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16. Abstract

The Texas Department of Transportation (TxDOT) was the administering agency for the Traffic Management (TM) Program, which was funded with Oil Overcharge funds made available by the Governor's Energy Office. The TM Program was approved by the United States Department of Energy as part of a package of transportation-related programs with the objective of reducing energy consumption. This grant program provided the sum of $7.5 million to local city governments across the state for minor geometric improvements at intersections, optimization of traffic signal timing plans, and implementing other traffic management techniques. As stated previously, the program's objective was to reduce traffic congestion and facilitate the flow of traffic, with the goal of achieving more efficient use of energy resources.

With 51 completed projects, the TM Program has resulted in benefits that will pay for the cost of the program many times over. These benefits were estimated from the required ""Before" and "After" studies that were submitted by the cities. These studies document the major goals of the TM Program -- reductions in fuel consumption and unnecessary delay and stops. All projects were evaluated using the same unit costs. The TM Program resulted in 862 intersections in 26 cities being improved; the expenditure of $9.6 million of program funds and local matches; and reductions in fuel consumption, delay, and stops of 18.2 percent (14.9 million gallons), 32.7 percent (13.1 million hours), and 13.1 percent (457 million stops), respectively. The total savings to the public in the form of reduced fuel, delay, and stops will be approximately $152.4 million ($118.6 million in the next year alone). In regard to fuel savings, Texas motorists are realizing $1.55 in savings for every dollar spent, and if stops and delay are included, Texas motorists are realizing $15.81 in savings for every dollar spent. These savings will continue to accrue in future years without any additional expenditures; therefore, the benefits to the public will be even greater.

This report is the first of two volumes. The other volume is:

Benefits of Texas Traffic Management (TM) Grant Program: Volume II. Appendices C - D

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BENEFITS OF THE TEXAS TRAFFIC MANAGEMENT (TM) GRANT PROGRAM

VOLUME I. EXECUTIVE SUMMARY AND APPENDICES A - B

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Sponsored by
The Texas Department of Transportation
and
The Texas Governor's Energy Office

November 1993

Texas Transportation Institute
Texas A&M University
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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
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mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
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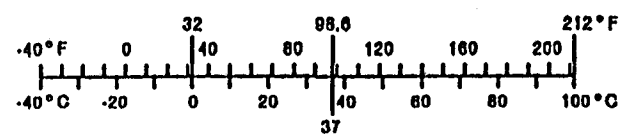
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



SUMMARY

The Texas Department of Transportation (TxDOT) was the administering agency for the Traffic Management (TM) Program, which was funded with Oil Overcharge funds made available by the Governor's Energy Office. The TM Program was approved by the United States Department of Energy as part of a package of transportation-related programs with the objective of reducing energy consumption. This grant program provided the sum of $7.5 million to local city governments across the state for minor geometric improvements at intersections, optimization of traffic signal timing plans, and implementing other traffic management techniques. As stated previously, the program's objective was to reduce traffic congestion and facilitate the flow of traffic, with the goal of achieving more efficient use of energy resources.

With 51 completed projects, the TM Program has resulted in benefits that will pay for the cost of the program many times over. These benefits were estimated from the required "Before" and "After" studies that were submitted by the cities. These studies document the major goals of the TM Program -- reductions in fuel consumption and unnecessary delay and stops. All projects were evaluated using the same unit costs. The TM Program resulted in 862 intersections in 26 cities being improved; the expenditure of $9.6 million of program funds and local matches; and reductions in fuel consumption, delay, and stops of 18.2 percent (14.9 million gallons), 32.7 percent (13.1 million hours), and 13.1 percent (457 million stops), respectively. The total savings to the public in the form of reduced fuel, delay, and stops will be approximately $152 million ($118.6 million in the next year alone). In regard to fuel savings, Texas motorists are realizing $1.55 in savings for every dollar spent, and if stops and delay are included, Texas motorists are realizing $15.81 in savings for every dollar spent. These savings will continue to accrue in future years without any additional expenditures; therefore, the benefits to the public will be even greater.

Besides the intuitive benefits of reducing unnecessary vehicle stops, delays, fuel consumption and emissions, the TM Program brought together the diverse transportation community of city staffs, consultants, TxDOT personnel and researchers to improve traffic operations at the state's signalized intersections. The program also has increased the expertise of transportation professionals in traffic management techniques and created a traffic data base that can be used for additional transportation projects. Most importantly, perhaps, the TM Program has enhanced the image of the transportation professional by improving of quality of traffic flow on arterial streets in Texas, and is helping to change the driver perspective of always stopping at a "red" light to not having to stop, at a "green" light.

ACKNOWLEDGEMENTS

The results reported herein were accomplished as a result of a program entitled "Traffic Management (TM) Grant Program." The program was administered by the Texas Department of Transportation and sponsored by the Governor's Energy Office in cooperation with the U.S. Department of Energy. Training and technical assistance for the program were provided by the Texas Transportation Institute and Texas Engineering Extension Service at Texas A&M University and the McTrans Center at the University of Florida. Program managers/supervisors were Robert L. Otto, P.E., with the Governor's Energy Office, Carlos A. Lopez, P.E., and Ronald T. Barnes with the Texas Department of Transportation, and Daniel B. Fambro, P.E., with the Texas Transportation Institute. The authors wish to acknowledge the contributions of the many people that helped make this program a success.

The Texas Department of Transportation secured the funding, prepared the grant manual, and was responsible for all contractual and administrative matters. TxDOT staff members making significant contributions to the TM Program include:

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DISCLAIMER

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CHAPTER ONE

INTRODUCTION

It has been estimated that approximately one-fifth of the total daily U.S. oil consumption is used by vehicles traveling in urban areas through signalized intersections. A significant portion of this consumption is wasted due to poor signal timing. In street networks with poorly timed traffic signals, the fuel consumed by vehicles stopping and idling at traffic signals accounts for approximately 40 percent of network-wide vehicular fuel consumption. Improving traffic signal timing improves the quality of traffic flow 24 hours a day, 7 days a week with no sacrifice required on the part of the individual driver. Driving is made faster and easier for all cars, trucks, and buses using the street system (1). When intersections are operating at near capacity conditions, however, signal timing improvements by themselves do not always result in noticeable improvements in traffic operations as improved signal timing can only increase the capacity of an intersection to a certain extent. In these instances, other measures to increase the capacity of an intersection need to be implemented. These measures can involve geometric changes, improved signing or installation of better signal equipment, and should be supplemented by proper signal timing to obtain good traffic flow.

It also has been estimated that of the approximately 240,000 urban signalized intersections in the United States, 148,000 need upgrading of physical equipment and signal timing optimization, while another 30,000 are in need of signal timing optimization only. These types of improvements generally provide noticeable improvements in traffic flow on arterial streets for relatively small costs (2). For example, past projects have reported benefit/cost ratios between 20 to 1 and 30 to 1 (1). More significantly, however, an average of 10 gallons of fuel was saved for each dollar that was spent on signal retiming projects. Similar benefits were obtained from the recently completed Traffic Light Synchronization Program I (3) which was implemented in a number of Texas cities. Signal timing optimization projects are extraordinarily cost effective - saving an estimated 20 to 30 gallons of fuel for each project dollar invested; i.e., only about 4 cents in project costs for each gallon saved (4). Signal timing improvements when supplemented with other traffic management techniques can be very effective in improving traffic flow in urban areas.

