upstream ramps

closed for 2 or 3 hours, it is best to close two upstream ramps. Again there is one anomaly; the incident with two lanes closed for 3 hours does not fit the pattern of best closures by incident type. This is also probably due to poor simulation convergence. When a response is warranted, closing the upstream ramps saves an average of 0.98 lane mi h (1.58 lane km h) of congestion on the expressway compared with doing nothing—a 10% reduction.

Spread of Congestion

As motorists experience delays due to incident-related congestion on their normal routes, some will divert around the freeway incident, eventually causing alternate routes to become congested. Five alternate routes parallel to the Edens Expressway between Willow Road and Tower Road were defined: Forestway Drive, Frontage Road, Green Bay Road, Hibbard Road, and Sunset Ridge Road. Three major perpendicular routes provide access from the expressway to the parallel alternate routes: Lake Avenue eastbound, Lake Avenue westbound, and Willow Road westbound. Willow Road eastbound was included as a part of the Forestway Drive alternate route. Figure 2 maps the alternate routes, and Table 5 shows the alternate routes VISTA reports as congested at some point during the 3-hour simulation due to incidents of various scales and durations.

The Edens Expressway (I-94) is always congested at some time during the 3-hour simulations, even during the base-case scenario; this is a reasonable reflection of the current reality. The same is true for Lake Avenue in both directions. No alternate routes parallel to the expressway are congested until all three lanes are closed. When three lanes are closed for 1 hour, the congestion spreads to the two alternate routes nearest the expressway: Frontage Road and Forestway Drive. When three lanes are closed for 2 or 3 hours in the simulation, Hibbard and Green Bay Roads are impacted by traffic congestion as well. The next alternate route to the west is Sunset Ridge Road, which is not impacted by the spread of congestion due to any simulated incidents. The next alternate route to the east is Sheridan Road, which was not monitored in the simulation because the VISTA software failed to assign vehicles to the route.

Effects of Early Response on Congestion for One Incident Type

Preplanning response actions is expected to allow more time to find effective traffic control actions and also to facilitate quicker implementation of those responses. Figure 3 presents simulation results for the congestion on I-94, the Edens Expressway, and in the indirectly impacted area as a function of response time. Four different simulations tested the effect of responding 0 minutes, 15 minutes, 30 minutes, and an hour after onset of the worst-case incident scenario, which

TABLE 5 Alternate Routes Impacted by Congestion

Incident Scale (Lanes Closed)	Incident Duration (h)	# Parallel Routes Impacted (Route Names)	# Perpendicular Routes Impacted (Route Names)
0	0	0	2 (Lake EB & WB)
1	1	0	2 (Lake EB & WB)
1	2	0	2 (Lake EB & WB)
1	3	0	2 (Lake EB & WB)
2	1	0	2 (Lake EB & WB)
2	2	0	2 (Lake EB & WB)
2	3	0	2 (Lake EB & WB)
3	1	2 (Forestway & Frontage)	2 (Lake EB & WB)
3	2	4 (Forestway, Frontage, Green Bay, & Hibbard)	3 (Lake EB, WB, & Willow WB)
3	3	4 (Forestway, Frontage, Green Bay, & Hibbard)	3 (Lake EB, WB, & Willow WB)

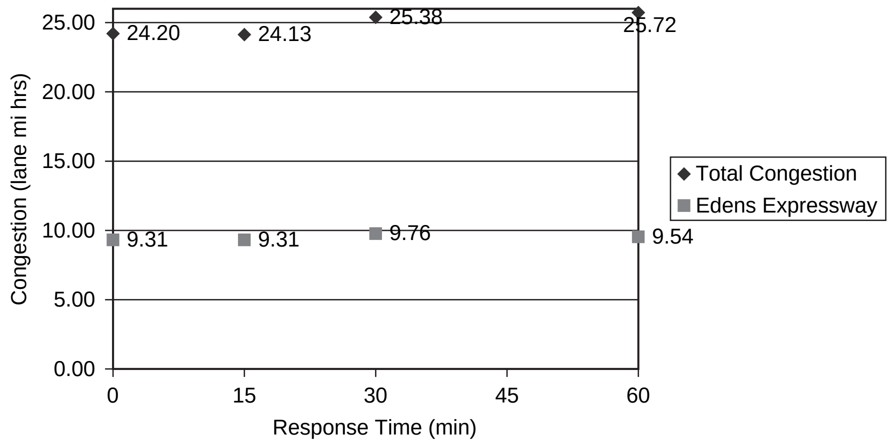

FIGURE 3 Congestion versus response time: incident, three lanes closed for 3 hours; response, closure of three ramps immediately upstream of incident.

closes three lanes for 3 hours. The response tested closes the three northbound on ramps immediately upstream of the incident, from Skokie Road, Old Orchard Road, and Dempster Street to the northbound Edens Expressway. This action previously saved 1.49 lane mi h (2.40 lane km h) of congestion in the indirectly impacted zone and 0.15 lane mi h (0.24 lane km h) on the directly impacted expressway. It was expected that delaying response would increase congestion. Figure 3 indicates that the lane mile hours of congestion do increase with delayed response but not by much. The relatively small increase in congestion could be because VISTA is modeling user-optimal traffic conditions, which assume that drivers have perfect information and react instantly to incidents and closures. A delayed response to the incident could have more profound impacts in reality.

