Maintenance Costs of Traffic Signals

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A current major research project is aimed at developing guidelines for the selection of types of traffic-signal control at individual (noninterconnected, "isolated") intersections. Most traffic engineers prefer to install fully actuated signals at such locations; however, these are somewhat more costly to maintain than semiactuated or pretimed signals. Traffic engineers need to take into account the incremental maintenance costs of the more sophisticated types of control. Almost two years of maintenance-cost data from the California Department of Transportation (Caltrans) are reported for 121 actuated traffic signals of various designs. The costs include those for field maintenance, bench repair, travel, and parts. Also reported are the annual costs of the time required for the field maintenance of almost 1800 pretimed and actuated signals of the New York State Department of Transportation (NYSDOT). The frequency of repair of various types of controllers and detectors is reported for eight other cities and states. The Caltrans and NYSDOT data were merged to reach conclusions for the total annual cost to maintain electromechanical and solid-state controllers, including microprocessors, for various numbers of phases.

A major research project is currently under way to develop guidelines for the selection of the type of traffic-signal control to be used at individual (noninterconnected or "isolated") intersections. The choice of pretimed, semiactuated, basic fully actuated, or density fully actuated signals weighs the low price and economical maintenance of the pretimed controllers against the reduced costs, delays, etc., of the traffic-responsive models. The staff of the research project found that traffic engineers generally prefer to install fully actuated signal control at individual intersections. However, there is some concern over the cost of maintaining fully actuated controls, which is higher than that for semiactuated or pretimed controls. The professional literature sheds little light on the magnitude of these higher costs. Therefore, traffic engineers are at present unable to document the cost-effectiveness of their preference for traffic-responsive control.

An essential element in the selection of type of traffic-signal control is a knowledge of the maintenance burden of the various designs. We believe this paper is the first to provide that information.

The project staff found that traffic-signal maintenance costs are of some concern throughout the country. These costs seem to be a particular worry, however, in some northeastern and upper midwestern states. Loop detection needs to be of especially high quality in the snow belt because of severe winters, deteriorating pavements, and other reasons. There have been low-bid barriers to the purchase of high-quality "amplifiers", and difficulties in hiring and retaining technicians capable of installing and maintaining modern, sophisticated detectors and controllers. There has been a growing feeling that, if a fully actuated controller cannot be kept in fully actuated operation but must be placed on recall to one or both phases, it would then have been more economical to select semiactuated or pretimed control at the outset. It was this climate of concern that prompted the research to determine the maintenance costs of traffic signals.

RESEARCH APPROACH

Telephone contacts were made with many state and local traffic engineering agencies throughout the United States in an effort to obtain maintenance data. Most of the agencies responded that their data are in raw form—handwritten malfunction reports—that could not be summarized at reasonable cost. However, a few were found to have manual tabulations or computerized summaries of raw data in a form susceptible to tabulation at reasonable expense.

1. California Department of Transportation (Caltrans): The Caltrans Maintenance Management System (MMS) included data for 23 recent months on the total cost to maintain 121 actuated traffic signals of various designs. Total cost includes field maintenance, bench repair, travel, and parts.
2. New York State Department of Transportation (NYSDOT): NYSDOT maintains a computerized file of the work hours required for the field maintenance of the approximately 2500 pretimed and actuated traffic signals in its jurisdiction. The costs of bench repair, travel, and parts are not included. Data for two recent years were obtained.
3. Ohio Department of Transportation (DOT): Ohio DOT furnished approximate data for 1976 on the frequency of repair of their 558 actuated traffic signals, divided into three levels of sophistication.
4. Minnesota Department of Highways: The Minneapolis District furnished data covering several years for the frequency of repair of 135 actuated controllers and several hundred detectors of various types.
5. Cincinnati, Ohio: Computerized maintenance summaries for $2\frac{1}{2}$ years were obtained for the frequency of repair of more than 700 controllers and their detectors, which were of various types and ages.
6. Tampa, Florida: A computerized record of frequency of repair was obtained for 1974 for almost 400 controllers of various types and ages.
7. Charlotte, North Carolina: In 1977, Charlotte purchased 72 microprocessor controllers of type 190 design. As of May 1978, 50 had been installed. The project staff obtained 14 months of maintenance data on these signals and 6 months of data on the other 388 signals in Charlotte.
8. Springfield, Illinois: Data on the frequency of repair of Springfield's 144 pretimed and actuated signals were obtained for 1976.
9. Winston-Salem, North Carolina: Four years of detailed maintenance cost data were obtained for one example each of pretimed and fully actuated traffic signals.
10. Washington, D.C.: Maintenance data for one year were obtained on a total of 497 loop detectors.

