Incident Management via Courtesy Patrol: Evaluation of a Pilot Program in Colorado

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A courtesy patrol program was operated by the Colorado Department of Transportation on urban freeways during peak periods to reduce congestion attributable to incidents. In this article are described the program's implementation using two approaches to service delivery, the types of incidents encountered, services provided, and impacts on traffic flows. During the pilot program, the duration of incidents was reduced by 8.6 to 10.5 min. Using a deterministic queuing model, average delays were estimated to be reduced by 71 to 98 vehicle-hr per incident, depending on roadway position, time of day, and assumptions regarding lane blockage effects. The program's benefits far exceeded its costs.

The Colorado Department of Transportation (CDOT) initiated a courtesy patrol program on a pilot basis in the summer of 1992 to provide incident management on major roadways during rush hour periods, with the goal of reducing congestion. This article is drawn from a larger evaluation (*1*) and includes reports on program implementation, incident type, service levels, and program effectiveness.

PROGRAM APPROACH AND IMPLEMENTATION

Congestion and Incident Management

Congestion is an increasingly serious problem. Nationally, congestion on urban freeways is responsible for as much as 2 billion vehicle-hr of delay and $16 billion in costs (*2*). In addition, congestion contributes to poor air quality, wasted fuel, and accidents.

While some amount of congestion stems simply from traffic volumes exceeding roadway capacity, studies have shown that incidents—vehicle breakdowns and accidents on or along the road—account for as much as 60 percent of all congestion. Incidents include major accidents that tie up several lanes for hours; minor accidents and stalled vehicles that block only one lane for short durations; vehicles stopped in shoulders; spilled loads; construction, utility, and maintenance activities; and special events that generate heavy traffic volumes (*3*).

According to a Federal Highway Administration report (*3*), incidents blocking one lane of a three-lane road will reduce capacity by almost half. Even an incident on the shoulder that does not physically block a lane, such as a stalled vehicle or a law enforcement stop, can cause a 25 percent capacity reduction. Capacity reductions occur even when lanes are not blocked, due to the "gawking" effect, which is caused by drivers slowing to observe the incident. The faster an incident can be cleared from the roadway, the less impact it has on traffic flow. The California Department of Transportation estimates that for each minute the time to clear blocked lanes is reduced, a motorist's delay is reduced by 4 to 5 min (*3*).

How quickly vehicles are moved off the roadway depends on a number of factors, including how fast an incident is detected, how quickly help arrives, the motorist's response to an offer of service, the time it takes to provide the service, and the legal framework that governs vehicles disabled along the roadway.

Program History

The idea for the courtesy patrol came from the Colorado Incident Management Coalition (CIMC), a multidisciplinary task force convened by CDOT in 1991. The CIMC recommended implementation of a comprehensive incident management program. Continuous flows of information concerning volume, speed, accident information, and lane closures would be sent to a Traffic Operations Center, which, in turn, could direct response and relay information to motorists. Full implementation of the plan required creation of a new high-technology infrastructure involving electronic and communications equipment.

The courtesy patrol was one part of the system that could stand alone. Hence, the first of CIMC's recommendations to be implemented by CDOT was the Mile High Courtesy Patrol (MHCP).

The Program Model and Implementation

The program model is depicted in Figure 1. Colorado tried two approaches to service delivery. CDOT entered into contracts with the Colorado State Patrol (CSP) to provide service in one zone and the American Automobile Association (AAA) in another. See Table 1.

Cooperative relationships were established between CDOT and numerous other entities. Metro Traffic Control, various media organizations, and sky-based traffic observers were important partners. These organizations play a role in incident detection and in communicating to the broader public information regarding traffic conditions. Links were established with the Denver Police Department, which has responsibility for traffic law enforcement and emergency response within Denver city limits. Also, various private businesses were involved in program planning and operation. For example, businesses allowed specific parking lots to be used as "safe havens" for disabled vehicles moved by the MHCP from the interstate.

