CONNECTICUT DEPARTMENT OF TRANSPORTATION

BUREAU OF HIGHWAYS

OFFICE OF TRAFFIC ENGINEERING

BEFORE AND AFTER EVALUATION OF COMPUTERIZED URBAN TRAFFIC CONTROL SYSTEMS IN THE GREATER HARTFORD AREA

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I. INTRODUCTION

This document summarizes the results of a "Before" and "After" study of a computerized traffic responsive Urban Traffic Control System (UTCS) installed initially by the Connecticut Department of Transportation in 1982 and subsequently expanded throughout the Greater Hartford area as part of a Federal Highway Administration Project.

This came about when the Department of Transportation, concerned over the increasing amount of commuter traffic using its primary and secondary road system, sought to improve traffic flow by incorporating the lastest state-of-the-art technology in computerized traffic control management. Initially, it was decided to try this methodology on 37 traffic signals along Route 44 between the towns of Hartford and Canton, as a test project.

Immediately, upon completion, a significant improvement in traffic flow was realized, which prompted the Department to expand this technology along 8 additional arterials in the Greater Hartford area encompassing over 200 traffic signals. Another 120 traffic signals along Route 1 in the south-west corridor of the State, also, came under computer control using a "Closed Loop" method of management. However, this report will only reference the UTCS system.

The results of this study will show system wide improvements, noted below, even with a 21 percent increase in traffic volume during the study period:

38% reduction in average delay time
28% reduction in average number of stops
11% reduction in average travel time
9% increase in average travel speed
7% reduction in number of accidents

A by-product of these improvements was the substantial reduction of fuel consumption and auto emmissions along with corresponding improvement of vehicle hours traveled. Actual figures were not developed because of flucuations in the algorithms used to determine fuel consumption and auto emissions that only speculates this benefit to the road user. The intent of this study is to emphasize the benefits in terms of measurements of effectiveness and the impact of traffic performance on each arterial system. Another by-product of the UTCS system, not covered in the report, is the ability of the computer to monitor traffic signal equipment and changing traffic volumes which improves maintenance and operations activities. These are all positive elements that translate the use of the UTCS system into a highly efficient traffic management tool.

II. DESCRIPTION

The Traffic System's Computer Unit in the Office of Traffic Engineering conducted "Before" and "After" studies on six arterial systems to determined what benefits were achieved through computer control. By conducting travel time and delay studies, before and after installation, traffic performance of each system was determined and measurements of effectiveness (MOE's) in terms of volume, trip travel time, average speed, delay time, and number of stops was achieved.

The contents of this report references data procured from Routes 5, 15, 44, 99, 159 and 187 (see Figure 1) in the Greater Hartford area and reflects arterial traffic performance indicators, summaries and analysis.

Study Objectives:

Major objectives of the study were to:

- Measure difference in system performance before and after installation.
- Evaluate the measurements of effectiveness (MOE's) and the impact on traffic flow.
- Analyze the performance of system hardware, software, and signal system timing patterns.

III. EVALUATION PROCEDURE

Approach:

Data collection for system evaluation was developed to provide comparable statistics against that collected prior to the traffic signal system installation. "Before" study evaluations were accomplished manually. "After" study evaluations were accomplished by the use of an in-vehicle computer. Actual volumes were retrieved from system detectors strategically located throughout each system. Although the process varied, consistency was essential in data collection to ensure that the "After" study replicated the "Before" study. Therefore, the results of the studies reflect the performance of the entire system as accurately as possible.

Data Collection Periods:

The data collection periods for the "Before" and "After" studies were taken during the peak hour travel times of 7:00 - 8:30 AM and 4:00 - 6:00 PM (week days). However, in an effort to maintain consistency with typical weekday activity no data collection took place during the Monday AM peak and Friday PM peak hours.

Table #1 represents the time periods of data collection for each arterial. The "After" study data was collected in 1986-87 subsequent to contract approval of subject arterials. Table 2 reflects the study limits of each arterial.