In recognition of these potential savings and as a result of the Oil Overcharge Restitutionary Act, the Texas Department of Transportation (TxDOT) in conjunction with the Governor's Energy Office secured funding and developed the Texas Traffic Management (TM) Program for minor geometric improvements at intersections, retiming traffic signals, and implementing other traffic management techniques. The objective of this program was to reduce traffic congestion and facilitate the flow of traffic, with the goal of achieving more efficient use of energy resources. This objective was accomplished by:

1. Selecting projects and administering grants;

2. Training local staff/consultants in the use of computer technology for timing traffic signals;

3. Providing technical assistance in the use of computer models;

4. Providing technical assistance in collecting data; and

5. Providing for the construction of minor geometric improvements at intersections, installation of advance street name signs, and development of improved traffic signal timing plans.

The following sections describe the Texas TM Program in greater detail.

Program Description

TxDOT was the administering agency for the TM Program, which was funded with Oil Overcharge funds made available by the Governor's Energy Office. The TM Program was approved by the United States Department of Energy (DOE) as part of a package of transportation-related programs with the objective of reducing energy consumption. This grant program provided the sum of $7.5 million as program funds to local city governments across the state for minor geometric improvements at intersections, optimization of traffic signal timing plans, and implementation of other traffic management techniques. As stated previously, the program's objective was to reduce traffic congestion and facilitate the flow of traffic, with the goal of achieving more efficient use of energy resources.

Besides the intuitive benefits of reducing unnecessary vehicle stops, delays, fuel consumption and emissions, the TM program brought together the diverse transportation community of city staffs, consultants, TxDOT personnel and researchers to improve traffic operations at the state's signalized intersections. The program also has increased the expertise of transportation professionals in traffic management techniques and created a traffic data base that can be used for additional transportation projects. Most importantly, perhaps, the TM Program is continuing to enhance the image of the transportation profession by improving the quality of traffic flow, and helping to change the driver's perspective of always stopping at a "red" light to not having to stop at a "green" light.

Funding Distribution

TM funds were expended through contracts administered by TxDOT on projects proposed by local city governments. There were two major funding categories: large cities (cities with populations over 200,000) and medium/small cities (cities with populations under 200,000). The approved program of work shown in Table 1 in included 51 projects in 26 cities, and involved 862 traffic signals.

Two-thirds of the available funds were expended in large cities, with each of the eight Texas cities presently over 200,000 population assigned an allotment proportional to its population; the remaining one-third of the available funds were expended in the 18 medium/small cities participating in the TM Program. This distribution of funds helped to achieve one of the goals of the TM program -- a widespread, geographic distribution of funds which allowed indirect restitution to a large segment of the population that was overcharged by the oil companies.

Table 1. Traffic Management Program of Work

Funding Category	Cities	Systems	Signals
Large Cities	8	29	637
Medium/Small Cities	18	22	225
Totals	26	51	862

Selection Criteria

Projects were recommended for funding using criteria developed by an advisory panel composed of local government officials and TxDOT personnel. These criteria were as follows:

1. **Operational Characteristics of the Roadway** - Operational characteristics such as existing level-of-service, average daily traffic, etc., were considered to determine the amount of benefit a project could produce.

2. **Potential for a High Benefit to Cost Ratio** - The ability of a proposed project to provide the greatest benefits (i.e., maximize fuel savings, provide a high percentage of capacity increase, lower existing peak hour volume-to-capacity ratio) at the lowest possible cost will allow for the most efficient use of funds.

3. **Use of High/Innovative Technology in the Proposed Project** - The installation of components included in systems for signal coordination, surveillance, communication, and control, etc., could enhance the capacity of existing roadways. High/innovative technology was further defined as a project that proposes work beyond, for example, normal geometric improvements and /or signal retiming; however, proposed projects were **not** required to include a high/innovative technology component.

4. **Other Criteria** - Other criteria included the date of most recent improvements made, potential for project completion in a timely manner and certification that Oil Overcharge Traffic Management Funds would supplement and not supplant existing funds.

Reimbursement Guidelines and Eligibility

Up to 75 percent of project costs were eligible for reimbursement. If a project was funded, the local government or TxDOT paid a minimum 25 percent of the total direct costs of the project in matching funds and/or in-kind services. TxDOT provided a local match when a project contained roadways that were maintained and operated by TxDOT, unless the local government and TxDOT agreed otherwise.

Costs eligible for reimbursement under the program included training for the staff at the required TM workshop, salary and benefits for the city staff assigned to the project, travel costs of the city staff assigned to the project, planning, design, and construction of traffic management improvements, and consultant contract costs including salary and benefits, travel, direct costs and indirect costs, and profit. TM Program funds could not be used to supplant or replace existing funds earmarked for specific projects. That is, if existing funds were authorized for traffic management expenditures, those funds could not be released and then replaced by TM funds.

Training and Technical Assistance

One of the program's major objectives was to train local staff in the use of the PASSER II, PASSER III, and TRANSYT-7F signal timing computer models to facilitate ongoing maintenance of efficient timing plans. Local governments awarded a grant were required to have local project staff and/or their consultant attend specialized training workshops that were offered at the onset of the program. TxDOT secured the services of the Texas Transportation Institute (TTI) to provide computer model training and technical assistance to cities during project development. The Texas Engineering Extension Service (TEEX) at Texas A&M University and the McTrans Center at the University of Florida assisted TTI in the computer model training phase of the program. TTI also provided in-depth analysis of Before and After studies submitted by the cities, and prepared the Final Report to the Governor's Energy Office documenting reductions in fuel consumption, stops and delay accomplished as a result of the TM Program.

Three training courses were offered through the TM Program: a three-day training course was held February 26-28, 1991, and two one-day training courses were held on March 5th and 7th, 1991. All three of these courses were held in Austin at TxDOT's training facility. Through these courses, 59 transportation professionals were trained (listing shown in Appendix A). Also, each of the participating cities were furnished copies of the PASSER and TRANSYT computer software. This training of city, consultant and TxDOT personnel helped achieve another TM goal - providing statewide expertise in signal retiming and traffic management techniques so that these efforts can continue long after the last TM dollar is spent.

TM General Facts

The following general facts relate to the TM Program:

o	Program Cost:	$9,642,035
o	Date Started:	June 12, 1990 - Request for Proposals issued; December 21, 1990 - TxDOT Commission approves Program of Work.
o	Number of Participating Cities:	26 (8 large, 18 medium/small)
o	Number of Projects:	51 projects were funded
o	Number of Signals Retimed:	862
o	Date Completed:	November, 1993 - Report submitted to TxDOT and the Governor's Office.

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CHAPTER TWO

RESULTS

As mentioned in Chapter One, previous traffic signal retiming projects have reported benefit/cost ratios of 20 to 1 to 30 to 1 and an average fuel savings of approximately 10 gallons per dollar spent (1). It should be noted that conservative values for time were used in computing these benefits, and if more realistic values had been used, the resultant benefit/cost ratios would have been much greater. The two signal retiming programs cited most often in the literature are the Federal Highway Administration's (FHWA's) National Signal Timing Optimization Project (1) and California's FETSIM (Fuel Efficient Traffic Signal Management) Program (4).

In both programs, TRANSYT-7F was used to estimate motorist benefits as the hourly difference in fuel consumption and delay between the before and after retiming conditions. These differences were converted to annual differences and then multiplied by unit costs for fuel consumption and vehicular delay to obtain an estimate of annual benefits. The estimated improvements were validated with arterial street travel time data from field studies during the Before and After conditions. The same procedure for estimating benefits was followed in the Texas TM Program.