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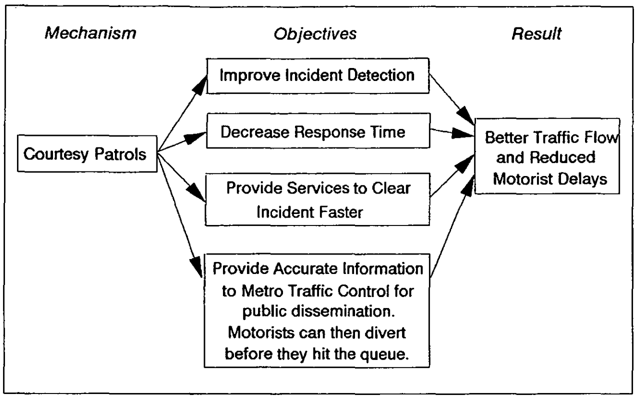

FIGURE 1 Mile High Courtesy Patrol program model.

Time and Place of Operation

Six courtesy patrols operated during rush hours on approximately 43 km along I-25 and a short stretch of I-70 near where it intersects I-25. These corridors were chosen because they have high traffic volumes, flow difficulties attributable to changes in road geometry (e.g., shift in number of lanes) or construction activities, or they lack a shoulder. Three zones were established, each patrolled by two MHCP vehicles.

Vehicles

Two types of vehicles were used by MHCP. AAA used Class A tow trucks and could tow vehicles to safe havens off the freeway. The CSP, with its four-wheel-drive vehicles equipped with heavy push bumpers, could move a more limited range of vehicles, and only for short distances.

Staffing

Each MHCP vehicle was staffed 6 hours a day, split between morning and evening periods. The CSP used 18 off-duty officers who volunteered to work on an overtime basis. They added a 3-hour MHCP shift at the beginning or end of a regular work day or worked one or more shifts on their days off.

AAA staffed the courtesy patrol with 10 regular AAA drivers who volunteered to participate in the pilot project. Their work week was structured, however, so that MHCP substituted for other work. Drivers worked three 12-hour days, splitting their time between MHCP (during rush hours) and regular AAA duties (during the middle of the day).

Patrol operators were required to study volumes detailing MHCP procedures, but other than that they received no special training. State patrol officers had received basic life support training, such as CPR and First Aid, when they first joined the CSP. When they are first hired, AAA's drivers take a 2-day training course that includes defensive driving, drivers' education, and general mechanical training (such as changing a flat tire, jump starting a vehicle, and diagnosing problems on the scene).

INCIDENT OCCURRENCE AND MANAGEMENT

Between August 28, 1992 and February 26, 1993, the courtesy patrol reported 3,393 incidents, an average of 27.6 incidents per day.

TABLE 1 Comparison of Key Features: CSP versus AAA Implementation of the Courtesy Patrol Program

	CSP	AAA
Territory	I-25 between Colfax and 84th Avenue; I-70 between Federal and Washington	I-25 between Colfax and County Line Rd.
Equipment	Four Wheel Drive vehicle equipped with push bumpers and removeable magnetic signs designating courtesy patrol on door and roof.	Standard Tow Truck, with removable magnetic signs designating courtesy patrol on door and roof.
Personnel	Off-Duty,uniformed, state patrol officers	Regular AAA tow truck drivers
Communication	Linked by stationary radio to CSP dispatcher; Linked by portable radio to state base's construction-based communications system and to Metro Traffic Control.	All communication via stationary radio to AAA dispatcher. Dispatcher communicates by phone with Metro Traffic Control.
Number of Patrol Units	2	4
Roadway		
Center Line Km.	20	25
Lane Km.	147	157
Incidents (excl. abandoneds) Per Patrol Unit	529	395
Per Lane Km.	7	10

Cars accounted for 61 percent of incidents; pickup trucks or vans accounted for another 29 percent. Larger vehicles such as trucks, vehicles with trailers, or buses, which could pose greater difficulty for the MHCP in terms of movement, accounted for just under 9 percent of incidents.

In almost three-quarters (72.7 percent) of the incidents reported, the vehicle was not in a lane of traffic. Most vehicles (63 percent) were found on the right shoulder. Six percent of incidents were in the left lane, 4 percent in the middle lane, 10 percent in the right lane, and 8 percent in an acceleration lane or on-ramp.

Abandoned vehicles—a problem that the MHCP could do little about—accounted for 22 percent of all incidents. Courtesy patrol operators reported the following causes for disabled vehicles: miscellaneous mechanical problems (34 percent), flat tire (14 percent), gas outage (11 percent), and accidents (9 percent).