Caltrans Data

Traffic-signal maintenance-expense records for 121 selected locations are stored in the Caltrans computer. These costs include the dollar expense of all scheduled and nonscheduled field and bench maintenance of all electrical equipment at the location, including lampouts, detector malfunctions, and knockdowns. (Caltrans has a group relamping program; therefore, lampouts should be negligible in these statistics.) Table 1 shows data for the 23 months from July 1, 1976, to May 30,

Table 1. Caltrans annual maintenance costs for selected locations.

	Annual Cost per Signal						
	Two-Phase		Three- to Four-Phase		Five- to Eight Phase		All
Controller Type	N	Cost ($)	N	Cost ($)	N	Cost ($)	Cost ($)
Electromechanical							
Full volume-density	-		1[a]	1162	5[a]	1506	1449
Basic three-phase (nondensity)	-		6	753	4[a]	1209	935
Solid state							
Analog timing, transistors	-		4	657	7	1610	1263
Digital timing, noncomputer							
Brand A	1	429	4	796	9	815	782
Brand B	-		5	949	5	2600	1775
Brand C							
Two-phase	6	597	-		-		597
Two- to four-phase	2	694	11	612	-		625
Five- to eight-phase	1	354	-		10	1623	1508
Digital timing, minicomputer	-		-		33	1004	1004
Digital timing, microprocessor	-		1	421	4	757	690

[a]Apparently using minor movement controllers.

1978, adjusted to 12 months by multiplying the raw cost data by 12/23.

For two-phase digital controllers, Table 1 shows that the annual maintenance cost varies from $354 to $694, depending on the brand of manufacture. The weighted average of these data is $575.

Table 1 data for three- and four-phase, solid-state digital machines are complicated by the fact that the brand B digitally timed controllers had to be modified in design by Caltrans personnel in order to keep them operating acceptably. The model was soon discontinued by the manufacturer. If the maintenance costs for this model are therefore rejected as atypical outliers, then the average of the remaining data is $646. This is very close to the $657 for analog equipment, somewhat less than the $753 required to maintain the electromechanical controllers of basic (nondensity) design, and far less than the $1162 spent to maintain a single electromechanical volume-density controller of early vintage. Of all the three- and four-phase machines, the microprocessor design has the lowest cost—$421. The significance of the microprocessor's advantage here is clouded by the fact that only one location is included.

Controllers of five to eight phases vary widely in maintenance cost; the average is $1067 for solid-state, digital models (again omitting brand B). Once more the basic electromechanical models are somewhat higher than the digital machines, and the volume-density machines are much higher. The solid-state analog controllers were the highest of all—$1610/year—even after discarding a five-phase outlier that consumed $8065 of maintenance funds over the 23-month period. Again, the microprocessor design is significantly less expensive to maintain.

After 16 months of maintenance data had been obtained, Caltrans removed all of the electromechanical volume-density controllers, half of the 10 basic machines, and several solid-state controllers. The 16-month data for these controllers were properly annualized for inclusion in Table 1.

Table 1 suggests these general conclusions:

1. The five microprocessor controllers have significantly lower average maintenance costs than do the other types. These microprocessors are not the new type 170 but are of the special-purpose type that has nonvolatile memory.
2. Electromechanical volume-density controllers are particularly costly to maintain in comparison with their solid-state counterparts.
3. The increase in maintenance cost of three- to four-phase controllers over two-phase models is very small, probably less than $100/year. However, the jump from two-phase to five- to eight-phase controllers could easily double maintenance costs to more than $1000 unless a microprocessor controller is specified.