The benefits from the FETSIM Program (4) through 1988 were substantial - with an average first year reduction of 14 percent in stops and delay, 7.5 percent in travel time, and 8.1 percent in fuel use. Reductions in fuel usage in the first year were four times the program cost, and the first year benefit to cost ratio was 16 to 1. The state cost per signal, including retiming, training, and technical assistance was approximately $1,500 per intersection. Similar to the TM Program, expenditures were allowed for all aspects of signal timing: data collection, data processing, timing plan development, implementation, and field evaluation. Unlike the TM Program, however, expenditures were not allowed for minor geometric improvements or traffic management projects other than signal retiming. Because geometric improvements are generally more costly than signal retiming, the cost per signal in the TM Program will probably be higher and the benefit to cost ratio will probably be lower than in the FETSIM Program.

The preceding discussion illustrates the range of benefits that have been obtained from other signal retiming projects, and serves as a basis for comparison for the TM Program. The following sections describe the results of the TM Program in more detail and compare those results to other signal retiming programs.

Program Results

With 51 projects completed, the TM Program has seen results that will pay for the cost of the program many times over. These results were estimated from the required Before and After studies that were submitted by the cities. These studies document the major goals of the TM program - reductions in fuel consumption and unnecessary delay and stops. All projects were evaluated using the same unit costs. The cost for fuel was based on current prices ($1.00 per gallon) and costs for delay and stops were based on values suggested by AASHTO ($10 per vehicle-hour of delay and 1.4 cents per stop). A summary of the results as of August 1993 follows:

- 51 projects completed;
- 862 signalized intersections in 26 cities have been improved;
- Approximately $9.6 million of program funds and local matches have been expended (several cities expended more than the required local match);
- 15 million gallons of fuel will be saved as a result of this project (of these 15 million gallons, 12.2 million gallons will be saved within the next year).
- In fuel savings alone, Texas motorists are realizing $1.55 in savings for every program dollar spent;
- Reductions in fuel consumption, delay, and stops were 18.2, 32.7, and 13.1 percent, respectively;
- The total savings to the public in the form of reduced fuel, delay and stops will be approximately $152 million ($118.6 will be saved within the next year); and
- TM Program benefit to cost (b/c) ratio is 15.8 to 1; in other words, Texas motorists are realizing $15.8 in savings for every program dollar spent.

The expected benefits after implementation of the traffic management improvements are summarized in Table 2. Note, that the average benefit to cost ratio for projects in large cities and medium/small cities was 12.3 to 1 and 25.1 to 1, respectively.

Table 2. TM Program Benefits

	Stops	Delay	Fuel	Savings	Cost
Large Cities	257,231,865	7,537,112	7,034,038	86,006,304	6,996,304
Medium/Small Cities	199,718,925	5,571,122	7,947,628	66,454,908	2,645,731
Total	456,950,790	13,108,234	14,981,666	152,461,213	9,642,035

Program Benefits

The benefits estimated for each project were calculated on the basis of a 300-day year and a 10- to 15-hour day, depending on local traffic conditions. These hour per day values were used in order **not** to claim benefits when traffic volumes were low; i.e., retiming probably will not benefit weekend or late night traffic. In other words, an intentional effort was made to **not** overestimate benefits. Furthermore, field data from the required Before and After arterial travel time runs or intersection stopped delay studies were used to verify the benefits that were being estimated. These travel time and/or delay improvements were comparable to the fuel, delay, and stop reductions estimated by the signal timing optimization models.

Program benefits and changes in measures of effectiveness are illustrated in Tables 3 and 4 for each of the 26 cities in the program. While the benefits for signal retiming projects were calculated for one year, the benefits for projects involving geometric improvements were calculated for five years. Note that although the number of large cities were less than the number of medium and small cities, almost 50 percent of the benefits were in the large city category. Given that there were a larger number of traffic signals retimed and higher traffic volumes are generally found in the larger cities, this result was expected. When interpreting this table, one should not try to compare between cities, as the number of retimed signals and the types of projects varied greatly between the cities. Generally, the more intersections that were retimed, the larger the improvements. For example, Richardson retimed 48 intersections whereas Odessa retimed 12 intersections. As expected, the savings in Richardson were greater than the savings in Odessa. The percentage improvement in stops, delay, and fuel consumption in Odessa, however, was comparable to that in Richardson.

Table 3. Program Benefits By City

Cities	Number of Intersections	Stops Change	Stops Percent	Delay (hrs) Change	Delay (hrs) Percent	Fuel Consumption (gal) Change	Fuel Consumption (gal) Percent	B/C Ratio
Large Cities								
Arlington	4	22,068,000	10.4%	876,000	30.9%	877,500	19.6%	1.7 to 105.9
Austin	7	31,758,450	13.1%	774,435	32.9%	694,440	23.7%	-0.7 to 25.0
Corpus Christi	2	26,564,850	34.5%	2,315,250	67.5%	1,032,300	58.8%	40.1
Dallas	19	39,194,625	10.6%	446,663	16.0%	537,300	5.8%	4.6
El Paso	27	52,645,200	10.8%	826,866	16.1%	1,941,792	20.5%	19.6 to 28.3
Fort Worth	310	7,829,520	12.1%	514,390	70.0%	424,719	42.0%	0.98 to 17.0
Houston	121	38,651,220	15.5%	1,621,560	46.5%	1,012,995	19.6%	2.2 to 31.8
San Antonio	147	38,520,000	22.8%	161,910	12.7%	513,060	11.5%	1.0 to 5.1
Total	637	257,231,865	13.7%	7,537,112	34.2%	7,034,038	18.2%	-0.7 to 105.9
Other Cities								
Baytown	8	(4,018,500)	-21.5%	21,300	15.0%	128,700	21.2%	7.3
Beaumont	33	(10,543,950)	-8.1%	1,015,245	38.2%	3,432,870	59.8%	48.2
Bellaire	11	16,738,800	22.0%	9,780	3.2%	94,260	8.4%	2.1
Brownsville	2	3,120,000	11.4%	101,700	36.2%	79,500	20.6%	4.9
College Station	37	8,374,800	6.3%	135,348	10.8%	128,190	2.8%	5.3
Copperas Cove	5	58,767,000	36.9%	463,950	37.9%	157,200	3.5%	74.9
Del Rio	4	717,000	6.1%	11,220	13.1%	12,576	8.2%	5.0
Denton	6	12,618,000	12.6%	165,360	16.6%	198,168	13.4%	23.8 to 26.3
Garland	8	931,875	0.6%	26,138	2.6%	27,525	0.7%	4.2
Grand Prairie	4	9,171,000	15.5%	16,560	4.0%	159,600	12.1%	0.8 to 3.6
Laredo	29	4,782,600	15.6%	22,416	12.7%	24,459	7.3%	1.9
Leon Valley	1	8,385,000	28.4%	145,275	56.3%	135,968	43.3%	3.8
Longview	8	7,194,600	21.5%	133,140	45.6%	123,780	16.1%	14.0
N. Richland Hills	7	3,498,900	9.3%	33,765	8.3%	17,103	1.4%	3.5
Odessa	12	19,301,400	14.6%	512,850	42.2%	775,500	20.1%	52.3
Richardson	48	56,681,400	13.7%	2,571,600	37.7%	2,303,400	18.5%	132.8
San Angelo	1	454,500	5.5%	4,575	8.3%	5,955	6.0%	1.4
Waco	1	3,544,500	7.9%	180,900	36.3%	142,800	25.8%	11.6
Total	225	199,718,925	12.4%	5,571,122	30.8%	7,947,628	18.2%	0.8 to 132.8
Grand Total	862	456,950,790	13.1%	13,108,234	32.7%	14,981,666	18.2%	-0.7 to 132.8

