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A Methodology for Developing a Traffic Surveillance Investment Program: An Application to Caltrans District 4

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A METHODOLOGY FOR DEVELOPING A TRAFFIC SURVEILLANCE INVESTMENT PROGRAM: AN APPLICATION TO CALTRANS DISTRICT 4

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ABSTRACT

A method for determining how to develop the most effective traffic surveillance investment program given available resources is developed. The complicated decision structure for deciding where and when to install traffic surveillance and what type of surveillance to install is broken down into a series of steps: identifying information needs, determining which can be met by traffic surveillance, setting criteria for and evaluating the benefits of surveillance in various locations, identifying alternative surveillance methods and estimating their capabilities and costs, comparing the ratios of benefits to costs, and finally matching cost-effective investments with available funds.

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A Methodology for Developing a Traffic Surveillance Investment Program: An Application to Caltrans District 4

BACKGROUND

California PATH has been working with Caltrans District 4 on a number of projects related to traffic surveillance, including new methods to estimate travel times from loops, error checking of the communications and data processing systems for incoming loop detector data, assessing the potential for using toll tag-equipped vehicles as a source of traffic data, and developing a method for implementing a cost-effective surveillance system, the subject of this paper.

District 4 has embarked on a program to upgrade its traffic surveillance system. But because of the wide range of options for upgrading the system and the multiple demands for surveillance information, the decisions regarding which investments to make in upgrading the system and which to make first are not easy. This paper develops a methodology for setting traffic surveillance investment priorities and developing a investment program. While this paper applies the methodology to District 4, it could be applied wherever decisions are being made regarding surveillance program investments.

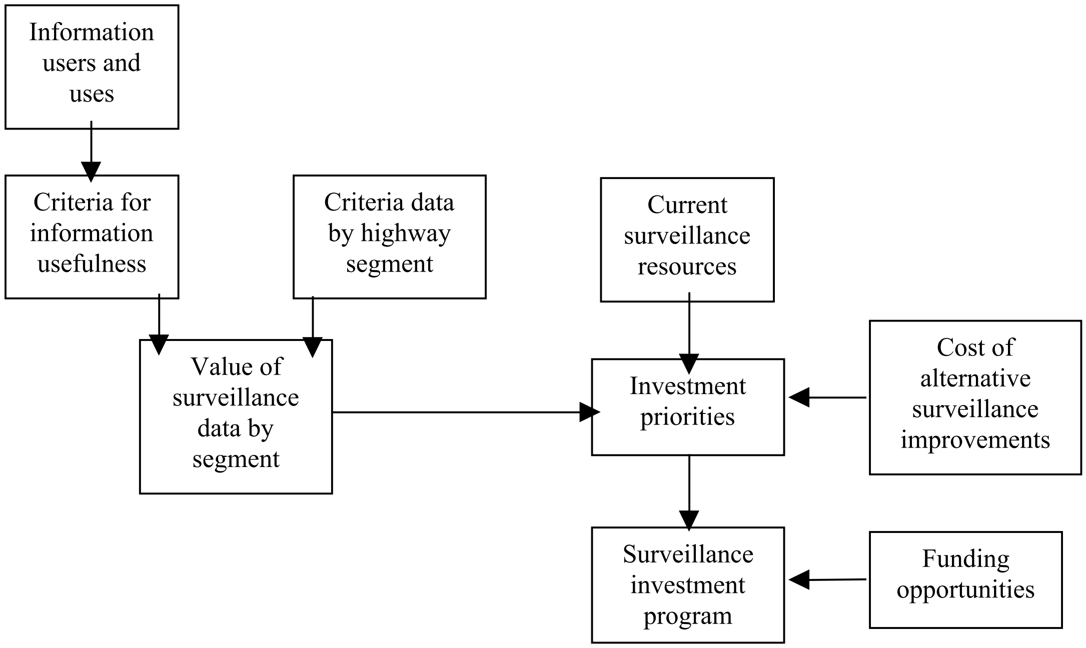
COMPONENTS OF THE METHODOLOGY

The first step is to determine the potential users and uses of traffic information. This will determine the type and format of information needed. The next step is to develop criteria for identifying the road segments for which traffic information is most useful. For example, real time information about a road that rarely experiences congestion will be of little use. Then data regarding these criteria for the road network is collected and the criteria are used to identify the road segments for which information would have the greatest use and thus the highest value. This would include all uses, not just those related to the organizational unit collecting the data. All of this can be thought of as the demand side of the problem.

To examine the supply side of the problem, the first step is to determine traffic surveillance resources already available for those road segments for which information would be most useful. If adequate surveillance in not already available, potential methods of obtaining the desired information are identified. Given this information, for each segment, the most cost-effective means of meeting surveillance needs can be determined and its cost can be estimated.

Next, the various road segments are ranked and organized according to the ratio of their benefits to their costs. Potential funding sources are identified. The ranking is then used to construct a traffic surveillance improvement plan and funding program. An “ideal” traffic surveillance plan would include all investments with benefits greater than costs. But, because transportation funding generally is less than what would be needed to fund all such improvements, a “cost-constrained” traffic surveillance investment plan is developed as part of the overall transportation improvement plan. If unexpected funds become available, they are used for the highest ranked un-funded segment eligible for such funding. These steps are shown in Figure 1.

Figure 1 Process for Developing a Traffic Surveillance Investment Program



USERS AND USES OF TRAFFIC INFORMATION

The top half of Figure 2 shows the various users of traffic information. Caltrans Operations Division is only one of the users, but Caltrans Operations Division is a major source of information, as shown in the lower half of the figure. The shaded boxes are those related solely to Caltrans. The cross hatched box indicates that Caltrans has access to the California Highway Patrol's (CHP) 911 vehicle call-in information but does not directly collect this information. Just as Caltrans Operations Division depends on information from other organizations such as the CHP, other organizations such as TravInfo (the Bay Area traveler information system), depend on information from Caltrans Operations Division.

Table 1 shows the information needs of the various users. Traffic surveillance typically provides only a portion of this information: the link-based data and incident information. However, this information is used by all users. Not all users need real-time information, but almost all need historical information, so a method of archiving and retrieving data is an important component of the surveillance system.