Caltrans now (1978) has a program under way to replace all 800 of its electromechanical traffic-actuated controllers over a three-year period. During that time, the state plans to install nearly 3000 microprocessor controllers of type 170 design. (These are purchased without factory software and the programs are loaded by the state.) As of early 1978, 50 type 170 controllers had been installed as Caltrans' standard unit for intersection or ramp-metering signal control on all safety or operational improvement projects. Since the first unit was installed in the field in September 1977, there were no maintenance data available as of April 1978. However, Caltrans expects that, since the type 170 has fewer connection points and a lower component parts count than other controllers, it will have an improved mean time between failures (MTBF). The 170's design should also result in a shorter mean time to repair (MTTR), because it is electrically organized in a more logical manner than earlier designs. It contains several self-test features intended to expedite bench repair.

Although the available California data do not include the data on the pretimed controller needed for this project, they do furnish total-cost benchmarks for other types. These benchmarks are incorporated in the comprehensive conclusions below.

NYSDOT Data

New York maintains a computerized inventory of its more than 2500 stop-and-go signals, flashers, and beacons. The work hours for the field portion of the maintenance of all of these signals are similarly catalogued. The top part of Table 2 provides a summary furnished by NYSDOT for a recent 12-month period for all of the regions except one. It includes controller maintenance only, not detector maintenance as well. The data show that, although the work hours per call are relatively independent of the type of controller, the work hours per signal increase with greater sophistication of the controller. At the request of the project staff, NYSDOT furnished a detailed computer printout of the controller and detector maintenance experience for the next 12-month period, October 1, 1976, to September 30, 1977. Selected data from the controller printout were tabulated by the project staff

Table 2. Portion of NYSDOT controller field-maintenance data for October 1, 1975, to September 30, 1976, and for October 1, 1976, to September 30, 1977.

Controller Type	No. of Signals	No. of Calls	Calls per Signal	Regular Work Hours	Overtime Work Hours	Total Work Hours	Work Hours per Call	Work Hours per Signal
October 1, 1975, to September 30, 1976								
Pretimed	168	479	2.85	704	605	1 309	2.73	7.79
Semiactuated	1243	5 500	4.42	8 201	5 442	13 643	2.48	10.98
Fully actuated	557	3 960	7.11	6 577	6 277	12 854	3.25	23.08
Flashing	506	537	1.06	950	744	1 694	3.15	3.35
Beacon	43	36	0.84	63	36	99	2.74	2.30
Total	2517	10 512	4.18	16 496	13 103	29 599	2.82	11.76
October 1, 1976, to September 30, 1977								
Electromechanical								
Pretimed	84	154	1.83	412	234	646	4.19	7.69
Semiactuated	583	1 520	2.61	3 918	1 345	5 263	3.46	9.03
Fully actuated	251	994	3.96	2 692	1 142	3 834	3.86	15.27
Volume-density	24	115	4.79	246	139	385	3.35	16.04
Mixed electromechanical and solid state								
Semiactuated	473	1 037	2.19	3 666	1 501	5 167	4.98	10.92
Fully actuated	194	626	3.23	1 772	826	2 598	4.15	13.39
Solid state								
Analog timing								
Semiactuated	28	27	0.96	178	36	214	7.93	7.64
Fully actuated								
Two- to four-phase	72	260	3.61	713	376	1 089	4.19	15.12
Five- to eight-phase	22	162	7.36	305	274	579	3.57	26.32
Digital timing, fully actuated								
Two- to four phase	37	54	1.46	155	154	309	5.72	8.35
Five- to eight-phase	14	58	4.14	145	155	300	5.17	21.43
Total	1782	5 007	2.81	14 202	6 182	20 384	4.07	11.44

Table 3. Cost of work hours for field maintenance of selected NYSDOT controllers for October 1, 1976, to September 30, 1977.