Table 4. Change in Measures of Effectiveness By City

Cities	Number of Intersections	Overall Stops Before	Overall Stops After	Overall Delay (hrs) Before	Overall Delay (hrs) After	Overall Fuel Consumption (gal) Before	Overall Fuel Consumption (gal) After	B/C Ratio
Large Cities								
Arlington	4	211,372,500	189,304,500	2,836,500	1,960,500	4,485,000	3,607,500	1.7 to 105.9
Austin	7	242,210,100	210,451,650	2,350,395	1,575,960	2,925,720	2,231,280	-0.7 to 25.0
Corpus Christi	2	76,897,800	50,332,950	3,427,800	1,112,550	1,756,200	723,900	40.1
Dallas	19	370,733,250	331,538,625	2,784,525	2,337,863	9,265,500	8,728,200	4.6
El Paso	27	488,776,200	436,131,000	5,142,576	4,315,710	9,490,752	7,548,960	19.6 to 28.32
Fort Worth	310	64,612,200	58,299,000	734,940	235,819	1,010,994	609,021	0.98 to 17.0
Houston	121	250,011,300	212,462,400	3,487,890	1,877,430	5,165,010	4,168,551	2.2 to 31.8
San Antonio	147	169,258,950	130,738,950	1,274,625	1,112,715	4,445,025	3,931,965	1.0 to 5.1
Total	637	1,873,872,300	1,619,259,075	22,039,615	14,528,873	38,544,182	31,549,426	-0.7 to 105.9
Other Cities								
Baytown	8	18,654,000	22,672,500	141,900	120,600	605,700	477,000	7.3
Beaumont	33	129,559,500	140,103,450	2,659,455	1,644,210	5,737,995	2,305,125	48.2
Bellaire	11	76,017,600	59,278,800	305,280	295,500	1,121,160	1,026,900	2.1
Brownsville	2	27,282,000	24,162,000	280,800	179,100	386,100	306,600	4.9
College Station	37	132,518,400	124,143,600	1,254,078	1,118,730	4,615,452	4,487,262	5.3
Copperas Cove	5	159,357,000	100,590,000	1,223,550	759,600	4,464,150	4,306,950	74.9
Del Rio	4	11,772,000	11,055,000	85,440	74,220	153,684	141,108	5.0
Denton	6	100,339,200	87,721,200	993,660	828,300	1,480,866	1,282,698	23.8 to 26.3
Garland	8	159,173,250	158,241,375	988,538	962,400	4,176,338	4,148,813	4.2
Grand Prairie	4	59,238,000	50,067,000	417,600	401,040	1,321,200	1,161,600	0.8 to 3.6
Laredo	29	30,607,800	25,825,200	176,916	154,500	337,059	312,600	1.9
Leon Valley	1	29,495,250	21,110,250	258,000	112,725	314,288	178,320	3.8
Longview	8	33,448,800	26,254,200	291,840	158,700	770,820	647,040	14.0
N. Richland Hills	7	37,475,700	33,976,800	408,600	374,835	1,240,005	1,222,902	3.5
Odessa	12	132,309,300	113,007,900	1,214,400	701,550	3,867,300	3,091,800	52.3
Richardson	48	413,949,600	357,268,200	6,819,600	4,248,000	12,445,800	10,142,400	132.8
San Angelo	1	8,311,500	7,857,000	55,125	50,550	98,820	92,865	1.4
Waco	1	44,688,000	41,143,500	498,150	317,250	553,650	410,850	11.6
Total	225	1,604,196,150	1,404,477,225	18,072,932	12,501,810	43,690,386	35,742,758	0.8 to 132.8
Grand Total	862	3,478,068,450	3,023,736,300	40,112,546	27,030,683	82,234,568	67,292,183	-0.7 to 132.8

The type of signal retiming project also had an impact on the estimated benefits. Generally, coordinating a previously uncoordinated system resulted in large improvements. Beaumont is an example of a city with this type of project and involved numerous major arterials. Also, projects that involved geometric improvements, improved signing, or traffic management improvements in addition to signal retiming resulted in low benefit to cost ratios. Austin, Leon Valley, and San Angelo are examples of cities with projects involving geometric improvements; Fort Worth is an example of a city with a project involving signing improvements; and Garland is an example of a city with a project involving traffic management improvements. Note that there were no cities with projects that resulted in increases in fuel consumption.

The cost side of the benefit to cost (b/c) ratios reflect both the time spent by local staff in developing and implementing timing plans and the total project costs (i.e., personnel and construction). Because geometric improvements and signing installed under a TM project will most likely last several years, an amortized value was used in the calculation of the b/c ratios. Benefits for these types of projects were assumed to last for five years, although in some instances they should last much longer than this time period. Benefits for signal timing projects were assumed to last only one year, when in reality some measure of the benefits will be realized over several years. Thus, the true benefits to Texas drivers were probably two to three times greater than the values reported in this report.

Benefits Per Intersection

Program benefits and changes in measures of effectiveness per intersection are illustrated in Tables 5 and 6 for each of the 26 cities in the program. Note that on the average, more than 17,300 gallons of gasoline (18 percent), 15,100 hours of delay (33 percent), and 527,000 stops (13 percent) per intersection were reduced as a result of this program. The values reported in these tables are somewhat easier to compare between cities and could be used to estimate a range of potential benefits from retiming, adding turn lanes, or improved signing for a certain number of signalized intersections; however, the discrepancy between different traffic volumes and types of projects in each of the participating cities still exists.

Note that the average benefits per intersection are higher for the medium and small cities than the large cities. This difference is a result of the large benefits per intersection from the Beaumont, Odessa, and Richardson projects which involved signal retiming and the smaller benefits per intersection from the Ft. Worth project which involved signing improvements. The range of benefits per intersection within each city size category, and in some cases, an overlap between categories is primarily a result of different types of projects. For example, coordinating a series of isolated intersections, generally produced greater benefits than simply retiming an existing system, and signal timing and geometric improvements produced greater benefits per intersection than improved signing. In other words, how bad or good the before condition was had a great deal to do with the benefits that were obtained. Benefits for each of the 51 TM projects are presented in Appendix B.