Figure 2 Users and Sources of Traffic Information

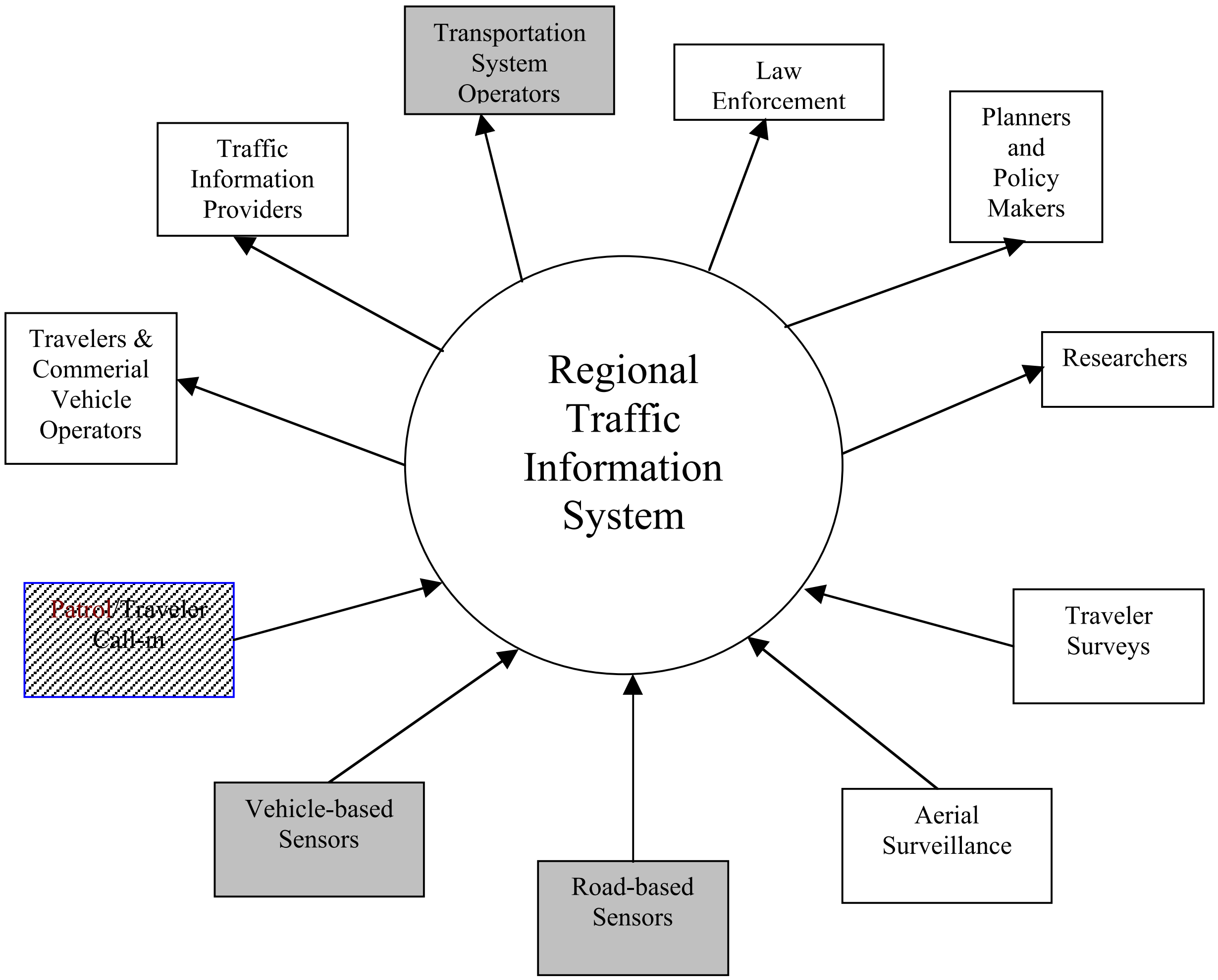


Table 1 Traffic Information Needs of Various Potential Users

Data Item	**Travelers and Commercial Vehicle Operators**	**Traffic Information Providers**	**Transportation System Operators**	**Law Enforcement**	**Planners and Policy Makers**	**Researchers**
Link-based Information						
Current link travel times	_	_	_			_
Historical link travel time distributions	_	_	_		_	_
Current and historical link densities and flows		_	_	_	_	_
Incident Information						
Indication of incidents	_	_	_	_		
Current incident particulars	_	_	_	_		
Historical incident records		_	_	_	_	_
Other Traffic Disruptions						
Current/planned road/street construction activities	_	_	_	_		
Current weather-related problems	_	_	_	_		
Special events affecting traffic	_	_	_	_		
Current Traffic Controls						
Current timing of ramp meters and signals		_	_			_
Other current controls	_	_	_	_	_	
Traveler-based Information						
Origin and destination patterns			_		_	_
Traveler numbers of trips and trip characteristics					_	_
Raw Surveillance Data						_

Table 2 links the information needs with various data sources. Two X's indicate that the source provides good information. One X indicates that the source provides some information. For example, travel times can be estimated from point speeds at road based sensors, but they can be more accurately estimated by vehicle probes or platoon tracking using various features captured by road based sensors and/or video cameras. The latter are currently under development, and may shortly elevate road-based sensors to XX status for collecting travel times. However, with vehicle-based sensors, travel times can be measured directly. Road based sensors are the best means for measuring flows and densities.

Table 2 Data Sources for Various Data Needs

Data Item	Road-based sensors other then CCTV	CCTV and Aerial Surveillance	Vehicle-based sensors	Patrol/Traveler Call-in	Traveler Surveys
Link travel times	X	X	XX		
Link densities and flows	XX	X			
Incident detection	X	X	X	XX	
Incident details		XX		X	
Origin-Destination patterns			X		XX
Traveler trip frequency and characteristics					XX

Although all sensors can detect incidents, in congested traffic they can not detect incidents quickly without also generating an unacceptably high number of false alarms. Traveler or patrol call-ins are the fastest and most reliable means of detecting an incident and getting incident details. But there are problems with dealing with high volumes of calls when an incident occurs, and these can work against prompt incident verification.

Vehicle-based sensors can provide information regarding the origin-destination patterns of the tracked vehicles, but the vehicles are not tracked in all locations and the tracked vehicles are not necessarily representative of the entire traffic stream. However, the relationship between tracked vehicles and the entire vehicle stream might be established through periodic traveler surveys and the vehicle-based sensors used to indicate changes in travel patterns between surveys.

From Table 2 it is clear that the traffic surveillance system should provide information on travel time and link densities and flows. It may play a role in incident detection, determining incident detail, and providing origin-destination data, but it will not be the only source of these data. Therefore, in developing a surveillance investment program, alternative investments will be judged on the basis of how they meet the primary information needs, for flow, occupancy, and travel time.