AND AFTER PERIODS

Route Number	Before	After
5	10/01/81-09/30/83	01/01/87-12/31/88
15	04/01/83-03/31/85	01/01/87-12/31/88
44	04/01/83-03/31/85	01/01/87-12/31/88
99	10/01/81-09/30/83	01/01/86-12/31/87
159	10/01/81-09/30/83	01/01/87-12/31/88
187	04/01/83-03/31/85	01/01/87-12/31/88

Table 2 - Before and After Arterial Study Limits

Arterial	Terminus Start	Terminus End	Travel Direction	No. of Signals	Mi.
Route 5	Willow St. E. Htfd	Bright Meadow Rd. Enfield	North/South	51	19.88
Route 15	Nott St. Wethersfield	No. Colony St. Berlin	North/South	19	9.84
Route 44	Belden St. Hartford	Route 179 Canton	East/West	43	14.24
Route 99	Jordan La. Wethersfield	Gorman Rd. Rocky Hill	North/South	20	5.72
Route 159	Meadow Rd. Windsor	Rte. 75 Windsor	North/South	14	3.32
Route 187	Albany Ave. Hartford	Park Ave. Bloomfield	North/South	8	2.68

Traffic Volume Collection

The procedure used to obtain volume data during the "Before" study period was by manual count of turning movements and machine counts of through movements. This method provided the required data necessary to develope initial timing plans. The "After" study volume data was obtained through system detectors (sampling detectors) located throughout each system. These six foot by six foot detectors provided the MOE's including volumes in fifteen minute increments and twenty four hour counts. A comparison was made and noted in subsequent tables.

Travel Time and Delay Studies

In-vehicle travel time and delay studies were conducted to evaluate the efficiency of an arterial system and determine where the most congested area was located. Each run determined the amount of time taken to traverse a system. A by-product during the "Before" study was the accumulation of data which provided engineering with much needed information required for progression algorithms.

Three morning and evening peak hour travel time runs were taken in each direction for every subsystem for both "Before" and "After" studies. The "Before" study runs were conducted manually using the following procedure:

- The driver had the responsibility of maintaining a speed representative of the posted speed limit and that of traffic flow.

- A passenger called a "recorder" had the responsibility of calling out the control points (usually intersecting streets) and recording where the points of delay occurred. The recorder noted pertinent data such as, elapsed time, start point, ending point, speed and control points.

"After" studies were conducted via an in-vehicle computer analysis procedure. A study vehicle equipped with a Numetrics-brand device wired into the transmission and attached to a portable computer provided the necessary analysis of a travel time delay study. The cumulative distance was output to the computer once per second and stored in memory and then processed back at the office. The information saved on disk, provided performance indicators such as; travel time of the subsystem, delay time (in seconds), average speed, cruise speed, number and length of stops, distance between intersections. An example of a typical run-summary report is shown in Figure 2.

Figure 2 - EXAMPLE OF RUN SUMMARY REPORT

Run Summary of: Route 5
From: Nott St.
To: North Colony Rd.
Date of Run: 11/12/87
Time of Run: 16:03:25
File: RT15.R08
Direction: South

Link	Cross St. at end of the link	Link Length Feet	Delay Time Seconds	Number of Stops	Travel Time Seconds	Average Speed MPH	Cruise Speed Mph
	Nott	-	-	-	-	-	-
1	Arrow	2595	0	0	46	38.5	41.4
2	Prospect	5459	0	0	74	50.3	50.5
3	Kitts	1970	27	1	70	19.2	37.3
4	Griswold	5582	0	0	90	42.3	45.1
5	Pascone	1385	0	0	25	37.8	39.8
6	Richard	1876	0	0	43	29.7	35.1
7	Pane	2660	0	0	49	37.0	38.6
8	Webster	826	0	0	14	40.2	40.2
9	Seldon	1365	0	0	20	46.5	47.7
10	Deming	3121	0	0	50	42.6	43.7
11	Woodlawn	3376	0	0	46	50.0	50.0
12	Woodruff	897	0	0	12	51.0	51.2
13	Middletown	5651	0	0	75	51.4	51.4
14	Worthington	3592	0	0	50	49.0	49.0
15	Orchard	3568	0	0	49	49.6	49.6
16	New Park	1161	0	0	16	49.5	51.3
17	Toll Gate	3827	0	0	49	53.3	53.3
18	No. Colony	3087	0	0	42	50.1	51.0
	Summary	51998	27 (0:27)	1	820 (13:40)	43.2	46.9

Accidents:

Using accident experience obtained from the DOT archives for the before and after time periods, a comparison was made with similar accident types. Specific types reviewed were rear-end and sideswipe (same direction). These accident types could be corrected by improving corridor progression through signal coordination. A comparison was made to determine how each arterial was affected in terms of total accidents (by type) as shown in table 8.