Integration of Simulation Results

To integrate all the results, linear regression models were estimated with congestion used as the dependent variable and with independent variables of scale, duration, a signal retiming dummy variable, and a dummy variable for each response action. Table 6 presents the best regression models for predicting the total lane mile hours at LOS F in the indirectly and directly impacted zones. Scale, duration, and the signal timing dummy variable are statistically significant for explaining congestion on both the expressway and in the indirectly impacted zone. Because closing entrance ramps to the expressway upstream of the incident location is not always a beneficial response action, it was not found to be a statistically significant variable for predicting congestion in the indirectly impacted zone or on the expressway.

CONCLUSIONS

A Useful Measure of Congestion

Quantifying congestion and the benefits of incident management programs has been difficult for many transportation agencies (*9*). This study presents a method for measuring the effects of incidents and response actions both in lane mile hours of highways at LOS F and in the spread of congestion to alternate routes around the incident. Quantifying congestion allows for determination of the best response actions for the given incident scenario.

Hypothesis 1

DTA software, specifically VISTA, has been shown to be capable of modeling the expected effect of incidents and helping to evaluate the effectiveness of response actions. Modeling traffic conditions dynamically is thought to be necessary to successfully identify and test

TABLE 6 Best Linear Regression Models

Zone	Variable	Unstandardized Coefficients β	*t*-Stat	Adj. R^2	SSE	*F*
Indirectly impacted	Constant	10.19	7.67	0.763	357.31	55.65
	Scale (lanes closed)	3.74	8.56			
	Duration (hours)	2.21	5.05			
	Signals retimed? (1=Y, 0=N)	–3.70	–4.31			
Directly impacted	Constant	8.94	7.57	0.524	282.31	19.71
	Scale (lanes closed)	1.30	3.35			
	Duration (hours)	0.84	2.17			
	Signals retimed? (1=Y, 0=N)	–4.25	–5.57			

N=52

the control actions necessary to manage nonrecurring events such as crashes and infrastructure failures.

Closing on ramps upstream of the incident location was found to be an effective response to reduce congestion and delay but only for larger-scale and longer-duration incidents. The best actions to minimize congestion in a given incident scenario were neither obvious nor intuitive, and implementing response actions that were not appropriate for the given traffic conditions worsened congestion on the directly impacted freeway and its surrounding highway network. For example, Tables 2 and 3 indicate that closing one upstream ramp in response to an incident closing one lane for 1 hour is expected to increase congestion by 7% in the indirectly impacted zone and by 12% on the freeway. Of course, taking full advantage of preplanned responses requires the capability to detect incident occurrence and scale rapidly and to predict the duration with reasonable accuracy. Advanced incident detection and verification tools have become quite common in practice, and some progress has been made in duration prediction (*10–12*).

Preplanning currently allows effective and creative incident response actions to be tested in advance. With faster computer processing speeds in the future, incident managers may be able to run simulations after incident detection to test several strategies and obtain results almost instantly. This would reduce the time and costs associated with preplanning at many locations for specific incidents that may not ever occur. Some preplanning would still be necessary to reduce the number of strategies to be tested in a faster than real-time environment.

Hypothesis 2

DTA was used to model the spread of congestion to alternate routes given incidents of various scales and durations. The spread of congestion to alternate parallel routes provides a basis for defining a major disruption, an event that causes congestion to spread well beyond the incident scene. In such cases, it may be particularly desirable to hand off incident management responsibility to a transportation agency with a broader perspective of the indirectly impacted zone—for example, a corridor or regional TMC. In the test setting, no alternate routes parallel to the expressway were found to experience congestion during the simulation until there was complete closure of the expressway. It is possible that a longer duration incident, as a part of a longer simulation, could also cause alternate routes to become congested, but incident scale was the defining factor for a major disruption in the 3-hour simulation in this study.