Controller Type	Cost per Signal ($) Two-Phase	Three- to Four-Phase	Five- to Eight-Phase	All
Electromechanical				
Pretimed	-	-	-	82
Semiactuated	92	-	-	92
Fully actuated	134	197	-	158
Volume-density	208	109	-	170
Mixed electromechanical and solid state				
Semiactuated	113	-	-	113
Fully actuated	113	155	-	140
Solid state				
Analog timing				
Semiactuated	75	-	-	75
Fully actuated	166	154	293	191
Digital timing, fully actuated	70	144	243	135

and are shown in the bottom part of Table 2 (in order to expedite the manual tabulation of the computer output, only those models installed at four or more locations in the state were included). The data in the bottom part are much more detailed in their breakdown by controller type than are the data above for the previous year.

Table 3 reduces the data from the bottom part of Table 2 to a dollar cost of the work hours for field maintenance for each type of controller by using NYSDOT-supplied labor costs of $9.00/h for regular time and $13.50/h for overtime (including an 80 percent overhead factor).

Tables 2 and 3 are incomplete because of their omission of detector maintenance data. Such data are tabulated by the NYSDOT by manufacturer rather than by type of traffic signal. The tabulation for 1976-1977 showed that 6190 detector-related service calls required 17 713 regular h and 7483 overtime h. The project staff distributed these calls and work hours among the various types of actuated controllers as judiciously as it could, according to the number of actuated phases of each controller type. These data were then merged with the controller-only data in the lower part of Table 2 and Table 3. The results are shown in Tables 4 and 5 as estimated data. Like Table 3, Table 5 uses the NYSDOT-supplied wage rates.

Table 5 is the most important because it presents controller-plus-detector costs, as does Table 1 for Caltrans. However, there are important differences between the two tables: Table 5 includes only the cost of field work hours, while Table 1 also includes the cost of repair vehicles, parts, and bench labor. By using the pretimed controls as a baseline at a field-maintenance cost of $82/year, Table 5 suggests these general conclusions:

1. A step up to two-phase semiactuated control will add approximately $110/year to the cost of maintenance, regardless of whether the controller is of electromechanical or solid-state design.
2. A further step up, from two-phase semiactuated control to any two-phase fully actuated controller that is not digital, will cost $143/year. A digital machine will reduce that increase in cost to only $76/year.
3. A two-phase electromechanical volume-density controller costs about $65 more per year to maintain than any basic controller of nondigital design and about $130 more than a digital model.
4. Basic actuated controllers of three and four phases cost an average of $462/year to maintain (if the "mixed electromechanical and solid-state" data are discarded as outliers). This is $380 more than pretimed control, $127 more than two-phase fully actuated nondigital control, and $194 greater than digital control.

Table 4. Estimated maintenance data for selected NYSDOT controllers and detectors for October 1, 1976, to September 30, 1977.

Controller Type	No. of Signals	No. of Calls	Calls per Signal	Regular Work Hours	Overtime Work Hours	Total Work Hours	Work Hours per Call	Work Hours per Signal
Electromechanical								
Pretimed	84	154	1.83	412	234	646	4.19	7.69
Semiactuated	583	2 874	4.93	7 797	2 984	10 781	3.75	18.49
Fully actuated	251	2 385	9.51	6 678	2 826	9 504	3.98	37.86
Volume-density	24	245	10.21	618	296	914	3.73	38.08
Mixed electromechanical and solid state								
Semiactuated	473	2 132	4.51	6 801	2 825	9 626	4.52	20.35
Fully actuated	194	1 820	9.39	5 191	2 270	7 461	4.10	38.46
Solid state								
Analog timing								
Semiactuated	28	95	3.39	373	118	491	5.17	17.54
Fully actuated								
Two- to four-phase	72	687	9.54	1 936	893	2 829	4.12	39.29
Five- to eight-phase	22	366	16.64	890	521	1 411	3.86	64.14
Digital timing, fully actuated								
Two- to four-phase	37	259	7.00	740	401	1 141	4.41	30.84
Five- to eight-phase	14	188	13.43	517	312	829	4.41	59.21
Total	1782	11 190	6.28	31 953	13 680	45 633	4.08	25.61

Table 5. Cost of work hours for estimated maintenance of selected NYSDOT controllers and detectors for October 1, 1976, to September 30, 1977.