Table 5. Benefits Per Intersection By City

Cities	Number of Intersections	Stops per Intersection Change	Stops per Intersection Percent	Delay per Intersection (hrs) Change	Delay per Intersection (hrs) Percent	Fuel Cons. per Intersection (gal) Change	Fuel Cons. per Intersection (gal) Percent	B/C Ratio
Large Cities								
Arlington	4	5,517,000	10.4%	219,000	30.9%	219,375	19.6%	1.7 to 105.9
Austin	7	4,536,921	13.1%	110,634	32.9%	99,206	23.7%	-0.7 to 25.0
Corpus Christi	2	13,282,425	34.5%	1,157,625	67.5%	516,150	58.8%	40.1
Dallas	19	2,062,875	10.6%	23,509	16.0%	28,279	5.8%	4.6
El Paso	27	1,949,822	10.8%	30,625	16.1%	71,918	20.5%	19.6 to 28.3
Fort Worth	310	20,365	9.8%	1,610	67.9%	1,297	39.8%	0.98 to 17.0
Houston	121	310,321	15.0%	13,310	46.2%	8,235	19.3%	2.2 to 31.8
San Antonio	147	262,041	22.8%	1,101	12.7%	3,490	11.5%	1.0 to 5.1
Average		399,707	13.6%	11,791	34.1%	10,981	18.1%	-0.7 to 105.9
Other Cities								
Baytown	8	(502,313)	-21.5%	2,663	15.0%	16,088	21.2%	7.3
Beaumont	33	(319,514)	-8.1%	30,765	38.2%	104,026	59.8%	48.2
Bellaire	11	1,521,709	22.0%	889	3.2%	8,569	8.4%	2.1
Brownsville	2	1,560,000	11.4%	50,850	36.2%	39,750	20.6%	4.9
College Station	37	226,346	6.3%	3,658	10.8%	3,465	2.8%	5.3
Copperas Cove	5	11,753,400	36.9%	92,790	37.9%	31,440	3.5%	74.9
Del Rio	4	179,250	6.1%	2,805	13.1%	3,144	8.2%	5.0
Denton	6	2,103,000	12.6%	27,560	16.6%	33,028	13.4%	23.8 to 26.3
Garland	8	116,484	0.6%	3,267	2.6%	3,441	0.7%	4.2
Grand Prairie	4	2,292,750	15.5%	4,140	4.0%	39,900	12.1%	0.8 to 3.6
Laredo	29	164,917	15.6%	773	12.7%	843	7.3%	1.9
Leon Valley	1	8,385,000	28.4%	145,275	56.3%	135,968	43.3%	3.8
Longview	8	899,325	21.5%	16,643	45.6%	15,473	16.1%	14.0
N. Richland Hills	7	499,843	9.3%	4,824	8.3%	2,443	1.4%	3.5
Odessa	12	1,608,450	14.6%	42,738	42.2%	64,625	20.1%	52.3
Richardson	48	1,180,863	13.7%	53,575	37.7%	47,988	18.5%	132.8
San Angelo	1	454,500	5.5%	4,575	8.3%	5,955	6.0%	1.4
Waco	1	3,544,500	7.9%	180,900	36.3%	142,800	25.8%	11.6
Average		887,639	12.4%	24,760	30.8%	35,322	18.2%	0.8 to 132.8
Overall Mean		527,067	13.1%	15,176	32.6%	17,335	18.2%	-0.7 to 132.8

Table 6. Changes in Measures of Effectiveness Per Intersection By City

Cities	Number of Intersections	Stops per Intersection Before	Stops per Intersection After	Delay per Intersection (hrs) Before	Delay per Intersection (hrs) After	Fuel Cons. per Intersection (gal) Before	Fuel Cons. per Intersection (gal) After	B/C Ratio
Large Cities								
Arlington	4	52,843,125	47,326,125	709,125	490,125	1,121,250	901,875	1.7 to 105.9
Austin	7	34,601,443	30,064,521	335,771	225,137	417,960	318,754	-0.7 to 25.0
Corpus Christi	2	38,448,900	25,166,475	1,713,900	556,275	878,100	361,950	40.1
Dallas	19	19,512,276	17,449,401	146,554	123,045	487,658	459,379	4.6
El Paso	27	18,102,822	16,153,000	190,466	159,841	351,509	279,591	19.6 to 28.3
Fort Worth	310	208,426	188,061	2,371	761	3,261	1,965	0.98 to 17.0
Houston	121	2,066,209	1,755,888	28,826	15,516	42,686	34,451	2.2 to 31.8
San Antonio	147	1,151,421	889,381	8,671	7,569	30,238	26,748	1.0 to 5.1
Average		2,941,715	2,542,008	34,599	22,808	60,509	49,528	-0.7 to 105.9
Other Cities								
Baytown	8	2,331,750	2,834,063	17,738	15,075	75,713	59,625	7.3
Beaumont	33	3,926,045	4,245,559	80,590	49,825	173,879	69,852	48.2
Bellaire	11	6,910,691	5,388,982	27,753	26,864	101,924	93,355	2.1
Brownsville	2	13,641,000	12,081,000	140,400	89,550	193,050	153,300	4.9
College Station	37	3,581,578	3,355,232	33,894	30,236	124,742	121,277	5.3
Copperas Cove	5	31,871,400	20,118,000	244,710	151,920	892,830	861,390	74.9
Del Rio	4	2,943,000	2,763,750	21,360	18,555	38,421	35,277	5.0
Denton	6	16,723,200	14,620,200	165,610	138,050	246,811	213,783	23.8 to 26.3
Garland	8	19,896,656	19,780,172	123,567	120,300	522,042	518,602	4.2
Grand Prairie	4	14,809,500	12,516,750	104,400	100,260	330,300	290,400	0.8 to 3.6
Laredo	29	1,055,441	890,524	6,101	5,328	11,623	10,779	1.9
Leon Valley	1	29,495,250	21,110,250	258,000	112,725	314,288	178,320	3.8
Longview	8	4,181,100	3,281,775	36,480	19,838	96,353	80,880	14.0
N. Richland Hills	7	5,353,671	4,853,829	58,371	53,548	177,144	174,700	3.5
Odessa	12	11,025,775	9,417,325	101,200	58,463	322,275	257,650	52.3
Richardson	48	8,623,950	7,443,088	142,075	88,500	259,288	211,300	132.8
San Angelo	1	8,311,500	7,857,000	55,125	50,550	98,820	92,865	1.4
Waco	1	44,688,000	41,143,500	498,150	317,250	553,650	410,850	11.6
Average		7,129,760	6,242,121	80,324	55,564	194,179	158,857	0.8 to 132.8
Overall Mean		4,034,882	3,507,815	46,534	31,358	95,400	78,065	-0.7 to 132.8

Comparison With Other Programs

The estimated benefits from the Texas TM Program are slightly higher than those reported by other statewide signal retiming programs; however, the cost to provide these benefits was also higher. TM reduced fuel, delay and stops by 18.2, 32.7, and 13.1 percent, respectively. California's FETSIM Program reduced fuel consumption by 8.1 percent and stops and delay by 14 percent. Texas motorists realized $1.55 in fuel savings for every program dollar spent, whereas California motorists realized $4.00 in fuel savings for every program dollar spent. It should be noted, however, that FETSIM only allowed signal timing improvements (i.e., lower cost projects) and also used a slightly higher cost per gallon for fuel in their analysis. In terms of average fuel savings per intersection, the TM program, Traffic Light Synchronization (TLS) program (3) and North Carolina's Traffic Signal Timing Optimization Program (5) estimated savings per intersection of 15,000 gallons, 13,400 gallons and 13,900 gallons, respectively.

The benefit to cost ratios were approximately 16 to 1 for both TM and FETSIM even though different delay costs and allowable program expenditures were used by the two programs. Thus, even though the reported benefit to cost ratios for both are similar, other results are not easily comparable. For example, even though the benefits of the two programs in terms of percent reductions in fuel, delay, and stops were essentially the same, the costs were higher for TM because of geometric improvements and equipment purchases ($11,000 per intersection in TM and $1,500 per intersection in FETSIM). As a result, the comparable benefit to cost ratios per intersection for TM program were lower than they were for FETSIM.