MHCP Activity

Ninety percent of all incidents reported were detected by the courtesy patrol. Nine percent were reported to Metro Traffic Control or the dispatcher who relayed the information to the courtesy patrols. The courtesy patrol took 7 min, on average, to arrive at the scene of an incident reported to them by any outside source.

The courtesy patrols were capable of providing a range of services to stopped motorists. They could fix flat tires, provide a free gallon of gasoline, fill radiators with water, jump-start stalled vehicles, and fix some other minor mechanical problems. If a vehicle had more a serious or difficult-to-identify mechanical problem, the courtesy patrol could move the vehicle or call for other assistance. In addition to providing services to the stopped motorist, the courtesy patrol would protect the scene (particularly if the vehicle was in a lane of traffic). Using its vehicle's emergency lights, the courtesy patrol would alert upcoming motorists to the problem and hence avoid accidents.

The courtesy patrol obtained permission from the motorist before providing any assistance. Service was refused in 14 percent of the cases. The usual reason for rejecting service was that the situation was under control or that help was already on the way.

Table 2 shows the proportion of incidents, classified by problem type, that received different kinds of service. In 36 percent of all incidents (not including abandoned vehicles) the courtesy patrol could provide a direct service related to the presenting problem, such as fixing a flat tire or providing gasoline. In other cases, they may have moved the vehicle to a safer location, protected the scene, or called for assistance.

Vehicle Movement

Vehicles were moved by MHCP, by a push or tow, in approximately one fifth of all cases. Vehicles disabled in traffic lanes were more likely to be moved than those stopped in other positions on the roadway. Table 3 shows that the MHCP provided a tow or push to roughly half the vehicles disabled in traffic lanes.

Vehicles were often moved by private tow operators as well as the courtesy patrol. All told, 66 to 78 percent of vehicles disabled in a traffic lane received a tow or push from someone.

Incident Duration

To minimize congestion, vehicles disabled in traffic lanes (or on the shoulder within 6 ft of traffic) must be moved off the road as quickly as possible. Table 4 indicates how long it took after MHCP arrival for the vehicle to be moved. On average, vehicles disabled in the traffic lane were moved out of that lane 9.9 min after MHCP arrived on the scene.

The courtesy patrol spent longer servicing each incident than is indicated by these movement times. The longer time is required because the move itself may have taken time, particularly if the

TABLE 2 Percent of Incidents Receiving Specified Service from the Mile High Courtesy Patrol

Percent Receiving:	Total Incidents	Presenting Problem						
		Tire	Gas	Radiator	Misc Mech	Debris	Accident	Other
Service Directly Corresponding to Problem	36%	72%	81%	51%	20%	87%	na	na
Tow/Move	21%	6%	4%	13%	36%	0%	23%	7%
Protected Scene	16%	6%	5%	4%	12%	24%	66%	19%
Call for help	15%	5%	3%	12%	19%	13%	36%	8%
Other Service	13%	10%	7%	18%	12%	2%	9%	48%
Service Refused	14%	10%	7%	20%	17%	2%	4%	26%
Count of Incidents	2559	457	356	106	1122	45	280	193

Note: The same case can receive multiple services. This is why percentages add to more than 100%. Also, the count of incidents may differ from table to table due to missing data.

TABLE 3 Movement of Disabled Vehicles Based on Initial Roadway Position

Vehicle Position	Percent Moved by:		
	Courtesy Patrol	Other Tow or Push	By Anyone
Left Lane	51%	41%	78%
Middle Lanes	48%	36%	69%
Right Lane	54%	20%	66%
Accel/Decel Lane	23%	17%	38%
Exit or Entr. Ramp	27%	13%	37%
Left Shoulder	26%	31%	45%
Right Shoulder	17%	7%	25%
Ramp Shoulder	13%	10%	18%
Off Road	10%	7%	17%
All Positions	24%	14%	35%

Note: This table shows a higher percentage of incidents receiving a tow or push from the courtesy patrol than does Table 3.5. There is some internal inconsistency in reporting. When asked on the form about the type of service provided, only 21% showed a tow or move. When asked about vehicle movement and who did it, some additional forms indicated movement by the courtesy patrol.

move was to a safe site off the roadway. In addition, the courtesy patrol may have provided a second service after the initial movement. For example, a car might run out of gas while in a lane of traffic. After moving the vehicle, the courtesy patrol would fill the car with a gallon of gas, enabling it to resume travel.

