Highway Robbery: Social Costs of Hazardous Materials Incidents on the Capital Beltway

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In the summer of 1988, three major truck incidents involving hazardous materials occurred on the Capital Beltway in Washington, D.C. The delays that were incurred and the social costs of the incidents, which ran into millions of dollars, are estimated in this paper. The impacts of policy options for reducing such delays and the associated costs are analyzed in the context of the three incidents.

In late summer 1988 three major incidents involving hazardous materials occurred on the Capital Beltway in less than a month. Together, they resulted in one fatality, 13 injuries (two truck drivers, three motorists, and eight firefighters), and hours of delay to hundreds of thousands of vehicle occupants. For months afterward, media attention focused on the problem as public representatives and safety experts debated solutions. Hazmat trucks were finally restricted to the two rightmost lanes. Those incidents are looked at more closely in this paper by estimating the delays that were created and the social costs that were incurred. It was observed that the cost of delay could have been reduced substantially if it had been factored into emergency plans and incident management decisions.

CAPITAL BELTWAY

Opened in August 1964, the Capital Beltway is a 63-mi long link in the Interstate highway system. It was originally intended to serve as a bypass around Washington, D.C. for long-distance travelers and, coincidentally, to provide an efficient evacuation route during national emergencies. Its first traffic jam took place on opening day, as eager users were backed up for miles while the ribbon-cutting ceremony was held near the New Hampshire Avenue exit. Since then, as the Washington suburbs have grown, it has become a major commuting artery, handling about 600,000 vehicles per day. Six to ten percent of that volume is trucks, which are involved in 17 percent of the accidents. On an average day, one of the six traffic accidents on the Beltway involves a tractor trailer. In a recent 16-month period, 4 of the 13 major truck accidents on the Beltway involved hazardous materials tankers.

The decision to impose the two-lane hazmat restriction following the three incidents in question was not universally supported. Detractors were concerned that it would tend to increase the density of hazmat tank trucks in the occupied lanes and introduce conflicts with exiting traffic, whereas supporters argued that it would help alleviate safety concerns associated with having small, maneuverable passenger cars occupy the same lanes as large, less maneuverable hazmat tank trucks. In another move made in the wake of these incidents, the Pentagon discontinued its fuel shipments during rush hours and 38 other federal agencies at 120 locations in the metropolitan Washington area followed suit. Other proposals have been made to ban all hazardous materials trucking on the Beltway during rush hours (which would divert tank trucks to other roads) and to introduce centralized tracking of all hazardous shipments (which would be expensive). The American Automobile Association (*1*) has recommended that any trucker causing an accident on the Beltway be fined an amount based on the level of delay that is created and that the proceeds be used to fund public information programs to improve highway safety.

In the future, the Beltway will be equipped with a driver information system whereby incidents will be detected with television cameras and instructions will be relayed to motorists electronically. Plans have also been proposed for carpool lanes that would become part of a regional high-occupancy vehicle network and for Interstate bypasses to the east and west of the Beltway. Considering the projections of 300,000 vehicles a day on some of its 8-lane segments by the year 2010, Beltway drivers will need all the help they can get.

SUMMARY OF INCIDENTS

The first of the three 1988 incidents took place at 3:20 p.m. on Friday, August 12, on the outer loop of the Beltway near Route 193 (Georgetown Pike) in McLean, Virginia. A truck carrying about 10 tons of potentially explosive potassium permanganate in powdered form caught fire while bound for a Fairfax water treatment plant, causing the entire Beltway to be closed down until 6:45 p.m., when the inner loop was reopened. The outer loop remained closed until 9:15 p.m. Eight firefighters were injured and more than 70 persons were evacuated. Traffic in downtown Washington was reportedly slowed by the incident.

On Thursday, August 25, the second incident occurred at 3:55 p.m. when a gasoline tanker on the inner loop hit the rear of a van that was attempting to pass the car in front of it, then crossed the concrete median wall and burst into flames. The location was New Carrollton, Maryland, just north of the

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Baltimore-Washington Parkway. A motorist traveling on the outer loop was killed when his car ran into the burning truck. Both sides of the Beltway were closed as firefighters spent more than two hours putting out the flames from the 3,000 gallons spilled. The inner loop was reopened at 8 p.m. and two of the four lanes in the outer loop were reopened at 11 p.m. The remaining lanes, 400 ft of which were melted by the fire, were repaved overnight. The drivers of the tanker and the van were both hospitalized, as were two other passengers in the van.