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CHAPTER THREE

CONCLUSIONS

The TxDOT experience in administering the TM Program has been very positive. The working relationship between TxDOT, city, and consultant transportation professionals has been enhanced and Texas motorists have benefited from improved operation at many intersections. These benefits will extend well beyond the life of the TM Program. Final program results are being shared with all 26 of the participating cities.

With 51 projects completed, the TM Program has seen results that will pay for the cost of the program many times over. These results were estimated from the required Before and After studies that were submitted by the cities. These studies document the major goals of the TM Program -- reductions in fuel consumption and unnecessary delay and stops. All projects were evaluated using the same unit costs. The TM Program resulted in 862 intersections in 26 cities (51 separate projects) being improved. The expenditure of $9.6 million of program funds and local matches resulted in reductions in fuel consumption, delay, and stops of 18.2 percent (14.9 million gallons), 32.7 percent (13.1 million hours), and 13.1 percent (457 million stops), respectively. Individual project summaries are presented in Appendices C and D.

The total savings to the public in the form of reduced fuel, delay, and stops will be approximately $152.4 million ($118.6 million in the next year alone). In regard to fuel savings, Texas motorists are realizing $1.55 in savings for every dollar spent, and if stops and delay are included, Texas motorists are realizing $15.81 in savings for every dollar spent. These savings will continue to accrue in future years without any additional expenditures; therefore, the benefits to the public will be even greater.

Benefits besides those that can be given a dollar value have been realized through the TM Program. The bringing together of the entire transportation community (local, state, and private) to try to reach a common goal has been rewarding. In the area of traffic signal retiming, the technical expertise of the transportation professionals has been enhanced. The driver perspective of the "stop" light or the "red" light is starting to change to that of the "green" light.

As a result of the success of this program and the first Traffic Light Synchronization (TLS) program, DOE and the Governor's Energy Office has provided an additional $5 million in Oil Overcharge funds to TxDOT to undertake a second TLS Program. This second program, which will run from January 1992 until August 1994, should allow the benefits of improved signal timing to be realized in more areas of the state.

Overall, the TM Program has been developed, funded and implemented on a multi-jurisdictional basis (local city governments and state agencies). The program has had a significant visible and positive effect on actual operation on a large part of the transportation system, as well as on the citizens' perception of the system. The direct savings in fuel consumption and delay represents significant increased efficiency, resulting in a more economical transportation system.

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APPENDIX A

LIST OF ATTENDEES

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List of Attendees
TRAFFIC MANAGEMENT
February 26-28, 1991

Susan Butler
City of Leon Valley

Thomas Cronick
City of Odessa

Dana Estep
City of Odessa

Jose Gaytan, Jr.
TxDOT - Pharr, Tx.

Karen George
Barton-Aschman Associates, Inc.

Earl Guillory, Jr.
City of Houston

Joan Hudson
City of Austin

Michael Jennings
City of Odessa

John Johnston
City of N. Richland Hills

Garry Lane
City of College Station

Anna Leos
City of Waco

Paul Luedtke
Barton-Aschman Associates, Inc.

Samileh Mozafari
City of Austin

Roberto Murillo
City of Laredo

Shelly Reams
City of Bayton

Lee Robinson
City of College Station

Robert Rodreguez
City of Laredo

James Sanders
City of Bayton

Mark Schoeneman
City of College Station

Larry Shrope
City of Copperas Cove

Andrew Souder
City of North Richland Hills

Michael Stoldt
City of Copperas Cove

Anthony Tangwa
City of Houston

List of Attendees
EVALUATING TRAFFIC MANAGEMENT TECHNIQUES
March 5, 1991

Don Abell
City of San Angelo

Rajiv Arya
City of Houston

Abel Beltran
McAllen, Texas

Joel Brundrett
Traffic Engineers, Inc.

Brian Burk
TxDOT - Austin, TX.

Larry Cervenka
City of Garland

Rick Charlton
City of Waco

Robert Esparza
City of Brownsville

Placido Garcia, Jr.
City of Brownsville

Nola Miles
City of Houston

Carl Mock
City of San Angelo

Ali Mozdbar
City of Arlington

Larry Parker
City of San Angelo

Eulalio Ramirez
City of McAllen

Elias Sassoon
City of Dallas

Tim Starr
City of Dallas

Brian VanDeWalle
City of Arlington

John Wernette
TxDOT - San Antonio, TX.

List of Attendees
EVALUATING TRAFFIC MANAGEMENT TECHNIQUES
March 7, 1991

Scott Booker
City of Fort Worth

Victor Bolanos
City of El Paso

Wilbert Brown
City of Galveston

Russell Fox
City of Grand Prairie

Don Glenn
Barton-Aschman Associates, Inc.

Paul Iwuchukwu
City of Denton

Walter Jarrin
City of Corpus Christi

Andy Johnston
City of Longview

Ray Latham
City of Corpus Christi

Jeff Milburn
Walton & Associates

Mark Mathis
City of Grand Prairie

Tom Outlaw
City of Houston

David Rasco
City of Fort Worth

Joe Ramirez
City of El Paso

John Russell
City of Longview

Brian Shewski
Barton-Aschman Associates, Inc.

Roy Wileman
City of Houston

Russ Wiles
City of Fort Worth

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APPENDIX B

BENEFITS BY TYPE OF IMPROVEMENT

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Table 1. Benefits for Traffic Management Projects in Large Cities.