CRITERIA FOR DETERMINING WHERE TRAFFIC SURVEILLANCE WOULD BE MOST USEFUL

Given that the priorities for surveillance coverage should relate to the benefits, the primary criteria for setting priorities should be the amount of delay and the variability of delay. Generally, the greater the average delay, the greater the variability in delay. But some locations, such as routes to beaches or weekend destinations, may generally have little delay but may sometimes have extreme delay. The maximum delay per vehicle is also something to consider. For example, 1000 people who are each delayed for 50 minutes probably experience more total disbenefit than 10,000 people who are each delayed 5 minutes, even though the total delay is the same in both cases. Another factor to consider is the existence of a generator of a large number of time-critical trips, such as an airport, stadium, or large entertainment facility. The existence of alternate routes that allow travelers to exploit any differences in travel time will also make travel time information more useful.

COLLECTION OF DATA AND APPLICATION OF CRITERIA

Once criteria are established, the next task is to collect data. Caltrans has collected data on daily vehicle-hours of delay (http://svhqsgi4.dot.ca.gov:80/hq/esc/D4HWOPS/98HICOMP/.html) and average daily traffic volumes on state highways (http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/1999all.htm). These data were used to construct Table 3. All of the highway segments for which Caltrans found significant delay in 1998 are included. They are arranged by route, and the post miles are included to show the spatial relationship between congested segments. In some cases the congested segments are the same in both directions. But in more cases the congested segments are different lengths or are in different directions. To the right of the delay column are three columns related to the factors described above: seasonal variation in traffic, proximity to time critical destinations, and availability of alternate routes. Immediately to the right of these columns are the rankings, first only in terms of delay with the low numbers indicating more delay, and then grouped into priority rankings on the basis of both the delay and other factors. The grouping is calculated by dividing the delay ranking by 10, adding 1, and subtracting the sum of the other factor values divided by 2 and taking the integer value of the result. The application and weighting of the other factors is somewhat arbitrary, and both should be reviewed and revised as necessary before such a ranking scheme is used for actual decision making. The delays should also be updated. Table 4 shows the results of sorting Table 3 by group rankings. As noted above, another factor to consider is the delay per traveler. There are three locations with very high delay per traveler: southbound Route 84 from Newark Boulevard to the Dumbarton Bridge toll plaza, southbound I-680 from Sunol Road to south of Route 262, Westbound I-80 from Route 4 to the middle of the Bay Bridge, and eastbound Route 92 from Foster City Boulevard across the San Mateo Bridge to Route 880. All of these are included in the highest priority rankings. These rankings give an indication of which surveillance needs should be addressed first.

Table 3
CONGESTED BAY AREA FREEWAYS WITH PRIORITY RANKINGS

						Other							Post miles			
			Delay				Tm	Alt	Rank				County 1		County 2	
Location	Rt	Dir	AM	PM	Total	Var	Crit	Rt	Delay	Grp	Lnth	County	From	To	From	To
Route 4																
Route 242 to Port Chicago Highway	4	E		620	620				54	6	0.8	CC	14.7	15		
Bailey Rd to Willow Rd	4	W	380		380				79	8	3.3	CC	20.1	17		
Bailey Rd to Loveridge Rd	4	E		1120	1120				31	4	4.2	CC	20.1	24		
Lone Tree Way to Railroad Rd	4	W	1020		1020				37	4	14.0	CC	37.1	23		
Route 17																
Lark Ave to Camden Ave	17	N	310		310	0.5			85	9	1.6	SCL	8.89	11		
At Lark Ave	17	S		70	70	0.5			130	13		SCL	8.89			
Route 24																
Broadway to Caldecott Tunnel	24	E	770	1590	2360				11	2	1.5	ALA	4.15	5.7		
Broadway to Route 580	24	W	610		610				55	6	3.8	ALA	5.65	1.9		
Gateway Blvd to Fish Ranch Rd	24	W		380	380				79	8	1.2	CC	1.2	0		
Camino Pablo to Fish Ranch Rd	24	W	510		510				66	7	2.3	CC	2.31	0		
First St to Route 680	24	E		530	530				63	7	2.6	CC	6.51	9.1		
I – 80																
Route 101 to Sterling St	80	E	260	2230	2490				9	1	1.0	SF	3.95	5		
Fremont St to Route 101	80	W		190	190				106	11	1.5	SF	5.45	4		
At Bay Bridge Toll Plaza	80	W		490	490				69	7		ALA	1.99			
At Route 580	80	E		840	840				42	5		ALA/SF	2.8			
Route 580 to Gilman St	80	E		1840	1840				12	2	3.8	ALA	2.8	6.6		
University to Route 580/880 interchange	80	W		400	400				76	8	3.0	ALA	5.82	2.8		
Route 4 to Ala/SF County Line	80	W	5840		5840			1.0	2	0	18.1	CC/ALA	10.1	0	8.04	0
Central Ave to Route 4	80	E		740	740			1.0	49	5	10.1	CC	0	10		
At Carquinez Bridge Toll Plaza	80	E		270	270				96	10		SOL	0			
Route 84																
Newark Blvd to Dumbarton Bridge Toll Plaza	84	S	2920		2920				6	1	1.7	ALA	4.88	3.2		