Controller Type	Cost per Signal ($)			
	Two-Phase	Three- to Four-Phase	Five- to Eight-Phase	All
Electromechanical				
Pretimed	-	-	-	82
Semiactuated	189	-	-	189
Fully actuated	330	489	-	391
Volume-density	398	398	-	398
Mixed electromechanical and solid state				
Semiactuated	210	-	-	210
Fully actuated	309	619	-	399
Solid state				
Analog timing				
Semiactuated	177	-	-	177
Fully actuated	365	449	684	474
Digital timing, fully actuated	268	448	633	411

5. Solid-state controllers of five to eight phases cost an average of $659/year to maintain. This is $210/year more than a three- or four-phase analog or digital machine.

Ohio DOT

Ohio furnished maintenance data for its 558 traffic signals as shown below.

Controller Type	No. of Signals	No. of Calls	Annual Calls per Signal
Electromechanical			
Actuated (basic)	296	412	1.39
Volume-density	84	169	2.01
Solid state			
Analog timing	178	237	1.33
Digital timing	Few	Unknown	—

The table shows primarily that electromechanical volume-density controllers require significantly greater maintenance than do their basic counterparts, and much more than modern solid-state controllers.

Table 6. Frequency of controller repair by the Minneapolis District of the Minnesota Department of Highways.

Controller Type	Age (years)	Years of Data	No. of Signals	Annual Calls per Signal
Electromechanical, fully actuated				
Two-phase	0-5	5.0	8	2.40
Three- to five-phase	0-5	3.0	4	4.70
Total	0-5	-	12	2.92
Solid state				
Analog timing				
Semiactuated	0-5	5.0	2	1.10
Fully actuated				
Three-phase	0-5	4.9	11	1.84
Five-phase	0-5	5.0	27	3.19
	6-10	2.5	23	2.40
Digital timing, fully actuated				
Three-phase	0-5	3.45	13	1.34
Five- to eight-phase	0-5	3.0	24	2.05
Total	0-5	-	100	2.37
	6-10	2.5	23	2.4

Minnesota Department of Highways

Table 6 shows the frequency of repair of 135 controllers in the Minneapolis District of the Minnesota Department of Highways. The table indicates a distinct advantage of solid-state over electromechanical design. As expected, the greater the number of phases, the more frequent the repair. The table indicates that the frequency of repair of solid-state controllers does not increase with the age of the unit.

The available data included the frequency of repair of the 811 loop detectors and 12 magnetic detectors used with the 112 controllers in Table 6. It was found that the loop detectors averaged 0.24 failures per detector per year, and the magnetic models averaged 0.26/year.

Cincinnati, Ohio

Cincinnati has used a computerized traffic control equipment maintenance summary for five years. These summaries have been used to reduce the number of chronically malfunctioning intersection controls from 17 in

1973 to only 2 today. The city has more than 700 traffic signals.

Table 7 provides a summary of 2½ years of computerized record keeping—March 1975 to August 1977. The project staff removed all "normal cycle" reports (indicating no malfunction found by the repair crew). The staff also removed all failure reports associated with system features, such as coordination units, since the emphasis in this project is on individual intersections.

Table 7 does not indicate any significant increase in maintenance load with an increase in sophistication from pretimed to semiactuated to fully actuated controls. Rather, the evidence is that the solid-state actuated equipment is more reliable than the pretimed.

Table 7 shows that the frequency of repair of electromechanical equipment increases with age to approximately the 10th year and then decreases with greater age. This same phenomenon is evident also in the data presented below for Tampa, Florida.