Cities	Projects	Number of Intersections	Stops Change	Stops Percent	Delays (hrs) Change	Delays (hrs) Percent	Fuel Consumption (gal) Change	Fuel Consumption (gal) Percent	B/C Ratio	Type of Improvement
Large Cities										
Arlington	Arbrook Boulevard/Cooper Street	1	661,500	0.9%	4,500	0.5%	21,000	1.3%	2.2	Geometric
	Green Oaks Boulevard/Collins Street	1	2,809,500	5.1%	75,000	13.8%	105,000	9.7%	22.0	Geometric
	IH-20/Matlock Road	1	16,203,000	26.6%	777,000	62.6%	724,500	46.6%	105.9	Geometric
	Park Row Drive/Susan Drive	1	2,394,000	12.2%	19,500	23.6%	27,000	11.8%	1.7	Geometric
Austin	East 12th Street at IH-35	1	(19,050)	-0.2%	(1,665)	-4.1%	(435)	-0.4%	(0.7)	Signal Timing (Dia)
	East 38th-1/2 Street at Red River Street	1	783,750	2.0%	77,025	22.6%	56,025	12.6%	14.3	Geometric
	Parkfield Drive at Peyton Gin Road	1	2,855,250	15.5%	15,450	23.4%	24,450	18.1%	1.3	Geometric
	Rundberg Lane at I-35 ESR	1	5,712,000	11.0%	218,775	28.7%	187,200	22.9%	23.6	Geometric
	Rundberg Lane at I-35 WSR	1	9,863,250	19.3%	269,400	44.1%	227,025	33.8%	25.0	Geometric
	West Gate Boulevard at Jones Road	1	2,001,000	12.4%	21,975	13.1%	33,000	13.2%	4.0	Geometric
	West Oltorf Street at South Lamar Boulevard	1	10,562,250	18.8%	173,475	48.2%	167,175	33.0%	14.5	Geometric
Corpus Christi	Corona-Williams Connection Project	2	26,564,850	34.5%	2,315,250	67.5%	1,032,300	58.8%	40.1	Geometric
Dallas	Ross and Live Oak Boulevard	19	39,194,625	10.6%	446,700	16.0%	537,233	5.8%	4.6	Geometric
El Paso	El Paso-Interconnect Project	22	28,582,200	19.9%	303,126	24.7%	1,425,342	30.1%	19.6	Signal Timing (Art)
	El Paso-Various Intersections	5	24,063,000	7.0%	523,740	13.4%	516,450	10.8%	28.3	Geometric
Fort Worth	Fort Worth - Signing Project	285	1,516,320	*	15,270	*	22,746	*	0.98	Signing
	Fort Worth - Various Intersections	25	6,313,200	9.8%	499,120	67.9%	401,973	39.8%	16.8	Signal Timing (Iso)
Houston	Close Loop Projects	23	6,795,900	8.7%	292,440	39.8%	477,825	24.0%	2.2	Signal Timing (Art)
	Houston Signing Project	79	1,102,320	*	11,100	*	16,536	*	0.9	Signing
	Southwest	19	30,753,000	17.9%	1,318,020	47.9%	518,634	16.3%	31.9	Signal Timing (Art)
San Antonio	Austin Highway System	9	2,463,000	24.1%	3,300	6.4%	33,900	12.2%	1.7	Signal Timing (Art)
	Bandera System	5	2,581,800	28.0%	19,560	21.6%	46,740	15.2%	5.1	Signal Timing (Art)
	Broadway/Nacogdoches	29	6,199,800	20.1%	12,600	9.4%	63,480	10.0%	2.5	Signal Timing (Art)
	De Zavala System	4	601,200	22.9%	540	5.7%	7,980	12.9%	2.4	Signal Timing (Art)
	Fredericksburg System	9	906,000	8.8%	5,850	9.1%	11,700	5.3%	1.2	Signal Timing (Art)
	Northwest	66	20,437,800	23.5%	103,200	12.8%	276,000	11.2%	2.8	Signal Timing (Art)
	Poteet Highway System	3	703,800	27.3%	600	4.2%	12,660	18.8%	1.5	Signal Timing (Art)
	Southeast Military System	7	1,945,200	24.2%	12,060	19.9%	33,000	15.8%	3.3	Signal Timing (Art)
	W.W. White	15	2,681,400	31.9%	4,200	10.0%	27,600	13.5%	1.8	Signal Timing (Art)
Total	29	637	257,231,865	7.2%	7,537,111	9.4%	7,034,039	6.3%	0.7 to 105.9	

Table 2. Change in MOEs for Traffic Management Projects in Large Cities.

Cities	Projects	Number of Intersections	Overall Stops Before	Overall Stops After	Overall Delays (hrs) Before	Overall Delays (hrs) After	Overall Fuel Cons. (gal) Before	Overall Fuel Cons. (gal) After	B/C Ratio	Type of Improvement
Large Cities										
Arlington	Arbrook Boulevard/Cooper Street	1	75,856,500	75,195,000	969,000	964,500	1,614,000	1,593,000	2.2	Geometric
	Green Oaks Boulevard/Collins Street	1	54,885,000	52,075,500	544,500	469,500	1,087,500	982,500	22.0	Geometric
	IH-20/Matlock Road	1	61,014,000	44,811,000	1,240,500	463,500	1,554,000	829,500	105.9	Geometric
	Park Row Drive/Susan Drive	1	19,617,000	17,223,000	82,500	63,000	229,500	202,500	1.7	Geometric
Austin	East 12th Street at IH-35	1	8,594,850	8,613,900	40,920	42,585	97,845	98,280	(0.7)	Signal Timing (Dia)
	East 38th-1/2 Street at Red River Street	1	39,960,000	39,176,250	341,400	264,375	445,575	389,550	14.3	Geometric
	Parkfield Drive at Peyton Gin Road	1	18,408,000	15,552,750	66,000	50,550	135,300	110,850	1.3	Geometric
	Rundberg Lane at I-35 ESR	1	51,879,000	46,167,000	763,125	544,350	818,550	631,350	23.6	Geometric
	Rundberg Lane at I-35 WSR	1	51,033,750	41,170,500	611,250	341,850	671,175	444,150	25.0	Geometric
	West Gate Boulevard at Jones Road	1	16,198,500	14,197,500	167,475	145,500	250,500	217,500	4.0	Geometric
	West Oltorf Street at South Lamar Boulevard	1	56,136,000	45,573,750	360,225	186,750	506,775	339,600	14.5	Geometric
Corpus Christi	Corona-Williams Connection Project	2	76,897,800	50,332,950	3,427,800	1,112,550	1,756,200	723,900	40.1	Geometric
Dallas	Ross and Live Oak Boulevard	19	370,733,250	331,538,625	2,784,889	2,338,189	9,265,481	8,728,249	4.63	Geometric
El Paso	El Paso-Interconnect Project	22	143,809,200	115,227,000	1,224,906	921,780	4,729,542	3,304,200	19.55	Signal Timing (Art)
	El Paso-Various Intersections	5	344,967,000	320,904,000	3,917,670	3,393,930	4,761,210	4,244,760	28.32	Geometric
Fort Worth	Fort Worth - Signing Project	285	*	*	*	*	*	*	1.0	Signing
	Fort Worth - Various Intersections	25	64,612,200	58,299,000	734,940	235,819	1,010,994	609,021	16.8	Signal Timing (Iso)
Houston	Close Loop Projects	23	78,326,700	71,530,800	734,460	442,020	1,987,728	1,509,903	2.2	Signal Timing (Art)
	Houston Signing Project	79	*	*	*	*	*	*	0.9	Signing
	Southwest	19	171,684,600	140,931,600	2,753,430	1,435,410	3,177,282	2,658,648	31.9	Signal Timing (Art)
San Antonio	Austin Highway System	9	10,212,600	7,749,600	51,240	47,940	277,560	243,660	1.7	Signal Timing (Art)
	Bandera System	5	9,228,000	6,646,200	90,420	70,860	306,960	260,220	5.1	Signal Timing (Art)
	Broadway/Nacogdoches	29	30,790,200	24,590,400	133,620	121,020	635,520	572,040	2.5	Signal Timing (Art)
	De Zavala System	4	2,629,800	2,028,600	9,420	8,880	61,860	53,880	2.4	Signal Timing (Art)
	Fredericksburg System	9	10,296,750	9,390,750	64,125	58,275	222,225	210,525	1.2	Signal Timing (Art)
	Northwest	66	87,095,400	66,657,600	808,800	705,600	2,460,600	2,184,600	2.8	Signal Timing (Art)
	Poteet Highway System	3	2,574,000	1,870,200	14,400	13,800	67,500	54,840	1.5	Signal Timing (Art)
	Southeast Military System	7	8,032,800	6,087,600	60,600	48,540	208,800	175,800	3.3	Signal Timing (Art)
	W.W. White	15	8,399,400	5,718,000	42,000	37,800	204,000	176,400	1.8	Signal Timing (Art)
Total	29	637	1,873,872,300	1,619,259,075	22,039,615	14,528,873	38,544,182	31,549,426	-0.7 to 105.9	

Table 3. Benefits for Traffic Management Projects in Medium and Small Cities.