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Location	Rt	Dir	AM	PM	Total	Var	Crit	Rt	Delay	Grp	Lnth	County	From	To	From	To
Route 84 (continued)																
At Route 880	84	N		90	90				126	13		ALA	6.01			
Route 85																
At Bernal Rd (metered connector from NB 101)	85	N	270		270			1.0	96	10		SCL	0.18			
At Union Ave	85	S		110	110			1.0	121	12		SCL	9.28			
Saratoga Ave to Winchester Blvd	85	S		110	110			1.0	121	12	2.7	SCL	13.7	11		
Stevens Creek Blvd to De Anza Blvd	85	S		590	590			1.0	58	6	1.8	SCL	17.7	16		
Route 280 to Fremont Ave & at Route 101	85	N	1700		1700			1.0	13	1	1.4	SCL	18.5	20		
Evelyn Ave to Fremont Ave	85	S		1050	1050				33	4	2.8	SCL	22.6	20		
Route 87																
Route 280 to Alma Ave & at Curtner Ave	87	S		1290	1290				19	2	2.3	SCL	5.15	2.8		
Route 92																
Route 101 to Hilldale Blvd & at Ralston Ave	92	W		290	290				92	10	2.8	SM	12.1	9.4		
Route 101 & at Alameda De Las Pulgas	92	W	40		40				136	14	1.6	SM	12.1	11		
Foster City Blvd to Route 880	92	E		3730	3730				3	1	11.6	SM/ALA	13.6	19	0	6.39
Route 880 to Industrial Blvd & at Toll Plaza	92	W	1540		1540				15	2	3.8	ALA	6.39	2.6		
US 101																
Cochrane Rd to Burnett Ave	101	N	420		420				73	8	1.0	SCL	17.8	19		
Route 85 to Scheller Rd	101	S		1030	1030				36	4	8.9	SCL	26.7	18		
At Tully Road	101	N	140		140				119	12		SCL	33			
Route 280/680 to Tully Rd	101	S		700	700				51	6	1.8	SCL	34.9	33		
Route 280 to Route 880	101	N	1250		1250				21	3	3.4	SCL	34.9	38		
Guadalupe Pkwy to Montague Expwy	101	N	550		550			1.0	62	6	2.1	SCL	39.9	42		
Montague Expwy to Great America Pkwy	101	N		190	190		1.0	1.0	106	10	0.8	SCL	42	43		
Great America Pkwy to 13th St	101	S		2880	2880		1.0	1.0	7	0	5.0	SCL	42.7	38		
Route 237 to Route 85	101	N		370	370			1.0	81	8	2.0	SCL	46.1	48		

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Location	Rt	Dir	AM	PM	Total	Var	Crit	Rt	Delay	Grp	Lnth	County	From	To	From	To
US 101 (continued)																
Ellis St to Lawrence Expwy	101	S	230		230			1.0	102	10	3.2	SCL	47	44		
Ellis St to Rte 85	101	N	160		160			1.0	111	11	1.1	SCL	47	48		
San Antonio Rd to Route 85	101	S		1270	1270			1.0	20	2	2.2	SCL	50.3	48		
Middlefield Way to University Ave	101	N		1140	1140				28	3	3.6	SCL/SM	49	53	0	0
Woodside Rd to Route 85	101	S	1050		1050				33	4	9.8	SM/SCL	5.39	0	52.6	48.1
Woodside Rd to Marsh Rd & at Willow Rd	101	S		150	150				114	12	3.5	SM	5.39	1.9		
Whipple Ave to Ralston Ave	101	N		780	780				46	5	2.9	SM	6.62	9.6		
Route 92 to Hillsdale Blvd	101	S	520		520				65	7	0.8	SM	11.9	11		
Route 92 to Third Ave	101	N	480	930	1410		1.0		17	2	1.6	SM	11.9	13		
At Poplar Ave	101	S	220	90	310				85	9	0.0	SM	14.3			
At Broadway	101	N		260	260		1.0		98	10	0.0	SM	16.6			
Millbrae Ave to Broadway	101	S		510	510		1.0		66	7	1.4	SM	18	17		
San Bruno Ave to Millbrae Ave	101	S	450		450		1.0		72	7	2.4	SM	20.4	18		
At Old Bayshore Blvd	101	S	150		150		1.0		114	11	0.0	SM	23.4			
From Alemany to Army St	101	N	800		800			1.0	44	4	0.9	SF	1.98	2.9		
Route 280 to Route 80	101	N		970	970			1.0	39	4	2.3	SF	1.98	4.2		
Army St to Harney Way	101	S	690		690			1.0	52	5	0.4	SF	2.92	2.5		
Route 80 to Fell St	101	N		60	60			1.0	132	13	1.1	SF	4.24	5.4		
South Van Ness to Fell St	101	N	40		40			1.0	136	14	0.3	SF	5.07	5.4		
South Van Ness to Route 80	101	S		80	80			1.0	127	13	1.1	SF	5.35	4.2		
Sausalito to Golden Gate Bridge Toll Plaza	101	S	1360		1360	0.5			18	2	2.3	MR/SF	0.32	0	11.8	9.86
Paradise Drive to Villa/Lincoln Ave	101	N		1130	1130				29	3	4.8	MRN	7.39	12		
At Sir Francis Drake Blvd	101	S	80		80				127	13	0.0	MRN	8.6			
South Novato Blvd to Route 580	101	S	3240		3240				4	1	9.1	MRN	19.1	10		
De Long Ave to Redwood Sanitary Rd	101	N		750	750				47	5	3.9	MRN	21.1	25		

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Location	Rt	Dir	AM	PM	Total	Var	Crit	Rt	Delay	Grp	Lnth	County	From	To	From	To
US 101 (continued)																
Old Redwood Hwy to South Petaluma Blvd	101	S	1240		1240				22	3	4.7	SON	7.65	2.9		
Santa Rosa Ave to College Ave	101	N		510	510				66	7	5.2	SON	15.5	21		
Todd Rd to Route 12	101	N	190		190				106	11	3.1	SON	16.5	20		
College Ave to Route 12	101	S	260		260				98	10	1.1	SON	20.7	20		
Mendocino Ave to Corby Ave	101	S		560	560				61	7	4.4	SON	22.9	18		
Route 237																
At Mathilda Ave & at North First St	237	E	170		170				110	12		SCL	2.99		6.91	
Lawrence Expwy to Route 101 & at Zanker Rd	237	W		310	310				85	9	10.1	SCL	4.6	2.5	7.99	
North First St to Route 880	237	E		2570	2570				8	1	2.4	SCL	6.91	9.3		
Route 880 to Zanker Ave	237	W	530		530				63	7	1.4	SCL	9.34	8		
I – 238																
Route 580 to Route 185	238	N	150		150				114	12	1.9	ALA	14.5	13		
At Route 580/238 interchange	238	N		150	150				114	12		ALA	14.5			
Route 880 to Hesperian Blvd	238	S		310	310				85	9	0.4	ALA	16.7	16		
Route 242																
Concord Ave to Route 680	242	S	1180		1180				27	3	1.5	CC	1.47	0		
I – 280																
At Route 101	280	N	60		60			0.5	132	13		SCL	0			
11th St to Route 87	280	N		290	290			0.5	92	9	1.3	SCL	1.2	2.5		
Route 87 to 11th St	280	S		80	80			0.5	127	13	0.8	SCL	1.99	1.2		
Route 87 to Route 880	280	N	400		400			0.5	76	8	2.9	SCL	2.52	5.4		
Meridian Ave to Route 880	280	N		600	600			0.5	57	6	1.4	SCL	3.99	5.4		
Moorpark Ave to Southwest Expwy	280	S		390	390			0.5	78	8	0.4	SCL	4.25	3.9		
Saratoga Ave to Foothill Expwy	280	N	680		680			0.5	53	6	5.5	SCL	5.95	11		
At Saratoga Ave	280	S	60		60			0.5	132	13		SCL	5.95			