Detector maintenance over two years in Cincinnati is shown below:

Detector Type	No. of Detectors	Annual Failures per Detector
Pressure	23	0.17
Magnetic	81	0.26
Loop	151	0.29
Sonic	37	0.32

The data indicate that the pressure detector is significantly more reliable than the other types listed. The data for magnetic and loop detectors are strikingly similar to the Minneapolis data reported above.

Table 7. Frequency of controller repair in Cincinnati from March 1975 to August 1977.

Controller Type	Age (years)	No. of Signals	Annual Calls per Signal
Electromechanical			
Pretimed	0-5	31	1.81
	6-10	35	2.17
	11-15	-	-
	16-20	139	1.99
	>20	72	1.74
	All	277	1.92
Semiactuated	0-5	2	1.50
	6-10	48	2.58[a]
	11-15	80	1.70
	16-20	54	1.65
	>20	38	1.68
	All	222	1.87
Fully actuated, operated semiactuated	0-5	16	1.13
	6-10	45	2.76[b]
	All	61	2.33
Solid state			
Semiactuated	0-5	2	1.50
Fully actuated, operated semiactuated	0-5	12	1.00
	6-10	7	1.14
	All	19	1.05

[a] High because of a single model.
[b] High because 20 units of an early-design phase-modular controller experienced 3.85 calls/signal each year.

Tampa, Florida

A computerized record of frequency of repair was obtained for almost 400 controllers for 1974. The record is summarized in Table 8; detector maintenance data are not included. Except for the pretimed controllers and the most recently purchased solid-state controllers operated as semiactuated, the maintenance load is extremely heavy compared with that reported above for Ohio, Minnesota, and Cincinnati. The higher rate for Tampa may be due to the severe lightning storms experienced frequently in Florida. Many of the Tampa rates are of the same order of magnitude as those obtained for New York State (Table 4).

Table 8. Frequency of controller repair in Tampa for 1974.

Controller Type	Age (years)	No. of Signals	Annual Calls per Signal
Electromechanical			
Pretimed	0-5	32	1.69
	6-10	93	2.33
	11-15	5	0.40
	16-20	1	1.00
	>20	45	2.76
	All	176	2.26
Semiactuated	0-5	1	0
	6-10	11	6.82
	11-15	38	8.71
	16-20	11	4.45
	>20	12	9.08
	All	73	7.73
Fully actuated	0-5	1	1.00
	6-10	3	4.33
	11-15	5	11.80
	16-20	4	7.50
	>20	1	5.0
	All	14	7.71
Semiactuated, operated fixed	0-5	1	2.00
	11-15	1	11.00
	All	2	6.5
Fully actuated, operated semiactuated	11-15	1	3.0
	16-20	2	5.0
	All	3	4.33
All			4.09
Solid state			
Semiactuated	6-10	29	5.48
	11-15	4	6.00
	All	33	5.55
Fully actuated	0-5	35	6.17
	6-10	33	9.09
	11-15	2	30.0
	All	70	8.23
Fully actuated, operated semiactuated	0-5	8	1.75
	6-10	8	5.00
	11-15	2	23.0
	All	18	5.56
All			7.04

Charlotte, North Carolina

Charlotte has a variety of actuated equipment of both electromechanical and solid-state design and has for many years provided adequate funding for traffic engineering operations. Therefore, maintenance data were readily available and, in addition, there was experience with a significant number of microprocessor controllers.

Their total of 438 controllers includes 72 type 190 microprocessors received in 1977. Unlike the five microprocessors reported on by Caltrans (Table 1), the Charlotte models are of the type that include volatile memory with battery backup in the event of power failure. The program for the type 190, unlike that for the type 170, is provided by the factory.

The installation of the Charlotte microprocessors began in March 1977. At the time of the visit by project personnel in October 1977, 24 microprocessors had been installed for an average of only about three months. The latest data available to us were as of December 1978; 69 microprocessors had been installed.