IV. ANALYSIS

An analysis of CONNDOT's computerized traffic signal system revealed that the efficiency of corridor traffic had improved considerably as noted in subsequent tables for volume, travel time and speed, delay time, reduction in stops and accidents.

Volume:

Approach volumes for each system were retrieved prior to installation from machine counts and after installation from system detectors. A comparison was made during the peak hours of traffic and noted in table 3 with a net change in percentage.

Travel Time and Speed:

Travel time and speed are two performance indicators used to measure system efficiency. Three travel time runs were conducted through each corridor during peak periods in each direction before and after installation with the results noted in figures 4 and 5. The overall travel time was reduced by eight percent during the AM peak period and by ten percent during the PM peak period.

The determining factors in reducing the travel time through each corridor can be attributed to the following:

1. The fine tuning of splits and offset relationships between adjacent traffic signals to actual field conditions.

2. Optimizing cycle lengths for each pattern selected through the traffic responsive mode of UTCS.

3. Quick response to equipment malfunctions detected by central control and reacted to by maintenance forces.

Table 3 - CHANGE IN AVERAGE VOLUME

Time Period	Route No.	Average Volume (VPH)		Change (%)
		Before	After	
AM PEAK	5	623.00	765.00	+23
	15	1121.00	1380.00	+23
	44	687.50	691.50	+ 1
	99	397.50	573.50	+44
	159	519.50	743.00	+43
	187	582.00	808.50	+39
PM PEAK	5	762.50	905.00	+19
	15	982.50	1172.50	+19
	44	666.00	758.50	+14
	99	587.00	640.00	+ 9
	159	733.50	865.50	+18
	187	596.50	682.00	+14

Table 4 - CHANGE IN AVERAGE TRAVEL TIME

Time Period	Route #	Average Travel Time (MIN)		Change (%)
		Before	After	
AM PEAK	5	40.00	32.30	-19
	15	14.40	13.95	- 5
	44	32.98	28.98	-12
	99	11.75	10.50	-11
	159	7.55	7.00	- 7
	187	6.18	6.30	+ 2
PM PEAK	5	41.00	33.25	-19
	15	14.95	15.40	+ 3
	44	30.94	29.43	- 5
	99	13.35	10.95	-18
	159	6.90	7.43	+ 8
	187	8.55	6.95	-19

Table 5 - CHANGE IN AVERAGE SPEED

Time Period	Route #	Average Speed (MPH)		Change (%)
		Before	After	
AM PEAK	5	28.50	33.50	+18
	15	41.60	42.65	+ 3
	44	26.00	29.60	+14
	99	29.25	31.20	+ 7
	159	26.30	28.55	+ 9
	187	25.95	25.60	- 1
PM PEAK	5	29.93	35.54	+19
	15	39.70	38.30	- 4
	44	27.80	29.20	+ 5
	99	25.50	29.75	+17
	159	28.75	32.30	+12
	187	18.95	23.15	+22

A comparison of before and after speeds (table 5) indicated an overall speed increase of eight (8) percent during the AM peak and twelve (12) percent during the PM peak.

TABLE 6 - AVERAGE DELAY TIME

Time Period	Route #	Average Delay (Min/Vehicle) Before	After	% Change
AM PEAK	5	6.30	3.40	-46
	15	1.38	0.97	-30
	44	6.69	3.71	-44
	99	2.33	1.26	-46
	159	1.24	0.62	-50
	187	0.64	0.69	+ 8
PM PEAK	5	5.65	3.30	-42
	15	0.84	1.30	+55 *
	44	5.39	4.08	-24
	99	2.50	1.35	-46
	159	1.02	0.89	-13
	187	2.40	1.05	-56

Stops and Delay Time - Table 6 & 7

The delay study was taken to evaluate the efficiency of traffic movement on each arterial in terms of average delay. The study period was during the AM and PM peak hours. The overall average delay time computed to be 38 percent with an overall average of 28 percent in stops.

* See next page.