Courtesy patrol operators reported that, in their judgement, 80 percent of incidents (excluding abandoned vehicles) were cleared when they departed from the scene. An incident was considered cleared if there had been an acceptable disposition of the vehicle involved and no further impact on traffic.

ANALYSIS OF TRAFFIC IMPACTS

A deterministic queuing model was used to estimate the average vehicle delay caused by incidents. Morales (*4*) found this type of queuing model to yield close estimates of accident delays on freeways. Janson and Rathi (*5*) describe the use of this approach for estimating vehicle delays due to accidents. Dynamic modelling was not feasible for this evaluation, but Janson and Robles (*6*) later performed dynamic traffic assignment simulations for the portion of I-25 discussed here. The preliminary results of accident scenarios within their framework do not contradict the magnitudes of delay estimates reported here.

All traffic incidents involve the following phases.

- Detection Phase: time from when the event first occurs to when people capable of responding are notified.
- Response Phase: time from notification to when the response team arrives at the scene.
- Service Phase: time from arrival to when the incident is sufficiently cleared to restore the highway to normal capacity.

TABLE 4 Incident Duration by Position of Disabled Vehicle on the Roadway

Incidents	Response Time	Service Time		Total Incident Duration
		Through First Vehicle Movement	Total	
All	1.1	9.6	11.2	12.0
Traffic Lanes	1.9	9.9	13.9	15.5
Left Shoulder/Ramps	1.2	10.4	12.4	10.8
Right Shoulder	0.8	9.3	10.2	13.4

- Queue Dissipation Phase: time from capacity restoration to when normal traffic flow resumes.

The total delay caused by an incident depends on the duration of each of these phases, the traffic volume on the highway approaching the incident, and the number of blocked and unblocked lanes. An incident causes queuing and vehicle delays because the vehicle arrival rate (hourly vehicle volume) exceeds the vehicle service rate (unblocked lane capacity) during the first three incident phases.

Figure 2 shows a graph of the queuing delays caused by a lane-blocking incident as estimated by a deterministic queuing model. The total travel time delay caused by an incident is equal to the shaded area in Figure 2, as described by Janson and Rathi, (5). The slopes of lines indicated by C_1 and C_2 equal the capacity of a highway during the incident clearing and during the queue dissipation phases, respectively. The incident clearing phase (sum of Phases 1 through 3) is from event time t_0 to time t_2 when all lanes are cleared. the queue dissipation phase (Phase 4) is from time t_2 to time t_3 when the queue disappears. At time t_2, when the incident is cleared from blocking any lanes, the road's capacity returns to its pre-incident level (C_2). Because C_2 exceeds the vehicle arrival rate V_2, the queue begins to dissipate. Morales (*4*) found that a highway may not return to its pre-incident service rate at one time, and that short intermediate steps or piece-wise linear segments between lines C_1 and C_2 can represent certain incident clearing processes in more detail. This additional detail was found to alter the total delay estimate by less than 10 percent in cases in which it was used.

The vehicle service rate of unblocked lanes during the incident clearing phase, denoted as C_1, depends on the number of open lanes, plus other factors such as smoke, debris, visible wreckage, and emergency equipment.

With regard to vehicle arrival rates, the delay calculation allows the arrival rate of vehicles at the rear of the queue to decrease at time t_1 because of route diversions or lessening travel demand. Increasing travel demand could actually cause the arrival rate to increase at t_1.

The queuing model is used to estimate the traffic delays associated with incidents occurring along the southern stretch of I-25 in northbound lanes. The model uses actual times and road positions associated with incidents and actual traffic volume data for the time of day that the incident occurred. The analysis is restricted to this portion of roadway because only there is the technology in place to provide accurate data on traffic volumes.

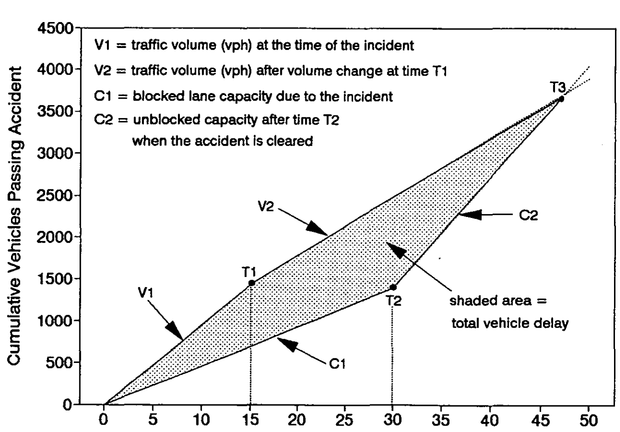

FIGURE 2 Estimation of vehicle delays due to incidents.