Cities	Projects	Number of Intersections	Stops Change	Stops Percent	Delay (hrs) Change	Delay (hrs) Percent	Fuel Consumption (gal) Change	Fuel Consumption (gal) Percent	B/C Ratio	Type of Improvement
Other Cities										
Baytown	Garth Road	8	(4,018,500)	-21.5%	21,300	15.0%	128,700	21.2%	7.3	Signal Timing (Art)
Beaumont	Calder/Phelan/Eleventh System	33	(10,543,950)	-8.1%	1,015,245	38.2%	3,432,870	59.8%	48.2	Signal Timing (Art)
Bellaire	Bellaire Boulevard and Bissonnet Street	11	16,738,800	22.0%	9,780	3.2%	94,260	8.4%	2.1	Signal Timing (Art)
Brownsville	Roosevelt Street	2	3,120,000	11.4%	101,700	36.2%	79,500	20.6%	4.9	Geometric
College Station	College Station Signal System	37	8,374,800	6.3%	135,348	10.8%	128,190	2.8%	5.3	Signal Timing (Net)
Copperas Cove	U.S. 190	5	58,767,000	36.9%	463,950	37.9%	157,200	3.5%	74.9	Geometric
Del Rio	Spur 239	4	717,000	6.1%	11,220	13.1%	12,576	8.2%	5.0	Signal Timing (Art)
Denton	Eagle Drive	5	9,117,000	24.6%	128,160	37.3%	149,208	21.8%	23.8	Signal Timing (Art)
	U.S. 380 at Carroll Boulevard	1	3,501,000	5.5%	37,200	5.7%	48,960	6.2%	26.3	Geometric
Garland	Belt Line	8	931,875	0.6%	26,138	2.6%	27,525	0.7%	4.2	Geometric
Grand Prairie	Great Southwest Parkway and Arkansas Lane	1	2,250,000	68.6%	630	2.4%	7,200	5.7%	2.1	Geometric
	Carrier Parkway and Marshall Drive	1	2,274,000	27.6%	210	0.3%	6,000	2.0%	3.9	Geometric
	Carrier Parkway and State Highway 303	1	2,937,000	6.9%	11,400	4.2%	128,400	18.6%	1.4	Geometric
	Great Southwest Parkway and I.H. 20	1	1,710,000	34.6%	4,320	10.6%	18,000	8.6%	3.6	Geometric
Laredo	Laredo Central Business District	29	4,782,600	15.6%	22,416	12.7%	24,459	7.3%	1.9	Signal Timing (Net)
Leon Valley	Huebner and Evers	1	8,385,000	28.4%	145,275	56.3%	135,968	43.3%	18.9	Geometric
Longview	High Street and McCann Road Systems	8	7,194,600	21.5%	133,140	45.6%	123,780	16.1%	14.0	Signal Timing (Art)
N. Richland Hills	Rufe Snow Drive System	7	3,498,900	9.3%	33,765	8.3%	17,103	1.4%	3.5	Signal Timing (Art)
Odessa	42nd Street	12	19,301,400	14.6%	512,850	42.2%	775,500	20.1%	38.4	Signal Timing (Art)
Richardson	Richardson-Entire Signal System	48	56,681,400	13.7%	2,571,600	37.7%	2,303,400	18.5%	132.8	Signal Timing (Net)
San Angelo	Main Street and 19th/18th Streets	1	454,500	5.5%	4,575	8.3%	5,955	6.0%	1.4	Geometric
Waco	Valley Mills	1	3,544,500	7.9%	180,900	36.3%	142,875	25.8%	11.6	Geometric
Total	22	225	199,718,925	9.3%	5,571,122	24.7%	7,947,628	18.4%	0.8 to 132.8	
Grand Total	51	862	456,950,790	7.8%	13,108,234	13.4%	14,981,666	9.5%	-0.7 to 132.8	

Table 4. Change in MOEs for Traffic Management Projects in Medium and Small Cities.

Cities	Projects	Number of Intersections	Overall Stops Before	Overall Stops After	Overall Delay (hrs) Before	Overall Delay (hrs) After	Overall Fuel Cons. (gal) Before	Overall Fuel Cons. (gal) After	B/C Ratio	Type of Improvement
Other Cities										
Baytown	Garth Road	8	18,654,000	22,672,500	141,900	120,600	605,700	477,000	7.3	Signal Timing (Art)
Beaumont	Calder/Phelan/Eleventh System	33	129,559,500	140,103,450	2,659,455	1,644,210	5,737,995	2,305,125	48.2	Signal Timing (Art)
Bellaire	Bellaire Boulevard and Bissonnet Street	11	76,017,600	59,278,800	305,280	295,500	1,121,160	1,026,900	2.1	Signal Timing (Art)
Brownsville	Roosevelt Street	2	27,282,000	24,162,000	280,800	179,100	386,100	306,600	4.9	Geometric
College Station	College Station Signal System	37	132,518,400	124,143,600	1,254,078	1,118,730	4,615,452	4,487,262	5.3	Signal Timing (Net)
Copperas Cove	U.S. 190	5	159,357,000	100,590,000	1,223,550	759,600	4,464,150	4,306,950	74.9	Geometric
Del Rio	Spur 239	4	11,772,000	11,055,000	85,440	74,220	153,684	141,108	5.0	Signal Timing (Art)
Denton	Eagle Drive	5	37,057,200	27,940,200	343,560	215,400	685,146	535,938	23.8	Signal Timing (Art)
	U.S. 380 at Carroll Boulevard	1	63,282,000	59,781,000	650,100	612,900	795,720	746,760	26.3	Geometric
Garland	Belt Line	8	159,173,250	158,241,375	988,538	962,400	4,176,338	4,148,813	4.2	Geometric
Grand Prairie	Great Southwest Parkway and Arkansas Lane	1	3,279,000	1,029,000	25,950	25,320	126,000	118,800	2.1	Geometric
	Carrier Parkway and Marshall Drive	1	8,247,000	5,973,000	79,440	79,230	296,400	290,400	3.9	Geometric
	Carrier Parkway and State Highway 303	1	42,774,000	39,837,000	271,350	259,950	688,800	560,400	1.4	Geometric
	Great Southwest Parkway and I.H. 20	1	4,938,000	3,228,000	40,860	36,540	210,000	192,000	3.6	Geometric
Laredo	Laredo Central Business District	29	30,607,800	25,825,200	176,916	154,500	337,059	312,600	1.9	Signal Timing (Net)
Leon Valley	Huebner and Evers	1	29,495,250	21,110,250	258,000	112,725	314,288	178,320	18.9	Geometric
Longview	High Street and McCann Road Systems	8	33,448,800	26,254,200	291,840	158,700	770,820	647,040	14.0	Signal Timing (Art)
N. Richland Hills	Rufe Snow Drive System	7	37,475,700	33,976,800	408,600	374,835	1,240,005	1,222,902	3.5	Signal Timing (Art)
Odessa	42nd Street	12	132,309,300	113,007,900	1,214,400	701,550	3,867,300	3,091,800	38.4	Signal Timing (Art)
Richardson	Richardson-Entire Signal System	48	413,949,600	357,268,200	6,819,600	4,248,000	12,445,800	10,142,400	132.8	Signal Timing (Net)
San Angelo	Main Street and 19th/18th Streets	1	8,311,500	7,857,000	55,125	50,550	98,820	92,865	1.4	Geometric
Waco	Valley Mills	1	44,687,250	41,142,750	498,150	317,250	553,650	410,775	11.6	Geometric
Total	22	225	1,604,196,150	1,404,477,225	18,072,932	12,501,810	43,690,386	35,742,758	0.8 to 132.8	
Grand Total	51	862	3,478,068,450	3,023,736,300	40,112,546	27,030,683	82,234,568	67,292,183	-0.7 to 132.8	