The third incident took place on Wednesday, September 7, at 11:05 a.m. when a gasoline tanker overturned on an entry ramp on the inner loop in Annandale, Virginia, at the intersection of Route 236 (Little River Turnpike), injuring the driver. The ensuing flames, which damaged the steel beams of the overpass, were put out by 12:30 p.m., but the outer loop was not reopened until 2:10 p.m. and the inner loop was kept closed until 5:30 p.m., when three of the four lanes were reopened. Pavement damage in the remaining lane was repaired overnight. The ramp has a high level of tank truck activity because of its proximity to a tank farm in Fairfax City and was previously the scene of a similar accident that proved fatal to the driver, who was apparently taking the turn too fast.

DELAY ESTIMATION

Associated with each incident is a total delay in each direction on the Beltway, as measured by the number of vehicle-hours of waiting time. The Federal Highway Administration (FHWA) has developed an analytical procedure for computing the delay during any kind of freeway incident that reduces the normal capacity of a road for some length of time [see Morales (*2*)]. The FHWA model was used to estimate the delay for each of the incidents, using various sources of data on the traffic volumes, the roadway capacities, and the lane closure times.

In the FHWA model it is assumed that there is a given freeway capacity S_1, which is reduced to an initial bottleneck capacity of S_3 during the time T_1 needed to detect the incident, followed by a capacity of zero during the time T_2 needed to respond to the incident and then an adjusted bottleneck capacity S_4 during the time T_3 needed to clear the lanes. From then on, the capacity is assumed to return to S_1. Any one or two of the times T_1, T_2, and T_3 can be zero. On the demand side, the initial level is S_2, which lasts for a time T_4 (which may be zero), after which the level changes to S_5. These parameters fully determine the total delay.

To estimate the demand flow levels, hourly traffic counts were obtained from the Virginia Department of Transportation for the appropriate days of the week in the preceding July near the locations of the first and third incidents. Similar data could not be obtained for the Maryland location, so Virginia data assumed for the first location were assumed for the second incident. To simplify the calculations, it was determined that the average hourly traffic volume for the "heavy" period from 6 a.m. to 10 p.m. and the "light" period from 10 p.m. to 6 a.m. for each of the two data sets, using the counts for the appropriate days of the week and making separate determinations for the inner and outer loops of the Beltway. Figures 1, 2, and 3 show the traffic counts that were used and the dotted lines show the averages for the heavy and light periods.

Table 1 lists the values of the parameters for the six model runs that were made to estimate the delays and Table 2 presents a summary of the results. In every case, in the absence of information to the contrary, it was assumed that S_3 and T_1 are zero, that is, that every lane was blocked immediately. The values of S_2 and S_5 in Table 1 are the appropriate averages from the traffic count data and the values of S_4 are taken from Owen and Urbanek (*3*). In addition to the total delay, the FHWA model estimates the time to normal flow (TNF), which is the time between the onset of the incident and the moment at which the delay stops accumulating. These estimates are listed in Table 2, along with the estimated delay per vehicle, which was found by dividing the total delay by the total demand during the TNF in each case.

The results in Table 2 show that the total delay ranged from about 350,000 vehicle-hours in the first incident to about 500,000 vehicle-hours in the second and over 1,000,000 vehicle-hours in the third. On a per vehicle basis, the average delay ranged from 2.4 hr in the first incident to 4.2 hr in the second and 6.8 hr in the third. Note that it was assumed in these calculations that vehicles were not free to leave the Beltway once the incident began, hence these numbers are likely to be overestimates. However, given that the delays that each incident induced on other roads were not accounted for, the combined vehicle-hours of delay in this table may in fact be underestimates of the systemwide delay for each incident.