TABLE 7 - CHANGE IN AVERAGE NUMBER OF STOPS

Time Period	Route #	Average Number of Stops/Vehicle		% Change
		Before	After	
AM PEAK	5	15.70	10.00	-36
	15	3.00	3.25	+ 8 *
	44	18.75	10.85	-42
	99	6.15	3.60	-41
	159	4.04	2.75	-32
	187	2.33	1.80	-23
PM PEAK	5	17.30	12.10	-30
	15	2.75	3.75	+36 *
	44	13.50	12.00	-11
	99	7.15	4.75	-34
	159	3.36	3.20	- 5
	187	5.15	3.35	-35

* Four major traffic generators were contributing factors in the increase of average delay time and average stops because of mid-block generation that caused unpredictable queques at adjacent intersections.

Accidents

Table 8 reflects the changes in accidents that have occurred during the study periods noted previously for the "Before" and "After" evaluation periods. Specific accident types (rear-end and side-swipe in the same direction) that are correctable by progression were totaled and compared for analysis.

TABLE 8 - ACCIDENT ANALYSIS

Route	Time Period	Total ACT.	Acc. ADJ.	% Change ACT.	% Change ADJ.	Rear-end & S.S. ACT.	Rear-end & S.S. ADJ.	TMVM (1)	ADT
5	Before	1502	1740			593	687	205.2842	14500
5	After	1636	1437			712	625	261.7852	18400
	Change	+134	-303	8.9	-17.4	+119	-62	233.5347	16450
15	Before	572	620			296	321	176.2948	24600
15	After	640	592			379	351	201.7944	28100
	Change	+68	-28	11.9	-4.4	+83	+30	189.0446	26350
44	Before	1786	1987			738	823	179.3202	17300
44	After	2010	1822			882	799	213.6697	20600
	Change	+224	-165	12.5	-8.3	+144	+19	196.4950	18950
99	Before	670	718			215	231	66.7665	16000
99	After	748	700			252	235	74.9667	18000
	Change	+78	-18	11.6	-18.0	+37	+4	70.8666	17000
159	Before	287	326			83	94	30.5279	12500
159	After	352	315			140	125	37.3819	15300
	Change	+65	-11	22.6	-3.3	+57	+31	33.9549	13900
187	Before	402	449			149	167	23.2885	11800
187	After	620	561			232	209	27.9003	14200
	Change	+218	+112	54.2	+24.9	+83	+42	25.5944	13000
Total	Before	5298	5923			2111	2366	686.7200	
	After	6071	5488			2625	2370	823.6600	
	Change	+771	-434	14.7	-7.3	+514	+4	755.1900	

Note: (1) TMVM - Total Million Vehicle Miles

When comparing the increase in volume to the increase in accidents that occurred by utilizing the Chi-Square @ 90% confidence level, the total number of accidents decreased by 7.3 percent. A decrease in accidents did occur throughout each arterial except for Route 187. Additional accident analysis revealed that wet weather accidents increased from 107 to 217 (102%) between the before and after periods.

V. ARTERIAL SUMMARIES

Data Accumulation Process:

Data for the "Before" and "After" studies was accumulated through test car methods. Three test car runs were performed and averaged for both before and after system installation by time period (AM & PM peak) and direction.

Before Study Approach

The "Before" study data was attained prior to project construction. These studies utilized forms from the Traffic Institute of Northwestern University for intersection delay travel time and delay runs, as well as percent stopping studies. These forms were used to provide traffic performance measures such as approach volumes for each intersection, delay time per vehicle, travel time per arterial test car run, number of stops per arterial test car run and average speed per arterial test car run.

After Study Approach

The "After" study data was accumulated from Micro-float and UTCS permanent count stations (system detectors). Micro-float provided traffic performance measures for each test car run performed. The UTCS permanent count stations provided volume data for the "After" study period.

Approach Comparison

Volume data from each permanent count station was averaged by direction, time period and arterial. The "Before" study approach required matching selected locations where existing permanent count stations existed for duplication of data accumulation. The other traffic performance measures were compared by the same average technique to provide the base for "Before" and "After" studies.

The Tables shown on the following pages reflect the traffic performance indicators, mentioned above, for Routes 5, 15, 44, 99, 159 & 187.