Improving Access to Alternate Routes

In the simulation tests described here, alternate routes parallel to the expressway did not experience congestion until there was a full closure, but some perpendicular routes experienced congestion during all scenarios, even the no-incident, base-case scenario. This, and the fact that retiming traffic signals reduced congestion significantly in the simulations, shows that major exit routes from the freeway need to be capable of carrying a potentially large volume of traffic diverting around incidents. This is likely to be true at most expressway exits, not only at this particular location. Access to uncongested alternate parallel routes needs to be accommodated by increasing the capacity of the perpendicular arterials, most likely through signal retiming and synchronization but perhaps also through highway widening.

LIMITATIONS

DTA Simulation Limitations

The major limitation of using VISTA (and other DTA models) is the built-in assumption that all motorists have perfect travel time information, which allows vehicles to be routed to user-optimal paths. User-optimal conditions approximate reality because drivers develop knowledge of traffic conditions on different routes at different times of day through experience. However, an incident is usually an unexpected event that alters traffic conditions in surprising ways; it is difficult or impossible for drivers to plan for it in advance and to react instantaneously when it occurs. In a well-managed highway system, drivers may find out about incidents via radio traffic reports, the Internet, or even variable message signs, but they still do not necessarily know the best alternate route based on current or future traffic conditions. Whereas research in Chicago has shown that more than 60% of drivers have used radio traffic reports to modify their trip decisions (*13*), many others, especially those unfamiliar with the local highway network, do not. These less-informed drivers probably spend more time traveling than necessary, representing a departure from the user-optimal traffic conditions simulated by VISTA. This model looks toward the future to assess the usefulness of preplanning alternate routes and other response actions when better travel information is widely available to motorists.

VISTA is currently better suited to modeling well-publicized, long-term construction closures than incidents occurring at unexpected locations and times, but the software is being updated to include a better algorithm for simulating incident conditions. Allowing only a fraction of the vehicles to divert to new paths, or imposing an extra cost of diversion, would improve on existing model assumptions. In general, it is expected that the effects of incidents and delayed incident responses modeled in this study would result in more congestion than is shown by the simulation. Therefore, response actions such as closing freeway entrance ramps upstream of the incident could have greater benefits in reality than in the simulation by forcing drivers to divert when incident conditions so warrant.

Data Limitations

Improving data also could improve model results. The demand data for the simulations were obtained from CATS. In the data obtained for the study, the demand on each link was not broken up by peak periods and therefore did not account for the fact that the traffic flow may be heavier in one direction than the other. Instead, a percentage of the total average daily traffic was assigned to the network. Using a more accurate demand profile to change the peak-period concentration in the model could reduce the need for a large artificial increase in total trips to create the desired level of congestion. Although a strong reverse commute by automobile in Chicago's northern suburbs creates nearly equal directional traffic flows, minimizing the error in the case of this study, peak-period traffic counts also could be used as a basis for reducing the need for the trip augmentation used in the model.

Keeping signal control and highway geometry data up to date is also important to model accuracy. Highways are sometimes newly built or widened and signal timings often change, but these changes are not automatically updated in VISTA. In this case, the highway geometry data were from 1999—in most cases, not so old that conditions had changed greatly. Most signal timing plans were generated by algorithms instead of from field measurement, which could affect the performance of the simulation, probably for the worse as shown by the statistically significant reduction in congestion when only 11 intersections were retimed manually.

FUTURE RESEARCH

Generalized Results and More Creative Response Actions

This study demonstrated the ability of DTA software to measure the congestion impacts resulting from simulated incidents and response actions at one location in the Chicago highway network. Although preplanning at one location is beneficial, measuring the impacts of incidents and response actions at many locations may identify more general response patterns. The scope of response actions tested also should be expanded by having local experts use a DTA model as a tool to test alternative incident scenarios and response actions. A validation process using historical incident data is needed to test the accuracy of the simulation.

Real-Time DTA Models

Preplanning cannot identify and prepare for every possible incident. Furthermore, few incidents remain stable in characteristics through their duration. To be fully useful, DTA models must be developed to run much faster than real time to support quick assessment of traffic management options as incidents occur and evolve.

Policy and Institutional Barriers

Traffic was observed to spill over to parallel alternate routes during a major disruption, supporting the logic of handing off network management responsibility around a major incident to a TMC. Implementing such subnetwork or corridor control will, in many cases, require interjurisdictional cooperative agreements and memoranda of understanding. This would allow local streets, for example, to come under regional control for the purpose of short-term incident management. This may require some compromise in operational objectives, but it would arguably be for the greater good of all travelers.

ACKNOWLEDGMENT

Funding for this study was indirectly provided by the U.S. Department of Transportation University Transportation Centers program through Northwestern University's Infrastructure Technology Institute.

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The Transportation Network Modeling Committee sponsored publication of this paper.