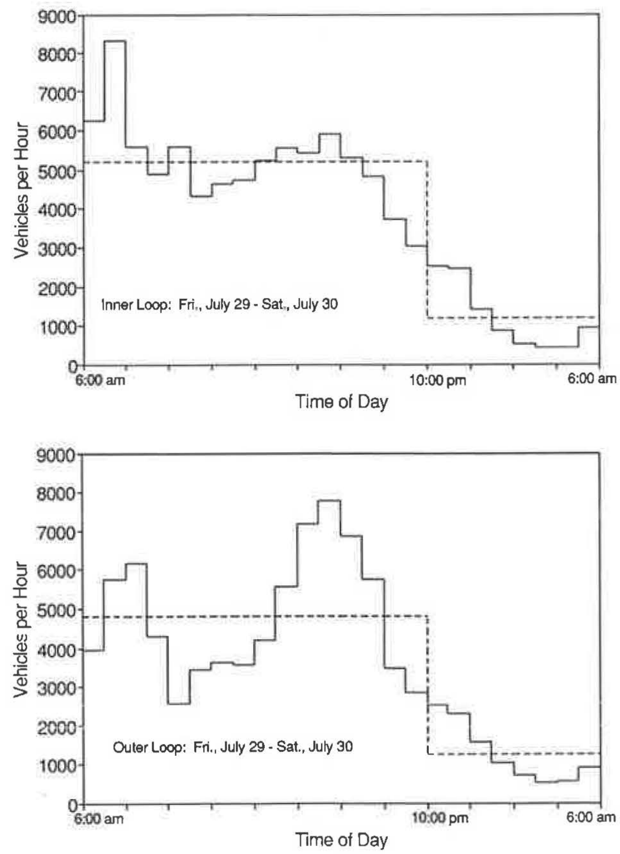


FIGURE 1 Hourly Traffic Counts on the Beltway—Route 193 to G.W. Parkway.

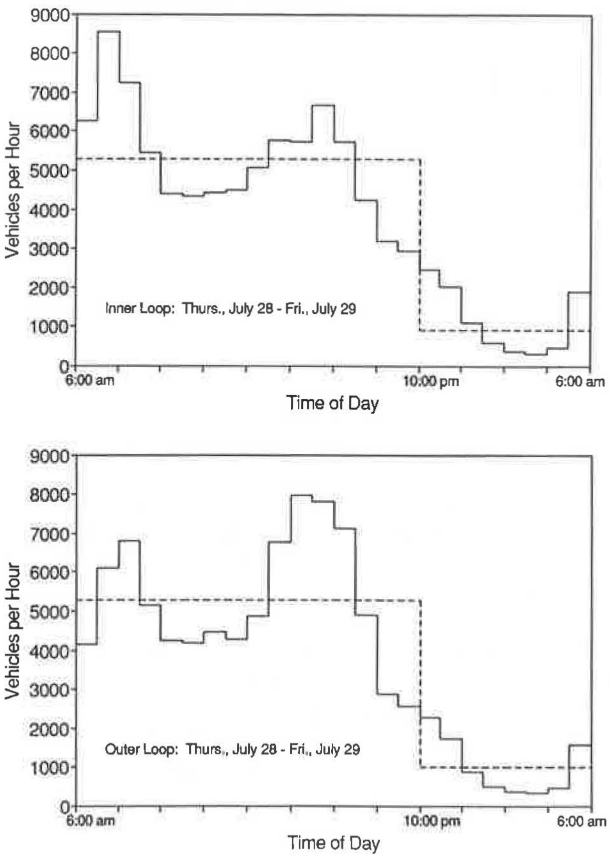


FIGURE 2 Hourly Traffic Counts on the Beltway—Route 193 to G.W. Parkway.