VI ARTERIAL TRAFFIC PERFORMANCE INDICATORS

Table 9 - ROUTE 5 - TRAFFIC PERFORMANCE INDICATORS

Direction of Travel	Traffic Flow Parameter	AM Peak		(%) Change	PM Peak		(%) Change
		Before	After		Before	After	
North	Volume (Vph)	535.00	626.00	+17	803.00	1084.00	+35
	Travel Time (Min)	37.00	28.60	-23	46.00	37.00	-20
	Delay Time (Min)	4.60	2.80	-39	5.40	4.50	-17
	Speed (Mph)	30.00	36.00	+20	28.16	37.38	+33
	Number of Stops	12.70	11.10	-13	16.30	14.50	-11
South	Volume (Vph)	710.00	904.00	+27	722.00	726.00	+ 1
	Travel Time (Min)	43.00	36.00	-16	36.00	29.50	-18
	Delay Time (Min)	8.00	4.00	-50	5.90	2.10	-64
	Speed (Mph)	27.00	31.00	+15	31.70	33.70	+ 6
	Number of Stops	18.70	9.00	-52	18.30	9.70	-47

Table 10 - ROUTE 15 - TRAFFIC PERFORMANCE INDICATORS

Direction of Travel	Traffic Flow Parameter	AM Peak		(%) Change	PM Peak		(%) Change
		Before	After		Before	After	
North	Volume (Vph)	1417.00	1749.00	+23	568.00	626.00	+10
	Travel Time (Min)	15.80	15.10	- 4	14.20	15.10	+ 6
	Delay Time (Min)	1.90	1.40	-26	0.73	1.40	+92
	Speed (Mph)	37.40	39.00	+ 4	41.80	39.00	- 7
	Number of Stops	4.50	4.50	0	2.50	4.00	+60
South	Volume (Vph)	825.00	1010.00	+22	1397.00	1719.00	+23
	Travel Time (Min)	13.00	12.80	- 2	15.70	15.70	0
	Delay Time (Min)	0.38	0.53	+41	0.95	1.20	+26
	Speed (Mph)	45.70	46.30	+ 2	37.60	37.60	0
	Number of Stops	1.50	2.00	+33	3.00	3.50	+17

Table 11 - ROUTE 44 - TRAFFIC PERFORMANCE INDICATORS

Direction of Travel	Traffic Flow Parameter	AM Peak		(%) Change	PM Peak		(%) Change
		Before	After		Before	After	
East	Volume (Vph)	952.00	982.00	+ 3	379.00	472.00	+25
	Travel Time (Min)	35.61	30.00	-16	28.16	28.50	+ 1
	Delay Time (Min)	8.20	3.81	-47	3.85	3.80	- 1
	Speed (Mph)	24.00	28.60	+19	30.30	30.00	- 1
	Number of Stops	22.50	11.00	-51	12.00	11.00	- 8
West	Volume (Vph)	423.00	401.00	- 5	953.00	1045.00	+10
	Travel Time (Min)	30.35	27.95	- 8	33.72	30.35	-10
	Delay Time (Min)	5.18	3.61	-30	6.93	4.35	-37
	Speed (Mph)	28.40	30.60	+ 8	25.30	28.40	+12
	Number of Stops	15.00	10.70	-29	15.00	13.00	-13

Table 12 - ROUTE 99 - TRAFFIC PERFORMANCE INDICATORS

Direction of Travel	Traffic Flow Parameter	AM Peak		(%) Change	PM Peak		(%) Change
		Before	After		Before	After	
North	Volume (Vph)	495.00	629.00	+27	568.00	626.00	+10
	Travel Time (Min)	11.50	12.00	+ 4	13.30	10.40	-22
	Delay Time (Min)	2.00	1.70	-15	2.80	1.60	-43
	Speed (Mph)	30.30	28.30	- 7	25.50	29.70	+17
	Number of Stops	6.00	4.50	-25	8.00	5.00	-37
South	Volume (Vph)	300.00	518.00	+73	606.00	654.00	+ 8
	Travel Time (Min)	12.00	9.00	-25	13.40	11.50	-14
	Delay Time (Min)	2.65	0.82	-31	2.20	1.10	-50
	Speed (Mph)	28.20	34.10	+21	25.50	29.80	+17
	Number of Stops	6.30	2.70	-57	6.30	4.50	-29