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			Delay				Tm	Alt	Rank				County 1		County 2	
Location	Rt	Dir	AM	PM	Total	Var	Crit	Rt	Delay	Grp	Lnth	County	From	To	From	To
I – 280 (continued)																
Route 85 to De Anza Blvd	280	S		110	110			0.5	121	12	1.3	SCL	10.7	9.4		
Page Mill Expwy to Magdalena Ave	280	S		790	790			1.0	45	5	4.3	SCL	18.4	14		
Sandhill Rd to Woodside Rd	280	N		180	180				109	11	3.3	SM	0	3.3		
Farm Hill Blvd to Woodside Rd	280	S	70		70				130	14	1.3	SM	4.65	3.3		
Crystal Springs Ave to Westborough Blvd	280	N		460	460				71	8	9.1	SM	13.6	23		
John Daly Blvd to Route 380	280	S	750		750				47	5	4.3	SM	25.3	21		
Geneva Ave to Route 101	280	N	160		160				111	12	2.6	SF	1.77	4.3		
Route 101 to Monterey	280	S		290	290			1.0	92	9	1.6	SF	4.34	2.7		
At Route 101 and at 4th St and 6th St off-ramps	280	N	110		110			1.0	121	12		SF	4.34		7.07	
6th St to Pennsylvania Ave	280	S		160	160			1.0	111	11	1.0	SF	7.07	6.1		
I – 380																
Route 101 to Route 280	380	W		110	110				121	13	2.0	SM	6.73	4.7		
I – 580																
Vasco to Route 84 & Livermore to El Charro	580	W	1200		1200				26	3	8.2	ALA	6.68	11	12.5	16.7
Redwood Rd to Route 238	580	W	250		250				100	11	1.4	ALA	29.4	31		
Strobridge to Route 238	580	W		220	220			0.5	103	11	0.5	ALA	30.4	31		
Foothill to El Charro Rd	580	E		1700	1700			0.5	13	2	18.4	ALA	35.1	17		
MacArthur to Fruitvale	580	W	290		290			0.5	92	9	1.5	ALA	39.9	41		
Oakland Rd to Coolidge Ave	580	E		210	210			0.5	104	11	3.1	ALA	44.3	41		
Route 24 to Route 80	580	W	350		350			0.5	82	8	1.3	ALA	45.2	46		
At Route 101	580	W		590	590				58	6		MRN	4.78			
I – 680																
King Rd to Mckee Rd	680	N	300		300			1.0	89	9	2.0	SCL	0.39	2.4		
Landess Ave to Scott Creek Rd	680	N		1230	1230			1.0	23	2	3.9	SCL	6.17	9.9	0	0.13
Route 237 to Mckee Rd	680	S		1100	1100			1.0	32	3	5.3	SCL	7.65	2.4		

Table 3
CONGESTED BAY AREA FREEWAYS WITH PRIORITY RANKINGS

						Other							Post miles			
			Delay				Tm	Alt	Rank				County 1		County 2	
Location	Rt	Dir	AM	PM	Total	Var	Crit	Rt	Delay	Grp	Lnth	County	From	To	From	To
I – 680 (continued)																
At Scott Creek & at Durham	680	N		480	480			1.0	70	7		ALA	0.13		4.02	
Sunol Rd to south of Route 262	680	S	7240		7240				1	1	10.1	ALA	12.4	2.4		
Bollinger Canyon Rd to Sycamore Rd	680	N		210	210				104	11	3.9	CC	2.89	6.8		
At Rudgear Rd	680	N	30		30				138	14		CC	12.4			
Rudgear Rd to Sycamore Rd	680	S	1020		1020				37	4	5.7	CC	12.4	6.8		
Rudgear Rd to Route 24	680	N		50	50				135	14	2.0	CC	12.4	14		
Route 24 to Treat Blvd	680	N		150	150				114	12	2.0	CC	14.4	16		
No. Main St. to Route 24	680	S		300	300				89	9	1.2	CC	15.6	14		
Geary Rd to Route 24	680	S	2390		2390				10	2	2.0	CC	16.4	14		
Concord/Contra Costa Blvd to Route 242	680	S	1540		1540				15	2	1.4	CC	17.3	19		
Arthur Rd to Benicia-Martinez Bridge Toll Plaza	680	N		1130	1130				29	3	2.8	CC	22.7	25		
Cordelia Rd to Route 80	680	N		120	120				120	13	0.0	SOL	13.1	13		
I – 880																
Bascom Ave to Brokaw Rd	880	N	1040		1040			1.0	35	4	2.3	SCL	1.25	3.6		
Route 101 to Bascom Ave	880	S		340	340			1.0	83	8	2.8	SCL	4.08	1.3		
Montague Expwy to Dixon Landing & at Route 101	880	N		950	950			1.0	41	4	3.7	SCL	6.71	10		
Great Mall Pkwy to Brokaw Rd	880	S		1230	1230			1.0	23	2	4.1	SCL	7.69	3.6		
Route 262 to Auto Mall Parkway	880	N		820	820			1.0	43	4	2.3	ALA	2.38	4.7		
Auto Mall Parkway to Dixon Landing	880	S	3030		3030			1.0	5	1	4.8	ALA	4.71	0	10.5	10.4
At Stevenson & Thornton to Fremont	880	N		590	590				58	6	5.2	ALA	6.24	11		
Decoto/Rte 84 to Mowry	880	S	420		420				73	8	3.1	ALA	10.3	7.2		
Fremont to Decoto	880	S		420	420				73	8	1.1	ALA	11.4	10		
Whipple to Alvarado	880	S	250		250				100	11	0.7	ALA	13	14		
Alvarado to Tennyson	880	N		1220	1220				25	3	2.6	ALA	13	16		
Alvarado to Route 92	880	N	610		610				55	6	3.6	ALA	13.1	17		