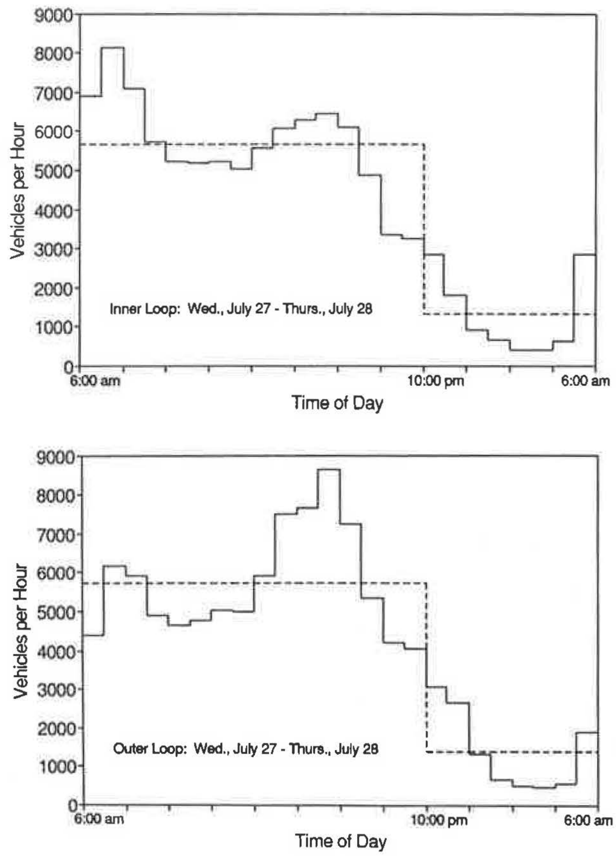


FIGURE 3 Hourly Traffic Counts on the Beltway—Route 236 to G.W. Parkway.

TABLE 1 FHWA MODEL PARAMETERS FOR THE THREE INCIDENTS

	August 12		August 25		September 7	
	Inner Loop	Outer Loop	Inner Loop	Outer Loop	Inner Loop	Outer Loop
S_1	7400	7400	7400	7400	7400	7400
S_2	5219	4820	5278	5262	5657	5714
S_3	0	0	0	0	0	0
S_4	0	0	0	2700	1300	0
S_5	5219	4820	5278	1013	1310	5714
T_1	0	0	0	0	0	0
T_2	205	355	245	425	385	185
T_3	0	0	0	360	690	0
T_4	0	0	0	365	655	0

Note: S values are in vehs per hr and T values are in mins.

TABLE 2 FHWA MODEL RESULTS FOR THE THREE INCIDENTS

	August 12	August 25	September 7
Total Delay (veh-hrs)			
Inner Loop	103,360	153,450	972,750
Outer Loop	241,980	339,720	119,210
Combined	345,340	493,170	1,091,960
Time to Normal Flow (hrs)			
Inner Loop	11.6	14.2	27.1
Outer Loop	17.0	16.7	13.5
Total Demand (vehs)			
Inner Loop	60,510	75,160	82,970
Outer Loop	81,800	42,730	77,330
Total	142,310	117,890	160,300
Delay per Vehicle (hrs)			
Inner Loop	1.7	2.0	11.7
Outer Loop	3.0	7.9	1.5
Combined	2.4	4.2	6.8

Figures 4, 5, and 6 show how the capacity, demand flow and bottleneck flow accumulate over time in each direction during each incident, according to the runs of the FHWA model. The area enclosed by the demand flow and bottleneck flow lines is equal to the total delay in each case.

SOCIAL COSTS OF INCIDENTS

In estimating the social costs of the three incidents, we accounted for: (a) the actual direct costs, and (b) the imputed costs of delay. Information on some of the direct costs was gathered from a variety of sources, including local fire departments, local and state transportation departments, and trucking firms. Table 3 summarizes this information under three categories: emergency response, clean-up, and truck and lading loss. Emergency response costs refer to the value of the time of hazmat units, fire personnel, and traffic controllers, and the equipment and supplies they used (strictly speaking, some of these costs would have been incurred even if no incidents had happened). Clean-up costs are expenses