Table 13 - ROUTE 159 - TRAFFIC PERFORMANCE INDICATORS

Direction of Travel	Traffic Flow Parameter	AM Peak		(%) Change	PM Peak		(%) Change
		Before	After		Before	After	
North	Volume (Vph)	326.00	421.00	+29	740.00	850.00	+15
	Travel Time (Min)	7.50	6.70	-11	7.00	8.50	+21
	Delay Time (Min)	1.42	0.65	-54	0.83	1.00	+20
	Speed (Mph)	26.30	29.80	+13	28.00	23.00	-18
	Number of Stops	4.33	2.50	-42	3.40	4.00	+18
South	Volume (Vph)	713.00	1065.00	+51	727.00	881.00	+21
	Travel Time (Min)	7.60	7.30	- 4	6.80	6.37	- 6
	Delay Time (Min)	1.05	0.58	-55	1.20	0.77	-64
	Speed (Mph)	26.30	27.30	+ 4	29.50	31.60	+ 7
	Number of Stops	3.75	3.00	-20	3.30	2.40	-28

Table 14 - ROUTE 187 - TRAFFIC PERFORMANCE INDICATORS

Direction of Travel	Traffic Flow Parameter	AM Peak		(%) Change	PM Peak		(%) Change
		Before	After		Before	After	
North	Volume (Vph)	322.00	496.00	+54	564.00	624.00	+11
	Travel Time (Min)	6.35	6.10	- 4	8.00	7.00	-14
	Delay Time (Min)	0.68	0.48	-29	1.70	1.00	-41
	Speed (Mph)	25.40	26.40	+ 4	20.00	23.00	+15
	Number of Stops	2.66	2.30	-13	4.30	3.00	-30
South	Volume (Vph)	842.00	1121.00	+33	629.00	740.00	+18
	Travel Time (Min)	6.00	6.50	+ 8	9.10	6.90	-24
	Delay Time (Min)	0.60	0.90	+50	3.10	1.10	-64
	Speed (Mph)	26.50	24.80	- 6	17.90	23.30	+30
	Number of Stops	2.00	1.30	-35	6.00	3.70	-38

SUMMARY

An analysis of the UTCS system revealed that the Connecticut Department of Transportation's attempt to improve the efficiency of major arterials in the Greater Hartford area by coordinating traffic signals via a central computer was a proven success. With a substantial increase in traffic volumes along the targeted corridors, improvements to traffic flow were found to be consistent as indicated by tables within the report.

However, in order to maintain the efficiency of these corridors, it was imperative that a total commitment by the Connecticut Department of Transportation be made to provide the necessary personnel and equipment for this effort. Without this support, it is conceivable that this project may have failed.

A major benefit of the UTCS system is its ability to monitor field equipment and local detector circuits to ensure that the integrity of the intersectional design is not being compromised because of malfunctioning equipment. Prior to computerization of traffic signal systems the condition of most traffic control equipment was uncertain. In many cases timing sequences were affected and equipment failures went undetected. However, under computer control this condition was eliminated and maintenance of the system improved 100 percent.

With the ability to adjust the timing of a signalized intersection by changing the splits, cycle lengths, force-offs and offsets from a central location via a telephone transmission, it was decided that further research into other types of computer systems would be undertaken. Subsequently, other computer techniques have been developed and implemented in other parts of the State with very good results.

In the Office of Traffic Engineering the Traffic Systems Computer Unit conducted a study (HPR task) to determine what groups of traffic signals on all State roads qualified for interconnection. The study, which took two years to complete, revealed that of the 1925 traffic signals investigated along 372 State Routes, there was a potential of 123 systems. If all these systems were installed, in terms of fuel efficiency and vehicle hours of travel saved, a reduction in the millions of gallons of fuel with a proportionate number of vehicle hours would be achieved with a reduction in accidents, delays, stops and auto emmissions.

The computer provides the tool required by the engineer to implement numerous traffic control strategies and to evaluate their effectiveness in terms of traffic performance and hardware reliability. Having this flexibility places the Department in an advantageous position to obtain traffic flow improvements in problem areas with a minimum expenditure and limited manpower resources.

The continued development in the application of computer technology for traffic control systems will eventually be expanded throughout the State of Connecticut to fulfill an obligation to the taxpayer and the motoring public to provide them with the most efficient transportation system possible.