Table 3
CONGESTED BAY AREA FREEWAYS WITH PRIORITY RANKINGS

			Delay			Other			Rank				Post miles			
							Tm	Alt					County 1		County 2	
Location	Rt	Dir	AM	PM	Total	Var	Crit	Rt	Delay	Grp	Lnth	County	From	To	From	To
I – 880 (continued)																
Route 92 to Hesperian Blvd	880	N		720	720		1.0	1.0	50	5	1.7	ALA	16.7	18		
Route 238 to Route 92	880	S	960		960				40	5	4.0	ALA	20.7	17		
Hegenberger Road to Hesperian Blvd	880	S		300	300		1.0	1.0	89	8	7.2	ALA	25.5	18		
High St to Oak St	880	N	340		340			1.0	83	8	3.4	ALA	27.7	31		

Table 4

Bay Area Freeways with Highest Surveillance Needs

						Other							Post miles			
			Delay				Tm	Alt	Rank				County 1		County 2	
Rt	Dir	Location	AM	PM	Total	Var	Crit	Rt	Delay	Grp	Lnth	County	From	To	From	To
80	W	Route 4 to Ala/SF County Line	5840		5840			1.0	2	0	18.1	CC/AL	10.06	0	8.04	0
101	S	Great America Pkwy to 13th St		2880	2880		1.0	1.0	7	0	5.0	SCL	42.73	37.73		
80	E	Route 101 to Sterling St	260	2230	2490				9	1	11.5	SF	3.95	4.99		
84	S	Newark Blvd to Dumbarton Bridge Toll Plaza	2920		2920				6	1	1.7	ALA	4.88	3.21		
85	N	Route 280 to Fremont Ave & at Route 101	1700		1700			1.0	13	1	1.4	SCL	18.45	19.88		
92	E	Foster City Blvd to Route 880		3730	3730				3	1	11.6	SM/AL	13.61	18.8	0	6.39
101	S	South Novato Blvd to Route 580	3240		3240				4	1	9.1	MRN	19.09	9.96		
237	E	North First St to Route 880		2570	2570				8	1	2.4	SCL	6.91	9.34		
680	S	Sunol Rd to south of Route 262	7240		7240				1	1	10.1	ALA	12.44	2.38		
880	S	Auto Mall Parkway to Dixon Landing	3030		3030			1.0	5	1	4.8	ALA	4.71	0	10.5	10.41
24	E	Broadway to Caldecott Tunnel	770	1590	2360				11	2	1.5	ALA	4.15	5.65		
80	E	Route 580 to Gilman St		1840	1840				12	2	3.8	ALA	2.8	6.62		
87	S	Route 280 to Alma Ave & at Curtner Ave		1290	1290				19	2	2.3	SCL	5.15	2.83		
92	W	Route 880 to Industrial Blvd & at Toll Plaza	1540		1540				15	2	3.8	ALA	6.39	2.59		
101	S	San Antonio Rd to Route 85		1270	1270			1.0	20	2	2.2	SCL	50.3	48.1		
101	N	Route 92 to Third Ave	480	930	1410		1.0		17	2	1.6	SM	11.9	13.46		
101	S	Sausalito to Golden Gate Bridge Toll Plaza	1360		1360	0.5			18	2	2.3	MR/SF	0.32	0	11.8	9.86
580	E	Foothill to El Charro Rd		1700	1700			0.5	13	2	18.4	ALA	35.11	16.7		
680	N	Landess Ave to Scott Creek Rd		1230	1230			1.0	23	2	3.9	SCL	6.17	9.94	0	0.13
680	S	Geary Rd to Route 24	2390		2390				10	2	2.0	CC	16.4	14.38		
680	S	Concord/Contra Costa Blvd to Route 242	1540		1540				15	2	1.4	CC	17.29	18.71		
880	S	Great Mall Pkwy to Brokaw Rd		1230	1230			1.0	23	2	4.1	SCL	7.69	3.57		
101	N	Route 280 to Route 880	1250		1250				21	3	3.4	SCL	34.87	38.3		

Table 4

Bay Area Freeways with Highest Surveillance Needs

						Other							Post miles			
			Delay				Tm	Alt	Rank				County 1		County 2	
Rt	Dir	Location	AM	PM	Total	Var	Crit	Rt	Delay	Grp	Lnth	County	From	To	From	To
101	N	Middlefield Way to University Ave		1140	1140				28	3	3.6	SC/SM	48.97	52.55	0	0
101	N	Paradise Drive to Villa/Lincoln Ave		1130	1130				29	3	4.8	MRN	7.39	12.19		
101	S	Old Redwood Hwy to South Petaluma Blvd	1240		1240				22	3	4.7	SON	7.65	2.93		
242	S	Concord Ave to Route 680	1180		1180				27	3	1.5	CC	1.47	0		
580	W	Vasco to Route 84 & Livermore to El Charro	1200		1200				26	3	8.2	ALA	6.68	10.69	12.5	16.7
680	S	Route 237 to Mckee Rd		1100	1100			1.0	32	3	5.3	SCL	7.65	2.38		
680	N	Arthur Rd to Benicia-Martinez Bridge Toll Plaza		1130	1130				29	3	2.8	CC	22.7	25.46		
880	N	Alvarado to Tennyson		1220	1220				25	3	2.6	ALA	13.02	15.65		

CURRENT SURVEILLANCE RESOURCES IN CALTRANS DISTRICT 4

Loop Detectors

Caltrans District 4 has a network of over 300 loop detector sites, but not full coverage of all congested segments. Furthermore, not all loops are reporting because of a variety of problems. There are problems with loops on reconstructed sections of highway not being properly connected to the controllers, with the controllers not functioning properly, with communications between the loops and the traffic operations center, and with the processing of data in the information system. Caltrans has engaged a consultant to inspect the non-functional loops and provide any needed repairs, and is installing wireless modems to replace the existing costly and often unreliable telephone communications. PATH has done diagnostic work on the processing of data in the information system. Caltrans has indicated that getting the existing loop detector system working and establishing a loop health monitoring system is its first priority. It may be that getting the entire loop detector network working is the most cost-effective way to obtain traffic data. But in deciding to make the investment needed (including diagnosis and correction of the problem, ongoing health checks and maintenance) to get a particular loop detector site operational and keep it operational, the cost of providing satisfactory data via another method should be considered, and if it is less, that method should be used.

Remote Transportation Microwave Sensors (RTMS)

Some RTMS units are also being installed. They will utilize wireless modems for communications with the traffic operations center. Additional units may be installed by the TravInfo traveler information system. Caltrans will have an opportunity to monitor their performance and determine if they are more effective and less expensive than loop detectors.