Table 9 summarizes six months of 1977 data for 438 Charlotte signals, except that the microprocessor controller data were updated to December 1978. The 69 microprocessor controllers were installed gradually between March 1977 and December 1978. Data on two installed less than a month before the December update

Table 9. Frequency of traffic-signal repair in Charlotte for April to September 1977.

Controller Type	Age (years)	No. of Signals	Annual Calls per Signal
Electromechanical			
Semiactuated	>20	75	1.95
Semiactuated (PR)	16-20	37	2.49
Fully actuated	0-5	3	0.67
	11-15	63	1.43
	>20	13	0.91
	All	79	1.29
All			1.83
Solid state			
Pretimed[a]	6-10	167	0.54
Semiactuated	0-5	1	2.00
	6-10	3	0.00
	All	4	0.50
Semiactuated (TPR)	6-10	11	1.82
	11-15	6	0.00
Fully actuated			
Digital, noncomputer	0-5	4	0.00
Microprocessor[b]	0-5	67	0.99
Analog, noncomputer	11-15	7	0.57

[a] These have four-phase frames but are operated in two phases, with only two load switches and without detectors or actuation module; a central digital computer operates them as pretimed controllers.
[b] March 1977 to December 1978.

were discarded, leaving data on 67 that had service records of 1-21 months. The project staff calculated the frequency of calls per year for each microprocessor individually, by using the number of months that each had been in place. This procedure was more precise than one that assumed that all 67 controllers had been in service for an average of 10.5 months. The table shows that Charlotte's electromechanical signals require service once or twice a year and that the new microprocessor controllers require close to one service call annually.

Springfield, Illinois

Springfield furnished maintenance data for a 12-month period in 1976-1977. These data for 144 signals are summarized in the table below, which shows an unusually high failure rate for semiactuated controllers.

Controller Type	No. of Signals	Annual Calls per Signal
Pretimed	117	2.37
Semiactuated	21	3.95
Fully actuated	6	1.67

The city traffic engineer explained that the city had had excellent operational results with two-phase semiactuated controllers for many years. Their maintenance problems began in 1975, when multiphase fully actuated controllers were purchased and operated semiactuated in an arterial system.

Winston-Salem, North Carolina

Four years of detailed maintenance cost data were obtained for one pretimed and one fully actuated controller at locations selected by the city as fairly typical; six of the eight calls for the pretimed controller were for preventive maintenance. The data, summarized below, show a very low cost to maintain the controllers (city costs of \$5/h for labor, truck, and supplies were increased by 80 percent to account for fringe benefits and overhead). However, the record of the loop-detector maintenance shows 33 trips in four years to retune, replace, and cut new loops.

Controller Type	Calls per Year	Maintenance Cost per Year (\$)
Pretimed	2.16	17
Fully actuated, three-phase, solid-state, digital	2.05	18
Loop detection for above controller	8.46	340

Washington, D.C.

A total of 497 loop detectors were installed as a part of the Urban Traffic Control System Research Project sponsored by the Federal Highway Administration. The installations were made only after a thorough study by the contractor of the available (crystal) electronics units and the procedures and materials for installing the loop wire and lead in. In the first year, there were 33 failures of the electronics units, for an annual rate of 0.07 failures/detector. During that period, 26 loops failed because of utility excavations; if these failures are added, the total annual rate becomes 0.13 failures/detector (1).

CONCLUSIONS

The foregoing findings provide the basis for conclusions about the total cost to maintain various types of controllers. Table 10 reflects these findings.

It was found that the Caltrans Maintenance Management System offers the only available data base of total maintenance costs, including both field and bench work, parts, and travel. It seemed appropriate, therefore, to plot the first points from those data. The table indicates the values determined directly from the Caltrans data in Table 1. The NYSDOT data (Table 5) were given second preference, because work hours were available only from that source.