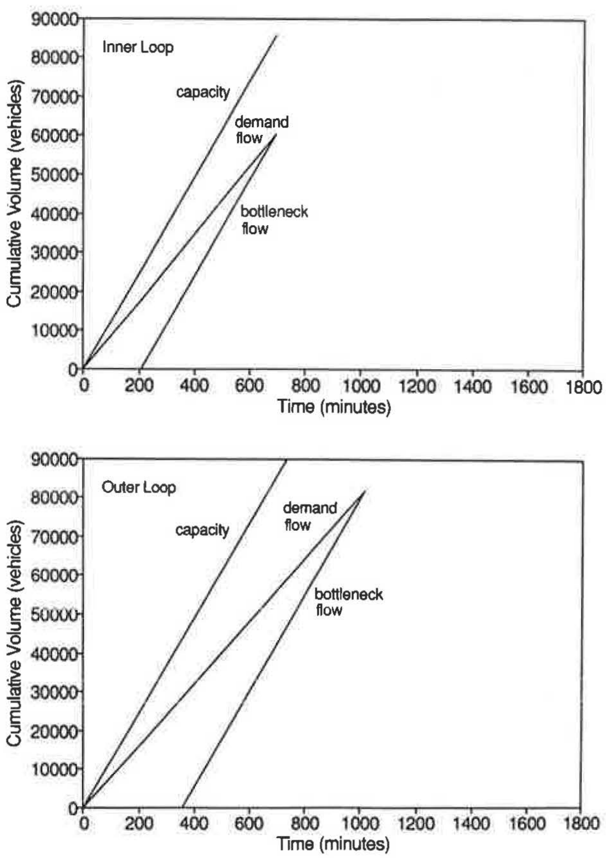


FIGURE 4 Estimated Delay—August 12 Beltway Incident.

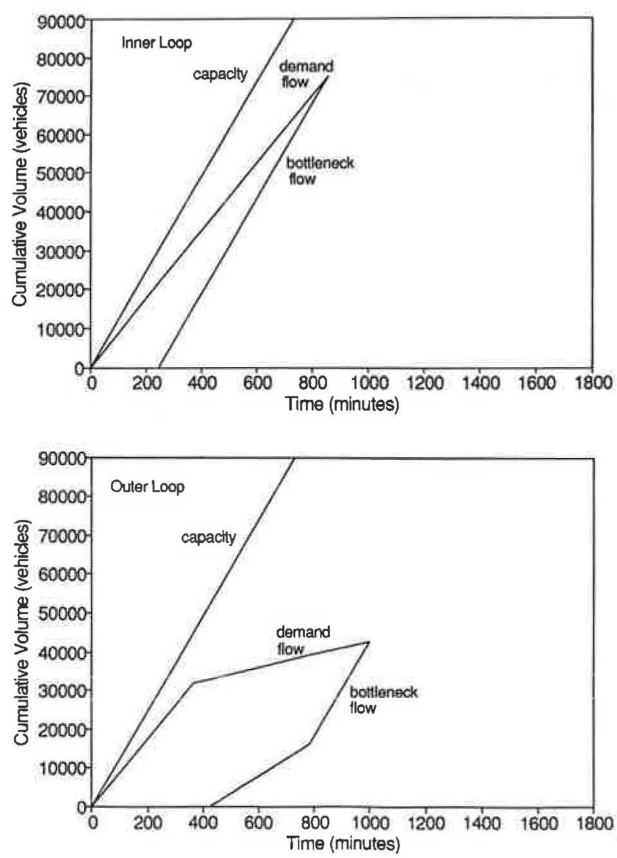
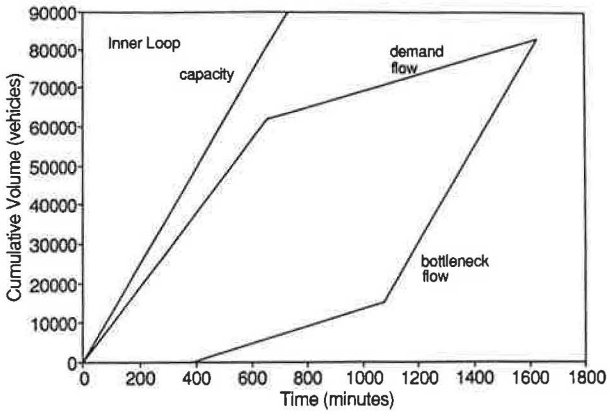


FIGURE 5 Estimated Delay—August 25 Beltway Incident.