Freeway Service Patrol

Some travel time data and incident detection is provided by the Freeway Service Patrol. But this is not sufficient for regular monitoring or planning.

CHP CAD

The CHP computer aided dispatch system provides the primary incident detection. With the proliferation of cell phones, it seems likely that this will continue to be the best source of information about the existence and nature of incidents. Improvements can be made to reduce the time from first report of an incident to verification and characterization. Such improvements must be made by the CHP, but because the speed with which incidents are verified and characterized strongly influences the extent of delay caused by the incident, Caltrans should do whatever is possible to encourage such improvements.

Video

Caltrans also has 128 video cameras installed in some of the most heavily traveled and congested locations in the area. These are useful for observing and managing incidents, when the incident is within the field of view of a camera. They also give traffic management personnel a graphical view of traffic conditions, and when available on the web, they give travelers a visual indication of travel conditions.

Potential New Surveillance Methods

Vehicle probes

The implementation of electronic toll collection on all of the Bay Area bridges, expected by the end of 2000, will provide a new surveillance opportunity. Each vehicle utilizing the electronic toll collection will be equipped with a toll tag (transponder) that can be read not only at the toll gate but anywhere else where tag readers are installed. Thus any of these vehicles that pass between two readers on a trip can provide information from which to calculate the travel time between the two readers. With 8 bridges distributed along the length of the Bay, carrying a total of 760,000 vehicles per day, there will be sufficient toll tag equipped vehicles to provide travel times during congested periods on not only the bridges and their approaches, but also on many other highways and arterials that ring the Bay. Toll tag traffic surveillance has already been successfully implemented in Houston, San Antonio, and NewYork/New Jersey. PATH has just completed a study of the prospects for toll tag surveillance in the Bay Area.

Another promising vehicle-based traffic surveillance system is travel time from cell phone probes. US Wireless is currently testing such a system in Washington and other cities, and is preparing to test it in the San Francisco Bay Area.

PATH also plans a field test of using cars equipped with GPS for obtaining travel times.

Travel time information from loop detectors

Until recently, travel times were estimated from loop detector data by applying the speed at the loop detector location to the entire link where the loop was located. This is subject to error because of speed variations on the link and errors in the speed estimates, particularly when there is only one loop. PATH has developed a relatively low cost method of estimating travel times on freeway links that have double loops by matching groups of vehicles based on their lengths. This method is already in use on a short section of I-80 just north of the Bay Bridge, and could be implemented in the many other locations where there are double loops.

Improved cards for loop detectors can facilitate more accurate counts and allow matching of vehicles by their inductance patterns so that travel time can be computed.

Other promising surveillance methods

Video image processing promises to be useful for sensing vehicle presence, as is done by loop detectors and RTMS, and for identifying and re-identifying vehicles so that their travel time between two points can be measured. Such systems are on the market and are used in several locations abroad, but have not been widely deployed in the US. Research continues.

PATH has developed and is currently testing a laser detection device, but it is not yet field ready.

Uses of Travel Time Information

All of these new surveillance methods, except the laser sensor, provide travel times, unlike conventional loop detectors or RTMS detectors, which provide only flows and occupancy. Not only is travel time the data of greatest interest to travelers, it is the key performance measure for system operators. Data on travel times between adjacent freeway ramps could trigger an incident alarm faster than changes in volumes or occupancies, because they more quickly reflect changes in available capacity[1]. Travel times may also allow for faster adjustment of ramp meters. Travel time data for individual vehicles allows computation of variance in travel times between different vehicles, information that is extremely useful for travelers but that is not available from current stationary detector systems. Although sensors that detect presence are needed for vehicle actuated traffic signals, travel times can be used to estimate queues at ramp meters when combined with the metering rate.

ALTERNATIVES FOR MEETING SURVEILLANCE NEEDS

For any particular highway segment for which additional traffic information is desired, there may be various surveillance investment alternatives:

- Make an existing system functional
- Install new loops
- Install new RTMS (radar)
- Install CCTV
- Install readers for toll tags
- Wait and employ cell phone probes when developed
- Install computers for tracking platoons between double loop locations for estimating travel time
- Install other road-based sensors or probe vehicle methods

For each segment there will also be communications alternatives. All forms of surveillance require communication from the sensor to the traffic management center. Caltrans is currently installing radio modems on many of its sensors. Many existing sensors utilize telephone lines. The communication

[1] As soon as the first toll-tag equipped vehicle passes the next reader downstream from the incident , the change in speed is registered. The changes in flow and occupancy are not registered until the end of the loop polling period after the first affected vehicle passes (up to 30 seconds) and may not be recognized as a significant change for another period.

methods are generally independent of the type of sensor used. Capital cost, operating cost, maintenance cost, and reliability should be considered in making the choice.

ESTABLISHING THE INVESTMENT PRIORITIES

Developing a surveillance system health check

Regardless of what traffic surveillance program is developed, the highest investment priority should be given to developing a system for checking the information coming into the traffic operations center for errors and completeness. Such a system is needed initially to determine what surveillance equipment is operating correctly, and thus to see where repairs are needed. The system should also be designed for on-going checking. If any element of the surveillance system is worth installing or making operational, it is worth checking, maintaining, and when necessary, repairing.

Developing an archiving system

Because historical traffic data is useful for a broad range of users, a system for storage and retrieval of information should also receive top priority. The potential users should help establish the specifications for the format of information and the levels of temporal and spatial aggregation. They might also be asked to help fund the system or contribute other resources.

Making the existing loop system fully functional

Once it has been determined which loop detectors or other components are not functioning properly, the next priority is to develop diagnostics for determining why, and then to develop methods for estimating the cost of making them fully functional. Having a standardized approach to testing and diagnosis should minimize the cost. A standard protocol should also be developed regarding the circumstances in which repairs are made at the time the problem is diagnosed, repairs are scheduled for a later time, or consideration is given to replacement rather than repair. The purpose of this would be to minimize repair cost, first by performing repairs in the most cost-effective manner, and second by avoiding repairs that would not be cost-effective.

Prioritizing freeway segment surveillance improvements

Preliminary cost estimates for new surveillance components

Although the cost of various surveillance systems varies depending on the circumstances in which they are implemented, it is possible to estimate the cost for surveillance components in particular environments. For example radar and toll tag readers are less expensive if they can be mounted on existing structures. Communication costs, also, will vary with the environment. The costs for all components should be estimated on a comparable basis based on the expected life of the surveillance systems, and should include installation, maintenance, and communications.