For electromechanical equipment, the coordination point selected between the Caltrans and NYSDOT data sets was for fully actuated three- or four-phase controllers. The ratio of California total cost to NYSDOT field cost for that cell is 753 ÷ 489 = 1.54. The values in the other cells of Table 5 were multiplied by 1.54 to obtain the values shown in Table 10. For solid-state equipment with analog timing, the coordination point between the Caltrans and NYSDOT data was again taken for the fully actuated three- or four-phase controllers. The ratio of the two cells is 657 ÷ 450 = 1.46, which is reassuringly close to the 1.54 calculated for electromechanical equipment. This factor was used to obtain the remaining values for solid-state analog controllers.

The factors of 1.46 and 1.54 indicate essentially that, for every dollar spent on work hours for field maintenance of actuated equipment, an additional 50 cents is required for the other items that constitute the total cost as defined by Caltrans. These items include the truck and its fuel, the parts used in the repair work, and the cost of the bench labor. If these items cost about the same for pretimed equipment as they do for actuated models, then it would be appropriate to derive the total cost of pretimed controller maintenance as 1.50 × \$82 (from Table 5) or \$123. However, bench-repair labor is certainly less for pretimed equipment than for actuated designs. Therefore, the project staff arbitrarily assigned a reduced cost of \$115 for that entry in Table 10.

Table 10. Derived conclusions on the total annual cost to maintain various types of traffic signals.

Controller Type	Cost per Signal ($) Two-Phase	Three- to Four-Phase	Five- to Eight-Phase	All
Electromechanical				
Pretimed	-	-	-	115
Semiactuated	291[a]	-	-	-
Fully actuated	508[a]	753[a]	1209[a]	-
Volume-density	613[a]	1162[a]	1506[a]	-
Solid-state				
Analog timing				
Semiactuated	258	-	-	-
Fully actuated	532	657[a]	1610[a]	-
Digital timing (except microprocessor), fully actuated	575[a]	661[a]	1090[a]	-
Microprocessor, fully actuated[b]	-	421[a]	757[a]	-

[a]Taken directly from the Caltrans Maintenance Management System data in Table 1.
[b]These data are for a few controllers from a single manufacturer. Other microprocessor controllers may have different maintenance requirements (see Charlotte data in Table 9).

ADEQUACY OF DATA

These data were gathered to assist in the future selection of type of control—pretimed, semiactuated, basic fully actuated, and density fully actuated. Data on microprocessor controllers must be included. In this context there are two fundamental inadequacies in the available data.

One is that none of the data sets provides the total maintenance costs for each of the four types of control. The Caltrans data quote total cost—field and bench labor, travel, and materials—but do not include pretimed control or the new type 170 microprocessor. The NYSDOT data include pretimed equipment, but only the cost of the field work hours can be obtained; bench labor, travel, and parts are not covered. Most of the other sources quote only frequency of repair, not dollar cost.

Another difficulty with these data is that future consideration of actuated control—at least for the future as we can see it now—will focus on the microprocessor controller and the digital loop detector. Almost all of the available maintenance data predate these recent innovations.

Respondents in California, New York, and Charlotte, for example, make it clear that microprocessor designs of type 170 (user programmed) and type 190 (factory programmed) are showing a longer MTBF and a shorter MTTR than have the other controllers reported herein. (However, hard data on this superiority are skimpy so far.) Presumably other designs of microprocessors will show similar benefits when their records are tabulated.

Moreover, the digital loop detector is proving to be significantly more effective than its analog counterpart. New York State, for example, found in 1978 that some digital loops are successfully operating even though they are in such poor condition that the locations had been scheduled for reinstallation of new loops. A number of other respondents indicated that they are extremely impressed with the digital unit's sensitivity and ability to operate under adverse conditions of loop condition, temperature, etc.

It is notable that this research project was conceived at a time when some states—particularly those in the Northeast and upper Midwest—were experiencing great difficulty in maintaining actuated controllers and loop detectors of conventional design. In 1977 and 1978, the microprocessor and the digital loop detector began to change this situation completely for some agencies. New York State, for example, now is able to consider selecting fully actuated control at individual intersections. It seems clear that this research project has been overtaken by technological breakthroughs that greatly diminish the potential attraction of pretimed or semiactuated control at individual intersections.

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