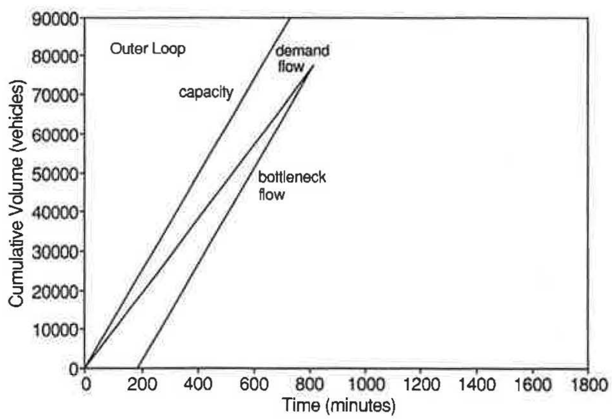


FIGURE 6 Estimated Delay—September 7 Beltway Incident.

for wreckage clearance, spill control and removal, and road repair and repavement. In the case of the third incident, we were only able to obtain a combined total for emergency response and clean-up (the reason this figure is so relatively high is that the damaged bridge had to be repaired). The costs of truck and lading loss, the third category, refer to the value of the truck cabs and trailers that had to be replaced and the cargoes that were lost.

Also under the heading of direct costs are the extra fuel consumption costs for the delayed vehicles. Assuming that all the engines were kept running the entire time in each incident, that idling engines consumed 0.58 gallons per hour, and that the gasoline cost $1.00 per gallon, these costs were calculated on the basis of total delay estimates in Table 2. The idling assumption underestimates the fuel consumption during stop-and-go periods and overestimates it for periods when some engines were shut off, so it was expected to be reasonable on the whole. When these costs are added to the ones above, the total estimated direct costs are seen to vary from about $375,000 for the first incident to about $455,000 for the second and almost $980,000 for the third. Most of these costs were borne by the members of the public who were caught in the traffic jam or whose taxes paid for emergency response and at least some of the clean-up costs. Note that the social costs of death, injury and evacuation were not taken into account [see Fisher, et al. (*4*) on the value of reducing risks of death and Witzig and Shilleen (*5*) on the evaluation of evacuation costs].

Significant as the direct costs may be, they pale by comparison to the monetary value of the delay itself. The estimates of this cost were developed on the basis of an average after-tax wage rate, assuming that this rate reflects the value of unexpected delay [see Deacon and Sonstelie (*6*) for a fuller discussion of the value of waiting time]. According to the Metropolitan Washington Council of Governments (*7*), about two-thirds of all Beltway travel is for trips within the D.C. area. Thus, we assumed an average hourly wage rate of ⅔($9.77) + ⅓($8.06) = $9.20, where $9.77 was the local wage rate in 1988 and $8.06 was the national wage rate. Further, an automobile occupancy rate of 1.24 persons was assumed. [This is the 1985 rush-hour estimate for the Beltway, which is close to the 1.3 figure employed by Teal (*8*) as a national average for all roads]. The results of multiplying the total delay estimates from Table 2 by this wage rate and occupancy rate are as shown in Table 3: about $4.2 million for the first incident, $6.0 million for the second, and $13.2 million for the third. Hence, the total cost of delay is estimated to have exceeded the total direct costs of the three incidents by as little as 11.2 to 1 and as much as 14.5 to 1, or about 13 to 1 on the average. Of course, this ratio could be even higher if successive increments of delay were considered to be increasingly burdensome, as suggested by Larson (*9*).

REDUCING THE COST OF DELAY

The finding that the cost of delay dominates the direct costs of the Beltway incidents by a wide margin raises the issue of

TABLE 3 ESTIMATED SOCIAL COSTS OF THE THREE INCIDENTS

	August 12	August 25	September 7
(1) Direct Costs ($)			
Emergency Response	10,717	4,900	*
Clean-up	40,000	60,081	*
Subtotal	50,717	64,981	237,123
Truck and Lading Loss	124,000	103,000	108,000
Extra Fuel Consumption	200,877	286,039	633,337
Total Direct Costs	375,594	454,020	978,460
(2) Cost of Delay ($)	4,195,840	5,974,656	13,228,877
Total (1) + (2)	4,571,434	6,428,676	14,207,337
Ratio (2) . (1)	11.2	13.2	14.5

*Breakout not available.