How to obtain both travel time and flow information

Loops and other road-based surveillance devices are effective in measuring flows and occupancies, but somewhat less accurate in measuring travel times. A judgement must be made regarding the value of more accurate travel time measurements. Where there are double loop detectors, travel times can be measured using platoons that are identified by the lengths of their constituent vehicles. The cost per station is relatively low. A similar method of re-identifying vehicles might be possible for RTMS and other road based systems. Alternatively, both a road-based and probe system could be used.

Probe systems do not provide absolute vehicle flows, but they can indicate a change in flow. It may be that if real time travel times and changes in flows are available, real-time flows are not needed. Flows might be estimated by periodic flow measurements using some sort of portable counting device, such as an RTMS.

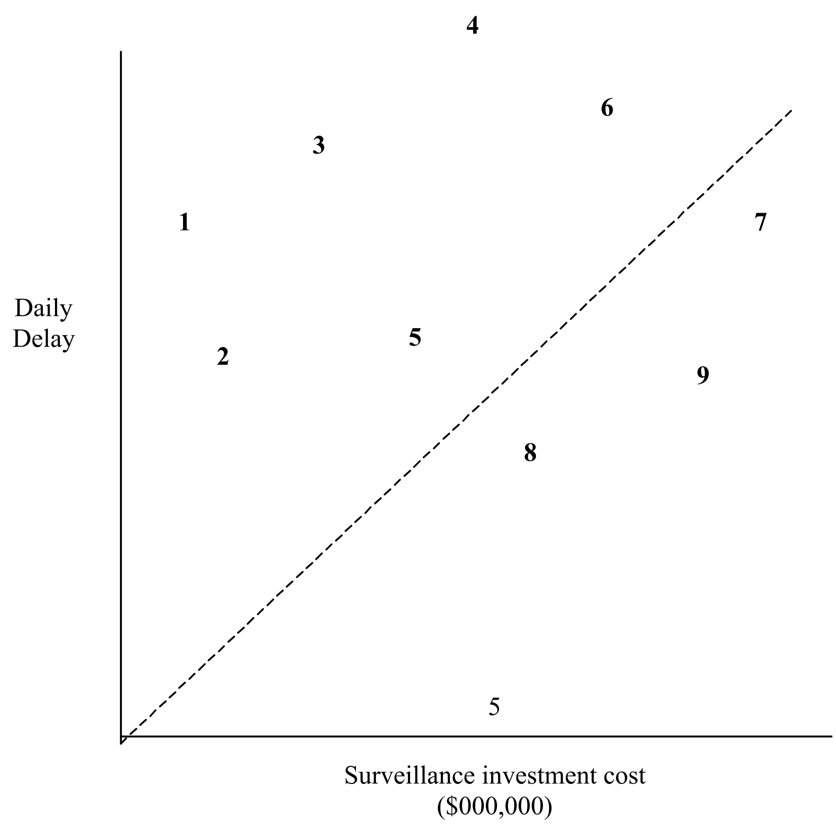
Organizing priority data

The highway segments for which traffic surveillance is important are extracted from Table 3 and Table 4 or a similar construct. In Table 3 they are arranged in adjacent segments so that if there are congested segments near each other, they can be considered as a whole. The existing surveillance resources on each are noted along with the estimated cost, if any, of making them fully functional. Wherever surveillance is lacking, the costs for least costly feasible[2] system, including communications, is noted. For a probe system, the cost might include the cost of periodic volume measurements.

A series of spreadsheets has been developed that provides not only Tables 3 and 4, but that facilitates the estimation and comparison of benefits and costs for high priority individual segments as well as groups of segments adjacent to the high priority segments. Groupings may be desirable in locations where two or more congested segments are located close together so that the cost for providing surveillance for the group is less than the sum of providing surveillance for each individually. For example, if surveillance is being provided on a freeway in one direction, the costs of providing it in the other direction will probably be less. The result is a set of estimated costs for both individual segments and groups of segments. Once costs have been estimated, each highway segment or group can be positioned on a graph with the total delay on the vertical axis and the cost of an adequate surveillance system on the horizontal axis as shown in Figure 3. The segments or groups of segments in Figure 3 are numbered in ascending order of the ratio of cost of their surveillance improvements to total delay, those below the line being the least cost-effective. This also allows easy selection of the most cost-effective group of projects to make with a given amount of funding. For example, if $5 million were available, the best group of investments would be 1, 2, and 3. If an additional $4 million became available, the best choice would be 5, because there would not be enough funding for 4. If funding became available that could only be used for a certain class of investments, it should be used for the most cost-effective investments that fell in that class and that had a total cost within the limit of the funding.

As noted earlier, one might want to increase the value for a segment or group if it were a route to a time-critical facility, such as an airport or stadium, had high seasonal delay, had a viable alternate route, or had very 0high delay per traveler.

Figure 3 Plot of the cost-effectiveness of alternate traffic surveillance investments



[2] Not all types of systems can be used in all locations. A toll tag system, for example, will be more in locations near toll facilities because more cars will have the tags.

On most segments the goal will be to obtain adequate information at minimum cost. But in some locations it may be desirable to test some of the newer surveillance methods in order to gain experience that will inform later decisions.

CREATING A SURVEILLANCE INVESTMENT PROGRAM

The program will include initial development and application of a surveillance health checking system and diagnosis and repair of surveillance components that are not functioning properly where such repair is deemed less costly than replacement. Then a construct like Figure 3 can be used to create and estimate the cost of the other elements of a surveillance master plan. The plan can be updated periodically as new delay estimates become available and as new surveillance methods are developed. It will serve as a guide for budgeting funds for surveillance, for input to transportation improvement plans, and for taking advantage of unanticipated funding opportunities.

SUMMARY

A systematic series of steps has been developed to inform investment decisions regarding traffic surveillance. The system is based on identifying information needs, determining which can be met by traffic surveillance, setting criteria for and evaluating the benefits of surveillance in various locations, identifying alternative surveillance methods and estimating their capabilities and costs, comparing the ratios of benefits to costs, and matching cost-effective investments with available funds.

A spreadsheet has been developed for displaying congested highway segments, ranking them by surveillance benefits, grouping segments in logical groups, and estimating surveillance costs for both segments and groups of segments.

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