The model allows estimation of what traffic delays would have been, assuming different times involved in incident detection, response, and service. Hence, estimated traffic delays during the period when MHCP was operating can be compared with estimates of what occurred prior to MHCP implementation.

Core Inputs to the Impact Analysis

Time Duration

Time duration involves detection, response, service time, and queue dissipation. No direct estimates of detection time are available either before or during the period of MHCP operations. Incidents were probably detected faster with the addition of regular patrols, but since there is no proof, it has been assumed that there was no difference in detection time. Detection time is estimated at 5.5 minutes, representing how long it takes to observe any given point along the roadway, given the patrol route.

Data are available on response and service times during the MHCP pilot. Understanding of incident response prior to MHCP is somewhat limited. It is based on data for I-25 collected by Metro Traffic Control in the three months prior to MHCP implementation. Metro Traffic Control's records indicate when incidents were first observed by the sky observers (or other means) and when they reported them cleared. Both observations depend on the flight pattern of the observers. Estimates of duration are only approximate, but are the best available.

The estimates are also based on only 4.4 reported incidents per day, a fraction of the total number of incidents now known to exist based on MHCP data. Incidents attributable to accidents and involving a lane of traffic comprise a larger share of the MTC reports than of the MHCP evaluation data base.

Estimates of incident duration are compared for the period of MHCP operation and the prior period for two different sets of incidents, those blocking a traffic lane and all others. As Figure 3 shows, incident duration decreased substantially after the courtesy patrol started operations. Incident duration decreased by 10.5 min for incidents blocking a lane of traffic, and by 8.6 min for those not involving a traffic lane.

Traffic Volumes

Traffic volumes are collected by the CDOT Region 6 traffic operations office for both 5-min and 1-hr intervals at 12 counter locations on the ramps and the main traffic lanes. To ensure conservative estimates of capacity reductions, the model assumes a higher-than-standard maximum saturation flow rate of 2400 vehicles/hr for all lanes, based on data that show that flows of this magnitude regularly occur.

On a three-lane road, whenever volumes per hour exceed 5000, delays could be expected to result even from a right shoulder stall. Most of the traffic volumes observed on I-25 during the hours of MHCP operation exceeded this amount.

Lane Blockages

An important factor in estimating vehicle delays is the fraction of highway capacity lost to lane blockage and driver slowdown. The number of lanes assumed to be lost for incidents occurring in different locations on the roadway are as follows: left shoulder, 0.7;

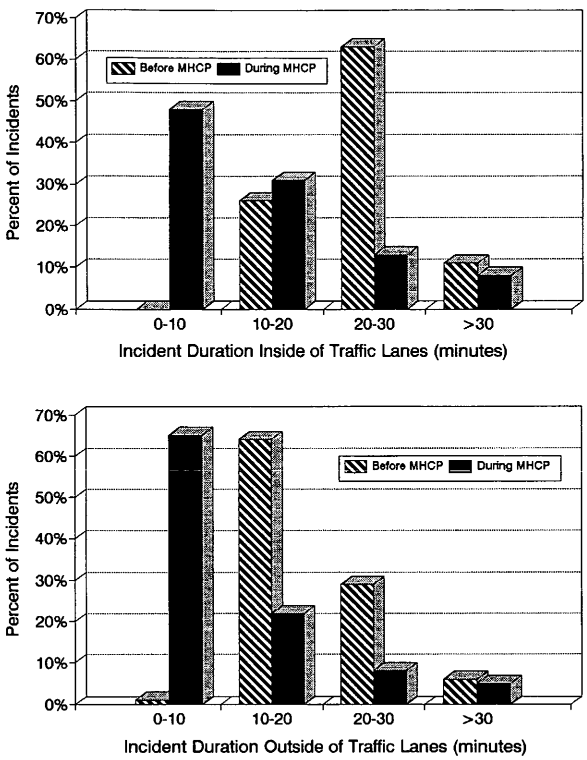

FIGURE 3 Estimated duration of incidents inside and outside traffic lanes, before and during MHCP operations.

left lane, 1.7; middle lane, 2.3; right lane, 1.7; right shoulder, 0.7; off-road 0.3; acceleration-deceleration lane or ramp shoulder, 0.0. These assumptions are rather conservative and should produce low estimates of actual vehicle delays.