TABLE 4 RESULTS OF THE SENSITIVITY ANALYSIS

	August 12	August 25	September 7
Reduction in Delay (%)			
(a) Shorten Duration by 10%	19.0	14.2	15.1
(b) Reduce Demand by 10%	25.1	18.4	19.1
(c) Increase Capacity by One Lane (opposite side only)	11.4	11.8	4.0
Saving in Cost of Delay ($M)			
(a) Shorten Duration by 10%	0.75	0.80	1.88
(b) Reduce Demand by 10%	0.99	1.04	2.38
(c) Increase Capacity by One Lane (opposite side only)	0.45	0.67	0.50

whether enough is being done to avoid such delays. Three general approaches to avoiding delay immediately come to mind: (*a*) shorten the duration of the incident; (*b*) reduce the demand during the incident; and (*c*) increase the capacity during the incident. The first approach requires rapid detection, response, or clearance. The second approach requires improved diversion of traffic away from the incident scene. The third approach, which is more controversial, requires that fewer lanes be closed or that some lanes be opened sooner (or, at least, that a shoulder be opened up to let some traffic through).

By changing the values of the parameters in Table 1, a sensitivity analysis was conducted that uses the FHWA model to show what impacts each of these approaches would have had on the delays (and the costs of delay) estimated for the three incidents. First all T_2 and T_3 values were reduced by 10 percent to shorten the incident duration. Then all S_2 and S_5 values were reduced instead by 10 percent to lessen the demand rate. Finally, to represent the situation in which the far right lane would be kept open throughout the incident on the opposite side of the road, the respective value of S_3 was increased from 0 to 1300 (the capacity when one lane is open), T_2 was reduced to zero, and T_l was replaced with the former value of T_2.

Table 4 was developed on the basis of the results of rerunning the model with these changes. It shows that fairly modest improvements in emergency management would have yielded substantial benefits, reducing the number of vehicle-hours of delay in an incident by as much as 25 percent (if the demand could have been reduced by 10 percent in the August 12 incident) and saving as much as $2.4 million in the value of the motorists' time lost in an incident (if the demand could have been reduced by 10 percent in the September 7 incident). The most controversial approach is the third one, since even in the relatively cautious case considered here—in which only the very farthest lane on the safer side of the highway is kept open during the incident—it might have led to an increase in risk in order to save waiting time. When (if ever) such tradeoffs are justified and how to evaluate them are questions that are beyond the scope of this paper, but as with other difficult social choices, there may be situations in which the price of extreme caution is too high and some risk must be accepted.

REFERENCES

1. American Automobile Association. *Potomac News*. Falls Church, Va., April 1989.
2. J. M. Morales. Analytical Procedures for Estimating Freeway Traffic Congestion. *Public Roads*, Vol. 50, No. 2, 1986, pp. 55–61.
3. J. R. Owen and G. L. Urbanek. *Alternative Surveillance Concepts and Methods for Freeway Incident Management—Volume 2: Planning and Tradeoff Analyses for Low-Cost Alternatives*. Report FHWA-RD-77-59, FHWA, U.S. Department of Transportation, March 1978.
4. A. Fisher, L. Chestnut, and D. Violette. The Value of Reducing Risks of Death: A Note on New Evidence. *J. of Policy Analysis and Management*, Vol. 8, 1989, pp. 88–100.
5. W. F. Witzig and J. K. Shilleen. *Evaluation of Protective Action Risks*. Report NUREG/CR-4726, U.S. Nuclear Regulatory Commission, June 1987.
6. R. T. Deacon and J. Sonstelie. Rationing by Waiting and the Value of Time: Results from a Natural Experiment. *J. of Political Economy*, Vol. 93, No. 41, 1985, pp. 627–647.
7. Metropolitan Washington Council of Governments. *Solving the Problem of Greater Washington's Main Street*. Washington, D.C., 1986.
8. R. F. Teal. *Estimating the Full Economic Costs of Truck Incidents on Urban Freeways*. Report UCI-ITS-RR-88-3, Institute of Transportation Studies, University of California, Irvine, Nov. 1988.
9. R. C. Larson. *There's More to a Line than Its Wait*. Technology Review, July 1988, pp. 60–67.

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