Traffic Impacts: Discussion of Results

Figure 4 shows estimated average vehicle delays of all incidents (stalls and crashes) served by the MHCP in the a.m. peak period during the evaluation period. The estimated difference in average delays experienced during MHCP operations relative to the prior period is 98 vehicle-hr per a.m. incident. In the afternoon rush hour, the reduction in delay was somewhat lower, at 75 vehicle-hr per incident on average. Although traffic flows were higher during the afternoon rush hour, the mixture of accident times and locations during the a.m. peak period made its estimated average delay and before-and-during difference greater than that of the a.m. period.

To examine the sensitivity of these average delay differences to capacity reduction assumptions, an alternative estimate was performed assuming that each crash or stall on the right shoulder only reduces highway capacity by 0.1 of a lane, versus 0.7 of a lane. Average savings of 78 vehicle-hr of delay were found for a.m. incidents and 71 vehicle-hr of delay for p.m. incidents.

COST-BENEFIT ANALYSIS

Even though the courtesy patrol offers substantial benefits in terms of reduced traffic congestion, it cannot be concluded that the program is a success until costs are assessed and compared with the benefits. See Table 5.

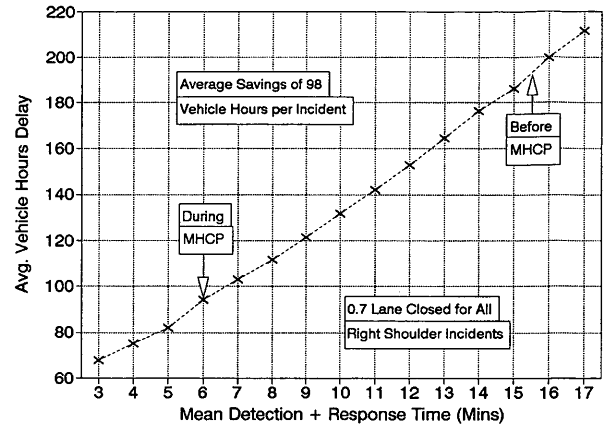

FIGURE 4 Average vehicle hours of delay per incident occurring in the morning peak period.

Assuming that the time saved is valued at $10 per vehicle hour, the courtesy patrol resulted in between $1.8 and $2 million worth of time savings over its 6 months of operation. In addition, motorists received direct services of substantial value including tire changes, minor mechanical repairs, and so forth.

The courtesy patrol program cost approximately $120,000 to operate over the same period. This figure, however, understates the true costs incurred. A comprehensive analysis showed the true cost per patrol unit per hour of operation to be $38 for CSP and $28 for AAA. CSP had lower equipment costs but higher labor costs than AAA. Using these more accurate hourly costs, the true cost of the program was estimated to be $168,000.

The contract cost during the pilot period has been used as the low-end estimate and CSP's true cost during the period (hypothetically applied to all six patrol units) as the high-end estimate of cost. Either way, the ratio of benefit to cost is very high, in the range of 10.5 or 16.9 to one.

CONCLUSION

Operating a courtesy patrol appears to be a cost-effective way of addressing congestion arising from incidents on crowded urban freeways. As a result of the evaluation, CDOT expanded patrol operations to additional corridors in the Denver metropolitan area during morning and evening rush hours.

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TABLE 5 Detail of Benefit-Cost Analysis

	AM	PM
Number of Incidents - 6 months	1095	1273
Estimated Hours of Traffic Delay Averted Per Incident		
High	98	75
Low	78	71
Estimated Dollars Savings from Reduced Traffic Delay		
High	$1,073,100	$954,750
Low	$854,100	$903,830
Hourly Cost of Operation Per Patrol Unit		
Equipment	$7	$17
Personnel	$31	$12
Estimated Costs (6 patrols)	$120,000 - $168,000	
Benefit Cost Ratio		
High	16.9	
Low	10.5	

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